Tropical Rainforests

lush, equatorial evergreen forests
→a belt of green extending ≥10º N & S of equator

receive an average rainfall of 50-260"/yr

plants are so densely packed that rain falling on the canopy can take as long as 10 minutes to reach the ground

temperature almost always in the 70's or 80's F

average humidity is ~83%

rainforests are one of oldest of terrestrial ecosystems once covered 20% of earth's land surface

→ millions of years ago would have looked very similar from the air as it does today

→ fossil evidence indicates tropical rainforests have existed since the Cretaceous (>60MY ago)

→ rainforests once existed on almost every continent

Location
Amazon in Brazil – world's largest
central and So America,
Africa
SE Asia

rainforests are the most **complex ecosystems** on earth

highest **diversity** of any terrestrial biome

→ has the greatest number of coexisting species

Today rainforests encompass 6% of earth's surface (13% of land)

(30,603,000 km^2 = 14 M sq mi)

support ~half of all known species of plants and animals

eg. 2/3rd's of all flowering plants

some estimate that less than 5% of all tropical species have been identified

1 hectare (2.2 acres) of rainforest supports:

42,000 different species of insects

up to 800 trees of over 300 species

1,500 species of other plants

more biomass and more species than any other ecosystem on earth

eg. 830 B tons of living matter on earth's surface
460 B tons (55%) are in tropical forest ecosystems

eg. temperate forests are often dominated by 1 or 2 tree species

rainforests have many dominant species

eg. lots of local endemics

eg. 1 hectare (2.2 acres) has >200 species of trees with trunks >12" diameter

[in New England forest ~10-25 species in same area]

eg. in 300 sq mi of rainforest up to 600 bird species were found → more than 4 x's number that is found in eastern US forests

eg. 90 species of frogs and toads in a few km
→ more than all species in whole USA

eg. 1 ha (2.2 acres)

eg. 1 tree yielded 54 species of ants

eg. 2000 sweeps of a net in ground level of Central American forest yielded 500 species of insects; usually much higher diversity in mid and upper level of canopy

eg. of 19 trees in one panama study 1200 species of beetles were collected and 80% of them were new species

→ reservoir for genetic diversity

descriptions of rainforest ecosystems tend to stress the remarkable or unusual

but standing inside to untrained eye it wouldn't look particularly distinctive

the diameter of most trees is not unusual

buttresses are found in many large trees even in temperate forests

vines are commonplace as are epiphytes

there are several subcategories of rainforests
most of the descriptions below refer to wet tropical rainforests

the uniqueness of the rainforest ecosystem is in its great diversity of life and in its complex layering of habitats

<u>Abiotic Features</u>

1. Climate

warm constant temperature throughout the year

→ no seasonal temperature changes

high precipitation almost daily

(200-450cm: 80-180"/yr)

humidity rarely below 95%

much of rainfall comes from locally recycled water from forest transpiration

→rainforest creates its own climate!

2. Soil

ancient soil

one paradox of the lush tropical rainforest is that the soil is nutrient poor

soil of rainforest is some of poorest of all forest soil

eg. in Northern deciduous forests ~ half of all nutrients in the ecosystem are in soil and the other half in the plants

in rainforests, most nutrients are in the plants and very little in the soil

canopy produces a continuous shower of dead leaves, twigs and blossoms

organic matter is decomposed rapidly

→ rapid recycling of nutrients

ants, termites, fungi and bacteria quickly decompose them

→ after 2-3 weeks they are mostly gone (temperate decomposition takes ~ 1 yr; conifers ~ 7-10 yrs

interwoven, shallow roots quickly absorb freed minerals from soil

most minerals and nutrients are tied up in biomass

root hairs and micorrhizae actually grow into the litter as it decomposes

→the nutrients are held in living organisms not in the soil

soil is just for anchoring the plants

when trees are cut and removed most of the nutrients are removed with them

when land is cleared and converted to agriculture or other use it can only be used a couple of years without massive additions of fertilizers

→ results in slash and burn; use an area for 2 or 3 years then clear another area

3. Light

intense competition for light

leads to stratification of plants and animals into 6 or 8 "layers"

tropical forests have more leaves/area than other forests

→ almost no direct sunlight reaches the forest floor in mature rainforest

→make optimal use of sunlight

<u>Biotic Features</u>

Plants

Trees

rainforests contain ~1/3rd (80,000) of the known flowering plant species

general features that characterize the tropical rainforest plants:

trees characterized by long straight trunks that may not branch below 100'

almost all rainforest plants are perennials

trees are the predominant lifeform, shrubs are rare

trees usually evergreen flowering plants (not conifers)

old leaves often have a film of cyanobacteria, green algae,

mosses, lichens and even small ferns

leaves commonly have "drip tips"
→ hastens the drainage of water
→slows growth of epiphytes

trees grow continuously; no dormant period

→ no growth rings in wood

(except in seasonal rainforest with dry/wet periods)

timing of leaf fall, flowering or fruiting is most closely related to seasonality in rainfall, not temperature

roots often shallow (<1') and form dense interconnected mat

many actually grow above the soil into the leaf litter

buttress roots & prop roots help support taller trees

vines

over 2500 species of vines grow in the erainforests

eg. **Lianas** begin life as small shrubs

sends out tendrils that attach to sapling trees

both grow together to reach canopy

the vines grow from one tree to another and may comprise 40% of all the canopy leaves

eg. **rattan vines** have spikes on underside of its leaves to grab onto trees

eg. **strangler vines** use trees as support and grow thicker and thicher as they reach the canopy

eventually kills its host tree

epiphytes

Rainforest Strata

a fully developed rainforest has 3 or 5 layers (strata):

A. canopy (>50M; >160'):

tall, straight, disproportionately slender tree trunks

canopy tree trunks rise 60-80' before branching into flattened crowns

eg. some grow to over 200' tall

entirely exposed to sun

exposed to more wind and air movements

more temperature and humidity extremes

trees often buttressed at base

seeds produced by canopy trees are often small and dispersed by wind

canopy trees support lots of **epiphytes**

eg. bromeliads

epiphytes can't use roots to absorb water so many are succulents or hold water

eg. some of the largest bromeliads can hold several gallons of water

become small aquatic ecosystems for aquatic fauna and frogs, etc

eg. strangler fig

starts life as an epiphyte

some roots grow quickly down trunk to the ground

as roots develop they surround the trunk and fuse into a rigid cylinder that restricts further growth of "host" tree

fig's branches and leaves overshadow the tree's foliage

eventually host dies and rots leaving strangler fig freestanding

eg. lianas

stems of lianas hang from upper branches of giants and grow in great loops between canopy trees

thicken and become woody but flexible

→ become highways for wildlife

→ bind the canopy together

but when old tree falls sometimes other healthy trees are pulled down with it

some trees grow **adventitious roots** to absorb water and nutrients from these pads of epiphytes

B. middle story (30-40M; 100-130')

dense, forms continuous canopy of leaves that trap most of the remaining sunlight

air currents are blocked so humidity is greatly increased

C. understory (ground level to several m)

have very low light (<5%) year round

almost all understory trees are perennials

→ better adapted to low light

annuals generally need lots of light to complete life cycle in one year

shrubs and herbs specialized for life in the

shade and seedlings of taller trees

generally few low growing species on forest floor

lots of bare areas

→its very open except around "holes" where an old tree has fallen, or at road cuts and river edges

(the old TV versions of hacking through dense undergrowth is an exaggeration)

little forest litter since it is rapidly decomposed

seedlings of large trees must adapt to conditions of each level as they grow toward the canopy

tropical vines grow up trees to find light (when young grow away from light!)

dark, humid

→ somewhat rivals a cave in constancy

lots of algae, lichens and mosses growing on plants

understory plants often have leaves that are smooth and slick and drooping to allow water to run off and discourage growth of algae, lichens and mosses

little or no wind in understory

→seeds of understory plants are most often dispersed by animals

When a large tree dies and falls to forest floor:

its decay releases a large burst of nutrients to the soil

shade loving plants in opening also die due to too much light

saplings in "opening" which normally grow very slowly (~1"/yr) now grow at ~40"/yr

even then it takes ~100 yrs to fill the gap

Animals:

especially diverse array of birds, ants, termites and other insects

often with adaptations for living entire life in trees

often brightly colored and patterned

loud vocalizations

diets heavy in fruits

insects are the largest single group

including huge colonies of ants

in various strata, the available foods, modes of

locomotion and ability to conceal vary greatly

eg. in treetops, animals can obtain large quantities of plant foods; leaves, flowers, fruits

most have limbs adapted to climbing or swinging, jumping and gliding

many of the birds, bugs, frogs of treetops rarely come down to ground level

the mosquitoes of canopy are different species than those found at ground level

eg. ground mammals – little or no climbing ability and depend for food largely on fruits and other plant materials that drop from above

also extremely diverse, and occurs in layers
monkeys,
sloths,
great diversity of insects,
reptiles,
amphibians
colorful exotic birds

lots of plant/animal interactions:

feeding types: flowers, fruits, leaves, roots

breeding sites

pollinators: birds, beetles, bees, flies, moths, bats, mammals

animals play key role in dispersal of seeds

Threats To Rainforest Ecosystems

Rainforests today are rapidly being destroyed

the destruction is larger in scale and much quicker than the forests lost to spread of western civilization across Eurasia and N America

it no longer forms an unbroken band along the equator

each year 5.8 Million hectares are destroyed (2002)
another 2.3 Million hectares are degraded (2002)
→ each year area size of Washington State is cleared
= size of football field lost each second

~1/3rd has already been destroyed;
→what is left is less than area of US
(6M km^2 (2.6 M mi^2))

the highest *rates* of deforestation are in SE Asia

→ ~1/2 if it is in 3 countries: Brazil, Zaire, Indonesia

Brazil is losing the **largest amount** of forest land/yr but since it also has the world's largest existing area of rainforests its rate of loss is less

because of thin soil layer clearing rainforest leads to its permanent destruction

major causes of deforestation:

1. subsistence agriculture

(slash and burn) (50-75%)
33,000 mi^2/yr

2. commercial logging (15-20%)
11,400 mi^2/yr

3. cattle ranching (10-15%)
5700 mi^2/yr

1. <u>Subsistence Agriculture</u>
(Slash and Burn Farming)

soil productivity declines quickly
soil fertility declines
soil erosion increases
regional climate changes
→more severe flooding and droughts
species extinctions
effective for only 2-3 years
→ then repeat in new area
need 20-100 years for recovery

was once done sustainable

entire Amazon jungle was farmed at one time or another during human history

small areas were used for one season the abandoned to allow regeneration

quicker recovery since not all the nutrients were removed

some native people today farm sustainably by planting crops in long rows along foot paths rather than destroying forest

2. <u>Wood Collecting & Commercial Logging</u>

firewood
~ half of wood cut worldwide is used for fuel wood and

charcoal
→ mostly in developing countries

>1/2 people in world depend on firewood or charcoal as main source of heating and cooking fuel

~1.5 B people can no longer find enough
ave = ~1m^3/person/yr

lumber

lumber, plywood, veneer, particleboard

total world wood consumption
~ 3.7 B tonnes/yr (3.7 B m^3/yr)

exceeds use of steel and plastic combined

international trade in timber, pulp and paper
= $114 B/yr

developed countries produce <1/2 of all wood but account for 80% of its consumption

developing countries produce >1/2 and use ~20%

timber could be harvested sustainably but today only ~0.1% is logged this way

~2/3rd 's of paper produced worldwide is made from virgin logs

the rest comes from wastepaper

Asian companies dominate rainforest logging worldwide

eg. 2006→ China is now the largest importer of illegally cut timber from tropical rainforests

US and UK are its two biggest markets for the furniture made from this illegal lumber

eg. Japan consumes 1/3rd the worlds wood exports
45% of this is from SE Asia

includes 11 Bil prs of disposable chopsticks
→ enough wood for 15,000 Japanese style houses/yr

3. <u>Cattle Ranching & Grazing</u>

effective for only 6-10 years
almost all cattle are exported for fast foods

<u>Solutions to the Problem</u>

is anything being done to solve the problem?

1. champion for the rights of indiginous peoples

   its not just an ecology issue it's a human rights issue

   eg. provide surveying and legal defenses

   eg. develop programs to pay indigenous peoples for medicines derived from rainforest plants

2. boycotts of beef from cattle raised in pastures created from the destruction of rainforests

3. include preservation of the rainforests as a means to reduce CO_2 emissions and fight climate change

   deforestation contributes 18% of annual world carbon emissions; second only to electricity generation (24%)

4. determine a monetary value for the "natural services" provided by natural ecosystems and the financial cost of their destruction

   then insist that these values be an integral part of any cost/benefit analysis for their direct commercial use

Economic Impacts of Tropical Rainforests

Biodiversity

tropical rainforests are some of the worlds greatest outdoor laboratories

also monuments to natural wealth
→ far older than the human species

forests offer habitat and refuge for diversity & commercially important species

livestock forage, water resources, fish and wildlife habitat, etc

a fundamental service provided by nature is ensuring that ecosystems are relatively **stable** and **resilient**
= the ability to withstand disturbance and bounce back

as ecosystems are affected by human activities they become simplified

and become more brittle and more vulnerable to decline

some species act as "keystone species"
→ their destruction would likely permanently alter the ecosystem in which they are found

cause a dramatic loss of species

wetlands have been converted to intensive aquaculture in several countries:

eg. Phillipines: 78% of coastal wetlands
eg. Ecuador 70% of coastal wetlands

→ can bring $11,600/ha/yr for ~ 5-10 yrs

using natural mangroves for fish, game, fuel, wood, medicines etc could bring $1000-10,000/yr indefinitely

about 1/4th of all the medicines we use come from rainforest plants

eg. curare cromes from a tropical vine used to relax muscles during surgery

eg. quinine from the cinchona tree is used to treat malaria

eg. potent anti-leukemia drug comes from the rosy periwinkle

eg. more than 1400 varieties of tropical plants are thought to be potential cures for cancer

yam, coffee, chocolate, bananas, mango, papaya, macadamia nuts, avocados and sugarcane all originally came from tropical rainforests

still mostly grown on plantations in regions that were formerly primary forest

eg. 1990's 40 M tons of bananas were consumed worldwide

eg. 13 M tons of mangos

eg. coffee exports from central america worth Billions of dollars

Rainforests also have many "nonextractive uses"

Release Significant Amounts of O_2

amt of O_2 produced by all the world's forests = 55,490,000,000 metric tons/yr or 16.9 tons per hectare

contribution of tropical rain forests = 15,300,000,000 or 28 tons per hectare per yr.

- represents only a small fraction of O_2 in atmosphere
→ probably the amt used by microorganisms decomposing dead organic matter

Essential role in global carbon cycle

trees remove CO_2 and store it = **carbon sequestering**

burning rainforests puts 2.4 B tons of CO_2 into atmosphere each year

globally, tropical deforestation releases 18% of human produced greenhouse gasses

→ conserving forests could reduce emissions
cost/benefit analysis found this a greater benefit than money derived from agriculture or logging

forests modify local climates

→ generate rain

→ stabilize temperature

Waste recycling, water purification, & pollution control

help to regulate the world's temperature and weather patterns

hold critical supplies of worlds freshwaters

eg. 20% of worlds freshwater is found in the Amazon basin (the largest area of rainforest)

roots reduce soil erosion, and create new soil

absorb, hold and slowly release water
→ making it available in dry periods and reducing flooding

recharge groundwater

plants, bacteria, fungi can remove toxins from air, water and soil:

eg. CO_2 and SO_2 are removed by vegetation
eg. CO is removed by soil microorganisms
eg. NO_x is removed by fungi and bacteria

worms, insects and microorganisms create and aerate soil and recycle nutrients

Recalculating the "Value" of Nature: Ecological Pricing

although societies value nature in many ways traditionally most of this "value" has never been converted to monetary terms

→ in terms of economy, a tropical rainforest, or coral reef is not worth a cent until it is cut for lumber, harvested, drained and filled for housing, etc

→ cost/benefit analysis always favors the destruction of a natural resource NOT its sustainable use

financial benefits from natural resources are given to private individuals and companies

but

costs of any loss are distributed across society = "**social costs**"

→ there is little economic incentive for those exploiting a resource to use it judiciously

eg. globally, government subsidies and programs shunt >$800 Bil/yr (98) toward activities that harm the environment

the least sustainable and truly profitable use of forests is for the production of a single commodity

→ yet this is exactly what economics encourages

eg. Indonesian forests
$3,600/ha → timber only
$4,800/ha → non timber uses:
fish, products, erosion control, etc

by not cutting these forests they could produce over $35 M/yr in sustainable use for 70% of the local population

our market system should reflect, not hide, ecological realities of our economy

more recently, conservationists have attempted to apply marketing economics to attach a monetary value to "**nature's services**" provided if the forest is NOT destroyed:
watershed protection
biodiversity conservation

need to develop "**ecological pricing**" schemes restructure costs, taxing, subsidies to reflect the true value

eg. Ecological Pricing of 1 hamburger
factor in value lost of forests destroyed to create range land for cattle
→ $200

how to calculate "ecological pricing"

known 1 time "market" values must be balanced with LOSS of value of sustainable uses

also need to factor in value of "nature's services"

>100 different studies have concluded that the current economic value of the world's ecosystems is *at least* $16-54 Trillion/yr

exceeds GWP of $28 T/yr

→if every service of every ecosystem type were measured the figure would be much higher

1. Sustainable Uses

today (2012) only about 10% of all tropical forests are sustainably used:

eg. timber could be harvested sustainably but today only ~0.1% is logged this way

eg. food, fiber, fuels, fertilizers, art objects, etc

providing these services requires healthy ecosystems

eg rattan trade (Asia)
$2.7 Bil/yr

in Thailand value of Rattan exports is 80% of legal timber exports

eg. market for 4 "obscure" plants in Oregon forests: beargrass, huckleberries, solal and sword fern = $72 Mil/yr

1989 study (Peters, Gentry, Mendelsohn, Nature June 29,1989) estimate:

that the net value of sustainable collection and sale of fruits, oils, rubber, and medicines from Amazonian rain forest would generate over $6330/ha/yr

vs cutting a rain forest for timber yields $1000/ha for one time use or $490/ha/yr from selective cutting

or tree plantation on a hectare of cleared forest is worth $3184/yr

or pastureland on one ha of cleared forest is worth $2960/yr

2. essential role in global carbon cycle

trees remove CO_2 and store it
= **carbon sequestering**

burning rainforests puts 2.4 B tons of CO_2 into atmosphere each year

globally, tropical deforestation releases 18% of human produced greenhouse gasses

→ conserving forests could reduce emissions
cost/benefit analysis found this a greater benefit than money derived from agriculture or logging

→ eg. 1 ha of "carbon storage" function of forests ~ $3000 value

3. Waste recycling, water purification, & pollution control

water purification and storage is a major part of the water cycle

eg would cost $100,000/yr to duplicate water purification and fish propagation value of 1 acre of wetland

eg. estimates for value of water recharge and storage services near large cities = $40,000/ha

eg. for each 1% increase in wetlands, downstream flooding increases 3% -4%

eg. total losses due to unsustainable wetland and soil practices:

US	=	$44 B/yr
World	=	$400 B/yr

4. Ecotourism

used for recreation
→observations and appreciation of wildlife and natural areas

US protects ~ 3% of all US land; >76M acres in alaska alone
→roads, timbering, motor vehicles etc are all prohibited

these areas are strictly controlled and are open to hiking, camping, canoeing

Parks
→ more intensive use; less fragile areas

US Natl Park Service was established >100 yrs ago with estab of yellowstone

established "to preserve natural areas of public lands considered unique because of scenery, history, wildlife, etc"

parks preserve another 76M acres in US

>100 countries have adopted our system of parks as a model

parks are intensively used

unfortunately while visitation has increased, maintenance budgets have been reduced
→ lead to commercialization of parks with increased vandalism, crime and crowds

tourism dollars are valuable commodities:

eg. Kenya
→ tourism is the largest single source of income for the country

eg. Companies hiring in Oregon have found

that potential employees are willing to take less pay (?$500/month)

→ combined total is = to all states lumber and wood products payrolls

5. Future Wealth

enormous future wealth in the variety of organisms if ecosystem is preserved
→ contribute to basic biological theory
→ pharmaceuticals

if forests and their inhabitants are used sustainabily it could be a continuing source of these and as yet unknown commercial products

a. Future Industrial Chemicals & Products

many important compounds come from or were 1st discovered in wild organisms

eg. rubber tree, antibiotics, aspirin, dyes, foods and spices, paper & clothing, etc

b. Future Medicines and Pharmaceuticals

US → 25% of all prescriptions and 60% of non prescription drugs contained active cmpds extraced from natural products (1996)

global pharmaceutical industry = $200B/yr
→ global forest derived drugs ~$40-100 B/yr

eg. digitalis → heart
quinine → malaria
antibiotics → fungi
aspirin → pain relief
taxol → anticancer

of 76 pharmaceutical products derived from plants only
→6 can be artificially synthesized at commercial levels

in some cases, collecting medicinal plants provides significant income to indigenous peoples

eg. Belize- gathering medicinal plants yields 2-10 x's the annual income of slash/burn farmers

not just plants, all kinds of organisms

eg. microorganisms (bacteria and fungi)
→ produce over 3000 antibiotics

eg. snakes → antivenoms, anticoagulants
amphibians → neurochemicals

only ~1% of rainforest species have been examined for their potential uses

only ~5% of all plant species worldwide have been screened for pharmacological substances

eg. of 275 species found in 1 ha of rainforest
→ 72 species yielded products that could be

exploited for direct economic gain

eg. of 842 individual trees
→ 350 yielded products with direct economic value

"potential" commercial products were not recognized as valuable until recently

eg. rubber tree's uses were completely unknown 150 yrs ago

est loss of potential pharmacological value from plants that have already become extinct
= $12 B in US alone

the more rare species that grow under unusual conditions are often the ones most important and most likely to be destroyed

c. Gene banks for agriculture and livestock

foundation for all agricultural plants and animals

all modern crop varieties were originally produced using native plants

traits were selected over 100's or 1000's of years

most crops in US are domesticated species from tropics

1. inbred species require gene infusions

maintaining wild varieties of crop plants allows us to select for new traits or revitalize aging genetic stock

2. may want to look for new genes in same species that might be useful

eg. 1.5 M acres of California farmland is threatened by salinization

→ trying to find salt tolerant strains of plants that can grow there

eg. 1970 So Corn leaf blight
1st in Fla → wiped out $1 B corn
all US corn was based on 6 inbred lines
now have a resistant strain to this disease

3. also, many countries have "Germ Plasm Repositories" for domestic crops.

but some seeds, esp larger seeds, lose viability after a few years.

seeds are planted and new seeds are collected

may need to collect new wild seeds to augment diminishing seed stores

est value of "gene banks" (crop ancestors) =$66 B

6. Social Values & Human Costs of Nonsustainable Uses

as rainforests are cleared the indigenous peoples usually suffer

greater chances of droughts or floods
new agricultural pests
loss of topsoil
sedimentation of streams and rivers
diminished yields from their crops
fewer fish in streams
shrinkng supplies of game, fruits, nuts

rising: alcoholism
drug abuse
domestic violence
homelessness
emigration

7. Aesthetic, Cultural, Moral and Ethical Values

eliminating a few species won't cause ecosystem collapse

probably won't irreversibly affect human progress

but

Do we have the right to "play god"
not only with individual lives
but with whole species and ecosystems

we don't have "divine permission" to kill them

Do species have a moral right to exist independently of our need for them

→ we must be global stewards

"If I decide to accept your offer to buy our land, I will make one condition. The white man must treat the beasts of this land as his brothers. I am a savage and do not understand any other way. I have seen a thousand rotting buffaloes on the praries left by the white man who shot them from a passing train. What is man without the beasts? If all the beasts were gone, men would die from great loneliness of spirit, for whatever happens to the beasts also happens to the man. All things are connected. Whatever befalls the earth, befalls the sons of the earth."

- Chief Seattle

also biological diversity adds to our quality of life

eg. landscape beauty: birds, flowers, wildlife, etc

some animals and plants have cultural significance

others we may never "see" in nature, but its nice to know they are there

eg narwhales, rainforests, etc

"Human intelligence is bound to the presence of animals…they further, throughout our lives a refining and maturing knowledge of personal and human being"
-Paul Shepard
'Thinking Animals'