Anthropogenic Changes on the Ground

Dust Storms originating in Deserts/Desertified Regions

- Earth can experience massive dust storms that transport sediments over long distances
- Loess: up to 30m high loess banks (very fine sand/silt formed during glaciation by glaciers grind on rocks) in Europe, Asia and America formed in and since the last ice age, when strong winds transported the loess across continents
- dust Storms in desertified regions are quite powerful and can carry dust and other particles high into the atmosphere. High winds can easily carry these particles across oceans.
- America's Dust Bowl: during the brought of the "Dust Bowl" in the 1930s, the top soil in North America was eroded away and transported across the North Atlantic to reach Europe
- Alaska dust storm: A satellite image showing a November 2006 dust storm that transported loess from Alaska far into the Pacific Ocean can be found at NASA's Earthobservatory. This dust storm was pushed by Chinook winds that are caused by a similar mechanism as our Santa Ana winds.
- the following example of dying corals in the Caribbean illustrates just how far-reaching local action/mistakes can be to the global environment
- Dust Clouds reaching the U.S.: can be generated as far away as the Gobi Desert. A storm driven dust cloud in April 2001 reached the West Coast only two days later and crossed the continents in 7 days. Implications of this is that pollution anywhere on the planet can be carried elsewhere to cause major damage. An example of this is the South East Asian Brown Cloud that is caused by industry and slash-and-burn deforestation.
- Dust Storms transport bacteria: example: sub-Saharan dust storms can pick up bacteria from poorly developed sewer systems; the bacteria can caused diseases near the coastline across the Atlantic. Observation: It has been a puzzle for some time why the Caribbean Islands experience "dusty skies" despite their tropical climate. The health of corals, sea fans, sea urchins and other marine organsims has been deteriorating. It turned out that the microorganisms responsible for this are pathogenic (e.g. bacteria of human origin) and come from open sewage ditches in Western Africa.
- reference: the paper by Griffin given below

Desertification

According to the Eden Foundation, land covers 14.9 billion hectares of Earth's surface. A UNEP (United Nations Environmental Programme) study shows that 41% of this is dryland of which 1 billion hectares are naturally hyperarid desert (7% of the total land). The rest of the dryland has either become desert or is being threatened by desertification. About 25% of world's population inhabit the drylands. While true deserts have a relatively stable environment, drylands can experience profound short-term climate changes. Extended droughts can caused devastating famines.

- deserts are probably the climatic zone that is least understood so the definition of "desertification" appears somewhat controversial
- some associate "deserts" with degradation of land
- Deserts - What are they, how do we know
  - a desert is defined as a region where vegetation is supported on no more than 15% of its surface area; it contains no permanent streams except for rivers that may bring water from a different climate belt (e.g. Nile); desert are typically associated with annual rainfalls of less than 25mm (10in);
  - factors that also play a role: evaporation rate, characteristics of precipitation
  - precipitation levels alone can be misleading; e.g. an area may have more than the 25mm of annual precipitation typical for a desert but precipitation could fall in one or few heavy rain storms once every or every few years, with extremely high run-off rates (i.e. useless for cultivation of land); there may be long dry spells/droughts in between
  - the extent of deserts is nowadays assessed by estimating the abundance of vegetation using satellite imagery; in terms of inhabitable land, this is sometimes controversial as satellites do not distinguish between vegetation that is more or less "useful" to humans
  - the gravity of recent desertification is difficult to assess as "dry" and "wet" phases in deserts may have oscillated in the past (e.g. Sahara)
  - natural causes of advancing deserts include climate shifts and fast-advancing sand dunes
  - drought problems especially severe in semi-arid regions where little shifts in climate can cause great droughts
  - severe sand storms can reach high into the atmosphere and carry dust to other continents; some West African sandstorms reach the Caribbean and North America; diseases were carried by such sand storms at least as far as the Caribbean

DID YOU KNOW? Antarctica is strictly speaking a desert; it has as little as 2cm of annual precipitation making it one of the driest places on Earth

- Human Impact
  - overgrazing: particularly goats eat anything, even small poorly growing plants
  - overpopulation: serious problem in semi-arid regions and deserts which could support nomadic people who adapted to desert life, but not permanent settlements
  - slash-and-burn technique: in tropical to semi-desert climates; clear rainforest or bushland for annual farming;
  - additional stress to environment by burning remaining crop stalks after harvest
  - after slash-and-burn event, land is often quickly depleted of its nutrients, forcing farmers to move on to new locations
  - land now particularly vulnerable to wind erosion; wind can blow top soil away, uproot seedlings and suffocate plants where soil later accumulates
  - once top soil is removed, land can no longer be used for farming
  - abandoned land also subject to massive water erosion, especially on slopes. The removal of soil results in severly furrowed badlands that cannot be used by humans
  - drought problems especially severe in Sahel where little shifts in climate cause great famine
- Example Sahel:
  - the Sahel is a belt of semi-arid dryland/savanna south of the Sahara desert. The Sahel receives 15-50mm (6-20in) of annual rainfall, primarily in the monsoon season between June and September. During summer, the northward shift of the intertropical convergence zone allows moisture rich air move in from the southwest to bring the rain (see Lecture 16). Soils in the Sahel are mostly acidic (which results in aluminum toxidity to plants), and are very low in nitrogen and phosphate (i.e. not very nutritious). Most people living in the Sahel are semi-nomadic, farming and raising cattle. This way of temporary landuse (transhumance) is probably the most sustainable way of utilizing the Sahel. People move to the usually drier north during wetter years because the soil there is more nutritious, having higher quality plants for grazing. People then move south for several hundred km where plants are more abundant but of less nutritional quality. Recently, the ratio of permanent settlements and farming has increased, which stresses the environment and leads to conflicts. A long wet period in the 1950s and 1960s was followed by a serious

drought in the 1970s and 1980s. Grazing and farming in the north became unsustainable which led to large-scale famine, killing a million people and afflicting more than 50 million people. Had it not been for massive humanitarian efforts, many more people would have starved to death.

- The critical role of the green belt: in some places, the northern part of the Sahel pastural land is protected from the Sahara desert by a natural green belt (e.g. in Niger). Several species grow large despite low rainfall, inhibiting wind and water erosion (desertification). According to a UNEP study, the greenbelt has survived because it is closer to the desert, hence drier, than the northern Sahel pastural land. The greenbelt is too dry for sustainable millet production (a type of grain). However, careless use could destroy this zone and expose the northern pastural Sahel to intense desertification. In some places, the northern Sahel pastural land appears to be degrading (see Eden website). Near the town of Tanout in Niger vegetation thinned in the last 40 years and millet harvest is only a small fraction of what it used to be 40 years ago (the Eden website quotes 1/7 of the harvest 40 years ago, on fields three times larger). Sand dunes are advancing and can reach roof level. These sand dunes are not advancing from the Sahara desert but form from regional soil erosion.
- pollution and the last Sahel drought: recent research suggests that the cause for the Sahel drought of the 1970s and 1980s had a human component. There is evidence that pollution in the atmosphere caused "global dimming" and generated enough aerosols to inhibit the formation of clouds necessary for extensive rainfall. It was initially suggested that local slash-and-burn practices were responsible for the pollution but recent studies suggest that the pollution was caused by coal burning in North America.

- Some Numbers
  - an estimated 2,500 km2 are being lost to desertification each year in Niger alone (the size of Luxembourg, twice the size of New York city)
  - according to the Eden website, peanut production in the Tessaoua area in Central Niger rose from 4,500 tons in 1928 to 78,900 in 1970 before it declined due to lower prices and disease. Peanuts were replaced by millet (72,000 hectares in 1970 to 162,000 hectares in 1980), occupying up to 80% of the area by 1981. Intense agriculture resulted in rapid decline of stable perennial vegetaion and desertification over wide areas. Species rich woodlands that harbored monkeys disappeared by 1981.

Deforestation

- There is no natural cause for complete deforestation, except for dramatic shifts in climate or the introduction of a new disease or pest. Forests hold soil to the ground
- Forests regulate the water supply to the surrounding region
- Forests are part of the climate system
- Forests are home to a rich variety of wildlife. Of all ecosystems, the tropical rainforest has the richest biodiversity.
- forests are a major producer of oxygen in Earth's atmosphere
- Logging is especially damaging to the environment. Without a strategy for replacing trees, permanent damage is inflicted.
- Soil
  - A typical soil profile has several distinct zones. The thickness of soil and its zones depend on the prevailing climate.
  - zone of leaching and zone of accumulation: similar to the coffee grounds in a filter, nutrients are in the upper regions of the soil profile. When rain percolates through the soil, the nutrients are leached from the top and accumulate further down
  - horizons: a soil profile is divided into various horizons. On the top, the O-horizon include the humus layer that contains partially decayed organic material. This is the horizon most important to plant growth. Below is the A-horizon in which the humus has decayed and mixed with minerals. The B-horizon comprises the subsoil into which the nutrients leach. The B-horizon also contains weathered rock from below.
  - The richest soil with large amounts of nutrients can be found in the temperate climate zone
  - In the tropical climate zone, the soil is very thick, comprised mainly of the A-horizon from which minerals are leached out. The B-horizon is missing. The humus layer is extremely thin. The reason is that in the warm humid environment, organic material decays so fast that humus cannot accumulate. The rainforest adapted by taking up nutrients through the roots faster than plants in temperate climates.
- Rainforest
  - cover less than 2% of Earth's total surface area, but are home to 50% of Earth's plants and animals

  - many plants (e.g. orchids) are unique to rainforest and provide base for important medical remedies, incl. some that have anti-cancer properties
  - rainforest can be found all over the world from as far north as Alaska and Canada (temperate rainforest) to Latin America, Asia and Africa (tropical rainforest)
  - the largest temperate rainforests are found on North America's Pacific Coast
  - rainforests regulate the world's temperatures and weather patterns
  - rainforests are critical in maintaining the Earth's limited sypply of drinking and fresh water
  - 20% of the world's fresh water is found in the Amazon Basin
  - rainforests provide important products, e.g. timber, coffee, cocoa
  - a typical 4 square mile patch of rainforest contains as many as 1500 flowering plants, 750 species of trees, 400 species of birds and 150 species of butterflies

- Human Impact
  - deforestation has been going on during the last 8000 years
  - between the 1960s and 1990s, 20% of the world's tropical forest was destroyed
  - clearcutting of temperate forests
  - temperate forests are often replenished with monocultures that can't sustain great biodiveristy
  - today, only 50% of temperate rainforests remain (75 Mio acres)
  - monocultures are more vulnerable to pest infestation than mixed cultures
  - slash-and-burn technique in rainforest for fuel, timber or farming
  - removal of forest especially problematic in tropical rainforest as nutricious humus layer is extremely thin and easy to erode and lost
  - additional stress to environment by burning remaining crop stalks after harvest
  - in tropical soil, only one year of agriculture can leave the soil depleted of its nutrients, forcing farmers to move on to new locations
  - land now particularly vulnerable to erosion
  - on slopes, abandoned land subject to massive erosion, resulting in mass movements and severly furrowed badlands that cannot be used by humans (e.g. Madagascar)
  - every second, rainforest of an area the size of a football field is lost (area the size of Iowa per year)

  - 57% of the originally 6 Mio square mi of tropical rainforest are now gone
  - tropical deforestation results in the loss of 100 species per day

- Impact on Humans
  - 57% of the world's forests, incl. most tropical forests, are located in developing countries
  - burning of tropical rainforest creates thick smoke that stresses the environment as well as people; particularly bad examples can be found in and around Indonesia where the smoke in far away large cities can be so bad that people have to wear masks
  - destruction of forest also has an impact on indigenous people. E.g. before 1500A.D., approx. 6 Mio indigenous people lived in the Brazilian Amazon. In the early 1900s, there were less than 250,000.
  - countries with the highest annual losses in natural forest: Mauritania, Niger, Nigeria, Sierra Leone, Cte d'Ivoire, Togo, Rwanda, Burundi, El Salvador, Nicaragua, Haiti
  - The rate at which forest is being lost is slowing, partly because of international concern, but partly because in many places there is little forest left to be cut down 1
  - For many poor countries, hardwood is the main reliable source of income to repay international debts

    DID YOU KNOW?
  - The Amazon rainforest produces 20% of the world's oxygen 2
  - 70% of the plants identified by the U.S. National Cancer Institute as useful in cancer treatments are found only in rainforests 2
  - Once the humus layer is removed, it takes 1000s of years for a tropical rainforest to grow back

Farming

to be augmented

- big-style farming as harmful to environment as monocultural temperate forests
- fertilizer gets into groundwater and contaminates it: some contains so much nitrate that water is unsuitable for feeding babies
- monocultures, herbicides and pesticides do not allow biodiversity
- growing corn that needs massive amount of herbicides is one of worst agricultural culprits

- farming has (unexpected?) far-reaching effects; e.g. some Sea Birds go to near-extinction (e.g. see California Brown Pelican below)
- much farming done in adverse climates, e.g. High Plains in U.S. that gets very little annual rainfall (see Ogallala)
- lowering of groundwater table due to overdrawing water (pumping exceeds rates of replenishment) causing shallow-reaching wells to go dry
- excess removal of groundwater leads to significant subsidence (see San Joaquin)
- agriculture in desert climates subject to salinization; extremely high evaporation rates leave salt behind; some land so salty that nothing grows anymore
- excess diversion of water to irrigation channels leave many streams devoid and shrink inland lakes; the most extreme example is the Aral Sea
- ignorant farming techniques lead to soil erosion (see Dust Bowl)
- poorer countries typically depend on farming for export
- compared to 1990, fertilizer has become more expensive while prices of agricultural products have declined
- Example Aral Sea: located in Uzbekistan; River water from Amu Darya diverted for farming since 1950s; river now runs low for more than 30 years; between 1960 and 1993 Aral Sea lost ¿ 40% of its area, 75% by 2004; now too salty to support fish; main fishing port Muynak is now stranded 20mi from water; salty dry soil carried by winds as far as Arctic ocean; fouls water supplies, cloggs carburators, induces throat cancer, highest infact mortality rate in FSU.
- Example Ogallala Aquifer: Ogallala Formation (largest aquifer in U.S.) underlies about 450,000km2 (175,000mi2) of the High Plains (one of the most agricultural regions in U.S.). The connection between Rockies and aquifer (naturally) severed so all replenishment must come from meager rainfalls. Aquifer first used for agriculture in 1800s. Nowadays, 170,000 wells are being used to irrigate 65,000 km2 (16Mio acres) of land which far exceeds rates of replenishment. Beginning in 1980s irrigated acreage has declined due to higher costs for pumping water out of greater depth (groundwater level dropped).
- Example San Joaquin: southern 2/3 of California's Central Valley; thick fill of sediments (870m/0.5mi on average); climate arid to semiarid (12-35cm/5-14in per year); strong agricultural economy requires extensive irrigation; 50% of this was met by groundwater; by 1970s groundwater levels had declined by up to 120m (400ft) and resulting ground subsidence exceeded 8.5m (29ft). One half of valley was affected (water level raised for

short time only to subside faster after a drought in 1976/77 after sediment compacted).

- Example Dust Bowl: one of greatest weather disasters in U.S. history. Excessive broad-scale farming in midwest without windbreakers or other measures to diminish wind erosion. Several years of drought in 1930s, starting in 1929 lead to drying out of soil. Little vegetation died and could no longer hold soil. A few storms made soil airborne high enough to catch jet stream to Europe. Affected 756 counties in 19 states. See also above under dust storms and chapter 11 in course book.

  DID YOU KNOW? it takes 30 years to grow 1 inch of U.S. soil!

Human Impact on Biodiversity

Farming, mining, industry and urbanization (see also Lectures 23, 25 and 26) have an impact on the natural flora and fauna. Logging is especially damaging. According to the IUCN (International Union for the Conservation of Nature and Natural Resources), large fractions of species are now threatened.

Table 1: Threatened Species (as of 2000)1

Kingdom/Class/Phylum/Kingdom	Fraction of Threatened Species
mammals	24%
birds	12%
reptiles	25%
amphibians	21%
fishes	30%
invertebrates	29%
plants	49%

DID YOU KNOW?
1.7 Mio species have been identified - less than 10% of the likely total

Recent Extinctions (see also Lecture 22)

- If current rates of extinctions will continue for anyother 200 years, experts have estimated that never in Earth's history have so many species disappeared in such a short time as now. Some of this may be natural (especially the extinctions of many animals during/after the last ice age) but most of it now is due to human action. it is now accepted that overfishing and hunting depletes the oceans; in some areas, fishing is done with dynamite which does not distinguish between the desirable individuals (big edible fish) and the undesirable ones (unedible but perhaps in the

food chain of the desirable fish and young edible fish); this type of fishing though still practiced is basically like cutting off the branch of a tree the fisherman is sitting on (why is this done? beats me!); the number of fish has dramatically decreased, especially the deep sea fish (have you looked at fish prices in the grocery store lately?); the size of animals caught along California's coast has dramatically decreased and some have disappeared within the last 10 years (e.g. abalone) (see Lecture 26)

- though the case is not (yet) proven, amphibians are declining at an alarming rate; some mutations are thought to be due to the thinning of the ozone layer
- some hatcheries (e.g. salmon) jeopardize and push out the native population
- perhaps surprisingly, the most severly hit class in the animal kingdom is probably that of birds
- birds are hunted and eaten (e.g. ducks everywhere and; sadly enough still, songbirds in Europe)
- birds are hunted for fashion statements (e.g. Dodo; Peacock?)
- birds, especially flightless ones are endangered by introduced predators (e.g. Dodo, Kauai O'o)
- bird are subject to introduced diseases (e.g. Kauai O'o)
- most birds probably go extinct due to loss of habitat (e.g. Calfornia Gnatcatcher, Kauai O'o)
- some birds go extinct due to human competition for food (anywhere in the food chain, not just at the end) (e.g. Canary Oystercatcher)
- some birds go extinct only short while after we discovered them (e.g. Aldabra Warbler)
- some birds go extinct due to poisoning (e.g. California Condor, California Brown Pelican)
- Example Dodo: Portugese name of a turkey-size (22kg) flightless birds on Mauritius. It was discovered in 1598, only to become extinct in 1681, less than 100 years later. Believed to be related to pigeons. Though some were sent to museums no complete specimen now exists. Inhabited forests, laid one egg in large pile of grass. Vulnerable to imported hogs which ate the eggs and young.
- Example Kauai O'o: extinct in 1987 due to habitat loss, predation by introduced black rat, disease by exotic mosquito

- Example Canary Islands Oystercatcher: extinct in 1981 due to loss of mollusk prey by human overharvest, predation by introduced cats and rats, disturbance by people in coastal habitat

- Example Calfornia Gnatcatcher: not yet extinct but disappearing at an alarming rate right in our backyard due to habitat loss

- Example Aldabra Warbler: discovered on island in Indian Ocean in 1967; extinct by 1983 due to rat predation and habitat degradation by introduced goats

- California Condor: condors are vultures and feed on carcasses, so they don't kill animals. It is often reported that the bird got extinct in the wild in the 1980s after the use of DDT made egg shells so thin that chicken could no longer hatch alive (see also Brown Pelican below). The Bald Eagle, the national bird of the U.S., also was seriously affected by DDT. However, DDT is not the main reason for the extinction of the California Condor. Its decline started earlier in the century due to shooting, pesticide poisoning and habitat disappearance (150 individuals left in 1939; 50-60 by 1967). Less than 30 individuals survived in the wild by 1980. Desperate breeding programs started in zoos (e.g. San Diego Zoo) with 27 surviving individuals (small gene pool!). The condor seems on its road to success as the number of living condors has increased to 219 by 2003. A reintroduction is extremely difficult but attempts started in 1993 in the Los Padres National Forest and are being done in Baja (2002) and the Grand Canyon (1996). The efforts often controversial as local people object. The year 2002 has seen the first chicken hatch in the wild since 1984 but quite a few birds did not survive their second year in freedom. Some were shot by ignorant individuals (either out of pure hunting instinct or they asserted that they kill sheep — Condors are vultures and do not kill animals!) and some flew into powerlines. Some carcasses contained significant amounts of (the poisoning) lead, some birds couldn't find food. As of July 2006, there are 289 California condors and 138 of these live in the wild (want to know more? go to Condor Ridge at the San Diego Zoo.

- DDT: dichlorodiphenyltrichloroethanol; very effective poison; used as insecticide; organisms store this in fat cells where it accumulates; the insects became resistant to DDT but birds greatly suffered by direct poisoning, sterility, fragile egg shells; DDT was banned by many countries in the late 1970s/early 1980s after a lot of damage has been done.

- A little success story: The California Brown Pelican: was luckier than the California condor. Brought to near extinction in the 1970s/80s, due to DDT. This is an intriguing connection to farming on land as the Brown Pelican only fishes in the oceans. Obviously, the Pelican was affected by run-off in stormdrains that started in farming areas. The Brown Pelican has come back after the use of DDT was outlawed. The pelican now enjoys soaring just inches above the ocean waves in much greater numbers and

drops like a rock to fish close to the beach. Its increase in numbers has prompted recent discussions to take the Brown Pelican off the endangered species list.

The Spread of Diseases

- may not have time to do this in the lecture. Diseases (to humans, animals and plants alike) many be local put do to modern globalization and related transport capabilities (ship and air traffic) an increasing global problem. An important natural way of spreading human diseases is by ways of dust storm clouds (see above). spreading of diseases to "new" territory extremely problematic as local individuals may no immunity
- spread and transmission of diseases vary greatly (e.g. inhalation of airborne agent; by touch; contact by bodily fluids) and death rate also varies; some diseases are extremely contageous, deadly but typically don't spread fast as agent exhausts host resources (e.g. ebola); a typical flu is less contageous and kills less but can spread between continents and affect great numbers of people
- can have profound impact on local economy (e.g. SARS that basically brought Eastern Asian tourist industry to its knees)
- spread of disease and success to fight it depends on locations (e.g. sad example is AIDS which has declining death rates in the U.S. but has devastating rates in most African countries); e.g. 40% of Zimbabwe's population is affected; treatment is too expensive for most of these people)
- eradicated diseases can be reintroduced by bringing the vectors (e.g. malaria now extinct in San Diego but could reappear if corresponding type of mosquito (anopheles) is introduced by accident)
- spreading diseases by dust storms: e.g. dust from storms in Sahara can be carried across Atlantic Ocean; diseases spread this way found in Caribbean (see section above)
- spreading diseases by air travel: most prominent recent example is probably SARS
- spreading diseases by ship: some disease-bearing mosquitos brought to California coast by ship from Asia (introduced with "luck-bringing bamboo")

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