FOREST ECOLOGY

LECTURE NOTES, STUDY OBJECTIVES, AND FIELD EXERCISE

prepared for

M.SC. Forestry Classes

PAKISTAN FOREST INSTITUTE

Peshawar

by

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Sept. 1992

INTRODUCTION

Forest ecology is one of the most important courses you will take during your Masters degree program. Most other courses including forest, range, wildlife, and watershed management are based upon the application of ecological principles.

These instructional materials were developed as a supplement to lectures I gave in the forest ecology course presented to the M.Sc. class of 1993. Three sections are included, lecture notes, student study objectives, and a field exercise.

The Lecture Notes are linked to the textbook, Forest Ecology, by J. P. Kimmins. Figures and tables referenced in the notes as Fig., or T, or in bold type refer to those in the textbook. Bringing the textbook to class is very helpful because the figures and tables can be discussed with students having a copy at hand.

The Lecture Notes have blank facing pages so that you can add more notes from your reading and lecture. Upon completion of the course you will have an ecological reference that may help you in other courses, or in your career.

The Student Study Objectives identify specific topics you should know in order to achieve an understanding and mastery of that section. You should continue your study until you can respond to each point identified by these objectives.

Ecology is a field science. The Field Exercise was added to introduce you to making ecological measurements, obtaining data in the field, and interpreting that data. I hope that more field exercizes will be added to this one in the future.

The final draft of these instructional materials benefitted from the editing skills of my wife, Jackie Cohen. The assistance of Mr. Asif Kamal in the preparation and publication is greatfully acknowledged. The preparation of these instructional materials was supported by the Forest Planning and Development Project, funded by the U. S. Agency for International Development through a contract awarded to Winrock International.

Mark Behan, Ph. D.
Peshawar, September 1992

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SECTION ONE

LECTURE NOTES

PART I - A

MAN AND THE FOREST

Key Points:

I. Human influence in the forest. Humans are the most important determinant of future impacts on forests because of their population size, attitudes, and demands on forest products.

II. Forest crops planted today will be harvested in about fifty years or more. How can the forest manager predict future forest product needs?

III. Man's Evolutionary Development. Humans have undergone several transitions during evolutionary history, and these changes have an impact on current conditions. Selective processes during our evolution have favored: habitat flexibility, i.e. being able to shift from an arboreal habitat to a grassland habitat; the development of tools to compensate for the lack of physical strength and speed of ground-dwelling carnivores; effectiveness as a hunter, so much so that many species became extinct because of over-exploitation; shift of subsistence from hunting to food gathering to farming; cultural development of communications, accumulation of knowledge, division of skills.

IV. Human Population Growth

A. Causes of population growth

1. In ancient times

a. Improved diet, first from improved hunting skills (tools), then improved farming beginning with the hydraulic societies (e.g. the Indus), and after invention of the moldboard plow, farming the heavier but more fertile soils of Europe

b. Improved yields from crop rotation - the alternative to leaving fields fallow; wheat-turnip-barley-clover

c. The increased efficiency of crop production freed a portion of society from farming for the labor and capital required for the industrial revolution.

2. In modern times

a. Increased availability of food

b. Reduced juvenile mortality (food, shelter, medicine)

c. These factors released man's great reproductive potential by decreased juvenile mortality, caused by:

i. Female egg potential - about 400 at birth

ii. Reproductive period from about 12 to 45 years, an extremely long period

iii. Estrus every 28 days, an extremely short period

iiii. Continuous sexual receptivity, which helps insure family stability during the long period of juvenile dependency, but also encourages pregnancies.

v. Human population growth patterns are in the ecological category of a species subject to high juvenile mortality and population catastrophe, retaining the potential for explosive growth to rapidly exploit new habitats and compensate for juvenile mortality. The dilemma is the absence of new habitats, and reduced juvenile mortality.

B. Limits to Population Growth

1. Malthusian limits: aggression, war, disease, pestilence, starvation, lack of water, space, shelter---but for the limit to be effective it must control the pre-reproductive and reproductive age class....not merely shorten life expectancy

2. Planned population control

a. Delayed family formation

b. Fewer children

a. increased juvenile survival - community health

b. old age security

c. The Chinese solution: one child per family

d. Increased spacing between children to insure each child receives the best care possible

3. Population growth will continue far into the future even if full family planning (i.e. 2.01 children/family) is initiated immediately. This is because of the population age structure, e.g. of Nepal, Europe, the U. S.

V. Effects of Population Growth of Forests

A. The current world timber famine

Area of Closed Forest in 1978 - 2.6×10^9 ha; in 2000 - 2.2×10^9 ha

Tropical deforestation for food: 11-30 million ha per year

B. Devaluation of timber value in developing (and developed) countries (Pakistan, U. S., Japan)

VI. Relentless human growth demands successful, sustained forest management based upon ecology - the relationship between organisms and their environment

PART I - B

HISTORY OF FORESTRY

I. Human Dependence on Forests

A. Ancient times

1. Arboreal habitat - food and protection

2. Post-ice age use of wood for fuel, shelter, protection, food storage, in cold winter climates

3. Forest clearing for food production

4. Excess food production stimulated trade

a. Wooden boats, animal carts, transportation

b. Wars for control of land

B. Recent times

1. Exploration and exploitation of forests

a. Timber for trade -building material, ships,paper

b. Timber for warfare

2. Recognition of other forest values

a. Watershed, wildlife, fodder, medicinal

b. Recreation, inherent value

C. Human impacts on forests

1. Patch agriculture - conversion of forests to crops

2. Warfare - boats, siege equipment

3. Grazing and fire for food production

4. Permanent loss of forests

5. Loss of soil

6. Deforestation to support metal production

II. Development of Forestry

A. The six stages of forestry development:

1. Unregulated exploitation of forests with no thought for depletion or conservation

2. Perception of real or threatened future shortages of forest resources

3. Exploitation of undepleted forests at more remote locations (stages 1 and 2 repeated) or

4. Institution of simple, non-ecological regulations concerning forest cutting and management

5. Realization that simple administrative dictates cannot ensure future supplies of forest resources

6. Initiation of a continuing development of ecologically based forest-resource conservation and management practices, usually accompanied by increasing success in the conservation and production of forest crops

B. Examples:

1. Ancient Egyptian forestry - stage 2, 3

2. Greek and Roman forestry - stage 2,3, then deforestation, substitution of horses and cows for sheep and goats as the land became less fertile, soil erosion causing the loss of growth potential for forests

3. Japan? U. S.? India? Pakistan? Brazil?

C. The Tragedy of the Commons

1. The management strategy that develops when natural resources become scarce, but there is a lack of identity of ownership. Since no one owns the land, everyone exploits it until it is destroyed.

2. Wood lot development in India now beginning to work because village people (instead of the government) are made responsible for its success and its benefit

3. Reforestation in Nepal successful under local control

4. Riverain forests in Pakistan face difficulty because of questionable land transfers to private parties

5. Coniferous forests in Swat may continue to be over-exploited unless government becomes more firm, or more likely, local people become involved.

D. Predictions of Forest Depletion

1. Thailand - 1952 - 58% covered by forest; 1973-39%, 1978-33%, Afghanistan - 0% forests by 1995, Malaysia - 0% forests by 2,000, Nepal - 0% forests by 2,000, Pakistan, 1992-5% covered by forest; 0% by ??

Predictions can error if conditions change, in situations where afforestation => deforestation; but uncontrolled deforestation has, throughout history, destroyed the ability of the region to support forests, mostly through soil erosion.

III. Forest Ecology - Dealing with Complexity

A. Forest ecology provides the basis for forest management by allowing predictions to be made concerning the result of management practices. The forester must make predictions because there no longer is the luxury of waiting to see the outcomes.

B. Biological events, including forest practices, are the result of antecedents, events, causes, or previous conditions. If the antecedents are known, predictions can be made.

C. The probability of accurate predictions decreases with an increase in the number of antecedents. Forests are composed of a number of potential antecedents, illustrated by the expression:

Vegetation = f(soil,climate,parent material, topography,biota, time)

Making forest predictions requires reasoned estimates of the effect of each of the probable antecedents. The illustration of predicting landslides resulting from clearcuts illustrates this point.

D. The Foresters responsibility: Establish a set of forest management objectives; develop methods of achieving the objectives based upon the biological capabilities and tolerances of the ecological system under management.

PART II

THE ECOSYSTEM CONCEPT and ECOLOGICAL ENERGETICS

I. THE ECOSYSTEM CONCEPT

A. Identify the levels of biological organization hierarchy that are of ecological concern. Assign the name of a sub-division of ecology associated with each level in the ecological hierarchy.

B. The ecosystem concept includes six major attributes: structure, function, complexity, interaction and interdependency, no inherent spatial dimension, and temporal change. Describe each of these attributes.

C. Compare the traditional view with the ecosystem view of ecology.

D. Explain why it is difficult to make predictions at one level of biological organization using information gathered at another, especially in ecology.

E. Why is the ecosystem concept especially important in forestry?

II. ECOLOGICAL ENERGETICS

A. As energy flows through an ecosystem it enters primarily as light, it may be stored as chemical energy (e.g. wood), transferred (e.g. from wood to a beetle), and eventually, in a natural ecosystem, leave the ecosystem in the "degraded" form of energy as heat.

Heat is a "degraded" form because it is the most difficult form of energy to capture and transform into other forms of energy.

The forester attempts to manipulate energy capture, transfer, and storage in order to achieve management objectives, e.g. wood production.

B. Define the energy source for: autotroph (producers), photoautotrophs, ,chemoautotroph, heterotroph (consumers), herbivores, carnivores, omnivores, saprotrophs

C. As an exercise organize a four-level trophic chain

D. Explain the difference between a trophic chain and a trophic web. Which is more realistic in ecosystems?

E. Explain the difference between ecological pyramids based upon numbers, biomass, and energy content. Which type most accurately represents ecosystem function? How can inverted pyramids occur?
F. Explain an energy flow diagram. Discuss how changes in energy flow can affect biomass accumulation in a forest.
G. Organisms in an ecosystem may be categorized by trophic levels. Trophic levels may be arranged as pyramids of numbers, biomass, or energy. Pyramids of number and biomass usually taper upwards through the trophic levels, but they can be inverted if energy flow is more rapid through a lower trophic level. Energy pyramids are never tapered because an inverted energy pyramid would violate the 2nd law of thermodynamics.
Energy flow diagrams assist in modelling ecosystems and allow predictions of impacts such as respiration, grazing, and disease loss to be considered.

III. PRIMARY PRODUCER TROPHIC LEVEL

A. Definitions:

<u>Crop</u>: harvestable volume or weight over a given time; varies 3-fold on definition of which plant parts are to be included.
<u>Standing crop</u>: Biomass in an area at one moment
<u>Yield</u>: rate of accumulation of harvestable crop
<u>Production</u>: analogous to crop
<u>Gross production</u>: total carbon accumulation
<u>Net production</u>: Gross production less respiration loss
<u>Primary production</u>: plant production
<u>Secondary production</u>: higher trophic level production
<u>Biomass</u>: Standing crop
<u>Productivity</u>: production per unit time

B. Producer Trophic Level

1. Input - Photosynthesis (Ps)

a. Ps efficiency:

Production of biomass/incident radiant energy x 100

i. Variables: area to be measured, season, photosynthetically active radiation (PAR), leaf absorption efficiency

ii. Ranges: 1-6% of incident radiation converted to primary production

b. Leaf Area Index (LAI) Leaf area per unit ground determines effectiveness of plants in absorption of PAR. Ideal value: 4 m^2 leaf m^{-2} ground. (Fig. 4.9)

2. Losses

a. Respiration (Table 4.2)

i. Ranges: 15-90%

ii. Variables: night time temperature, size,rate of growth and physiological condition of plants (e.g. stand age)

b. NET PRIMARY PRODUCTION (NPP) = GROSS PRIMARY PRODUCTION - RESPIRATION

c. Herbivore Consumption (Table 4.3)

i. Variables: portion of above ground parts that are palatable

ii. Termites - 37% NPP; 28% world NPP

iii. Defoliating insects - energy pulses throughout trophic levels

iv. Herbivory in forest ecosystems: litter decomposition, mineral cycling, stand age replacement, monoculture, tropical systems

d. Litter fall (Table 4.4): Variables:

i. boreal< temperate> tropical

ii. foliage retention - evergreen

iii. other: altitude, climate, soil moisture and fertility , season - before cold or drought period, continuous

e. Below ground turnover - root replacement

3. Summary - Old Forest Energetics - Table 4.6

4. Estimates of Productivity - Tables 4.5, 4.7

Causes for variation: LAI, diversity, fertility, climate, community respiration

C. Net Primary Productivity of Forests

1. Effects of stand age, foliar respiration, stem biomass, stand respiration

2. Effect of ecosystem type: grassland, forest, crop land

D. Primary Consumer Trophic Level (Herbivores)

1. The rule of tens in trophic level transfer of energy; about 10% of the energy available at one trophic level appears as productivity on the next level

2. The equations and flow of energy from one trophic level to the next is controlled by: amount of energy available in the previous trophic level; amount ingested; amount assimilated; and amount lost to respiration. Each transfer has losses, but animals vary greatly in efficiency of transfer. (Fig. 4.11)

3. Utilization efficiency - horses and goats

4. Assimilation efficiency - food selection; ruminants

5. Tissue growth efficiency - terrestrial animals, invertebrates

6. Ecological growth efficiency - hummingbirds, sparrows, carp, chicken

E. Detritus Trophic Chain

1. Detritus trophic web accounts for most of the post-producer energy flow in forests, but it is often overlooked

2. Saprotrophic organisms include vertebrates (vultures, hyenas), invertebrates (craps, worms, millipedes), bacteria and fungi. Soil mesofauna initiate decomposition by fragmenting litter; microfauna further decompose the litter; and bacteria and fungi may reduce organic matter to mineral matter (Fig. 4.12)

3. Bacteria dominate in the higher pH and base ion rich litter of angiosperms; fungi dominate in the more acid conifer litter.

4. Litter decomposition is affected by moisture, temperature, pH, O_2, abundance of soil fauna, chemical and

physical nature of litter, relative abundance of fungi and bacteria

5. Residence time (the index of decomposition):

forest floor weight/annual litter fall.

Residence time is decades in coniferous forests, years in deciduous forests, nearly seasonal in the humid tropics.

6. There are trophic levels in the detritus food chain as well as in the grazing food chain.

F. Photosynthetic (Ps) efficiency of forests

1 Canopy closure occurs when LAI =>4, the maximum LAI efficiency

2. Light intensity; apparent increase in Ps efficiency at lower light intensity may be temperature effect

3. Nocturnal CO_2 retention of forests (compare crops) causes higher daytime CO_2 and this stimulates Ps.

G. Leaf area and forest growth (Fig. 4.14)

1. Correspondence of LAI and vegetation across moisture transect, precipitation, elevation, water balance index, basal area of sapwood (Fig. 4.15, Table 4.14, 4.16)

2. Increase of LAI > 4 does not show linear relationship with productivity: increasing portion of leaves in deep shade; foliage as nutrient reservoir

H. Energy cost/benefit ratios of forest production (Table 4.15)

1. Tallying cost/benefit ratios may be used to analyze the economic feasibility of forest practices

2. Regardless of costs of intensive forest management, cost/benefit ratios of tree growth generally exceed by a great deal those of agriculture (benefits of agroforestry!) (Fig. 4.18)

I. Energy relations of clearcutting

1. Massive reduction in biomass - 700-3,500 t ha^{-1}, amounting to 1,000+ t ha^{-1} coal

2. Detritus food chain change

a. Reduction in forest floor

i. decreased litter fall

ii. accelerated decompositions

iii. Factors: water (5-80%), temp (2-40º), aeration, pH (increases after clearcutting), food supply (C/N ratio 25:1; wood 500:1; foliage 60:1)

iv. water and nutrient storage capacity

v. grazing food web change

Conclusions:

Forest productivity can equal and generally exceed agricultural production

There is virtually no Himalayan/Asian data! This is a serious lack because in much of the area where data was gathered the winters are wet and the summers dry. In the Himalaya the monsoons reverse this pattern.

PART III

BIOGEOCHEMISTRY

INTRODUCTION

I. Biogeochemistry: the study of the accumulation, storage, transfer, recycling, distribution, and dynamics of mineral nutrients in ecosystems. Nutrient activity is closely linked to organic matter activity and energy flow, thus to productivity.

II. Types of Cycles:

A. Geochemical cycles: exchanges of chemicals between ecosystems - marine sediments to land, streamflow transport, CO_2 transport across ecosystems

B. Biogeochemical cycles: transfers and exchanges of chemicals within an ecosystem - litter decomposition, foliar leaching, retention and accumulation of nutrients in an ecosystem

C. Biogeochemical cycles: redistribution of minerals within an individual organism - nutrient redistribution before litter fall, during fruit and seed development, before dormancy

III. Nutrients found in plants (Table 5.1)

A. Essential nutrients

1. Macronutrients C, H, O, P, K, S, Ca, Fe, Mg
2. Micronutrients B, Zn, Mo, Mn, Cu (Cl, Si, Co, etc)

B. Other - U, Au, Na, etc

C. Acquisition of nutrients

1. Root exploration of the soil solution
   a. Selective absorption
   b. Concentration many fold above soil solution

D. Nutrient deficiencies (Fig. 5.2)

Deficiencies result in decreased growth or reproductive performance. There is a relationship between concentration in the foliage and growth - designated as deficiency, transition, adequate, and luxury

E. Forest Nutrition

Forests generally occur on infertile soils. Most forests adapt to this by phased allocation of nutrients during the season (e.g. allocation to expanding buds in the spring and cambial growth latter), pulsing high demand activity (e.g. "mast" years of seed production), and frugal recovery of minerals before litter fall.

Nutrient requirements vary between forest types, e.g. pines are generally more tolerant of infertile soils than hardwoods (pines on ridges and hardwoods in valleys), some species are calcium dependent and some avoid calcium soils, some species prefer acid soils and others neutral soils

IV. Herbivore nutrition

Most grazers selectively consume the most nutritious plant parts, organic nitrogen (protein) is more important for most herbivores than carbohydrate, plant parts and species differ in palatability, herbivores differ in mineral requirements - ruminants (e.g. cattle) are much more efficient than non-ruminants (e.g. horses), animal distribution is controlled by plant distribution, animal - plant ecological relationships e.g. white bark pine and grizzly bears, lodgepole pine and squirrels.

THE GEOCHEMICAL CYCLE

Nutrient Cycling Between Ecosystems

Although the term "cycle" implies a return to the place of origin, "returns" between ecosystems may occur only at geologic time intervals, if at all. This section considers the circulation of minerals at the global ecosystem level.

I. Gaseous cycles

C, N, O, H, and S all have gas, liquid, and solid phases. Their global circulation patterns are as gases. Many pollutants have been introduced into the gas phase including SO_2 and acid rain, fluorinated hydrocarbons and the ozone layer, and CO_2 and methane and global warming.

II. Sedimentary cycles

A. Meteorological mechanisms - Table 5.2

Some minerals are transported from one ecosystem to another in dust, precipitation, wind, and water erosion. Examples include loess soil formation, volcanic dust, salt spray from the sea, and minerals in rainfall.

The quantity of minerals transferred by meteorological mechanisms may be sufficient to supply the requirements of slowly growing species.

B. Biological Mechanisms

Minerals may also be transported by plants as pollen and plant parts, seed, or by birds (return of P from the sea as guano), fish (return of N and P from sea-going fish such as salmon), animal migration (gazelles, caribou, cattle penned in holding stalls and fed fodder gathered in the forest). Man is a major transporter of nutrients through fertilizers, man-induced erosion, and transport of crops.

C. Geologic-Hydrologic Mechanisms

1. Minerals may become available or circulate through the geologic processes of weathering, erosion, and solubilization.

2. Minerals are transported by streamflow

Biogeochemical Cycles Within Ecosystems

I. Nutrient Uptake by Plants

A. From the soil solution

1. by roots

2. by mycorrhiza, which increase mineral availability, have increased ability to absorb and concentrate minerals, and is the normal mode of absorption in forests

B. Quantity of nutrients taken up by plants (Table 5.4)

1. Fertile and infertile soils

2. Stand age

3. Litter decomposition rate

4. Nutrient immobilization in litter and heartwood

II. Nutrient Distribution in Plants (Fig. 5.5,5.6)

A. Type of forest - deciduous forests high overall, especially in Ca

B. Foliage content varies with age and position

III. Nutrient losses from plants (Table 5.5)

1. Leaching of leaves by rainwater; K, Ca, Mg, Mn, organic matter

2. Defoliation by herbivores (Table 5.6)

3. Losses associated with reproduction - pollen, seed, mast years, biennial fruiting in apple, etc.

4. Losses in litterfall (Table 5.7)

IV. Litter decomposition

A. Type of forest - humid tropical vrs subarctic (Fig.5.7)

B. Effect of deep litter on soil - acidity, excessively wet, cold, poor root development, poor nutrition

C. Much of the problem of forest nutrition and fertility is related to the type and rate of litter fall, and its decomposition. Decomposition in coniferous forests can be stimulated.....by fire, lime

D. Factors that affect decomposition

1. Activity of soil fauna
2. Species producing the litter
3. Chemical composition of the litter
4. Acidity of the litter
5. Soil microclimate
6. Soil fertility

V. Nutrition of understory (Table 5.10)

The effect of understory on nutrient retention and availability to the overstory varies before and after crown closure

VI. Direct nutrient cycling - tropical forests

In the humid tropics decomposition is very rapid, and the leaching of the soil by heavy rainfall is very high. These factors reduce the ability of the soil to function as a reservoir of nutrients....nutrients are leached away as soon as decomposition occurs. Because of this slash and burn agriculture in tropical forests only lasts a few years before the soil becomes too infertile to farm.

Tropical forests compensate for high leaching losses by: a mycorrhizal mat at or near the soil surface which captures nutrients before they are leached away; in humid tropical forests most of the nutrients remain in the biomass instead of the soil, e.g. foliar nitrogen in temperature forests is commonly 1 - 3%, but in tropical forests foliar nitrogen is about twice that; tropical trees recover a substantial portion of the minerals in leaves before litter fall.

NUTRIENT CYCLES WITHIN PLANTS

I. Biochemistry cycle -Table 5.11

II. Internal redistribution

A. Most trees are very frugal with mobile minerals - N, P, K, Mg. Immobile minerals are generally fixed in the structure of the leaf and are not re-distributed. The efficiency of capture before litter fall is illustrated by larch, a deciduous conifer, in which 75% of foliar N based on dry weight is transferred to the twig before litter fall, amounting to over 90% on a per needle basis because of needle weight loss during abscission

B. Source of annual nutrient requirements -Table 5.12

C. Effect of forest fertilization. Major increases in foliar N and total foliage creates an N bank that can be used in subsequent years after internal redistribution. This is the reason the effects of forest fertilization last several years, but generally only one in crops.

D. Efficiency of internal cycling is greater in infertile soils, and less efficient the longer evergreen leaves are retained, (e.g. larch is more efficient than spruce). The large volume of old foliage (e.g. in spruce) represents a nutrient reservoir that can be withdrawn to support a relatively small annual increment of new foliage.

CYCLES OF MAJOR MINERALS

I. Carbon cycle Fig. 5.10

A. Most of the C cycle is in the geochemical phase; 99.9% of the global C is in coal, oil, limestone, and chalk.

B. CO_2 has increased from 290 ppm in the 18th century to 340 ppm today, and expected to increase to 600 ppm by 2030 -2070.

This increase is still less than that released from the burning of fossil fuels because:

1. Photosynthesis increases about 5% for each 10% increase in CO_2.

2. Until 1960 most of the CO_2 release was not from industry but from deforestation, wood burning, and forest floor decomposition.

3. CO_2 dissolves in ocean waters, but it is being added more rapidly than it can dissolve. The bicarbonate cycle helps to remove atmospheric CO_2 by carbonate precipitation

C. Global warming and the Greenhouse Effect

1. Absorption of long wave radiation by CO_2, preventing the radiation from going into space which causes warming

2. Warming of oceans, liberating more CO_2

3. Increased cloudiness, countering greenhouse effect

4. Process very complex, exact predictions impossible

II. Nitrogen Cycle — Fig.5.12

A. Biological nitrogen fixation — Table 5.14

1. Free living bacteria and algae

2. Symbiotic organisms in roots and leaves

3. Industrial fixation

B. N transformations in the ecosystem

1. Ammonification and nitrification

2. Significance of low nitrification in coniferous forests and its relationship to forest fertilization

3. Fate of nitrate and ammonium in the soil

4. Denitrification - anaerobic bacteria and the duel role of fire

III. Sulfur cycle

A. Acid rain is caused by increased SO_2 in the atmosphere from industry; conversion of SO_2 + H_2O to sulfurous and sulfuric acid in the atmosphere; and deposition of acid in precipitation' This causes acidification of lakes formed on non-limestone rocks and damage to forests

BIOCHEMICAL EFFICIENCY OF FORESTS

I. Biochemical efficiency of forests

A. Undisturbed forests are efficient in retaining nutrients; streams issuing from them are oligotrophic

1. retention of minerals in litter
2. retention of minerals in biomass
3. biochemical cycling
4. rapid absorption by fine roots and mycorrhiza

B. Forest floor is a key biogeochemistry component of forests

C. Minerals input into forests in precipitation and dust, mineral enrichment of precipitation by crown leaching, retention of minerals in the biomass, stream flows from undisturbed forests are low in dissolved nutrients

D. Forests function as water purification systems

II. Nutrient cycling in tropical forests

A. Large biomass, very productive, nutrient-poor soils, majority of nutrients in vegetation, large and rapid circulation of nutrients,

B. Vegetative removal depletes ecosystem nutrient capital

C. Slash and burn agriculture - ash makes soil more basic and adds fertility; cultivation is followed by re-acidification and soil leaching. Long cycles allow re-invasion of forest and recovery. Short cycles induced by population pressure do not permit recovery, and the soil becomes less fertile, erodes, and looses its productivity even for agriculture.

D. Nutrient cycling in tropical forests

1. Canopy collection of nutrients during throughfall
2. Collection efficiency of surface roots and mycorrhiza
3. Efficient internal cycling
4. Adaptation to acid soils with low Ca, P, and high H and Al by sclerophyllous leaves, evergreen, internal cycling
5. Leaf form to reduce throughfall time (thus leaching) and promote water shedding

6. Uptake of nutrients from precipitation and throughfall by epiphytes; N fixation by epiphytes (e.g. lichens)

7. Leaf chemical impeding decomposition expect by mycorrhiza

E. Vegetation removal converts some tropical forests to wet deserts by destroying nutrient cycling, including losses in biomass, accelerated decomposition, and leaching.

F. There are differences in the biogeochemistry of oligotrophic and eutrophic forest ecosystems, both in temperate and tropical regions, and their response to deforestation.

G. Examples from Viet Nam

Forest defoliation to uncover military highways caused rapid decomposition of the dead, defoliated trees. This caused a transient mineral enrichment of water ways from mineral leaching from the decomposing vegetation. Productivity of the enriched water ways increased, including fish harvests, but in the long term the productivity of the forests decreased because of the loss of nutrient capital once preserved in the biomass.

PART IV

GENETIC ASPECTS OF FOREST ECOSYSTEMS

I. The genetic composition of individuals and populations

A. Individuals contains a pair of chromosomes that determine appearance and function. The individual trait (e.g. eye color) is contained in a gene located on both members of the chromosome pair. The gene for that trait may be different on each pair (e.g. blue on one chromosome and brown on the other). Fig. 6.1.

B. The phenotype or appearance of an organism is controlled by dominance (brown eyes are dominant over blue), and by the environment. In many traits (e.g. leaf size) there are several genes that can be called into action by different environments (e.g. sun, shade). This is an adaptive response, and depends upon a trait having several alternative genes which can be induced into action by the environment.

Genetic crosses of different phenotypes provides an array of phenotypes in future generations (Fig. 6.3).

C. Populations have genetic diversity; individuals have only one set of chromosomes. The total wealth of genetic information of a population is scattered among its members. Populations with a rich gene pool exhibit the greatest variation, and are the most likely to adapt to a changing environment.

Variation occurs when individuals in the population exchange genetic information (sexual reproduction), creating an individual with unique genetic information and phenotype potential.

II. Natural Selection - Fig. 6.4

Far more seeds are shed by trees than can possibly survive. Part of the excess seed production provides for dissemination. But for each of thousands of seeds than land in a spot, only one will survive to maturity, and mortality will take a toll at each stage of its life cycle. The individual best adapted to that site at that time is most likely to survive. This is sometimes referred to as survival of the fittest....but "fit" is not the biggest, strongest, or most aggressive...it is that individual with the greatest reproductive potential. "Success" is preservation and expansion of the genetic information of an individual in future generations.

III. Define the difference between qualitative and quantitative variation.

IV. Describe directional selection by examples including disease and pest resistance, and adaptation to new environments. Fig. 6.4

V. Define ecotype, provenance, genome, gene pool, gene flow, cline

VI. Provide evidence for co-evolution in forests.

VII. Explain why introduced pests and diseases are much more likely to be harmful than indigenous ones.

VIII. Foresters should be concerned about genetic adaptation because:

a. The need to select seed from equivalent provenances to insure success

b. Preservation of diversity to insure adaptability to a variety of present and future environmental conditions (e.g. global warming).

c. To help preserve genetic resources even though their need may not be currently identifiable.

d. To be able to compare the probability of success of exotic with native species.

PART V

PHYSICAL FACTORS OF THE ENVIRONMENT

PART V - A

SOLAR RADIATION

I. Spectral composition of solar radiation (Fig. 7.1)

- A. Selective absorption of infra-red (I) by CO_2 and H_2O in atmosphere
- B. Selective absorption of red and I by clouds
- C. Absorption of red and blue by vegetation, leaving far-red enrichment below canopy
- D. Blue shade vrs. "green shade" spectral quality
- E. UV depletion by ozone
- F. Solar constant - 2 cal cm^{-2} m^{-1}; 12-50% reduction by atmosphere
- G. Daylength compensates for lower intensity at high latitudes; tropical vrs.temperature high altitude climates

II. Albedo (reflectance) of visible light; I; UV; by forests compared to grasslands, meadows, soil, snow; implications of albedo in ecological energetics (Table 7.1)

III. Radiation Balance (Fig. 7.2)

- A. Effect of cloud cover, vegetation cover
- B. Greenhouse effect
- C. Photoperiod differences
  1. Equinox, tropics of cancer and capricorn (23.5º latitude), solstices

IV. Effects of variations in spectral quality

- A. I - detection; heating
- B. UV - cuticle protection, auxin destruction, anthocyanin protection, vitamin D and skin pigmentation, nectar guides
- C. violet-blue and orange red absorption by canopy
- D. Role of sun flecks

V. Effects of variations in intensity

- A. Light compensation point (CP) when photosynthesis =

respiration

B. Saturation point (SP)

C. Comparisons of CP and SP in whole plants and leaves; effect of cuticle and other epidermal coverings

D. Relationship between temperature, respiration, and photosynthesis; the temperature compensation point (Fig. 7.5)

E. CP of trees; relationship to shade tolerance (Table 7.2)

F. Tree seedlings under a canopy

1. CP
2. sun flecks
3. altered red/far-red balance and effect on root/shoot ratio
4. effect of red/far red on seed germination
4. seed size
5. seeding/sapling size and duration of survival; opportunism in capturing canopy opening, selective cutting of shade intolerant species

G. Morphology

1. Heliophytes and sciophytes lack flexibility
2. Effect on stems (Fig. 7.4)
   a. Elongation in shade, etiolation in darkness, reallocation of photosynthate from root and stem diameter growth to stem elongation
   b. Effects under a canopy
   c. Effects in overstocked stands and plantations
   d. Wind throw on boundaries of clear cuts
3. Effects on leaves
   a. shade leaves are thinner, larger, less lobed, with fewer palisade layers (Fig. 7.7)

H. Shade Tolerance

1. Many factors may cause shade intolerance; it is not simply a seedling in an environment < its CP
2. Competition for water and nutrients may be as important as competition for light - e.g. effect of trenching

3. Root growth in shade
    a. effect of far-red > red light shift in shade
    b. reduced root growth
    c. nutrient deficiency
    d. water deficiency - drought susceptibility
4. Effect of R/FR on seeds
    a. light requirement induction in shade grown seed
    b. red requirement, far-red inhibition of germination
5. Seed size; dissemination vrs. survival
6. Prostrate growth forms in shade - sun fleck capture
7. Disease - higher relative humid and lower temp in shade promotes some diseases

VI. Effect of solar radiation intensity on animals
  A. Sight, photokinesis, phototaxis, and phototropism

VII. Ecological effects of temporal variations in solar radiation
  A. Biological rhythm
    1. Timing by "hour glass" or readiness
    2. Timing by diurnal changes of temperature or light
    3. Entraining rhythms
  B. Photoperiodism
    1. History of discovery - flowering in tobacco
    2. Phytochrome measurement of day and night periods
        a. conversion of PR to PFR by red and far red light
        b. decay of PRF in darkness measures night length
            i. effect of night light interruption
    3. Effect of latitude on daylength
  C. Short day (SD) and long day (LD) organisms
    a. induction of dormancy, flowering, height and diameter growth, etc
    b. latitudinal distribution of SD plants (near equator) and LD plants in high latitudes
    c. animal migration, reproduction, antler growth, fur and feather replacement, dormancy, etc. that is seasonally

induced depends upon photoperiod measurement.

d. Photoperiodism in plants

i. leaf abscission and dormancy

ii breaking of dormancy most commonly is thermal

iii. problems of SD plants in high latitudes -- extended growth but frost susceptible, too little warm weather left after floral induction for seed development; ability to use understory before canopy leaves out.

iv. ecotypes -latitude, elevation, aspect

v. SD plants in north grow larger because of delayed dormancy induction, but experience frost damage; LD plants at low latitudes loose competitiveness because they go dormant too soon, and grow slowly in short days

VIII. Light factor in forestry

A. importance of recognition of local ecotypes

B. effect of radiation on morphology, e.g. root/shoot ratios and nursery management

1. proposed transplant conditions
2. sun and shade leaves
3. pigmentation
4. solarization damage

C. sun scald - thin bark

D. epicormic branching,

E. light intensity and taper, stem straightness, knotting, diameter growth

PART V - B

ECOLOGICAL EFFECTS OF TEMPERATURE

I. Define thermal capacity, latent heat, heat of crystallization

II. Geographic and temporal variations in temperature

- A. Effects of latitude and altitude
- B. Effects of water and aspect

III. Radiation budget

- A. Nature of long wave (I) radiation
- B. Importance of microclimates - and rate of radiation loss
- C. Albedo
- D. Ground frost and dew formation
- E. Effect of forest cover
- F. Effect of thermal capacity

IV. Convection and conduction

- A. Soil temperature regimes
- B. Temperature profiles in snow

V. Topography

- A. Lapse rate - 0.4º per 100 m
- B. Low elevation air is dense, absorbs more heat, by conduction and convection from soil, holds more heat
- C. Inversions
- D. Diurnal valley winds
  1. thermal belts
  2. frost pockets

VI. Microclimates

Local conditions vary markedly in temperature, humidity, light, wind, and hourly changes to these factors. It is these local conditions that affect organisms, not monthly/daily averages.

VII. Temperature conditions

A. optimum , maximum, minimum temperature differ with species, ecotypes, activity, season, and conditioning

B. effect of duration of exposure

VIII. High temperature damage

A. Respiration> photosynthesis (or ingestion,assimilation)

B. Q_{10} effects

C. Protein coagulation (hot springs organisms)

D. Moisture loss

IX. Low temperature damage

A. Metabolic activity - Q_{10} effects

B. Intercellular ice and cell damage

X. Effects of temperature on plants

A. Growth response

1. Temperature variations in roots, leaves, stems,

Fig.8.8 2. Cardinal temperatures - definition, differences between plant functions, e.g. respiration, photosynthesis, effect of adaptation

3. Thermoperiodism - growth, dormancy (chilling requirement of buds and seeds)

4. Vernalization

5. Heat sum and degree day measurements

XI. Low temperature injury: frost - often caused by nocturnal radiation, frost pockets, periods of susceptibility, frost cracks, needle and ice heave, freezing damage, frost hardiness winter injury by desiccation

XII. High temperature injury: sun scald, stem girdle

XIII. Adaptations of plants to unfavorable temperature

A. Morphological

a. leaf size, shape, orientation (pine, legumes)

b. cuticles and other leaf surfaces -hair, scales,etc.

c. bark

d. serotinous cones

e. resistant stages - seeds, spores

Fig.8.13 f. life forms - location of overwintering part

B. Physiological

a. elimination of free water during frost hardiness

b. dormancy - photoperiod induction, full dormancy after cold period, chilling requirement, degree-day requirement to break dormancy

XIV. Animal adaptations to unfavorable temperature

1. Allen's rule - homoiotherm extremities, Berman's rule - shape, Golger's rule and color

2. Poikilotherms and homoiotherms

3. Adaptations to temperature

a. Physiological - diapause, aestivation, shelter below ground or snow, increased metabolism, hibernation, lowering cellular freezing point, temperature variation throughout body.

b. Morphological - control of radiation, convection, and conduction exchanges (feathers, fat, extremities), countercurrent circulation, radiation and convection loss - elephant and rabbit ears

c. Behavioral - thermal migration, thermal cover,

XV. Temperature and the distribution of organisms

A. Polar and high altitude

a. freezing

b. insufficient summer warmth

c. timberline - the 10º summer isotherm

d. conifer-broadleaf boundaries with mean polar air mass positions; treeline

B. Lower latitude and altitude

a. derangement of metabolic processes, e.g. respiration and photosynthesis

b. lack of winter chilling period

Fig. 8.17 c. life zones and biomes

d. Hopkins rule - spring delay 3-4 days per degree latitude and 100 - 103 m elevation

XVI. Temperature and forestry

A. temperature profiles during stand development

B. microsites - aspect, slope, shading, soil moisture and color, frost pockets, view factor

C. stem girdling

D. post clear cutting effects

PART V - C

WIND

I. Global wind patterns

A. Heated air rises in the tropics, cools, and descends in the horse latitudes (20 - 30º north and south) causing world wide arid belts.

B. Polar air descends flowing toward the equator, and rises 50 - 60º, causing a moist belt

C. Polar air cools the tropics, and tropical air warms the temperate and polar regions

II. Local winds

Fig.9.2,9.3

A. Day and night valley winds; glacier and snowfield winds

9.4 B. Turbulent and laminar flow

C. Windward and lee slopes; snow and rain distribution

III. Effect of wind on vegetation

A. Dissemination (walnut, popular, douglas fir - 300 m)

B. Physiological processes

1. Gas exchange
2. Transpiration
3. Desiccation

C. Morphological processes

1. Stem and root development
2. **9.6** Wind training, flagging, bending
3. Ice and sand scouring
4. **9.7** Krummholz formation
5. Wind break, wind throw

IV. Effect of wind on animals

A. Chill factor

B. Dissemination - locust spread in Pakistan

V. Effects of vegetation on wind

T9.2 A. Effect of forests on wind velocities

9.12 B. Shelter belts

1. Effect on transpiration, wind damage
2. Effect on distribution of precipitation

9.13 C. Effect of clear cuts

1. Acceleration of wind speed
2. Venturi effect

D. Lodging of grasses e.g. cereals

VI. Significance of wind in forestry

A. Seed dissemination and spacing of seed trees
B. Shelter belts
C. Design of clear cuts
D. Snow distribution
E. Wind blow

PART V - D

SOIL

I. Physical properties of soil

T10.1A. Texture -particle size distribution: sand, silt, clay)

F10.1B. Structure - degree and type of aggregation

1. Structureless, crumbs/granules
2. Blocky/prismatic on wet and dry cycles
3. Na^+ and Ca^{++} domination (Na causes dispersal of colloids, Ca causes flocculation)

T10.2C. Soil texture test

D. Porosity (pore space) affects infiltration, aeration,water movement

E. Consistence - stability

F. Bulk density - kg/m^3

II. Soil water

A. Osmotic, gravitational, and matrix potentials that affect the movement of water in the soil and from soil to plant

B. Available water - gravitational - capillary - hygroscopic

1. Effect of soil depth

10.3,.4 2. Effect of soil texture

C. Effect of texture on vegetation

D. Permanent wilting percentage

III. Chemical properties

A. Physical weathering - fracture of rocks into smaller particles by temperature, abrasion, etc.

B. Chemical weathering

1. Primary - solution, hydrolysis, carbonization, oxidation, reduction

2. Secondary - clay formation

3. Laterization - red soils of subtropics: hot, moist climates, high leaching, rapid decomposition, loss of Si. Exposure of lateritic soils to heating and drying leads to surface hardening

B. Cation and anion exchange capacity

1. Role of humus and clay

2. Importance in retention of soil minerals

10.5 C. Soil pH - effect on nutrient availability

10.6 D. Leaching - role of HCO_3^-, H^+, other ion couples, e.g. $SO_4^=$

E. Soil organic matter - decomposition rates, L, F, H layers, mor and mull type soils 10.12

IV. Soil Biology

A. Soil microflora

1. Bacteria

a. autotrophic - importance in nitrification, denitrification, oxidation or reduction of sulfur and iron (anaerobic soils)

b. Heterotrophic - nitrogen fixers (free living, symbiotic), microbial immobilization (especially of N)

10.8 2. Actinomycete - antibiotic properties, nitrogen fixation in woody plants - often at lower soil pH than bacteria

10.9 3. Fungi - decomposition, mycorrhizae

4. Algae - nitrogen fixing blue greens

B. Macroflora

1. Roots - the rhizosphere is a special zone of bacterial activity; organic matter added, channels

2. Root growth is affected by soil physical properties (e.g. hard zones), soil moisture and aeration, soil temperature, nutrition, root competition, soil chemistry

C. Soil fauna

10.12 1. Macrofauna (vertebrates, mollusks, earthworms, termites) are affected by aeration, structure, drainage, herbivores (seed and leaf), decomposition

2. Mesofauna and microfauna - decomposition (some), soil structure

V. Soil fertility

A. Measurement

1. Soil analysis - "available" nutrients, forest vrs. agricultural tests (annual vrs. perennial), variability in space

and time

2. Foliar analysis - species specific nutrient contents; dilution, diagnostic, and luxury concentrations; correlations between yield and foliar nutrient content

3. Fertilizer trials

a. timing of application

b. measurement of response: yield, color, needle volume or weight, radial increment, height growth

VI. Soil development

Soil = f(parent material + climate + biota (vegetation) + topography + time)

A. Parent material

10.15 1. Residual - granite, basalt, limestone, sedimentary

10,16 2. Transported - loess, lacustrine, alluvial, colluvial, glacio-fluvial, glacial till, talus

B. Topography - slope, aspect, elevation, valley bottom, terraces

C. Climate - precipitation and leaching, decomposition, vegetation, pedalfers and pedacals

10.17D. Biota - type of vegetation, mull and mor soils

E. Time - a millennia to develop a podzol! zonal soils and additions or erosion

VII. Ecological significance of soil

To plants: anchorage, moisture supply (effect of texture), nutrient supply (effect of CEC, pH, decomposition, parent material)

VIII. Importance of soils in forest management

A. soil is not replaceable

B. forest soils are less productive, and often more fragile

T10.6C. disturbance during logging

T10.7D. road building - primary and secondary effects - effects in Pakistan

T10.8E. soil stability - mass wasting, undercutting and road

10.19 construction

F. soil organic matter and nutrient loss

G. soil temperature - decomposition rates, surface heating and stem girdling

10.20H. Physical properties - compaction by implements and rain, which affects porosity and density, hydraulic conductivity, aeration, water retention, infiltration, reduced fertility

IX. Soil and man in Pakistan

A. Probable losses - arrange in order: wind, water, mass wasting

B. Estimate conversion from forest to agricultural land in order to maintain food production for an expanding population; compare erosion on agricultural land with forests; speculate on the effect of the loss of forest land on a timber famine in Pakistan

C. Effect on forests of increased reliance on forests for fuel

PART V - E

WATER

I. Unique properties of water

Specific heat, liquid at biological temperatures, heats of vaporization and fusion; polarity and its affect on adhesion, cohesion, and solvency; transport system, structural component

II. The Water cycle

11.1A. Causes of precipitation - convectional, orographic, frontal or cyclonic

B .Types of precipitation - rain, dew, fog, frost, snow, hail, rime

C. Effects of forests on precipitation - comparison of temperate and tropical forests

D. Interception losses

1. interception storage capacity, loss by evaporation, effect of vapor pressure deficit (VPD) and thus climate ($VPD = VP_{100\%\ rel.hum} - VP_{present}$)

T11.2 2. effect of storm size

F11.2 3. effect of crown shape, through fall, canopy edge drip, stem flow, tree spacing on redistribution of water

E. Evaporation losses

1. heat requirement, boundary layer, vapor pressure deficit
2. soil surface
3. conduction of water from deeper layers of soil
4. snow
5. water

F. Infiltration into the soil

1. Infiltration - normally rapid into forest soils with organic layer - little lateral movement - except when the soil exhibits hydrophobicity (chir pine?)
2. water holding capacity of the forest floor - wetting mineral soil below - effect on seedling establishment

3. Percolation
   a. soil organic matter and clay swelling
   b. soil structure, effect of compaction
   c. simple tests

G. Water in the soil
   1. osmotic, gravitational, and matrix potentials
   2. effect of texture
   3. wetting fronts
   4. capillary fringe
   5. ground water
   6. saline soil restoration

H. Transpiration losses
   1. variations with species, foliage quantity, soil water, solar energy

T11.4 T11.5
   2. variations with leaf morphology (stomatal position, opening, boundary layer, broad and needle leaves)
   3. variations with forest type

III. Availability of water to plants and animals - timing, soil moisture storage (depth and texture), drainage losses, solute concentration, aeration, precipitation intensity, evaporative power of the air (vapor pressure deficit)

IV. Role of water in plants
   A. germination
   B. growth
   C. transpiration stream
   D. structure (turgor)
   E. thermal stability
   F. adaptation as hydrophytes, mesophytes, xerophytes

V. Adaptations to excess water
   A. root aeration by internal cavities and pneumatophores
   B. anaerobic respiration tolerance
   C. tolerance of reduced compounds, e.g. H_2S, CH_4, Mn^+,etc

VI. Adaptation to moisture deficits
   A. Drought escaping ephemerals
   B Dehydration resistant
      1. water savers - succulents, dehydration resistant conifers and broadleaf evergreens with sensitive stomata

2. water spenders - rapid transpiration rates regardless of vapor pressure deficient of air, require dependable soil water source, high root/shoot ratio, good conduction and venation, rapid growth, phraeatophytes, e.g. mesquite

C. Dehydration tolerant - can loose substantial cellular water without damage, which is uncommon among higher plants except as seeds or related structures...cellular water loss is incompatible with the mechanism of cellular expansion in higher plants

1. reduction of respiration by dormancy to avoid "starvation" while stomates are closed
2. desiccation tolerance occurs mostly in lower plants

pp.279-280 3. xeromorphic forms for water conservation

T11.8 4. drought adaptations

5. animal adaptations - skin, lungs, excretion, aestivation, behavior, drought resistant stages, migration/nomadism, water from food, metabolic water

VI. Moisture and plant distribution in Pakistan

A. Precipitation/evaporation ratios

B Mangrove, riparian, shrub, chir pine, blue pine, juniper

C. deserts, orchards, grasslands

VI. Forestry and the water factor

a. watershed management - interception, infiltration, runoff, transpiration, snow melt control, bank erosion, stream temperature

b. species selection and plant moisture stress (PMS), species differences in maximum PMS, tree growth and PMS, nutrient and water regimes and growth

T11.9, F11.5, F11.6, F11.7

Part V - F

FIRE

I. Types of forest fires

A. ground, surface, crown; duration, intensity, rate of spread

B. Effects of fire types on soil organic matter, litter, seeds, forest floor

II. Effects of forest fires on soil

A. Organic matter - fire type, season, amount present

B. Structure and porosity - fire type, compaction, pH change

T12.3C. Moisture - reduced transpiration, soil texture effect, possible effects on infiltration

T12.4D. Temperature

F12.4E. pH - expect increase

F. Nutrient availability

1. nitrogen loss - effect of temperature
2. conversion of unavailable nutrients in organic matter to available forms, causing a transient increase in fertility

III. Effect of fire on plants

A. Adaptation -

1. Bark, fire resistance foliage (resin and moisture content, N/P content)
2 Protected buds - position (lignotubers, lateral roots)
3. Adventitious and latent axillary buds, rhizomes
4. Precocious flowering - species elimination
5. Seed dispersal - serotinous cones
6. Germination - after heating, allelochemistry
7. Self-pruning

IV. Effect of fire on animals

A. Immediate effects - size of burn, intensity, rate of spread, animal mobility, age

B. Indirect effects - environmental change, dependence of different animals on different environments, e.g. old-age stands, pioneer communities, seral communities, ecotones, different communities at different times of day or season

C. Permafrost development

V. Effects of fire on ecosystems

A. Energy flow

1. primary production - conversion to herbs and shrubs

2. secondary production - expect increase because of increased diversity, conversion to more palatable herbs and shrubs

B. Forest biogeochemistry

1. Nutrient exit in ash, streams, leaching, and if excessive, conversion of vegetation to species adapted to less fertile soils.

2. Nutrient increases because of enhanced decomposition

VI. Fire management

1. Effect of fire exclusion

- fire ladder formation, catastrophic fuel accumulation, removal of some species by disease, succession, e.g. mistletoe

2. Prescribed burning, vegetation mosaics

3. Post logging site management for disease, pests, unwanted biomass (slash burning), brush, season of occurrence

PART VI

POPULATION ECOLOGY

I. Populations - have attributes greater than individuals, e.g. birth rates, death rates, immigration, numerical growth

A. Dispersion patterns - random, aggregated, regular

1. Causes: dispersal, reproductive systems, variations in the physical environment, locomotion, environmental modification, biotic influences

2. Detection in plant communities - frequency

3. Importance - detection of factors affecting distribution

B. Advantages of being in a population - protection, reproduction, intraspecific competition

C. Disadvantages of being in a population - intraspecific competition, disease and pest transmission, physical interference

II. Population growth

13.4 A. Geometric growth:

13.5 dN/dt = rN; r = biotic potential of births and deaths

change in number/change in time = (r)(number at T_0)

B. Logistic growth - the effect of environmental resistance which models the check on growth of populations with enormous reproductive potentials

1. the sigmoid shape of the logistic growth curve

13.6 2. K - "carrying capacity"

3. environmental resistance - a "catch all" phrase

$$\frac{dN}{dt}=rN(1-\frac{N}{K})$$

signifying that population growth rate decreases as population size increases. In the above equation, as N approaches K, N/K = 1, and thus (1-1) = 0, giving a zero rate of population increase.

C. How applicable is the logistic growth equation to real populations?

1. yeast cultures

2. response to K - possible components: quantity and quality of food, shelter, disease, aggression, stress, territorial or other mating requirements, behavior

3. time lapse and overshoot with catastrophic collapse

13.9 4. change in K with populations

13.10 5. change in age structure

D. Life tables

1. key factor analysis - e.g. chir pine

2. survivorship curves - reproductive strategies

III. Determinants of population growth

A. Natality

1. biotic potential, r

2. realized natality

T13.2 a. variation during life span, effect of aging population

T13.4 b. effect of age variation and age structure on population growth

3. replacement fertility

4. brood size - environmental and genetic variation

5. K and r strategists - bears and lions, houseflies, rabbits, invaders, pioneers, and climax species

B. Mortality

1. Causes: disease, predation, parasitism, antibiosis, starvation, malnutrition, temperature, dehydration, physiological aging

2. age specific effects on population size - man, salmon, bears

C. Immigration and emigration

1. population pressures

2. genetic and behavioral selection - mice, man, locusts

3. territorial animals and reserve reproductive potential

IV. Population regulation theory

A. Malthus - geometric increase controlled by increased mortality rather than reduced natality

B. Density dependent population control - as population density increases natality, mortality, and/or emigration increases

C. Density independent population control - controlling factor affects populations without regard to density - climate

D. Self-regulation

1. changes in genetic makeup with population density

a. "quality deterioration" - man with protein deficiency causing loss of intelligence

b. tent caterpillars

2. changes in behavior - aggression, food competition, territorial requirements, breeding behavior and displays, social hierarchy (wolves), sub-optimal habitats

E. Different factors m. operate at different phases of the life cycle, encouraging the eco'ogist to study the changing key factors regulating survivorship and natality throughout the life cycle.

13.13F. Range of tolerance

V. Predation

13.17A. Gause's experiments with *Paramecium* and *Didinium* demonstrated the difficulty of prey control by predators; in fact, predator control by prey seems more common

13.15B. Laboratory approaches to the Lotka-Volterra equation require a heterogeneous environment to prevent the predator from consuming the prey and then dying of starvation

C. Biological control

1. the hazards of pesticides

2. the added hazards of pesticides in the tropics

3. successes in biological control - wolves and moose, cactus in Australia, spotted knapweed, vedalia beetle and cottony scale

4. hazards of introduction of even an apparent control predator

D. Functional response of predator to prey

13.18 1. portion of prey consumed increases with prey density

2. portion of prey consumed decreases with density

a. consumption/digestion limited

b. overpower time limited (woodpeckers and bark beetles)

3. initial increase,, followed by decrease - sigmoid curve

a. search image

b. capture efficiency

4. large animals (e.g. lions) vrs. small animals (e.g.wasp) as predators - killing by large animals is dangerous to the predator (as well as prey), but generally not so with small predators

13.19 5. shrew and mice predation on pine sawfly cocoons

6. mast seed years and predation escape

7. leaf fall and the removal of leaf pests and parasites

8. long term survivability of perennial

VI. Plant population biology

A. What is an individual plant? what is the life span of a plant?

T13.6 B. Plant fecundity, seed rain,, seed banks, seedling banks

13.20 C. Juvenile mortality

13.22 D. Age distributions in pioneer, seral, and climax stands

E. Intraspecific competition and its effect on stand composition

F. Interspecific competition and succession

VII. Population ecology and forestry

A. age distribution and survivorship - predictions of mortality, stand tables, harvest schedules

B. Intraspecific competition and nursery management, stocking density, juvenile mortality

C. Stand mortality and sustained yield - teak

D. Disease control and predation E. Wildlife management

PART VII

COMMUNITY ECOLOGY

I. Terms

Biotic community: an assembly of plants, animals, and microorganisms that live in an environment and interact, forming a distinctive living system with its own composition, structure, environmental relations, development, and function.

Biocoenoses: biotic component of a community

II. Structure, life form, and pattern in plant communities

14.1 A. Structure - vertical arrangement and spatial organization

14.2 B. Growth forms

C. Physiognomy - appearance of the landscape; e.g."dry subtropical, broad leave forest"

D. Plant formations - similar physiognomic groups around the world

p439 E. Biome - group of ecosystems with a similar primary producer life form

III. Distribution of plants along environmental gradients

14.3 A. Patterns range from strong associations between layers with sharp boundaries to no associations and independent boundaries. Consider the gradient from the dry scrub thorn forests to blue pine forests along an elevational gradient.

B. Theories of species distribution

1. Species are associated in more or less mutually exclusive groups with fairly distinct boundaries called associations (general), or phytocoenose (specific). The association is composed of species adapted to each other, with similar habitat requirements and some integration (European school)

2. Species are distributed along an environmental gradient. The species may be independent and non-interactive, responding to the physical environment by genetic, physiologic, and life cycle characteristics that adapt them to particular zones along the gradient...the continuum hypothesis

14.4,14.6 3. The continuum hypothesis proposes that species are distributed individually along gradients. The gradient may be identifiable (e.g. moisture, elevation), or generated by analysis of the importance values (relative density, cover, and frequency) of species in the communities. This hypothesis proposes that associations occur when the distribution of two or more species overlap. Associations imply ecological group of species with similar environmental requirements. The continuum concept recognizes that although the distribution of species may overlap in one part of their range, it may not in another.

IV. Forest Ecotones (transition zones caused by many factors)

14.7 A. Low elevation tree lines may be caused by changes in soil texture, precipitation/evaporation ratios, fire, grazing, temporal variations, cold air drainage, etc.

14.7 B. High elevation tree line or timberline

14.8 1. Temperature - heat sum during the warmest month <10º

a. elevation - latitude isotherm..110 m elevation = 1º latitude above 30º

b. low tree line in coastal regions

T14.3 c. north and south slopes

14.11 d. frost heaving

14.9 e. radiation frost

f. benefit of ground hugging growth forms

g. time required for bud development and hardening

2. Carbon balance

14.10 3. Wind

a. windward and lee slopes

b. wind training and pruning

c. scouring and desiccation

4. Snow duration

5. Animals

V. Interactions between species

A. Mutualism

1. Continuous contact : mycorrhizae, N-fixing bacteria (some), lichens

2. Discontinuous: pollination, protection, wood boring

beetles and fungi

B. Commensalism: epiphytes, vegetation shelters

C. Exploitation

1. Physical, non-consumptive: some climbers, nest raiding, bot flies, cow birds, oropendula, and bees

2. Physical, consumptive

a. parasitism - epidemic and endemic phases; host susceptibility and introduced parasites

b. predators - beneficial effects

c. antibiosis - adaptive responses

14.14 d. allelopathy - water soluble, vapors, heather and mycorrhizae, widespread occurrence

3. Competition - neither partner benefits

VI. Competitive Exclusion Principle

14.17 No two species with identical requirements can persist in the same community.

VII. Niche Concept

A. Each species has a unique set of environmental requirements and interactions with other species which define its niche, or function, occupation or role in the community. The co-existence of species depends upon niche separation - utilizing different resources, or utilizing them at different times.

Species avoid competition by evolving different adaptations, tolerances, behavior, environmental requirements, etc.

B. Functional niche - the maximum range of conditions under which an organism can survive (but less well at its extremes)

C. Realized niche - the actual range of conditions under which an organism occupies under competition, and it is narrower than the functional niche

VII. Community Diversity

A. Analysis of diversity

1. Importance value (IV) - most communities have a few species with high IV, and many with low IV

2. Communities in harsh environments or stressed by pollution, etc., have low diversity. Heterogeneous environments

have high diversity

3. Diversity decreases with altitude and latitude

4. α diversity - number of species present

5. β diversity - number of communities in an area

B. Explanations of latitudinal variations in diversity

1. Time hypothesis: evolution has continued for a longer time in the absence of glaciation at low latitudes

2. Speciation rate hypothesis: increased interspecific competition and barrier to gene flow by geography or the sedentary habit encouraged diversity in the tropics

3. Predation hypothesis: predators encourage diversity in the tropics by maintaining low prey populations, thereby reducing competition and dominance, and increasing spacing (seed predation and seed shadows)

4. Environmental stability hypothesis: stable environments encourage speciation - lcw extinction rates

5. Environmental heterogeneity hypothesis: environmental heterogeneity develops more habitats and encourages the selection of species or races best adapted to each habitat

VIII. Island Biogeography - Species diversity on "islands" depends upon the rate of species extinction and immigration. Small "islands" have fewer resources and variety of habitats, and thus support fewer species. Islands are not just land surrounded by water, but biological islands such as a forest surrounded by a sea of agricultural land.

The island hypothesis has importance in the management of parks, wildlife, special vegetation types. It leads to interesting questions such as whether it is better to have one large island, or many small ones connected by corridors, in order to protect and encourage the diversity of plant and animal communities.

IX. Importance of diversity in forestry

Effects of single species overstory management in pest control, loss of genetic diversity and potential ecotypes, loss of species, failure to anticipate future needs, habitat preservation.

X. Community stability, structure, and forestry

A. Resilience and resistance to damage from perturbations (e.g. to logging, fire)

B. Fragility and robustness - a community which is stable only under a narrow range of environmental conditions is fragile

C. Conventional Wisdom: the greater the species diversity, the more stable the community. This is difficult to prove; indeed, the opposite seems as common.

In a stable environment there is high K selection meaning high competitive ability, high survivorship, low reproduction rates, and high resistance to perturbations, but once perturbed, the community has little capacity to recover (low resilience). r-selected populations have little resistance, but high resilience.

XI. Community ecology and Forestry

A. Classification of forest types based on associations

B. Recognition of life forms, forest structure, and their relationship with the environment

C. Productivity and interactions - competition, symbiosis, parasitism, predation, etc.

D. The niche concept and species selection for different habitats

E. Biological diversity, forest stability, and genetic richness

PART VIII

SUCCESSION

I. Categories of change in ecosystems
   - A. Long term changes in the physical environment
   - B. Changes in the genetic composition
   - C. Changes in community composition with changes in the environment (succession)

II. Succession occurs in stages (seres) or seral stages
   - A. Primary succession - soil development
   - B. Secondary succession - vegetation modification on developed soil
   - C. Xerarch, mesarch, and hydrarch succession, lithosere, halosere, oligotrophic succession, eutrophic succession
   - D. Directional and cyclic succession

III. Causes for succession
   - A. Vegetation changes the physical environment - autogenic
   - B. Geologic changes - allogenic
   - C. Biological changes - biogenic (e.g. grazing)
   - D. Climax community - very slow rate of change - communities with a characteristic structure, floristics, also called plant formations, biomes, plant associations

IV. Classical models of succession
   - A. Monoclimax theory - vegetation determined by the regional macroclimate, but climax may be delayed by "atypical" conditions, e.g. soil
     1. subclimax, disclimax, sere climax
     2. concept of vegetation as a supra organism with its own life cycle
     3. concept of ecological convergence - similar climates produce similar vegetation
     4. Problems: sere sequence is not consistent from place to place; geologic time is required to achieve climatic climax
   - B. Polyclimax theory - many factors in addition to climate determine the type of climax - edaphic climax, biotic

climax, etc

1. concept of a mosaic of communities, each with its own climax type, within a large ecosystem, ie, one type on dry sites and another on mesic sites.

C. Climax pattern hypothesis - the continuum hypothesis

D. Is the climax hypothesis useful?

Pro: climax provides an indication of the degree and direction of vegetation development in a region, a basis for comparative studies, and the means to identify types of physical environments including local climates

Con: predictions are not always accurate; how is the climax type recognized? in cases of no rapid allogenic change? no further autogenic change? predictable non-climatic influence, climax as a period of **relative** stability; change continues in the most so-called climax communities, but at a much slower rate

V. Mechanisms of successional change

A. Colonization

1. invasion and survival of pioneer or fugitive species - large numbers of propagules, efficient dispersal, seed banks, symbiosis, variation, relay floristics, each sere replaced by another

15.4 2. differentiation between initial floristics and relay floristics

B. Alteration of the physical environment

1. Soil development - N accretion, organic matter
15.5 incorporation, bulk density decrease, pH decrease
2. Temperature moderation - especially decreased range
3. Moisture regimes - increased humidity, improved soil water holding capacity, lower evapotranspiration potential
4. Light
5. Displacement by antibiosis, a' otoxicity, competition

C. Rates of succession

1. Rate of environmental change during succession

        a. primary succession is slower
        b. xerosere and hydrosere are slower
    2. Rate of biota alteration of the environment
        a. size and growth rate of organisms
        b. amount of alteration required for next stage
        c. more rapid in climates with high NPP
    3. Longevity of dominant organism
        a. short during early mesosere dominated by annuals and biennials
        b. long during shrub thickets and long-lived trees
    4. Community resistance to invasion
        a. efficient competition for light, etc.,
        b. suppression of germination or seedling development

VI. Types of seres
  A. Xerarch succession
    1. water and nitrogen limited, wide temperature ranges
    2. lichens, mosses the pioneer stage with humus accumulation; annual/biennial/shrub stage and continued humus/soil development
    3. pioneer tree invasion
    4. climax tree invasion
  B. Mesarch succession
    1. deep, medium textured soil, generally mid slope,
15.6 2. mostly secondary succession
    3. pioneer stage of herbaceous plants
  C. Hydrarch succession
    1. floating biota, lake filling
    2. bottom-rooted aquatic plants, organic sediments
    3. shrub invasion when litter accumulation exceed water table
    4. continued litter accumulation, lowered water table by evapotranspiration, pioneer tree invasion
    5. climax, shade tolerant, tree invasion

VII. Linear and cyclical succession

1. many climax types have a degeneration phase followed by a
15.8 cyclical pattern of regeneration phases. These may occur in patches imbedded in an ecosystem

2. Gad dynamics in forests attempts to predict microsuccession in small patches

VIII. Modern models of succession

A. Markov models

T15.2 Succession is a random process of species replacement in which probability values can be assigned to replacement of one species with another

B. Stand models - refinement of Markov model by assignment
15.10 of more accurate replacement probabilities based upon seed supply, species environmental requirements, and unoccupied niche space occurrence

C. Three path model - facilitation, tolerance, and
15.11 inhibition path

D. Multiple path model

15.12 1. persistence (dispersed seed, stored seed, canopy seed, vegetative propagation

2. conditions (tolerant, intolerant)

3. critical life history (ample propagules, maturity, senescence , loss or elimination of species

IX. Changes in ecosystem function with succession

A. Ecological energetics

15.14 1. net production (NP) exceeds respiration (R) in early stages, in theory NP = R in later stages

2. the NP/R ration >1 is very prolonged in forests

B. Biogeochemistry

1. Geochemistry

15.15 a. increased weathering, balanced mineral input and output at early stages, less mineral export later, increased N fixation, nutrient accumulation during early stages

2. Biogeochemical cycles - trees appear to "hoard" nutrients by direct cycling and inhibited mobilization, helping

to perpetuate the climax community by "mineral starvation" of invaders

3. internal cycle - increases with succession

X. Succession and stability

15.16 It is important to define what type of stability is being referred to...inertial stability? resilience? and the type of perturbation - depletion of organic matter? or mere conversion

XI. Succession in animal communities

15.18 A. Animals are habitat specific; some have narrow ranges and others broad ranges, several require ecotones

15.19 B. Animals can arrest succession

XII. Forest management and succession

A. Clearcutting - alters microclimate, soil, vegetation, animal and microbial conditions

1. disturbance designed to maintain mid-seral species
    a. inappropriate soil conditions for them
    b. remove competition
    c. water table management - saline soils
2. reduced disturbance to maintain climax species
    shelterwood, patch, and selective cutting schemes

B. Slashburning

timing - site conditions (xerosere vrs. mesosere), vegetation control (shrub removal; shrub encouragement), forest floor reduction (early sere promotion), fuel reduction (future fire protection)

PART IX

FOREST CLASSIFICATION

1. Types of Classification

A. Climatic - climates are classified by evapotranspiration/ precipitation ratios, temperature, and growing season. World maps have been prepared, and local applications can be made using more detail concerning radiation, season and amount of precipitation, and date of last frost, etc.

16.1, 16.2, 16.3

B. Vegetation

T16.2 1. Physiognomic - classification by similar life forms which appear around the world in similar climates.

16.4 2. Dominance type - classification by dominant species; low information input, useful in broad scale, weak where

T16.3 vegetation is heterogeneous

3. Floristic composition - classification by dominant overstory species which identify broad vegetation (and climatic) type; and ground vegetation of more limited distribution which identifies sub-types.

16.7 a. Braun-Blanquet approach - diagnostic species identify associations, a community of definite floristic composition and uniform physiognomy occurring in a uniform habitat; character species have narrow range of distribution and identify particular associations. They must have high fidelity for a particular vegetation unit.

16.8 b. Habitat approach of Daubenmire - overstory species defines unions across the overstory range as a climax species; understory species of limited distribution defines association; the physical environment of associations defines habitat types. These result in a landscape and floristic hierarchy, and management strategies and seral information can be superimposed upon the habitat type..

C. Ecosystem classification

1. hygrotopes - indicate the moisture regime of the site

2. biogeoclimatic zones - indicate the climatic climax found on mesic sites with zonal (developed) soils. These may be subdivided.

3. Topographic subdivisions

16.9,16.10 a. Trophotpes - site fertlity; b. topography

16.11 4. Management recommendations such as regeneration, distribution of associations, and slash burning policy can be superimposed on associations

II. Comparisons of the practicality and desirability of these classification systems in Pakistan's forests: climatic, vegetation, floristic (including habitat types), and ecosystem classification.

PART X

FOREST MANAGEMENT IMPLICATIONS OF NATURAL RESOURCE RENEWABILITY

I. Definitions

A. Renewable - a resource that can be restored to the point of reuse within an economically or socially acceptable time e.g.,some (not all) forests - those with regeneration cycles less than 200 years.

B. Non-renewable - some fuels (but not necessary wood, peat), some minerals (but not necessarily those of biological origin).

C. Resource - a concentration phenomena, metals in mining, trees in forests with volumes per hectare sufficient for economic harvesting

1. biological resources are created by energy capture of sunlight by photosynthesis, and the rate of resource creation is a function of the efficiency of solar energy capture

2. mineral resources are created over geologic time scales, as are some biological resources

3. the lower the energy flux, the slower the rate of resource formation, the less renewable the resource

II. Renewability and use

A. clear cutting lithosere forests

B. forest fertilization

C. logging in Pakistan

D. Timer mining vs. sustained yield

18.1 1. timber mining of a non-renewable tree resource occurs on sites with energy capture too low for regeneration within socio-economically acceptable time, <u>or</u> by using harvest methods of regeneration attempts that cause retrogression of the site to an earlier seral stage.

2. the decision to engage in timber mining should be studied, evaluating the relative values of stand conversion, harvest value, and loss of renewability.

III. Sustained yield

A. Rotation type:

1. ecological rotation period to return to predisturbance condition
2. technical rotation - period to produce of product
3. economic rotation -
4. maximum volume rotation

B. Succession and ecological rotation

18.2 1. consequence of the degree of disturbance on sites at different seral stages

18.3 2. effect of rotation on site nutrient capital

5.17 p122 a. nutrients are depleted by harvesting, either by removal in the crop, or disruption of nutrient retention mechanism releasing them into the water or atmosphere

b. repeated harvests with rotation periods shorter than the ecological rotation will reduce fertility

c. degree of nutrient depletion depends upon harvesting and replacement rate, thus sites differ in impact

IV. Non-renewable components of forests

A. the gene pool of its organism

1. ecotypes
2. environmental gradients
3. species diversity and adaptation to environmental changes
4. the value of genetic - ecological reserves to preserve gene pools and diversity

B. Soil

1. site variation in loss
2. site variation in recover,
3. species selection for impoverished soils

SECTION TWO

STUDENT STUDY OBJECTIVES

PART I

HISTORY OF MAN IN THE FOREST

When you have completed your study of Part I you should be able to:

1. Describe the causes for human population growth, both in ancient and modern times

2. List the six stages of forestry development, including an example of the stage reached by Pakistan at present, and probable stages in the future.

3. Define the concept of "Tragedy of the Commons". Comment on whether you believe this tragedy is occurring in Pakistan, and if so how it might be curtailed.

4. Define the foresters responsibility as it relates to the management of the forest.

PART II

ECOLOGICAL ENERGETICS

When you complete your study of Part II you should be able to:

1. List at least five trophic levels

2. Describe the difference between trophic chains and trophic webs

3. Interpret diagrams of ecological pyramids, including explanations of the differences that may occur between pyramids of number, biomass, and energy in some ecosystems

4. Define: crop, standing crop, yield, net and gross production, biomass, and productivity

5. Describe the factors that affect energy inputs (photosynthesis) and losses and the producer trophic level

6. Describe the relationship between net productivity, biomass, respiration, and stand age

7. Provide reasons for the differences in net production of the major world ecosystems

8. Describe how energy flow through the primary consumer (herbivore) trophic level may differ with respect to utilization, assimilation, tissue growth, ecological growth, and trophic efficiencies

9. Define the "rule of tens" as applied to the number of trophic levels in an ecosystem

10. Describe the role and importance of detritus trophic chains in forests, especially with reference to nutrients

11. Explain the relationships between leaf area, sapwood area, and the environment

12. Explain the effects of clearcutting on energy flow through the detritus food web, and list the environmental factors that affect the detritus food chain

PART III

BIOGEOCHEMISTRY

When you complete your study of Part III you should be able to:

1. Describe the mechanisms by which nutrients cycle between ecosystems.

2. Describe biogeochemical cycles within ecosystems with special reference to:

a. nutrient uptake by plants including the role of mycorrhiza and stand age

b. nutrient losses from plants by leaching, defoliation, reproduction, and litterfall.

3. List the factors that affect litter decomposition.

4. Describe the role of the understory in forest nutrition.

5. Describe three ways in which tropical forests preserve nutrients in the ecosystem in spite of high rates of leaching and decomposition rates.

6. Describe nutrient cycling within plants with reference to internal redistribution, a list of nutrient sources that supply annual nutrient requirements, and factors that affect the efficiency of internal cycling.

7. Describe the effect of CO_2 enrichment of the atmosphere on photosynthesis, CO_2 dissolved in the oceans, global warming and the greenhouse effect, and possible increased cloudiness.

8. List four sources for biological nitrogen fixation

9. Define mineralization, ammonification, nitrification, and denitrification.

10. Describe the factors that affect the biogeochemical efficiency of forests including:

a. retention in litter and biomass

b. absorption by fine roots and mycorrhiza

c. the role of the forest floor

d. enrichment of minerals in precipitation, dust, and leaching

e. the special characteristics of nutrient cycling in tropical forests such as canopy collection during throughfall, mycorrhizal efficiency, internal cycling, and adaptation to acid soil.

12. Describe the effect of vegetation removal on the biogeochemistry of tropical forests.

13. Describe the effects of complete vegetation removal on nutrient retention in temperate forests.

14. Describe the cause and effects of acid rain on forests.

15. Describe the effects of clearcutting on forest biogeochemistry with reference to:

a. factors affecting the magnitude of nutrient losses

b. effect of harvest frequency, portion of tree removed, fertility of the ecosystem, and nutrient demand

c. the Assart effect and factors affecting post-harvest nutrient capture

d. leaching losses affected by harvest procedures, and the capture potential of pioneer plants.

16. Suggest harvest and post-harvest procedures that might minimize nutrient losses in Pakistan forests.

PART IV

GENETIC AND EVOLUTIONARY ASPECTS OF ECOSYSTEMS

After completion of your study of Part IV you should be able to:

1. Describe the basis of diversity in organisms by explaining the sources of natural variation, and the difference between qualitative and quantitative variation

2. Give one example of a selection pressure that has altered the genetic composition of a population.

3. Define: ecotype, cline, provenance, hybrid vigor, gene pool, genome, gene flow, and co-evolution.

4. Site an example of co-evolution in forests.

5. Explain why introduced diseases and pests are more likely to cause serious damage than indigenous diseases and pests.

6. What is meant by "fitness" or "survival of the fittest"?

7. List the major factors that determine the rate of evolution. Compare the probable rates of evolution in houseflies, trees, annuals, and tigers.

8. Explain why the forester must take care to preserve natural gene banks. Cite an example of how gene bank preservation can be incorporated into forest practices.

PART V - THE PHYSICAL ENVIRONMENT

SECTION V - A

SOLAR RADIATION

When you complete your study of Part V - A you should be able to:

1. Describe the changes in spectral quality of light as it passes through the atmosphere, clouds, and vegetation; the difference in light quality of blue and green shade; and the potential effects these differences in light quality may have on plants.

2. Define albedo by giving comparative examples for different surfaces.

3. Be able to recognize the principle components that determine global radiation balance.

4. Describe the roles of UV radiation on plants.

5. Define light compensation point and light saturation point.

6. Use the following factors to develop a general explanation of the cause of shade tolerance in trees: light spectral quality, compensation point, saturation point, plant age, fertilization, temperature, leaf morphology,, root/shoot ratio, water and nutrient competition, seed size, leaf respiration, disease, sun flecks, and branch elongation.

7. Describe the effect of photoperiod on stem growth, reproduction, dormancy, and ecotype formation.

8. Explain why the forester should be aware of the influence of light on plant morphology, sudden changes of light intensity, and photoperiodism.

PART V - B

TEMPERATURE

When you have completed your study of Part V - B you should be able to:

1. List the three important geographical variables that determine temperatures

2. Describe how the radiation budget is affected by clouds, surrounding vegetation, albedo, ground frost, forest cover, and thermal capacity

3. Explain heat transfer by convection and conduction, and how these processes affect soil temperatures at different depths and seasons.

4. Explain mountain temperatures by defining lapse rate, diurnal wind patterns, inversions, and frost pockets

5. Explain the ecological importance of microclimate

6. List the principal effects of excess temperature on organisms

7. Describe the effects of temperature on photosynthesis, respiration, dormancy, vernalization, and seed stratification

8. Explain the causes of frost damage, sun scald, and stem girdle

9. Relate life forms with the thermal environment

10. Describe the process of achieving full dormancy

11. Define Allen's rule, diapause, and hibernation

12. Describe ways in which animals can regulate their temperature by morphological or behavioral means

13. List the two major causes of tree lines caused by polar and attitudinal limits, and of lower latitude or attitudinal limits

14. Define Hopkins rule; give an example of its application in Pakistan.

15. Describe the effects of extreme temperatures on buds, stem and patch girdling.

16 List four effects of clearcutting on temperature.

PART V - C

WIND

1. Describe how terrain features such as valleys, glaciers, and lakes develop wind patterns

2. List six ways in which wind affects vegetation

3. Describe the effect of forests on wind velocities

4. Explain the effect of shelterbelts on transpiration, wind breakage, and distribution of precipitation

5. Describe how the design of clear cuts may affect wind patterns and induce wind throw.

PART V - D

SOILS

When you have completed your study of Part V - D you should be able to:

1. Define soil texture and describe its affects on soil water relations and fertility.

2. Define soil structure

3. List the factors both related to structure and to water potentials that affect the movement of water in soils

4. Describe the types of weathering that occurs in soils

5. Define cation exchange capacity and its effect on fertility

6. Describe two ways to assess the fertility of forest soils, and the advantages and disadvantages of each.

7. Describe the effect of pH on nutrient availability

8. List the factors that affect soil development

9. Define five types of transported soils

10. Describe how forest soils can be protected during tree harvest and road building with reference to extraction method, erosion control, mass wasting control, protection from soil temperature extremes, organic matter and nutrient loss, and compaction damage. State why such protective measures are important.

11. Describe the special threats to forest soils in Pakistan.

PART V - E

WATER

When you finish your study of Part V - E you should be able to:

1. List at least six unique properties of water

2. Describe the water cycle, including the causes and types of precipitation; factors affecting interception and evaporation; infiltration and percolation of water into the soil; run off; soil water including wetting fronts, capillary water, and ground water; and the factors affecting transpiration.

3. List the factors that affect the availability of water

4. Describe how plants adapt to excess water

5. Explain how plants adapt to moisture stress by describing drought escaping plants, dehydration resistant water savers and water spenders, and dehydration tolerance.

6. List some morphological and physiological characteristics of xerophytes

7. Describe how forest exploitation may affect watersheds

8. Describe the relationship between plant moisture stress PMS and tree growth and tree species distribution

Part V - F

FIRE

When your finish your study of Part V - F you should be able to:

1. List the major types of forest fires

2. Describe the effects of forest fires on soil organic matter, pH, and nutrient availability

3. List four plant adaptations to fire

4. Describe how forest fires may increase the abundance of some animals, but decrease that of others.

5. Describe the effects of fire on the nutrient budgets of a forest

6. List two possible effects of fire exclusion

7. Describe three reasons why a forester may wish to consider prescribed burning

Part VI

POPULATION ECOLOGY

When you finish your study of Part VI you should be able to:

1. Describe the three major dispersion patterns of plants and give an example of a cause for each pattern.

2. Using a diagram of age structure make a prediction of population growth, stability, or decline.

3. Recall the logistic growth equation and define its terms.

4. Describe a life table and one of its uses.

5. Recognize the three types of survivorship curves and give an example of a plant or animal reproductive strategy for each type.

6. List the three major determinants of population growth with three characteristics, causes, or variables for each determinant.

7. Define K and r strategies, including an example of each.

8. Define density dependent population regulation and list one factor that regulates populations by this means.

9. Define density independent population regulation and list one factor that regulates populations by this means.

10. Describe how population growth might be controlled by self-regulation.

11. Define "range of tolerance" and "intraspecific competition"

12. Explain why it is difficult in laboratory experiments to demonstrate the biological validity of the Lotka-Volterra model of the control of prey populations by predators; relate this phenomena to natural conditions.

13. Explain the difference between the ability of large and small predators (e.g. lions, wasps) to control populations.

14. Discuss the potential hazards of using pesticides in forests with respect to their possible impacts on biological control and pest population growth. Make special reference to tropical forests. Include an evaluation of biological control in forests.

15. Speculate upon the effect of mast years of tree seed production and tree longevity on susceptibility to predation.

16. Give an example of each of the following population

attributes in forest management: age distribution, survivorship, age specific mortality and natality, predator-prey relationships.

PART VII

COMMUNITY ECOLOGY

When you complete your study Part VII you should be able to:

1. Define life form, community structure, and physiognomy

2. Describe the continuum hypothesis including the causes of species distribution along environmental gradients, overlap of ranges, and the nature of species interaction proposed by this hypothesis

3. List four possible causes of the low elevation limit of forests

4. Describe four ways in which temperature affects the upper limit of trees, and then list two other factors that may affect this limit

5. Define by example mutualism, commensalism, and non-consumptive physical exploitation; list two types of consumptive physical exploitation

6. Define the competitive exclusion principle

7. Distinguish between the fundamental and the realized niche

8. Define α and β types of diversity

9. Provide an explanation for the decrease in community diversity with latitude

10. Describe the island biogeography hypothesis and give an example of its application

11. Define resilience, resistance, fragility, and robustness in relation to community stability

12. Discuss the relationship between community diversity and stability, both from the aspect of "conventional wisdom" and reproductive strategy

13. List three applications of community ecology in forestry

PART VIII

SUCCESSION

When you complete your study Part VIII you should be able to:

1. Distinguish between primary and secondary succession

2. Define climax

3. Describe the major propositions of the monoclimax, polyclimax, and climax pattern or continuum hypotheses.

4. Describe the mechanism of succession with special reference to colonization, types of colonization, and environmental modification.

5. Describe two factors that affect the rate of succession

6. Describe the seres expected in xerarch, mesarch, and hydrarch succession

7. Distinguish by example the difference between linear and cyclic succession. Discuss the implication, if any, of the concept of climax in relation to and cyclic succession

8. Define the Markov model of succession; describe how this model has been expanded upon by the stand, three path, and multiple path models of succession

9. List two changes each in ecological energetics and biogeochemistry that are expected with succession

10. Discuss the differences in forest management of mid-seral forest species in contrast to climax species

PART IX

FOREST CLASSIFICATION

When you have finished your study of Part IX you should be able to:

1. Distinguish between climatic, physiognomic, dominance, and floristic classification systems

2. List the components of the habitat type classification scheme; describe how habitat types are named, and the possible forestry application of the habitat type system.

3. List the components of the ecosystem classification scheme, and the possible forestry applications of this system.

4. Compare the practicality and desirability of each of these schemes for Pakistan forestry.

PART X

FORESTS AS RENEWABLE RESOURCES

When you complete your study of Part X you should be able to:

1. Define the terms renewable, non-renewable, and resource when used in the context of natural resource renewability.

2. Describe the principal factor that determines the rate of resource creation in forests.

3. List at least two ways in which the renewability of a forest resource can be altered by exploitation or management.

4. Distinguish between "timber mining" and "sustained yield", including a definition of sustained yield.

5. Define the four major types of forest harvest rotations.

6. List the non-renewable resources of the forest.

SECTION THREE

FIELD EXERCISE

FOREST ECOLOGY FIELD EXERCISE

INTRODUCTION TO METHODS OF VEGETATION DESCRIPTION

There are many techniques for describing vegetation, and the selection of a particular one depends upon the objective of the study. The flow diagram in Fig. 1 provides a means of selecting a method after the objectives of the study have been defined.

All methods require that representative stands be selected. The investigator should survey comparable stands to become familiar with the distribution, and their variations. A representative stand should contain all of the elements of the community type in general, and none of its extremes. Often variation is so great that several stands will have to be sampled. In some studies stands are arranged along an environmental gradient in order to detect changes in composition in response to the gradient (e.g. altitude, moisture).

I. Floristic Systems

Floristic systems do not require quantitative sampling. A common floristic method is description by life-form (Fig. 9.4). Vegetation may also be described by strata or layers (Fig. 9.6).

A good example of a floristic description is that in *Forest Types of Pakistan* by H. G. Champion, S.K.Seth, and G. M. Khattak. Representative descriptions of the chir pine type are attached. The authors describe the environment, vegetation by strata, and include a note concerning abundance.

II. Quantitative Systems

Quantitative systems generate measurements of density (the number of individuals per unit area), cover (crown projection, basal area, etc., per unit area), and frequency (distribution of species across the area, e.g. random, aggregated, regular).

Density, cover, and frequency measurements can be used to compute additional values. For example, density, cover,, and frequency, when expressed in relative terms (i.e. number of species "x" in the sample/total individuals measured), can be summed to give Importance Value IV. IV measures the significance of a species in a community giving greatest value to species that are not only plentiful (high density), but large (high cover), and distributed throughout the stand (high frequency).

This field exercise is designed to acquaint you with some quantitative techniques of vegetation description. Should you choose to use these techniques in research you should consult a standard reference in order to insure that the technique is being used in a valid fashion[1].

III. General Instructions

The class will be separated into teams of six. Ten sampling stations will be used. At each station the herbaceous vegetation will be sampled by means of a 1 m^2 quadrat, shrubs will be sampled by a 10 m long line transect, and trees will be measured using the quarter method. One pair of students should collect quadrat data, another line transect data, and the third pair the quarter method data. Pairs may wish to exchange duties in order to gain experience collecting data by all techniques.

All students should determine the length of their stride in order to collect quarter method data using the stride as a unit of measurement.

Each team will be assembled at a spot in the stand and given a bearing along which the sampling stations will be placed. My first guess is that stations should be 20 meters apart. For people of an average stride this will be about 12 double paces.

IV. Specific instructions

A. Quadrat method

Tie sticks to a piece of string 58 cm long. Place one stick at the sampling point along the bearing, and scribe a circle with the other stick. This circle will encompass an area of 1.0 m^2.

Count the number of each species present in the sample area, and record them on the form provided. If you do not know the name of a species, create one, and save a specimen for reference in other plots and to see if it can be identified at the end of the exercises.

Obtain measurements in ten plots 20 m apart along the bearing.

After completing the measurements you will have sampled an area of 10 m^2. Multiply the total number of each species counted by 1,000 in order to obtain density of each species per hectare.

Determine frequency for each species as the percentage of plots in which it was sampled.

Since no measure of cover was obtained in these plots, it cannot be calculated. There are techniques whereby cover can be estimated using the quadrat method.

B. Line Transect

Line transects can be plotless by just measuring the vegetation under the line. This technique is especially useful in shrub communities.

Place a 10 m line at a right angle to the bearing line. The origin of the transect is the sampling point on the bearing. Measure the distance each shrub occupies along the line.

Sum the distances for each species, first along each

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[1]Barbour, M. G., J. H. Burk, and W. D. Pitts. 1987. Terrestrial Plant Ecology. Chap. 9. Methods of sampling the plant community.

sampling line, then for all ten samples. Ignore non-shrub species.

Determine relative density as the percentage of occurrence of species "x" compared to the occurrence of all species.

Determine relative cover as the total distance of species "x" compared to the sum of all distances occupied by shrubs.

Determine relative frequency as the percentage of transect in which species "x" was sampled, compared to all transect.

Determine the importance value for all species by summing the percentage for relative density, cover, and frequency.

C. Quarter Method

This technique is especially useful for trees, but it can be used for other types of vegetation. It is based upon the relationship that the more dense the vegetation, the shorter the distance between a point and a plant.

Examine sketch (b). Notice that a point has been selected along the bearing line, and that another line was been drawn at right angles, dividing the sector into four quarters. Collect data by pacing off the distance to the closest tree in each of the four quarters; enter distance, species, and diameter at breast height (DBH) for the 4 trees at the each point.

When you have made measurements at the ten sampling points, sum all of the distances, and divide by 40, (the number of distances measured) to obtain the average distance. Square the

$$MeanArea = (AverageDistance)^2$$

average distance to obtain the mean area. The mean area is the average area occupied by an individual tree.

The number of trees per hectare can be computed by dividing mean area into 10,000 m $hectare^{-1}$.

The density of species "x" can be determined by:
((Number of species "x" tallied)/ 40)(trees per hectare)

Cover is measured as basal area. Convert the diameter measurement to basal area using Table 4.

Frequency is measured by the number of points of occurrence of species "x"/ 10 points measured.

Compute the density and basal area per hectare for each tree species measured.

QUADRAT DATA SHEET

SPECIES	QUADRATE NUMBER 1	2	3	4	5	6	7	8	9	10

Enter the number of each species counted in each quadrate.

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LINE TRANSECT DATA SHEET

SPECIES	LINE NUMBER 1	2	3	4	5	6	7	8	9	10

Enter the distances covered by each species. You will probably have several distances for a common species in the box associated with it at the line number.

QUARTER METHOD DATA SHEET

POINT	DISTANCES	SPECIES AND DBH Chir Pine				
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Enter the four distances measured at each point in the box so labelled. Enter species names on the lines above the blank spaces. There are five columns, enough to accommodate up to five tree species, but in the chir pine forest it is probable that only one column will be used. Enter DBH or convert to BA in the species box associated with each point.

Sum all the distances and compute the mean distance.

Compute mean area. Compute the total number of trees per hectare.

Compute the number of trees of each species per hectare.

Determine the basal area by species per hectare by determining the mean BA and multiplying that times the number of trees of a particular species.

Determine frequency by the number of plots of occurrence.

Determine importance value.

DISTRIBUTION

On the hills generally above 3,000 ft. and extending to 6,000 ft. and higher on well-drained ridges with southerly aspect. It meets the kail zone at about 5,500 ft. to 6,000 ft. It comprises the bulk of the managed chir forests

LOCALITY FACTORS. As given for the group.

FLORISTICS

(*i*) *Batrasi, L. Siran division*, 4,000 ft. on coarse granite, annually burnt. (Plate).

- I *Pinus roxburghii**.
- II Nil. (*Ficus palmata, F. roxburghii, Pyrus pashia* present in dwarfed condition).
- III *Zizyphus oxyphylla* (a), *Zanthoxylum* (f), *Glochidion velatinum* (f), *Inula cappa* (a), *Indigofera pulchella* (o), *Woodfordia* (la).
- IV *Senicio nudicaule* (f), *Viola* (f).
- IVa *Heteropogon contortus* (a).
- V *Clematis* sp. (r).

Note. Under forest management the pine has locally formed a full uniform canopy and a ground fire is run through annually. The residual ground vegetation is predominantly that of the Siwalik subtype but the site is at its upper limit.

(*ii*) *Bazkhan Cl, L. Siran division*, 3,500 ft. on gneiss. W. aspect.

- I *Pinus roxburghii.**
- II Nil.
- III *Mallotus* (r), *Zanthoxylum* (r), *Ficus palmata* (r), *Astragalus pyrrhotrichus* (la), *Berberis lycium* (o), *Rubus ellipticus* (o), *Inula cappa.*
- IV *Senicio nudicaalis* (o), *Oxalis* sp. (o). *Viola* sp. (o).
- IVa *Heteropogon contortus* (f), *Aristida* sp. etc.

Note. Under forest management, this area is a regular fully stocked immature crop of good quality growing at the upper limit of the subtype.

(*v*) *Shinkiari-Kund ridge, Siran division*, 4,200 ft.

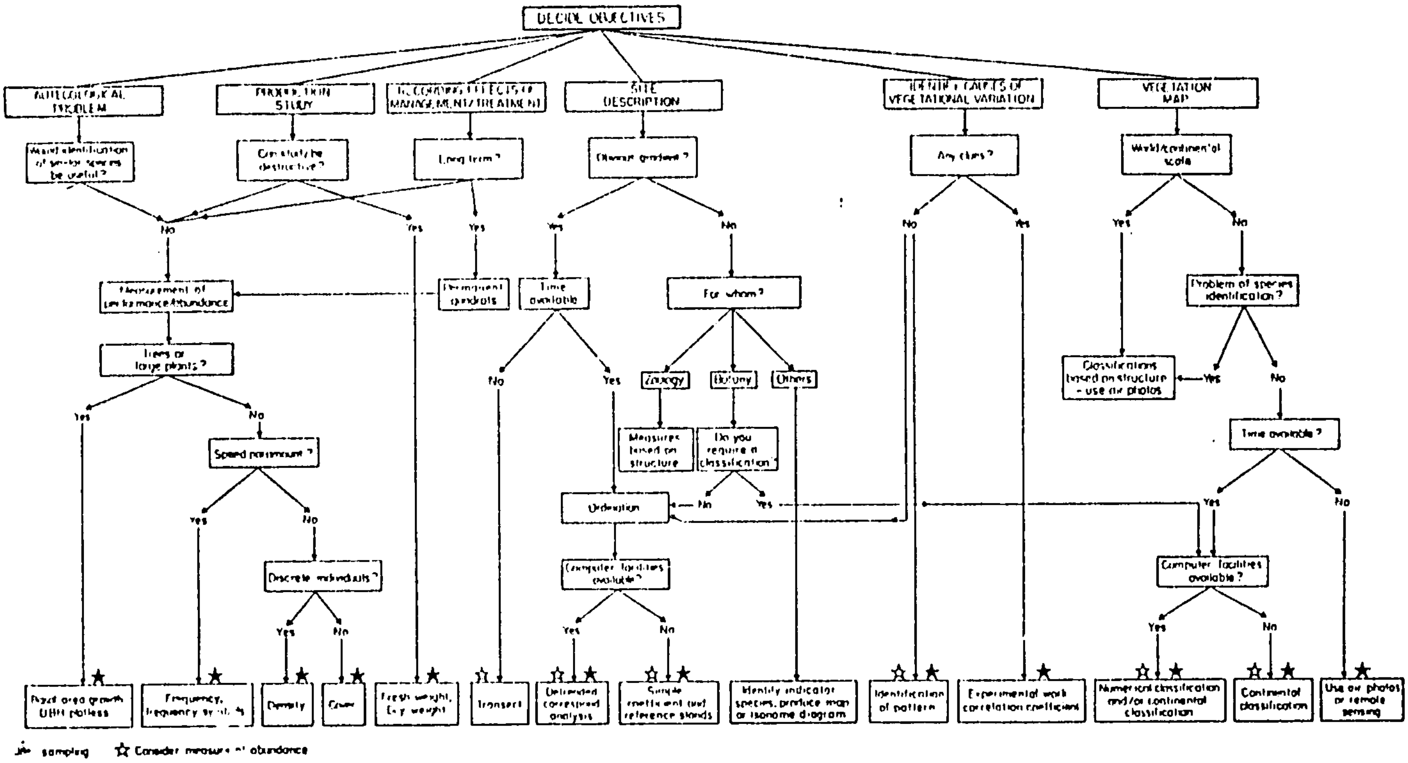
- I *Pinus roxburghii**.
- II *Quercus incana* (f), *Rhododendron arboreum* (lf).
- III *Lyonia ovalifolia* (f), *Ficus palmata* (o), *F. roxburghii* (o), *Pyrus pashia* (o), *Rubus ellipticus* (f), *Indigofera* sp. (o).
- IV *Viola* sp. (f), *Valeriana* (f).

Note. An irregular pure chir crop of moderate density.

(*vi*) *Ghoragali Rest House, Murree Hills*, 5,300 ft.—N. aspect.

- I *Pinus roxburghii* (f).
- II *Quercus incana* (a), *Pyrus pashia* (o), *Euonymus pendulus* (f),
- III *Myrsine* (a), *Berberis lycium* (f), *Rosa moschata* (f), *Jasminum humile* (o), *Indigofera* sp. (lf), *Lonicera quinquelocalaris* (o), *Daphne cannabina* (r), *Olea cuspidata* (r).
- V *Hedera* (f), *Smilax* sp. (f).

Note. This example illustrates the ecotone to temperate forest dominated by *Quercus incana.*



.I Some considerations to be used in choosing an appropriate method for describing or analysing vegetation.

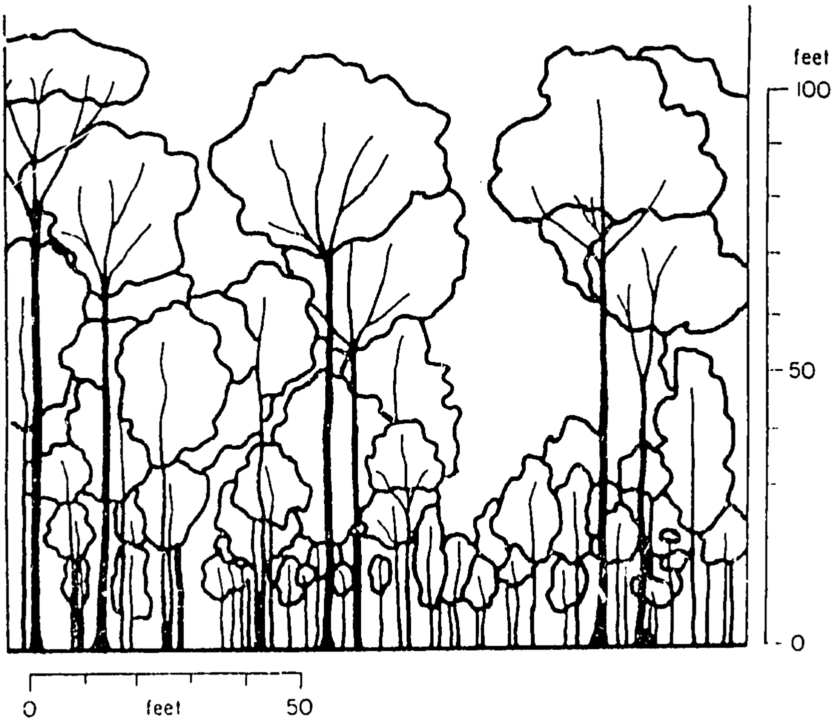
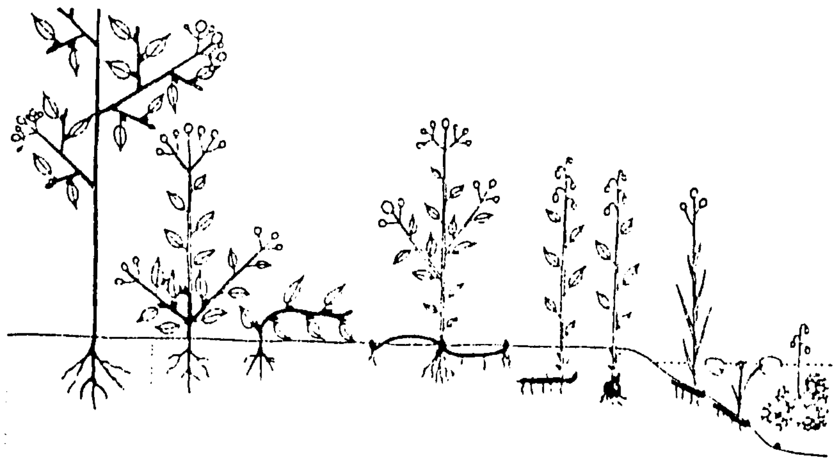
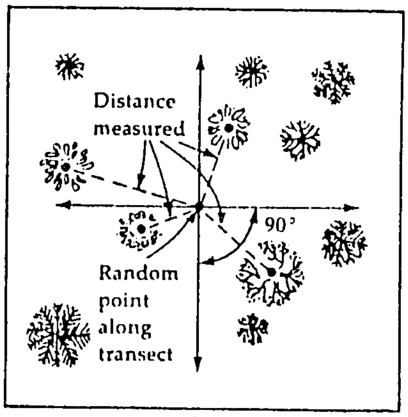


Figure 9.6 Profile diagram of forest ,after Davies & Richards, 1933).



Parts of the plant which die in the unfavourable season are unshaded; persistent axes with surviving buds are black.

Figure 9.4 Diagrammatic representation of Raunkiaer's life-forms (from Raunkiaer, 1934).



(b)

Table 4. Diameter (cm or in.) to basal area (sq cm or sq in.) (Other figures necessary may be obtained from any edition of the "Handbook of Physics and Chemistry," in the numerical tables for reciprocals, circumference, and area of circles.)

1.0– 0.78	11.0– 95.03	21.0–346.4	31.0– 754.8	41.0–1320
1.5– 1.77	11.5–103.9	21.5–363.1	31.5– 779.3	41.5–1353
2.0– 3.14	12.0–113.1	22.0–380.1	32.0– 804.2	42.0–1385
2.5– 4.91	12.5–122.7	22.5–397.6	32.5– 829.6	42.5–1419
3.0– 7.07	13.0–132.7	23.0–415.5	33.0– 855.3	43.0–1452
3.5– 9.62	13.5–143.1	23.5–433.7	33.5– 881.4	43.5–1486
4.0–12.57	14.0–153.9	24.0–452.4	34.0– 907.9	44.0–1521
4.5–15.91	14.5–165.1	24.5–471.4	34.5– 934.8	44.5–1555
5.0–19.63	15.0–176.7	25.0–490.9	35.0– 962.1	45.0–1590
5.5–23.76	15.5–188.7	25.5–510.7	35.5– 989.8	45.5–1626
6.0–28.27	16.0–201.1	26.0–530.9	36.0–1018	46.0–1661
6.5–33.18	16.5–213.8	26.5–551.5	36.5–1046	46.5–1698
7.0–38.48	17.0–227.0	27.0–527.5	37.0–1075	47.0–1735
7.5–44.18	17.5–240.5	27.5–593.9	37.5–1104	47.5–1772
8.0–50.27	18.0–254.5	28.0–615.7	38.0–1134	48.0–1809
8.5–56.75	18.5–268.8	28.5–637.9	38.5–1164	48.5–1847
9.0–63.62	19.0–283.5	29.0–660.5	39.0–1195	49.0–1886
9.5–70.88	19.5–298.6	29.5–683.5	39.5–1225	49.5–1924
10.0–78.54	20.0–314.2	30.0–706.9	40.0–1257	50.0–1963
10.5–86.59	20.5–330.1	30.5–730.6	40.5–1288	50.5–2003

INSTRUCTORS GUIDE

INTRODUCTION TO METHODS OF VEGETATION DESCRIPTION

I. This exercise can be conducted in about six hours, including orientation, data gathering, computation, analysis and discussion. The chir pine forests near the PFI field station at Shinkari offer an interesting place to conduct the exercise, and the data gives a good basis for discussion of the ecology of chir pine.

II. If the exercise is conducted at Shinkari a good spot is the forest south of camp, reached by going through the fence gate on the water line trail.

III. Before leaving the base area have the students determine the length of their pace by counting steps over a 50 m course. Field time will also be made more efficient if students are given a demonstration of exactly what measurements are to be taken at each of the ten sampling points in the field.

IV. Measurements

Organize the groups of students about 20 paces apart up and down the hill side. Tell them that the bearing is along the contour line of that hill side, with the result that the groups of students will be going parallel with each other, about 20 paces apart, along different contour lines. They should set up a sample point at each 20th pace.

A. At each point a 1 M circular plot is set up, and all plants, especially pine seedlings, are counted.

B. At each point a 10 M line transect is laid out at a right angle to the bearing line. The length of shrubs (only) that fall under the line is tallied (there will not be much shrub coverage in most areas).

C. At each point four quarters are established by drawing a perpendicular line across the bearing line at the point. Pace the distance to the nearest tree in each quarter, record the number of paces and the species and diameter.

V. Data analysis

After collecting the data students sum the paces to each tree (40 measurements). Using the length of the average pace determined earlier, convert the average pace to distance in meters. This is used to find the mean area and density. Mean area divided in 10,000 meters per hectare yields trees per acre.

Students should determine the density of seedlings per hectare by multiplying (1 m quadrat)(10 quadrats taken)(1,000) = seedlings per hectare.

The average diameter (in cm) can be converted to basal area, and then multiplied by density to give basal área ha^{-1}.

VI. Data interpretation and discussion

The density in the Shinkari stand will be about 300 trees per hectare, which is a fairly low stocking rate compared to most forests. Have the students list environmental reasons for low stand density.

Only chir pine will have been encountered. If stand data were also collected from a higher elevation, e.g. Kund, density will be much greater, as well basal area ha^{-1}, and species diversity, allowing a discussion of concepts about biodiversity and productivity.

Chir pine seedlings will tally 15,000 to 20,000+ ha^{-1}. This allows discussion of the 99% mortality that takes place between the seedling and overstory stages of the life cycle of chir pine. Further, even though students will average about 1.8 trees per quadrat, these trees will only occur in a few quadrats, yielding low frequency. Low frequency suggests aggregated distribution (as compared with regular, i.e. in a cornfield, or random distributions). Discussion can take place concerning possible causes for aggregated distribution, e.g. aggregated seed dispersal (not likely), seed placement in rodent or bird caches, special environmental requirements, e.g. bare ground, etc. Speculation on the magnitude of the seed shower should be encouraged, perhaps by cone sampling and estimates of the seeds per cone.

One of the most interesting observations that will emerge is that although there is an abundance of seedlings in the forest, there are very few saplings, and those that do occur will be restricted to special groves where many occur in a small area (very aggregated distribution - low frequency). Discussion should be encouraged to suggest causes for mortality in the seedling class, relationships between the natural seedling mortality observed and that to be expected in transplanting, and seedling stocking rates to test and account for mortality. Speculation should also be encouraged concerning the relationship between the general failure of seedling survival and shade intolerance in chir pine. The same trend encourages speculation concerning shade intolerance and the low mature tree natural stocking rates, as well as drought survival, poor root/shoot ratios in the shade, etc.