PRACTICALMANUAL

ON

AgroforestrySystems

FSA5043(2+1)

M.Sc.Forestry

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2022-23

RANILAKSHMIBAICENTRALAGRICULTURALUNIVERSIT Y,JHANSI

AgroforestrySystemsandManagement

FSA504, 3(2+1)

NameofStudent.....

RollNo.....

Batch.....

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Semester.....

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CourseNo.:.....**Credit**.....

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CERTIFICATE

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semesterintheyear. .....

intherespectivelab/fieldofCollege.

Date: CourseTeacher

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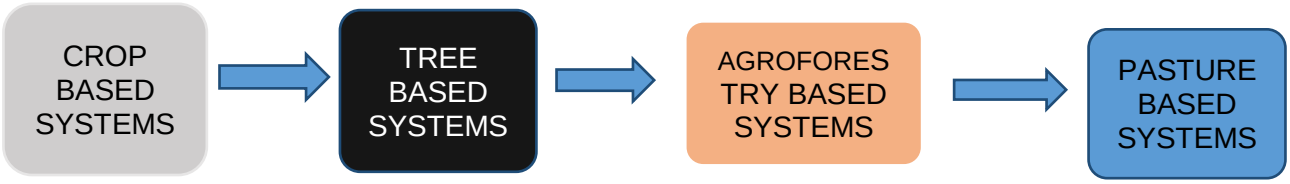
Exercise No. 1

Objective: Survey and analysis of land use systems -1

Land-use systems

A combination of one land unit and one land utilization type (with one set of land-userequirements) constitutes a land-use system (LUS). A single-land-use system is theconfiguration whose performance is analyzed in assessment of land suitability.Multiple-land-use systems (i.e. more than one crop on a field at one time) andcompound-land-use systems (i.e. single or multiple systems in rotation) can behandled by combining analyses of single-land-use systems. Where appropriate, competition for light, water and nutrients are taken into account.It consists of Cropping Systems, Agroforestry Systems, Pasture Systems.

DIFFERENT TYPES OF LAND USE SYSTEMS IN BUNDELKHAND REGION



1. **CROP BASED SYSTEMS/CR0PPING SYSTEMS**

- It is defined as the order in which the crops are grown or cultivated on a piece of land over a same period of time.
- Cropping system is the most important component of a farming system.

2. **TREE BASED SYSTEMS**

- Tree based systems/models use a decision tree to represent how different input variables can be used to predict a target value.
- In this system woody perennials play a significant environmental, social and economic role.

3. **AGROFORESTRY BASED SYSTEMS/ MODELS**

- Agroforestry is a collective name for land use systems and technologies where woody perennials (trees,shrubs,palms,bamboos)are deliberately used on the same land management units as agricultural crops and animals, in some form of spatial arrangement or temporal sequence.

4. **Pasture based systems**

- It is a land management system in which forests are managed for the production of wood as well as for rearing of domesticated animals.

- It includes management of fodder grasses in natural forests or in plantations or in grassland with a view to obtaining the maximum production of wood, fodder & other products.

Field Exercise:

❖ **TYPES OF CROP BASED SYSTEMS IN NEARBY AREA**

1. SEED PRODUCTION ON BARLEY

- Crop/variety: Barley – DWRB 137
- Special features: High protein content and high hectolitre wt.

2. SEED HUB ON OILSEEDS

- Crop/variety: Indian Mustard 'DRMR-IJ-31'(GIrIraj)
- Special features: bold seeded

3. CHICKPEA GERMPLASM(ICRISAT:NBPGR)

- CHEEKS: RLBGK 1, BG 3062, PHULE VIKRAM, RVG 204
- Crop/variety: Pigeon Pea
- Special features: medium size seed with oval shape and purple coloured seed coat and resistant to wilt.

❖ **TYPES OF TREE BASED SYSTEMS IN NEARBY AREA**

1. ARBORETUM AND BIODIVERSITY PARK

- Area – 2 ha
- Spacing – 4*4 m
- No. of plants per species – 5

➢ **TREE SPECIES PRESENT IN ARBORETUM**

Arjun	Harad	Malabar neem	Ritha	A. babul	Kokum
Bakain	Imli	Molsari	Ritha	Kumttha	Poison nut
Ber	Jangaljalebi	Mitragyna	Shahtut	Rohan	Kapila
Bhilawa	Casurina	Neeligulmohar	Shami	Karaya	Anjani
Chirol	Kachnar	Nilgiri	Shisham	Jarul	Jangalibadam
Chironji	kadamb	Nirgundi	Simarubba	Sitaashok	White siris
Dhaman	Karanj	Olive	Sinduri	Indian kino	Khirni
Gamer	Kapok	Paraspipal	Bixa	Monkeypod tree	Simal
Vijaysar	Sal	Medhshingi	Lasoda	Dhaura	Pink cassia

❖ **TYPES OF AGROFORESTRY BASED SYSTEMS IN NEARBY AREA**

1) Intercropping of legume crops under *Gmelinaarborea* based industrial agroforestry systems

2) Intercropping of legume crops under *Neolamarckiacadamba* based industrial agroforestry system
3) Intercropping of legumes under neem based agroforestry system
4) Intercropping of legumes with Bamboo plantation
5) Spacing and MAP based agroforestry trial of Anjan*(Hardwikiabinnata)*
6) Intercropping of legume crops under *Meliadubia b*ased industrial agroforestry system
7) Development of Triphala (Harad, Amla and Bahera) based agroforestry system
8) Establishment of *Buchananialanzan, Madhuca indica* and *Schleicheraoleosa*based NTFP based agroforestry model
9) Sustainable livelihoods through Non-Wood Forest Products (NWFP's) from the degraded lands
10) Intercropping of legume crops under *Dalbergiasissoo*based industrial agroforestry system

❖ **TYPES OF PASTURE BASED SYSTEMS IN NEARBY AREA**
Horti-Silvi-pasture system

❖ **Tree spacing (S)**

- Spacing -5mx4m, and 5 m x 3m

❖ **Tree species (T)**

Chilbil (*Holopteleaintegrifolia),* Pomegranate (*Punicagranatum),* Custard apple (*Annonareticulata)*

- Grass : *BN hybrid*

List important land use system in adjoining area of RLBCAU campus

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Exercise No. 2

Objective: Survey and analysis of land use systems -2

List important land use system in adjoining area of RLBCAU campus

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Exercise no. 3

Objective: To study existing Agroforestry systems in RLBCAU Campus-1

AGROFORESTRY BASED SYSTEMS/ MODELS

Agroforestry is a collective name for land use systems and technologies where woody perennials (trees,shrubs,palms,bamboos)are deliberately used on the same land management units as agricultural crops and animals, in some form of spatial arrangement or temporal sequence.

AGROFORESTRY SYSTEMS IN BUNDELKHAND REGION

1) **Intercropping of Legume Crops Under *Gmelina Arborea* Based Industrial Agroforestry Systems**

RABI CROPS-Grass pea (*Lathyrussativus),* Lentil *(Lens culinaris*), Chickpea (*Cicerarietinum)*
TREE SPACING: 5m X 5m, 5m X 4m, 5m x 3m

2) **Intercropping of legume crops under *Neolamarckiacadamba* based industrial agroforestry system**

RABI CROPS- Grass pea (*Lathyrus sativus),* Lentil *(Lens culinaris*), Chickpea (*Cicer arietinum)*
TREE SPACING: 5m X 5m, 5m X 4m, 5m x 3m

3) **Intercropping of Legumes Under Neem Based Agroforestry System**

RABI CROPS : Jack bean (*Canavaliaensiformis),* Broad bean *(Viciafaba),* Grass pea *(Lathyrussativus),* Lentil (*Lens culinaris*), Chick pea *(Cicerarietinum)*
Tree spacing: 6 mx 5 m

4) **Intercropping of legumes with Bamboo plantation**

Bamboo spacing: 8 m x 6 m
Intercrops : Jack bean (*Canavalia ensiformis),* Broad bean *(Vicia faba),* Grass pea *(Lathyrus sativus),* Lentil (*Lens culinaris*), Chick pea *(Cicer arietinum)*

5) **MAP based agroforestry of Anjan*(Hardwikiabinnata)***

- Tree Spacing: 5 X4, 5X3, 5X2 m
  MAP Intercrops: Aloe vera, Lemon grass, Ashwagandha, Tulsi, Asparagus

6) **Intercropping of legume crops under *Meliadubia b*ased industrial agroforestry system**

RABI CROPS- Grass pea (*Lathyrus sativus),* Lentil *(Lens culinaris*), Chickpea (*Cicer arietinum)*
TREE SPACING: 5m X 5m, 5m X 4m, 5m x 3m

7) **Development of Triphala (Harad, Amla and Bahera) based agroforestry system**

- **Tree components:***Terminaliachebula*(Harad), *Terminaliabelerica* (Bahera), *Emblicaofficinalis*(Amla)

Tree spacing : 5m x 6m

- **Kharif crop**- *Pisumsativum*(field pea)
- **Rabi crop**- *Chenopodium quinoa* (Quinoa)

8) **Establishment of *Buchananialanzan, Madhuca indica* and *Schleicheraoleosa*based NTFP based agroforestry model**

Endangered multipurpose tree species: *Buchananialanzan(*Chiraunji), *Madhuca indica*(Mahua), *Schleicheraoleosa*(Kusum)
Tree spacing: - 6 x 5m
Intercrops: Moong, Sanaya

9) **Non-Wood Forest Products (NWFP's) based multitier agroforestry in degraded lands Tree Species**

BLOCK -1

- *Tectonagrandis* (teak)- Top strata
- *Tamarindus indica (*Imli)- Middle strata
- *Annona squamosal* (Custard Apple)- Lower starta

BLOCK -2

- *Artocarpusheterophyllux (*Kathal*)* – Top strata
- *Pangamiapinnata (*Karunj*)*- Middle strata
- *Carissa Carandas(*karonda*)*- Lower strata

BLOCK-3

- *Meliaazaderach*(Bakain) – Top strata
- *Diospyrusmelanoxylon*(Tendu)- Middle strata
- *Ficus carica (*Fig) - Lower strata

BLOCK-4

- *Dalbergialatifolia (*Rosewood)– Top strata
- *Buchananialanzan* (Chiranji)Middle strata
- *Murraya koenigii* (Curry Leaf)- Lower strata

10) **Intercropping of legume crops under *Dalbergiasissoo*based industrial**

agroforestry system

Crops

Jeak bean *(Canavaliaensiformis)*

11) Development of Horti-Silvi-pasture system

- **Tree spacing (S):** 5mx4m, 5 m x 3m

❖ **Tree species (T)**

- Silvi component-Chilbil (*Holopteleaintegrifolia)*
- Horti component - Pomegranate (*Punicagranatum)*
- Horti component- Custard apple (*Annonareticulata)*
- Grass species: *BN hybrid*

List important land useagroforestry system in RLBCAU campus with crops

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Exercise no. 4

Objective: To study existing Agroforestry systems in RLBCAU Campus-2

List important land useagroforestry system in RLBCAU campus with crops

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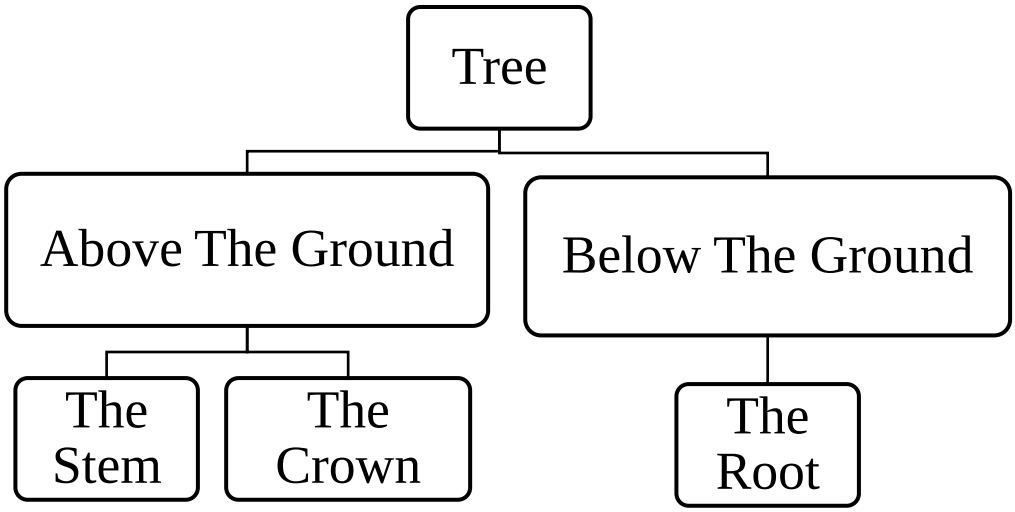
Exercise no. 5

Objective: To study the Tree Crown Architecture:

Tree Architecture refers to the study of the morphological developments of a tree in its ecological region right from the germination to its senescence

Components of Tree Architecture

All the components of the tree are parts of its architecture.



The tree architecture above the ground consists of:

1) The Crown:

The crown is defined as the upper branchy part of the tree above the bole. It is formed by the foliage of the branches springing above the bole.

The architecture of the crown can be described based on the following factors:

1. The shape and size of the crown
2. The branching pattern
3. The leaves

i)The shape and size of the crown:

- The **length, height and diameter** of the crown greatly determines the shape and size of the crown. It is also the result of branching behaviour of the tree.
- It also varies with the species and the environment in which they grow.

Based on the above factors crown can be of the various types such as :

Conical: Examples include Pines and *Cedrusdeodara.*

Cylindrical: Examples include *Abiespindrow, Piceasmithiana, Euclayptus,* etc.

Spherical: Examples include *Mangiferaindica, Madhucaindica, Azadirachtaindica, Tamrindusindica,* etc.

Broad and flat topped: Examples include *Acacia planifrons.*
Broom shaped: Examples include *Acacia nilotica.*
Frondose: Examples include *Prosopisjuliflora.*
No branching: Examples include *Phoenix, Cocus, Borassas.*

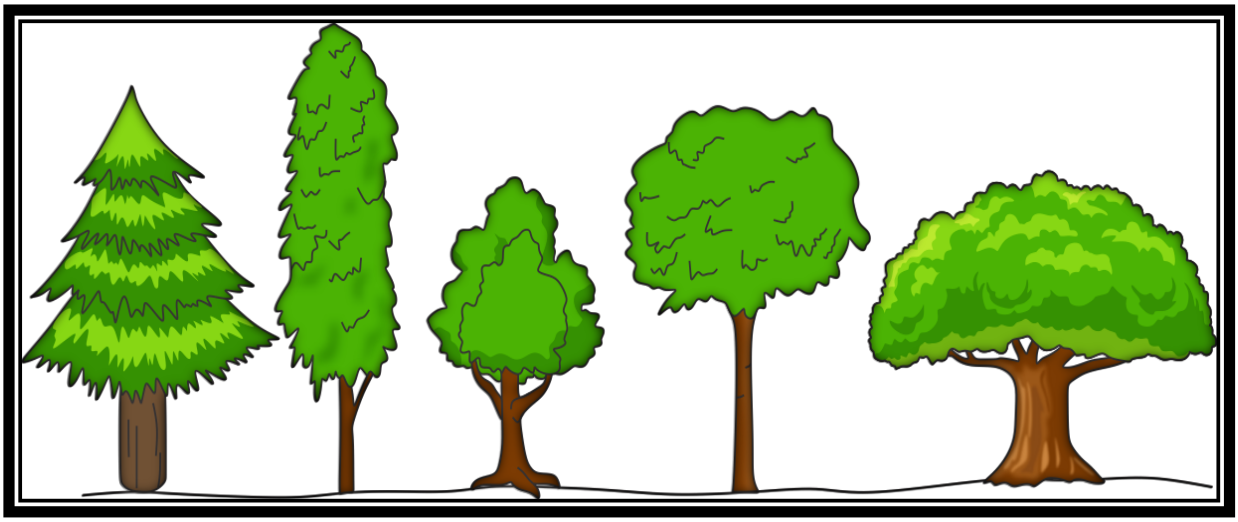


Figure: Different shapes of crown: (a) Conical, (b) Cylindrical, (c) Broom-shaped, (d) Spherical and (e) Broad and flat topped

Spherical Crown of Mango Tree

Cylindrical Crown of *Piceasmithiana*

Conical Crown of Deodar

Broom shaped Crown of *Acacia nilotica*

2) The branching pattern:

Angle made with the Main Axis:

The angle made by the lateral branches differ in the following manner:

1. **Angle of 60° -70°:** This is the case of branching in mostly all species.
2. **Angle of 20°-30°:** It is the case in species like *Populusnigra*, *Cuppressussemipervens*
3. **Angle of 90°:** It is the case in species like *Bombax*, Old Deodar, *Duabangasonneratioides*
4. **Drooping:** As in case of *Terminaliamylocarpa*, twigs of spruce, young Deodar

3)The leaves:

Leaf refers to the green, flattened, lateral structure attached to the stem and functioning as a principle organ for photosynthesis and transpiration.

The leaves differentiate the trees based on the following factors:

- The leaf colour
- Size and texture of the leaves
- Leaf Shedding

i)The leaf colour

Generally, leaves are green in colour. But certain species exhibit different colours of leaves such as:

- White coloured leaves in *Quercusleucotricohphora*
- Brown coloured in *Quercussemicarpifolia*,
- Dark red leaves in young leaves of Mango.
- Young leaves are pinkish or purplish in *Quercusinacana*
- Young leaves are bright red in case of *Acer caesium and Schleicheraoleosa*
- Young leaves aredark brown in *Cassia fistula*

ii) Size and texture of the leaves

Size: The size of leaves depend on the rainfall as leaves of trees in low rainfall area are small and vice versa. Examples of size variation include:

- unusually large leaves in species such as teak and *Dillenia*
- leaves of conifers are needle shaped hence are called needles.

Texture: The texture of the leaves can be of two types:

- soft and membranous as in *Grewia, Ougeinia*, etc.
- hard and coriaceous as in sal and conifers

iii) Leaf Shedding

1. **Deciduous Trees:** These trees remain leafless for sometime during the year. Eg: *Tectonagrandis*,*Azadirachtaindica*,*Bombaxceiba*, etc.

2. **Evergreen Trees:** These trees are never entirely without green foliage as the old set of leaves persist until a new set has appeared. Eg: *Abiespindrow*, *Cedrusdeodara*, etc.

4) The Stem:

The stem is defined as the principle axis of the plant from which buds and shoots are developed.

- The stem can differ in size (shape and length) according to the species and the conditions in which it grows.
- According to the above mentioned factors, following main differences can be observed in different plant species:
  - Long and straight stem with relatively few branches.
  - Crooked stem with more or less branching.

Standard Tree Classification based on Crown Classes:

A. **Dominant trees (D)**: Trees form uppermost leaf canopy and have their leading shoots free.

▶ **Predominants (D1)** : Tallest trees which determine general top level of Canopy.

▶ **Codominants(D2)** : 5/6 th of height of the Predominants

Dominants are further classified according to their vigor and soundness:

i. Trees with normal crown development and good stem form (Class symbol Ia)
ii. Trees with defective stems and crowns (Class symbol Ib)
iii. Trees with very defective stems (Class symbol Ic)
iv. Whips (Class Symbol Id)

B. **Dominated trees(d)**:- Trees which do not form uppermost leaf canopy and their leading shoots are not overtopped by neighbouring Trees. It is 3/4th of height of the tallest trees

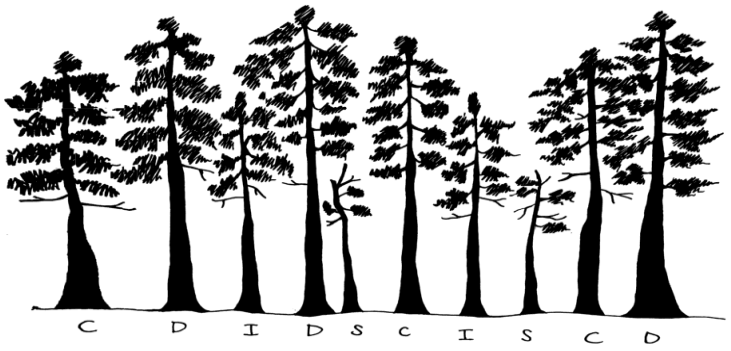
They are classified as:

i. Trees with normal crown development and good stem form (Class symbol IIa)
ii. Trees with defective stems and crowns (Class symbol IIb)

B. **Suppressed trees(s) :-** ½ to 5/8th of the height of predominant and leading shoots overtopped by other neighboring trees. (Class symbol III)

C. **Dead and moribund trees(m) :-** bent over or badly leaning trees (Class symbol IV)

D. **Diseased trees(k):** Trees infected by Parasites and Diseases. (Class symbol V)



"D" = Dominant; "C" = Co-dominant; "I" = Dominated and "S" = Suppressed

Give crown structure of agroforestry system in RLBCAU campus

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Exercise no. 6

Objective: To study the Detail set up and operation of the ICAR- AICRP on Agroforestry

Introduction:

The All India Coordinated Research Project (AICRP) on Agroforestry was started in 1983 with 20 centres and it has now expanded to 37 centres – 26 in SAUs, 10 in ICAR Institutes and 1 in ICFRE Institute representing all agroclimatic zones in the country.

The Coordinating unit of AICRP-Agroforestry was shifted from ICAR Headquarters to NRCAF now CAFRI, Jhansi on 1 April, 1997 with the following specific mandates:

- Screening and genetic upgrading of selected plant species for their compatibility in different agroforestry systems.
- To optimize tree-intercrop combination for different regions.
- Performance enhancement of the pre-dominant agroforestry systems being already practiced by the farmers.
- To upgrade and refine the existing technologies for higher productivity and sustainability.

Objectives: ·

- Diagnostic survey and appraisal of existing farming system and agroforestry practices and farmers' preference.
- Collection and evaluation of promising tree species, cultivars of fuel, fodder and small timber for agroforestry interactions.
- Studies on management practices of agroforestry systems such as agri-silviculture, boundary plantation, silvipasture, silvi-horticulture, agri-silvi-horticulture, multistorey, homestead, etc.
- To analyze economics of agroforestry systems.
- To explore and attribute the role of agroforestry in environment protection.
- To conduct studies on post-harvest technology, fishery, apiculture, lac, etc. in relation to agroforestry system

AICRP-Agroforestry Centres across the country in SAU's :

1) OUAT, Bhubaneshwar	14) GBPUA&T, Pantnagar
2) TNAU, FCRI, Mettupalaym	15) RPCAU, Pusa
3) BSKKV, Dapoli	16) MPKV, Rahuri
4) UAS, Dharwad	17) BAU, Ranchi
5) ANDUAT, Ayodhaya	18) SDAU, SK Nagar
6) SKNAU, ARS, Fatehpur-Shekhawati	19) YSPUH&F, Solan
7) CCSHAU, Hisar	20) SKUAST-K, Srinagar
8) PJTSAU, Hyderabad	21) KAU, Thrissur

9) JNKVV, Jabalpur 10) TANUVAS, IAN, Kattaupakkam 11) PAU, Ludhiana 12) AAU, HRS, Kahikuchi 13) PDKV, COA, Nagpur	22) BCKVV, RRS, Jhargram 23) UAS, Bangaluru 24) CSKHPKV, Palampur 25) UAHS, COF, Ponnampet 26) SKUAST-J, Jammu

SystemResearchandTreeGermplasmCollection,EvaluationandImprovementworks in different AICRP Centres:

Nameofthecentre/State	**MPTSworkingupon**	**Agroforestrymodelsundertrial/development**
AssamAgriculturalUniversity-HRS,Kahi-kuchi	Gmelina*arborea*,Bamboo speciesevaluation	*Gmelinaarborea*based Agrisilvicultural system,JackfruitbasedAgroforestrysystem, *Acaciamangium*basedAgrisilviculturalsystem
Prof. JayashankarTelanganaState Agricultural University, Hyderabad	*Azadirachtaindica*	*Meliadubia*based Agroforestry system, Custardapple based Hortipastoral system, Mango basedAgrihorticulturalsystem
BirsaAgriculturalUniversity, Ranchi	(MPTs)	*Meliaazedarach*underSilvi-PastoralSystem,Tephrosia hedgerow under Alley cropping basedAgrisilviculturesystem
BidhanChandraKrishiViswavidyalaya, WestBengal-Jhargram	*Acacia auriculiformisNeolamarckiacadamba* Bamboosp.	*Gmelinaarborea*andmango-basedAgroforestrysystem, *Anthocephaluscadamba*and mangoAgroforestrysystem
Dr.BalasahebSawantKonkanKrishiVidyapeeth,Dapoli	*Meliadubia*	*Meliadubia*basedmedicinalAgroforestrysystemArecanutbasedplantationAgroforestrysystem
ChaudharyCharanSinghHaryanaAgriculturalUniversity,Hisar	*Populusdeltoids, Meliacomposita*	EucalyptusbasedAgroforestrysystem,PoplarbasedAgroforestrysystem,Eucalyptusclone-basedAgroforestrysystem
ChaudharySarwanKumarHimachalPradesh KrishiVishvavidyalaya,Palampur	*Toona ciliata, Sapindusmukorossi Leucaenaleucocephala*	Harar based silvipastoralsystem, *Leucaenaleucocephala*silvipastoralAgroforestrysystem
TamilNaduAgriculturalUniversity,Mettupulayam	*Meliadubia, Ceibapentandra*	Fodderbank *Melia*basedmedicinalAgroforestrymodel,
JawaharlalNehruKrishi	*Dalbergiasissoo*	MangobasedAgri-horticulturesystem

VishwaVidyalaya,Jabalpur		
KeralaAgriculturalUniversity,Thrissur	*Tectonagrandis*	Boundaryplantationoffast-growingfoddertrees;Bamboo-basedAgroforestry
MahatmaPhuleKrishiVidyapeeth,Rahuri	21-tree germplasmunderevaluation	Agri-horticulturalsystemofdifferentfruittreespecies,TeakbasedAgroforestrysystem
AcharyaNarendraDevaUniversityof Agriculture and Technology,Ayodhya	*Dalbergiasissoo*	*Casuarina equisetifolia* and *Psidiumguajava*basedAgri-silvi-hortisystem,*Dalbergiasissoo* basedAgri-silviculturesystem
OdishaUniversityofAgricultureandTechnology, Bhubaneshwar	*Gmelinaarborea*	Silvipastoralsystem(*Acaciamangium,Acacia auriculiformis, Samaneasaman*) Mango +Pineapple Agrihorticulturalsystem,AgrisilviculturalSystem (*Acacia mangium,Tectonagrandis*)
PunjabAgriculturalUniversity,Ludhiana	*Populusdeltoides, Meliacomposita*	PoplarbasedAgroforestry
Dr. PanjabraoDeshmukhKrishiVidyapeeth,CollegeofAgriculture,Nagpur	*Tectonagrandis, MeliadubiaBamboosabalcooa*	CitrusbasedAgroforestrySystem,BamboobasedAgri-silviculturesystem,Tectonabasedsystem
Dr. Rajendra Prasad CentralAgriculturalUniversity,Pusa	*Populusdeltoides*	*Bombaxceiba*basedAgrisilviculturalsystem,
SardarKrushinagarDantiwadaAgriculturalUniversity,SKNagar	*Ailanthus excels, Azadirachtaindica*	*Ailanthus*-basedmedicinalplantsagroforestrysystem,BoundaryPlantation
SriKaranNarendraAgricultureUniversity, ,Fatehpur-Shekhawati	*P.cineraria, A.nilotica, A.tortilis*and*H.binata*	Hardwickiabasedsystem,DifferentAgroforestrysystemsonbiomassandcarbonstockinaridzoneofRajasthan
Sher-e-KashmirUniversityof Agricultural Sciences andTechnology of Jammu,Jammu(J&K)	-	*Terminaliacehbula*basedSilvipastoralSystem, *Melia composite* basedAgroforestrysystem
Sher-e-Kashmir University ofAgricultural Sciences	*Salixalba*var.*Caerulea*	Applebasedsystem,Apricotbasedagroforestrysystem,Walnutbasedagroforestrysystem,Salixbasedsilvi-pastoralsystem

andTechnologyofKashmir,Srinagar		
Tamil Nadu Veterinary and AnimalSciencesUniversity,Kattapukkam	*Azadirachtaindica. Gliricidiasepium*	Hortipasture in degraded wastelands, *Psidiumguajava*basedpasturesystem,GliricidiabasedSilvipastoral system, Cocusnucifera basedHortipastoralsystem
TheUniversityofAgriculturaland Horticultural Sciences,Shivamoga	Bamboospp.	-
UniversityofAgriculturalSciences,Bengaluru	*Simaroubaglauca, Tamarindusindica*	*Meliadubia* ,Mango, Jamun,, Cashew and Mahagony basedAgroforestrysystem
UniversityofAgriculturalSciences,Dharwad	*Pongamiapinnata, Tamarindusindica,*Thornlessbamboo	NeembasedAgroforestrysystem,Sapota-timberspecies-basedAgroforestrysystem
Dr. Y SParmarUniversityof HorticultureandForestry,Solan	-	FruittreebasedAgroforestrysystemsandpeach-basedAgroforestrysystem
G.B.PantUniversityofAgriculture And Technology, Pantnagar	94+ 54 indigenousand exoticMPTsincluding 7 +14 speciesofBamboo	ShishambasedAgroforestry;Turmeric *Curcumalonga*L.)under11different Agroforestry tree species (12 years old)

Give crown structure of agroforestry system in RLBCAU campus

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Exercise no. 7

Objective: To study Important Agroforestry systems at different agro-climatic zones.-1

Important Agroforestry systems at different agroclimatic zones

S.N.	Agro-climatic Zone	Agroforestry systems	Tree Component	Crop/Grass
1.	Western Himalayas	Silvipasture	*Grewiaoptiva* *Morus alba*	Setaria spp. Setaria spp.
		Agrihorticulture	*Maluspumila*	Millets, Wheat
		Agrihorticulture	*Prunuspersica*	Maize, Soyabean
2.	Eastern Himalayas	Agrisilviculture	*Anthocephaluscadamba*	Paddy
		Agrihorticulture	*Alnusnepalensis*	Large Cardamom/ Coffee
		Silvipasture	*Bamboos, Parkiaroxburghii, Morus alba, Bauhinia variegata, Ficus,*	Napier
3.	Lower Gangetic Plains	Agrisilviculture	*Eucalyptus, Albizialebbeck*	Paddy
		Agrihorticulture	*Mango/Banana/Litchi*	Wheat, Paddy Maize
		Silvipasture	*Morus alba, Albizialebbeck*	Dicanthium, Pennisetum
4.	Middle Gangetic Plains	Agrisilviculture	*Populusdeltoides*	Sugarcane-Wheat
		Agrisilviculture	*Eucalyptus spp.*	Rice-Wheat
		Agrisilviculture	*Dalbergiasissoo*	Sesamum
		Agrihorticulture Silvipasture	*Mango/Citrus* *Albizialebbeck*	Rice-Wheat ChrysopoganDicanthium
5.	Trans Gangetic Plains	Agrihorticultore	*Emblicaofficinalis*	Black gram/ Green gram
		Agrisilviculture	*Azadirachtaindica*	Black gram /Wheat

				/Mustard
		Silvipasture	*Bauhinia variegata. Albizialebbeck*	Cenchrus, Pennizecum
6.	Upper Gangetic Plains	Agrisilviculture	*Populus deltoids*	Wheat, Bajra, fodder
		Agrisilviculture	*Eucalyptus*	Rice-Wheat
		Silvipasture	*Bauhinia variegate, Albizialebbeck*	Chrysopogon, Poa
7.	Eastern Plateau	Agrisilviculture	*Gmelinaarborea*	Paddy Linseed Hills
		Agrisilviculture	*Acacia nilotica*	Paddy
		Silvipasture	*Acacia mangium A nilotica, bamboas*	----
		Silvipasture	*Leucaenaleucocephala*	Chrysopogon, Pennisetum, Dicanthium
8.	Central Plateau & Hills	Agrihorticulture	*Psidiumgujava*	Bengal Gram Groundnut
		Agrihorticulture	*Emblicaofficinalis*	Black gram/Greengram
		Agrisilviculture	*Acacia nilotica, Leucaenaleucocephala, Azadirachtaindica, Albizialebbeck*	Soyabean Black gram-Mustard/Wheat
		Silvipasture (RF & degraded lands)	*Albiziaamara, Leucaenaleucocephala, Dichrostycuscinerea*	Chrysopogon, *Stylotantheshamata S scabra*
		TBO	*Jatrophacurcus*	-
9.	Western Plateau & Hills	Agrihortisilviculture	*Tectonagrandis, Achruszapota*	Paddy Maize
		Agrihorticulture	*Areca catechu*	Black pepper Cardamom
		Silviculture	*Prosopisjuliflora, Ailanthus*	-
		Silvipasture	*Acacia mangium*	Cenchrus, Albizaamora
10.	Southern Plateau &Hills	Agrisilviculture	*Eucalyptus*	Cotton
		Agrisilviculture	*Eucalyptus*	Chilli
		Silviculture	*Leucaenaleucocephala*	
		Agrihorticulture	*Tamarindusindica*	Chilli
		TBOs	*Pongamiapinnata*	
11.	East Coast	Agrisilviculture	*Allanthusexcelsa Acacia*	Cow pea

	Plains & Hills		*leucophloea*	
		Silviculture	*Casuarinaequisetifolia, Leucaenaleucocepha*	
		TBOs	*Pongamiapinnata*	
		Silvipature	*Artocarpusspp*	Chrysopogon, Napier, Cenchrus
12.	West Coast Plains & Hills	Agrisilviculture	*Acacia auriculiformis*	Black Pepper
		Agrihorticulture	*Artocarpusheterophyllus*	Black Pepper
		Agrisilviculture	*Acacia auriculiformis*	Paddy
		Agrihorticulture	*Cocosnuciferal Areca catechu*	Paddy
		Agrisilviculture	*Casuarinaequisetiofolia*	Paddy
		Silvipasture	*Hardwickiabinata, Albizialebbeck*	
13.	Gujarat Coast plains & Hills	Agrisilviculture	*Azadirachiaindica*	Cow pea
		Silviculture	*Prasopis juliflora. , Acacia nilotica*	-
		Agrisilviculture	*Ailanthus excelsa*	Green gram
		Silvipasture	*Leucaenaleucocephala*	Cenchrus, Setaria
14.	Western Dry Region	Agrisilviculture	*Prosopis cineraria, Azadirachtaindica*	Pearl millet
		TBOs	*Jatrophacurcas*	-
		Silvipasture	*Albizialebbeck*	Cenchrus
15.	All Islands	Agrihorticulture	*Cocosnucifera*	Paddy
		Silvipasture	*Bauhinia, Erythrina. Leucaena*	Cenchrus, Pennisetum

Enlist Important Agroforestry systems at different agro-climatic zones

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Exercise no. 8

Objective: To study Important Agroforestry systems at different agro-climatic zones.-1

Enlist Important Agroforestry systems at different agro-climatic zones

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Exercise no. 9

Objective: Explorative design and plan of suitable Agroforestry models for improvement of Bundelkhand Region-1

Introduction

Agroforestry is a land use management practice that combines woody perennials and herbaceous crops on the same piece of land to meet diverse needs of humans and domestic animals. India has 25 Mhaarea under Agroforestry land use, supporting almost half of fuelwood, two thirds of small timber, 70-80% wood for plywood industry, 60% raw material for paper pulp and 9-11% of green fodder requirement of livestock.

Agroforestry is practiced in India in various ways, such as tree on field boundary, block plantation, alley cropping, scattered trees in field, home gardens and homestead gardens. Bund plantation is a common practice, and the industrial hub for plywood and pulp has developed eucalyptus and poplar based agroforestry system on 8-9 lakh ha area in Tamilnadu, Andhra Pradesh, Maharashtra, Karnataka, Punjab, Haryana and western Uttar Pradesh. Traditional agroforestry systems include khejri (*Prosopis cineraria*), alder (*Alnusnepalensis*), *Grewiaspp* in western Himalaya, *Acacia nilotica* in Central India, *Acacia leucophloea* in Tamilnadu and Homegarderns in Kerala. Fruit components in agroforestry systems help to increase adoption rate and mid-term income of farmers. Promotion of agroforestry is becoming a well-proven solution in various parts of countries to cater the needs of farming community and environmental.

Bundelkhand region

Bundelkhand region is a rich storehouse of tree-based traditional knowledge and has immense potential for holistic planning. It comprises 14 districts of Uttar Pradesh and Madhya Pradesh, with a total forest area of 1.24 m ha. Agroforestry is grouped into agrihorticulture, agrisilviculture, silvipasture, and other systems. Agrohorticulture involves incorporating fruit plants with crops, while agrisilviculture involves planting grasses and forest trees together. Silvipasture involves rehabilitating non arablelands by planting grasses and forest trees together.Agroforestry systems are essential for sustainable farming in the Bundelkhand Region, providing food, fodder, fuel and timber, supporting alternate livelihoods and employment, and reducing land and water degradation.

Prominent Agroforestry Systems of Bundelkhand Region

1. Aonla Based Agroforestry

Aonla is a non-perishable fruit with deciduous nature, making it ideal for Agroforestry land-use. It can be grown in rainfed regions of Bundelkhand, NA 10, NA 7 and Kanchan varieties, and can be harvested with urd, moong, groundnut, wheat, mustard and Rabiseason. After 6-90 years, it can be obtained from single trees up to 40 years.

2. Eucalyptus Based Agroforestry

Eucalyptus is an important industrial species with over 700 species spread over 22 million hectares worldwide. It is suitable for areas with 250-600 mm annual rainfall and can also grow in high-rainfall areas. It requires only 785 litres of water to produce one kg of biomass, and can be transplanted anytime during the year except May-June. Bund planting is popular and yields up to 60-70 Mg ha-1 in 6-year rotations.

3. Teak-based Agroforestry

Teak is widely planted in Bundelkhand due to its lucrative price and sturdy nature. It is planted in different models, combinations with crops and pastures, block plantation, and with kharif and rabi crops, with an average yield of 12-15 cft after 25 years.

4. Kumat Based Agroforestry

Kumat (Acacia senegal) is a highly drought tolerant forest with high prices and good fuel wood and brush wood for fencing. It can be practiced under 3 m x3m, 5 m x 5m in silvipasture, 10 m x 1o in agrisilviculture and 2-4m away in boundary plantation.

5. Neem Based Agroforestry

Neem is a traditional Agroforestry system used to establish earthen structures and mediate micro-climate. It is used as a tooth brush, seeds collected for medicinal purposes, and branches used as small timber. The average sizedNeem tree is reported to give 20-25 kg of fruits.

6. Bamboo-based agroforestry

Bamboo "Green gold" based agroforestry system is promoted to improve the lives of farmers in Bundelkhand region. It is divided into two species Dendrocalmusstrictus (male bamboo) and Bamboosa vulgaris (green). Bamboo can be planted along irrigation channels or bund he as fencing, providing at least 6-8 culms after four years.

Prominent Agroforestry Species

Prominent Agroforestry tree Species for various system are given below:-

Live fencing :Karaunda, Kumat, Mehdi, Agave, Editle Cactus

Agrihorticulture :Bael, Ber, Aonla, citrce, cutard apple

Agrisilviculture:Encalyptus, Babul, Neem, Teak, Bamboo, Mahuasspp.

Bund/Boundary :Ardu, Bamboo Kaitha, Jungle jalebi, Teak, Khajoor .

Agroforestry should be an integrated part of watershed management programmes, opening up new vistas for alternate livelihood supports, and creating employment opportunities. It should also be exempted from felling restrictions, top working of unproductive fruit plants on non-forest and forest land, and establishing wood based industry in the Bundelkhand region. Finally, ecosystem services should be recognized and patronized to encourage growth.

Enlist Important Agroforestry systems of Budelkhnad region and new systems

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Exercise No. 10

Explorative design and plan of suitable Agroforestry models for improvement of Bundelkhand Region-1

Enlist Important Agroforestry systems of Budelkhnad region and new systems

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Exercise No. 11

Objective: Case studies on Social Forestry and Community Forestry

Social forestry is a forestry system which aims to create a flow of protection and recreation to the community. The word "social forestry" was coined by Westoby at the Commonwealth Forestry Congress during 1968 in Delhi.Social forestry is defined as "of the people, by the people and for the people." It means the management and protection of forests and afforestation on barren lands with the purpose of helping in the environmental, social and rural development, as against the traditional objective of securing revenue (Negi 1986).

ECONOMIC AND ENVIRONMENTAL BENEFITS OF SOCIAL FORESTRY

1. Employment Potential: It has a great advantage in providing job to local people. The poorest section gets more benefit as the labour component is unskilled or semi-skilled which includes works such as nursery works, preparation of beds, sowing, planting, hoeing. watering, etc. Social forestry also provides benefits indirectly by providing raw materials to the cottage industries such as furniture, walking sticks, making sports goods etc.

2. Capital Gain: Besides providing benefit in the form of employment, plantations through social forestry also help to create economic capital to the rural poor.

3. Increased Production of Food and Fodder. When a forest is properly maintained, it increases food and fodder production.

4.Cottage Industries: Social forestry plantations open up a big storage and supply of raw materials for cottage industries which may be used in house-hold goods, house building, sports goods and industrial goods.

5. Forest Industries: It also provides forest based raw materials such as resin, pulpwood,match industry and minor forest products such as gums, resins, honey, lac, katha, etc.

6. Regulation of Water Cycle: It acts as an interception which prevents direct hitting ofraindrops on the ground. Forests present near the catchment areas helps to maintain the water regime. Trees also traps rain water and prevent floods during rainy season.

7. Carbon Sequestration: It is an important way of sequestering atmospheric carbon, thereby mitigating greenhouse effect and climate change. 8. Increased Life of Dams and Reservoirs. Planting of trees through social forestry programme near the catchment areas protects the reservoir from being silted up. Soil erosion is prevented, reducing the flow of silt into the reservoirs.

9. Flood Control: Both human life and property are damaged by floods. Increased silt in the river causes river to overflow. So planting of trees along the river bed reduce surface runoff and control the rise of river bed.

10. Energy Requirements: Villagers collect fuel wood from forest for their daily use which

results into depletion of forest. Apart from these villagers, even industries also need fuel wood. Thus planting more trees helps to reduce depletion and provides required amount of fuel wood both to villagers as well as industries. It will also reduce pressure on forest and solving the energy problems**.**

CLASSIFICATION OF SOCIAL / PARTCIPATORY FORESTRY

National Commission on Agriculture (1952) has classified social forestry to include three broad classes, viz., farm forestry, rural forestry and urban forestry.

FARM FORESTRY

Farm forestry is defined as the practice of forestry in all its aspects on farm or village lands, generally integrated with other farm operations (BCFT 1953). Presently, the social forestry programmes have been taken up in the form of both commercial and non-commercial farm forestry. Farm Forestry is another name for agroforestry which is a part of social forestry. Commercial farm forestry: Commercial farm forestry is defined as the process under which farmers grow trees on commercial basis on farm lands (Negi 1986). It is usually undertaken in areas where there is a ready market of wood or other forest based products. FAO describes this as turning peasants into entrepreneurs and producers,

RURAL FORESTRY OR COMMUNITY FORESTRY

Community forestry is defined as raising of trees on public or community land rather than on privately owned lands as in case of farm forestry (Negi 1986). The common feature of this programme is to provide benefits or services to the community as a whole. This form of forestry is one of the approaches for tackling the problem of deforestation of village common lands brought about by the local people through mutual cooperation. The government has the responsibility of providing seedlings, fertilizer but the community has to take responsibility of protecting the trees. Some communities manage the plantations sensibly and in a sustainable manner so that the village continues to benefit. Some others take advantage and sell the timber for a short-term individual profit. Common land being everyone's land is very easy to exploit. Over the last 20 years, large-scale planting of Eucalyptus, as a fast growing exotic, has occurred in India, making it a part of the drive to reforest the sub-continent and create an adequate supply of timber for rural communities under the augur of social forestry.

URBAN FORESTRY

It is the practice of growing trees on non-forest land in urban areas for recreational purposes and aesthetic value.

EXTENSION FORESTRY

Planting of trees on the sides of roads, canals and railways, along with planting on wastelands is known as extension forestry for increasing the boundaries of forests. Under this programme, there has been creation of wood lots in the village common lands, government wastelands and Panchayat lands. Schemes for afforesting the degraded government forests that are close to villages are being carried out all over the country.

JOINT FOREST MANAGEMENT (JFM)

It is partnerships in forest movement involving both the state forest departments and local communities. Joint forest management is concept of developing relationships between fringe forest groups and forest department on the basis of mutual trust and jointly defined roles and responsibilities for forest protection and development. Joint Forest Management originated in West Bengal in 1988. National Forest Policy of 1988 and the Joint Forest Management Guidelines of 1990 of the Government of India have details for JFM operational procedures

Enlist Important case studies of social and community forestry in India

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Exercise No. 12

Objective: To study frame and procedure of Diagnosis and Design approach in agroforestry

Agroforestry D & D is a family of procedures for the diagnosis of land management problems and potentials and the design of agroforestry solutions. The ICRAF has developed an approach to assist agroforestry researchers and development fieldworkers to plan and implement effective research and development projects.

Key Features of D and D approach

i) ***Flexibility:*** D & D is a flexible discovery of procedure, which can be adopted to fit the needs and resources of different users

ii) ***Speed:*** D & D has been designed with the option of a 'rapid appraisal' application at the planning stage of a project with In-depth follow-up during project Implementation.

iii) Repetition: D & D is an open-ended learning process. Since initial designs can almost always be improved. The D & D process need not end until further Improvements are no longer necessary.

Basic logic of AF Diagnosis and Design

Basic question	**Key factors to consider**
Prediagnostic stage Which land-use system? How does the system work?	Distinctive combinations of resource technology and land-user objectives. Production objectives and strategy subsystems and components.
Diagnostic stage How well does the system work?	Problems in meeting objectives, causal factors, constraints, and intervention points.
Design and evaluation stage How can the system be improved?	Specifications for problem-solving or performance-enhancing interventions.
Planning stage How can the Improved technology be developed and disseminated?	D & D needs, extension needs.
Implementation stage How can the plan of action be adjusted to new information?	Feedback from research trials, independent farmer innovations etc.

Procedures of AF Diagnosis and Design

The procedures of AF D & D are usually done of three ways as per the scope and extent /

region of the study for agroforestry diagnosis and planning

i) MACRO D & D

An agroforestry research programme normally begins with a macro D & D exercise covering an entire ecological zone within a country. This consists of a rapid appraisal, based primarily on secondary information complemented by a few selected surveys in the field.Macro D & D includes on assessment of existing land use system constraints, agricultural policies and institutional arrangement, current agroforestry practices and the potential for improving productivity and sustainability through agroforestry interventions. The study zone is a broad region chosen for its importance at the national level.

ii) MESO D & D

It is carried out at lager area than micro for a larger landscape but not macro level. 4-6 villages or a regional basis.

ii) MICROD & D

A central aspect of macro D & D is the delineation of land-use systems within the chosen ecological zone, leading to the selection of target systems for more detailed analysis by micro D & Ds. A land-use system is defined as a distinctive combination of crops, livestock, trees and other production components.

The primary focus of analysis is the management unit that makes decisions and shares resources, objectives, labour and products. Analysis of a land-use system comprises all the characteristics that affect its management and performance.

Criteria of Good Agroforestry Design

i) Productivity: There are many different ways to improve productivity with agroforestry viz., increased output of tree products, improved yields of associated crops, reduction of cropping system inputs, increased labour efficiency, diversification of production, satisfaction of basic needs and other measures of economic efficiency or achievement of biological potential.

ii) Sustainability: By seeking improvements in the sustainability of production systems, agroforestry can achieve its conservation goals while appealing directly to the motivation of low income farmers , who may not always be interested in conservation for its own sake

iii) Adoptability: No matter how technically elegant or environmentally sound an agroforestry design may be, nothing practical is achieved unless it is adopted by its intended users. This means that the technology has to fit the social as well as environmental characteristics of the land-use system for which it is designed.

Develop a framework of D and D for agroforestry development in Bundelkhand region

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Exercise No. 13

Objective: To study the regulatory and ecological services of agroforestry-1

Important realized ecosystem services of agroforestry are well documented and the major ecosystem services delivered by agroforestry systems are categorized into:

- Microclimate Modification
- Soil Enrichment
- Soil Stabilization and Erosion
- Flood Mitigation Agroforestry for Water Yield and Quality
- Agroforestry and Pest Control
- Pollination Improvement.
- Carbon Sequestration and Air Quality
- Climate Change Mitigation
- Biodiversity Conservation Agroforestry for Aesthetics and Cultural Services

AGROFORESTRY FOR MICROCLIMATE MODIFICATION

Simultaneous growing of trees on farm land along with agricultural crops has the ability to modify the microclimatic conditions including temperature, water vapour content and wind speed, improvement of crop-water efficiency and energy balance which can have beneficial effects on crop growth and animal welfare (Brenner 1995; Jose et al 2004). Microclimatic modifications in agroforestry is manifested through soil moisture and soil temperature relations resulting primarily from the use of trees for shade, or as live supports and live fences, or windbreaks and shelterbelts. The shade of trees on farm land in tropics causes a net effect of complex interactions which extend far beyond the simple reduction of heat and light (Willey 1975). In crop production system, temperature, humidity and movement of air, as well as temperature and moisture of the soil, directly affect photosynthesis, transpiration and the energy balance of associated crops (Rosenberg et al 1983) and the net effect of which may translate into increased yields. Presence of trees on farm land would have blanket effect on soil surface. In general. Shading causes a reduction of temperature and temperature fluctuations as well as the vapour pressure deficit under tropical conditions.

In wheat based farming system of Punjab (India), yield reduction due to higher temperatures during reproductive stage is often mitigated through introduction of trees on farm land. Tree row orientation and distance influence the growth behaviour of the crop but the effect of sun angle (which changes with season) can modify this influence. Lower heat load during grain filling and subsequent increased duration of grain filling case mitigate the effect of quantitative reductions in radiant energy and of poor quality light during the initial stages of crop growth (Kohli and Saini 2003). In this context, the use of deciduous trees such as Dalbergiasissoo, Trewianudiflora, Populusdeltoides and Sal alba with leaf fall coinciding with the vegetative stage of the crop could be a good proposition for agroforestry. Tree canopy

pruning as a management tool can also be advocated to provide a favourable microclimate to the intercropped wheat.

Reduction of wind on farm land has significant effect on farm production. Wind speed reductions can extend to 30 times the height of tree belts on the leeward side (Tamang et al 2010).Thus agroforestry, under any given set of environmental conditions, can improve the microclimatic conditions when proper selection of tree species, optimizing the tree spacing and proper root pruning as well as shoot pruning are made a part of the technology for crop growing in agroforestry.

AGROFORESTRY FOR SOIL ENRICHMENT

Land degradation and declining soil fertility pose a major peril to agricultural production. Use of artificial or synthetic fertilizers to augment soil nutrient status could not succeed to afford satisfactory result because majority of the commercial fertilizers are expensive or unavailable in majority of poor developing countries in tropics. Incorporation of trees in the farm land can facilitate the sustenance of the nutrient pool and enhance soil fertility both under sequential and simultaneous agroforestry (Young 1997). Intermixing of trees that are able to fix nitrogen biologically along with crops is fairly common in tropical agroforestry systems. Non N-fixing trees can also enhance soil physical, chemical and biological properties by adding significant amount of above and belowground organic matter and releasing and recycling nutrients in agroforestry systems (Jose 2009). Influence of trees in enhancing the soil fertility status has been described by several researchers (Young 1997; Nair and Latt 1997; Schoth and Sinclair 2003; Jose et al 2004). Agroforestry promotes closed system with internal recycling of nutrients, whereby nutrients are accessed from lower soil horizons by tree roots and returned to the soil through leaf fall, agroforestry systems enhance soil nutrient pools and turnover and reduce reliance on external inputs.Trees on farm land play a crucial role in improving soil physical and biological properties (Rao et al 1998). One of the important roles of trees in agroforestry is the enrichment of organic matter in the system. Role of organic matter in enhancement of soil physical properties such as soil structure, aggregation, porosity, moisture retention, and erosion resistance is well documented. Apart from enrichment of soil nutrient status, trees on farm land can reclaim the degraded soils. Tejwani (1994) reported that salt affected farm lands could be reclaimed through agroforestry. Introduction of trees on farm lands significantly enhanced diversity of birds, insects, and earthworms; increased soil organic carbon content and N cycling; and improved soil health (Thevathasan and Gordon 2004).

The mechanisms by which trees in agroforestry improve soil physiochemical and biological properties are as follows:

- Release of nutrients from tree litter and prunings.
- Nitrogen input through biological nitrogen fixation (through N-fixing trees) Phosphorus input through mycorrhizal associations.
- Reduced soil erosion and nutrient leaching.

- Nutrient capture from the subsoil through deep-rooted trees Redistribution of nutrients through lateral roots of some trees.

AGROFORESTRY FOR SOIL STABILIZATION AND EROSION CONTROL

Soil management is a key feature of agroforestry systems, and in both tropical and temperate climates, agroforestry systems are designed and implemented to counter soil erosion and degradation, and improve soil quality and health. Trees on farm land play a crucial role in soil stabilization and erosion control. The probable role of trees in soil conservation can be perceived in the following way:

• Increase of soil cover, by litter and prunings

• Provision of partly permeable hedgerow barriers

• Lead to the progressive development of terraces, through soil accumulation upslope of hedgerows

• Increase soil resistance to erosion, by maintenance of organic matter Stabilization of earth structures by root systems

AGROFORESTRY FOR FLOOD MITIGATION

Changes in climate and weather patterns are having a dramatic impact on ecosystem - based livelihoods, especially in agriculture, a key source of income for majority of the countries in tropics. One factor contributing to household vulnerability is the use of monoculture production systems, which lead to reliance on one crop for income. Agricultural diversification, particularly when undertaken in relation to environmental or economic risks, has the potential to increase household adaptive capacity under climate change (Smit and Skinner 2002) and contribute to agrobiodiversity and the sustenance of vital functions, structures, and processes in agroecosystems (Mijatovic et al 2011).The integration of trees into cultivated land, or agroforestry, is one approach to agricultural diversification that has been shown to provide a range of potential benefits. Agus et al (2003) found that tree-based farming systems maintain most of the flood mitigation capacity exerted by forest. Trees, undergrowth and woody debris on farm land would increase "hydraulic roughness" of the flood plain slowing down the passage of flood flow. On farm land, trees and woody debris could direct or concentrate flows forming multiple channels and back water floods enhancing flood storage that could result in net effect of delayed and reduced size of flood peak. Thus, risk of flash flooding following periods of heavy rainfall could be reduced in agroforestry systems, with the tree roots and trunks acting as permeable barriers to reduce sediment and debris loading into rivers following floods.

AGROFORESTRY FOR WATER YIELD AND QUALITY

Civilization on the earth began by felling trees, further development and advancement in civilization resulted in clearing natural forests to grow crops or to build infrastructure to human

habitation. In the recent past, most of the developmental activities in tropical countries are being undertaken at the cost of natural forests. Clearance of forests for expansion of agriculture, development of infrastructure for industry and human settlements, and urbanization resulted in reduction of water that enters the soil and increase in the overland mud stream flow. Scarcity of land in certain regions lead to building on floodplains and wetlands which can reduce water storage and buffer capacity and put the new developments at risk of flooding. Additionally, human habitation and industry can lead to streams becoming polluted while increasing the demand for clean water. Thus, the need to increase water productivity and quality is a growing global concern as the demand for water will increase every year.Trees on farm land increase the water-holding capacity of the soil, reduce soil evaporation, increase water infiltration into the soil (Nair 1993), and efficiently capturerainwater compared with traditional agricultural practices (Lott et al 2003).

Trees on farm land are useful in reducing the water requirement of the production system. The shade provided by the trees requires the plants being grown beneath them to be watered less. Also, the presence of tree on farm land reduces loss of water through evapotranspiration from the farm land. Trees can increase the quantity of water used on- farm for tree or crop transpiration and may also improve the productivity of the water that is used by increasing the biomass of trees or crops produced per unit of water used. Recently, it has been proposed that trees can efficiently increase water productivity, particularly under semiarid regions (Ong and Swallow 2003; Ong et al 2007).Agroforestry also improves water-use efficiency and increases environmental sustainability. Combination of trees with agricultural crops in agricultural production system can contribute considerable hydrological services.

AGROFORESTRY FOR CARBON SEQUESTRATION AND AIR QUALITY

Agroforestry is one of the important land use systems which has both annuals and woody perennials. The role of land use systems, such as agroforestry as a climate change and adaptation strategy, has gained considerable importance lately following the realization of the ability of these systems to capture atmospheric carbon dioxide and store the carbon in plant parts and soil (Nair 2012). Agroforestry systems have attracted particular consideration in view of their perceived advantages of the large volume of aboveground biomass and deep root systems of trees. The potential of agroforestry seems to be substantial, but it has not been even adequately recognized and exploited. Proper design and management of agroforestry practices can make them effective carbon sinks. As in other land use systems, the extent of carbon (C) sequestered will depend mainly on the amounts of C in standing biomass and recalcitrant C remaining in the soil. The potential of agroforestry systems to sequester carbon varies dependingupon the type of the system, species composition, and age of componentspecies, geographic location, environmental factors, and management practices (Jose 2009).

Another indirect avenue of C sequestration is through the use of agroforestry technologies for soil conservation, which could enhance C storage in trees and soils. Agroforestry systems with perennial crops may be important carbon sinks, while intensively managed agroforestry systems with annual crops are more similar to conventional agriculture. In order to exploit this vastly unrealized potential of C sequestration through agroforestry in both subsistence and commercial enterprises in the tropics and the temperate region, innovative policies, based on rigorous research results, have to be put in place (Montagnini and Nair 2004).

AGROFORESTRY FOR CLIMATE CHANGE MITIGATION

It is explicit that the earth's climate is changing at an unprecedented rate which is the result of increased emission of greenhouse gases to the atmosphere both directly and indirectly by the anthropogenic activity. Climate change will have consequences for farmers all over the developing world. These effects will play out over long periods of time, while farmers and policy makers tend to have relatively short planning horizons. The effects of climate change are geographically inequitable, varied and unpredictable with potentially devastative for the existence of life on earth chiefly human survival. Plants are of particular importance as they are major regulators of global climate and are the keystone of the carbon cycle. The uptake of carbon dioxide (CO2), one of the principle greenhouse gases, during photosynthesis is the major pathway by which carbon is removed from the atmosphere and made available to animals and humans for growth and development. Agroforestry which combines woody perennials along with agricultural crops has potential role in climate change mitigation.Agroforestry offers a potential as biomass energy provider and has the potential to reduce reliance on fossil fuel consumption in a number of ways. Production of firewood from arable or grazing land or by product of timber production presents interesting opportunities in CO, mitigation through the substitution of fossil energy consumption by using wood as energy sources and the protection of existing forests and other natural landscapes. Biomass energy from agroforestry is a carbon-neutral source of energy that doesn't contribute to CO, enrichment of the atmosphere

Agroforestry practices in the humid tropics are part of a continuum of landscapes ranging from primary forests and managed forests to row crops or grasslands. In agroforestry systems, there is a reduced need for supplementary nitrogen applications. and recycled nitrogen from leaf litter provides a quantifiable contribution to adjacent crops that can replace inorganic N additions and thus reduce N2O emissions. A decrease in nitrogen leaching out of the rooting zone will reduce NO, emissions as a result of denitrification in surface water resources.

AGROFORESTRY FOR BIODIVERSITY CONSERVATION

Agroforestry is increasingly being acknowledged as an integrated land use that can

directly enhance biodiversity and contribute to the conservation of landscape biodiversity. Biodiversity plays a vital role in sustaining human life and the health of our planet. Biodiversity is defined as the totality of genetic, species and ecosystem diversity that constitutes life on Earth. Biodiversity which contributes immeasurably to the sustainable production of many goods and services is continued to decline at an alarming rate. Some of the important responsible factors for the current affairs of biodiversity are overexploitation of species, invasion by alien species, environmental pollution and contamination, global climate change, alteration of ecosystems, and degradation and loss of habitats (Rands et al 2010). Alarming rate of important ecosystems and species disappearance in sustaining human life and the health of our planet called for immediate action to conserve biodiversity worldwide. Several researchers documented and elucidated the mechanism of agroforestry in enhancing the biodiversity

Agroforestry systems by their very nature are more diverse than monocultures of crops and livestock; this increase in 'planned' biodiversity, i.e. the components chosen by thefarmer, increases the 'associated' biodiversity i.e. the wild plants and animals occurring on the farm land. Role of agroforestry in conserving tropical biodiversity has been documented by the various researchers of the world. These studies demonstrate that agroforestry systems support floral and faunal assemblages that can be as species-rich, abundant and diverse as forests, but often with modified species compositions that include non-forest species (Harvey et al 2007). Thus, in agroforestry integration of trees and livestock on farm land increases biodiversity, this varies with land management practices, cropping pattern and arrangement of different components.

AGROFORESTRY FOR AESTHETICS AND CULTURAL SERVICES

The visual impact of monocultures of crops or trees is unattractive for many people and in agroforestry integration of trees into agricultural landscapes can increase the diversity and attractiveness of the landscape (McAdam et al 2008). Traditional agroforestry systems such as traditional homegardens, tree based coffee farming, grazed orchards, parkland and wood pastures are valued for their visual appeal. However, establishing modern agroforestry systems which tend to be more artificial, geometric and rigid in appearance than traditional systems causes aesthetic changes at a landscape scale, and such changes must be carefully considered in the design and location of such systems (Bell 2000

Thus, agroforestry can sustain human life through production of food, wood and in addition to environmental services such as climate change mitigation, enhanced water quality and quantity, and biodiversity conservation. Today, the provision of ecosystem services generally, and the subset of environmental services in particular, is being challenged as never before by the combined effects of expanding populations, rapid economic growth and greater global integration. A mechanism should be developed to generate growing interest in agroforestry through payment for such ecosystem services

Develop a framework of ecological and environmental services from agroforestry for calculating ecological economics

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Exercise No. 14

Objective: To study the regulatory and ecological services of agroforestry-2
Develop a framework of ecological and environmental services from agroforestry for calculating ecological economics

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Exercise No. 15

Objective: To study Rapid Rural Appraisal (RRA) and PRA (Participatory Rural/Relaxed Appraisal) tools in agroforestry problem diagnosis.

RRA is an extractive research methodology consisting of systematic, semi-structured activities conducted on-site by a multi-disciplinary team with the aim of quickly and efficiently acquiring new information about rural life and rural resources.

Rapid Rural Appraisal

RRA is a social science approach that emerged in the late 1970s. The basic idea of RRA is to rather quickly collect, analyse and evaluate information on rural conditions and local knowledge. This information is generated in close co-operation with the local population in rural areas. Therefore, the research methods had to be adjusted to local conditions, i.e. they had to meet the communication needs of illiterate people or people who are not used to communicating in scientific terms.

Tools like mapping, diagramming and ranking were developed or improved in order to gather information for decision-makers in development agencies. One of the key principles of RRA is the visualisation of questions and results by using locally comprehensible symbols. A main reason for developing RRA was to find shortcuts in the search for relevant information on rural development issues in order to avoid costly and time consuming research procedures.

In most of the cases RRA is carried out by a small team of researchers or trained professional in one to three days in a kind of workshop. The role of the local population in RRA is to provide relevant local knowledge for research purposes and development planning. The RRA team manages the process and maintains the power to decide on how to utilise this information.

Participatory Rural/Relaxed Appraisal

During the 1980s, PRA was firstly developed in India and Kenya, mainly supported by NGOs operating at grass-roots level. Until today PRA evolved so fast in terms of the methodology, the creation of new tools and specifically in the different ways it is applied.

Compared to RRA which mainly aims at extracting information, PRA places emphasis on empowering local people to assume an active role in analysing their own living conditions, problems and potentials in order to seek for a change of their situation. This changes are supposed to be achieved by collective action and the local communities are invited to assume responsibilities for implementing respective activities. The members of the PRA team act as facilitators. Here it is no longer the external experts but rather the local people themselves who “own” the results of a PRA Workshop. Consequently an important principle of PRA is to share the results of the analysis between the PRA team and the community members by visualisation, public presentations and discussions during meetings.

Most PRA workshops last from 3 to 5 days and the planning of the workshop and the facilitation of tools is done in a multidisciplinary team of insiders and outsiders which is gender balanced.

Some Principles that are shared by PRA and RRA:

· **Offsetting biases** through different: perspectives, methods and tools, sources of information, people from different background and places, background of team members (spatial, person, gender, age groups, interest groups, key informants, wealth groups, seasonal, professionals, disciplines)

· **Rapid and Progressive Learning:** (flexible, interactive)

· **Be Gender sensitive** at all times

· **Reversal of roles** (Learning from, with and by local people, eliciting and using their symbols, criteria, categories and indicators; and finding, understanding and appreciating local people's knowledge)

· **Focussed Learning:** (not finding out more that is needed and not measuring when comparing is enough. We are often trained to make absolute measurements and to give exact numbers, but often relative proportions, trends, scores or ranking are all that is needed for decision making and planning of activities)

· **Seeking for diversity and differences:** People often have different perceptions of the same situation!

· **Attitude:** In order to make the PRA or RRA workshops an success it is most important build a positive relationship with local women and men. Outsiders must have an attitude of respect, humility and patience, and a willingness to learn from the local people.

Exercise No. 16

Objective: To Prepare Resource map of agroforestry and other supporting components for a village area

Resource Map

The Village Resource Map is a tool that helps us to learn about a community and its resource base. The primary concern is not to develop an accurate map but to get useful information about local perceptions of resources. The participants should develop the content of the map according to what is important to them.

To learn the villagers' perception of what natural resources are found in the community and how they are used.

Key Questions:

1. What resources are abundant?
2. What resources are scarce?
3. Does everyone have equal access to land?
4. Do women have access to land?
5. Do the poor have access to land?
6. Who makes decision on land allocation?
7. Where do people go to collect water?
8. Who collects water?
9. Where do people go to collect firewood?
10. Who collects firewood?
11. Where do people go graze livestock?
12. What kind of development activities do you carry out as a whole community? Where?
13. Which resource do you have the most problem with?

Specialists from biophysical and socioeconomic fields including soil science, agronomy, horticulture, animal science, forestry, agricultural economics and rural sociology or anthropology. All team members should have experience in both research and extension work. To ensure that the results of the D & D exercise are taken fully into account, the scientists who carry out the D & D should participate at least in the design and analysis and, better still, also in the implementation of the ensuing research programme. The characteristics to be studied include the following:

- Location: Administrative and political divisions
- Environmental characteristics:
- Socio-economic characteristics
- Land-use:
- Resources/supporting service
-Development activities and policies.

Develop a framework resource map

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