Wollo university college of agriculture
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PPT: Climate change adaptation and mitigation

Credit hour 3

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Chapter 1 Introduction

1.1 Climate change and variability

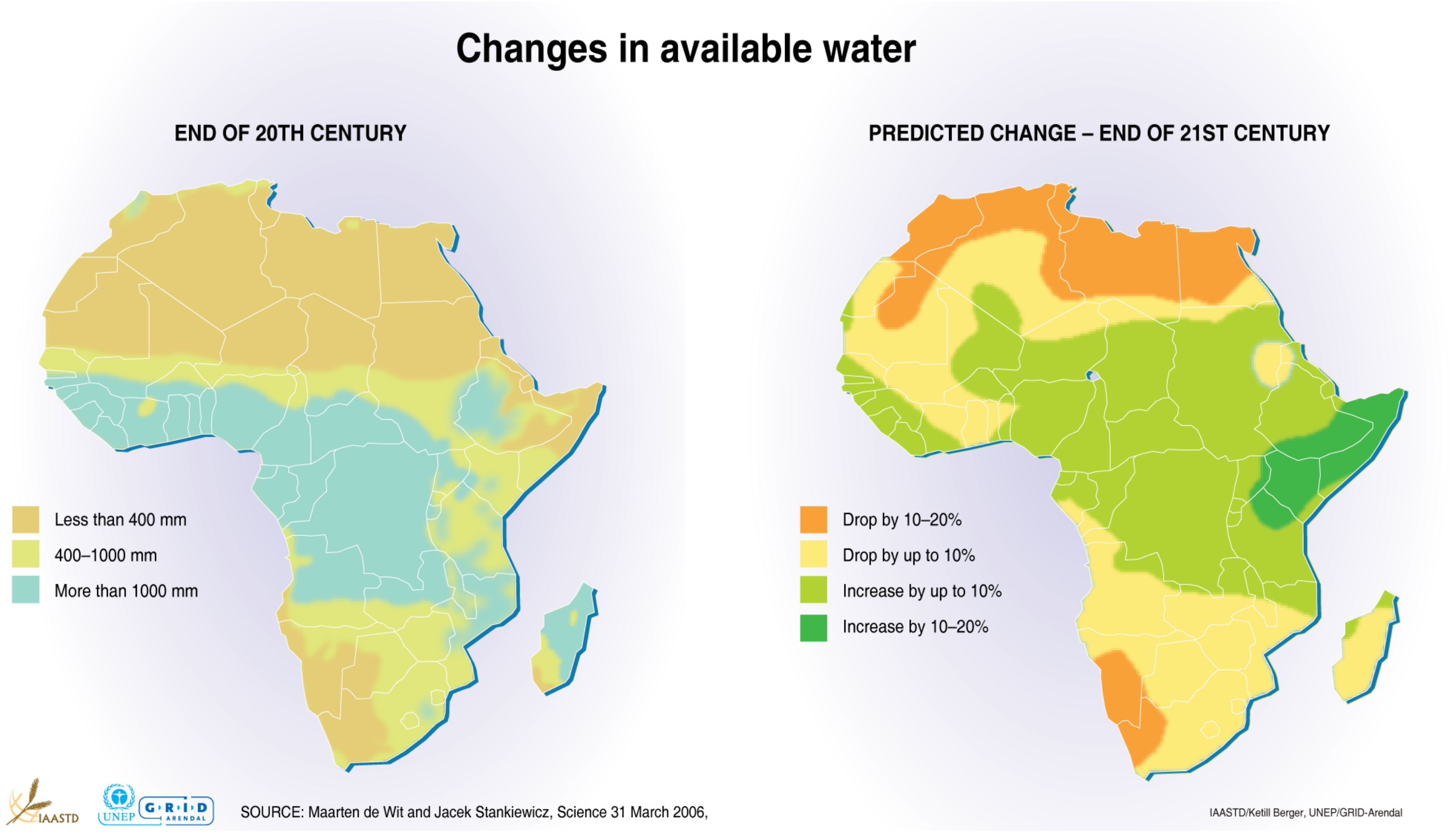
- Climate change is along term change of climate and weather elements such as rainfall,temprature, wind pressure and solar radiation for longer period of times usually 30 years or
- A measure of long term statically significant continuous decrease or increase in climate
- Where climate variability is a short term climate fluctuation below or above over long-term average

---introduction

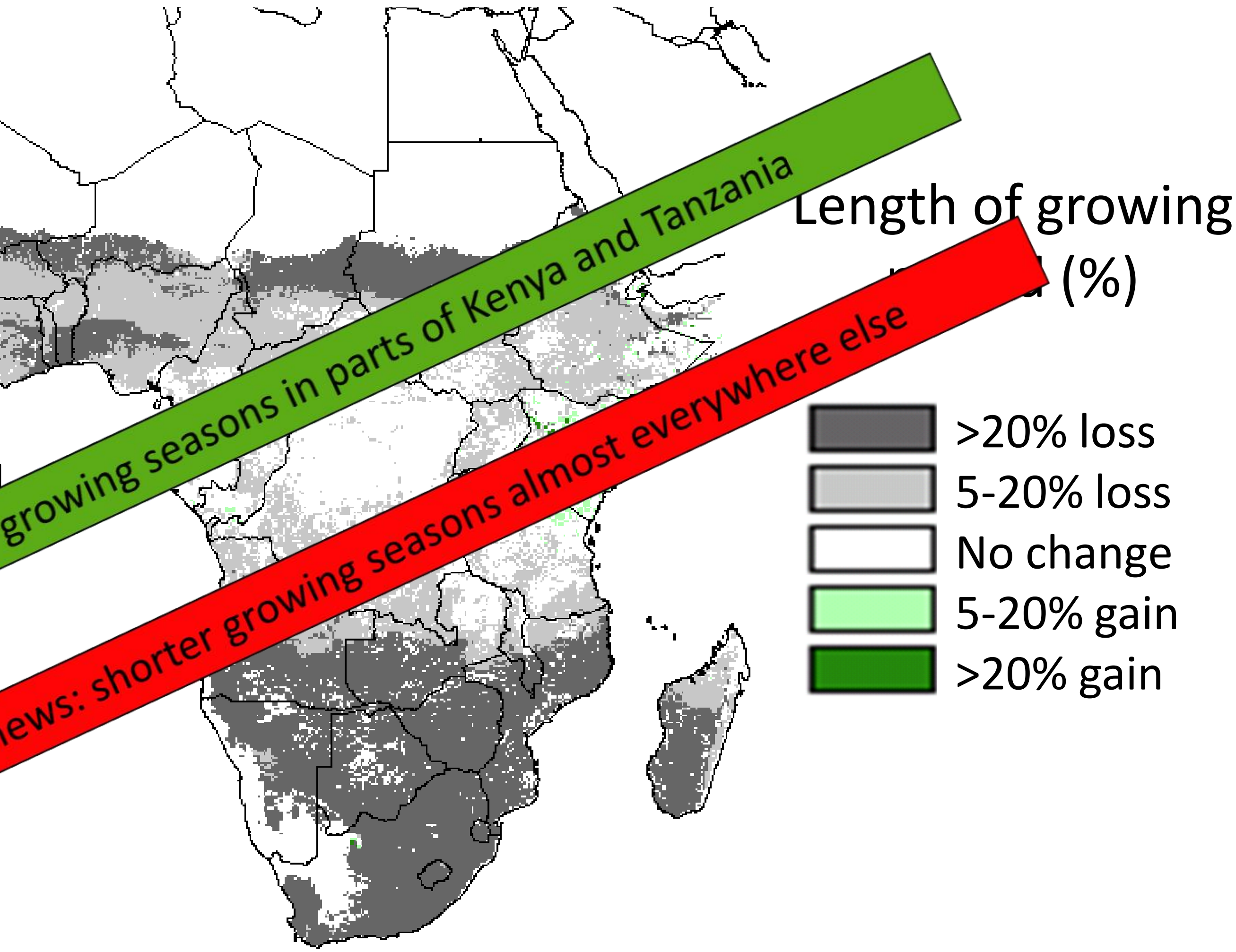
1.2. Past, present and future predictions of climate change

- The IPCC (2001, 2007) projects for Africa are:
  - Warming of 0.2 - 0.5^{o}C per decade
  - 5-20% increase in precipitation in the wet months (December to February)
  - 5-10% decrease in precipitation in the dry months (June-August)
- The rising temperatures and rainfall patters are expected to produce an increase/ intensification in the present impacts (El Nino, severe droughts, floods, food shortage, diseases spread

Predicted changes in water availability



Impacts 1: Long-term trends in temperature and rainfall

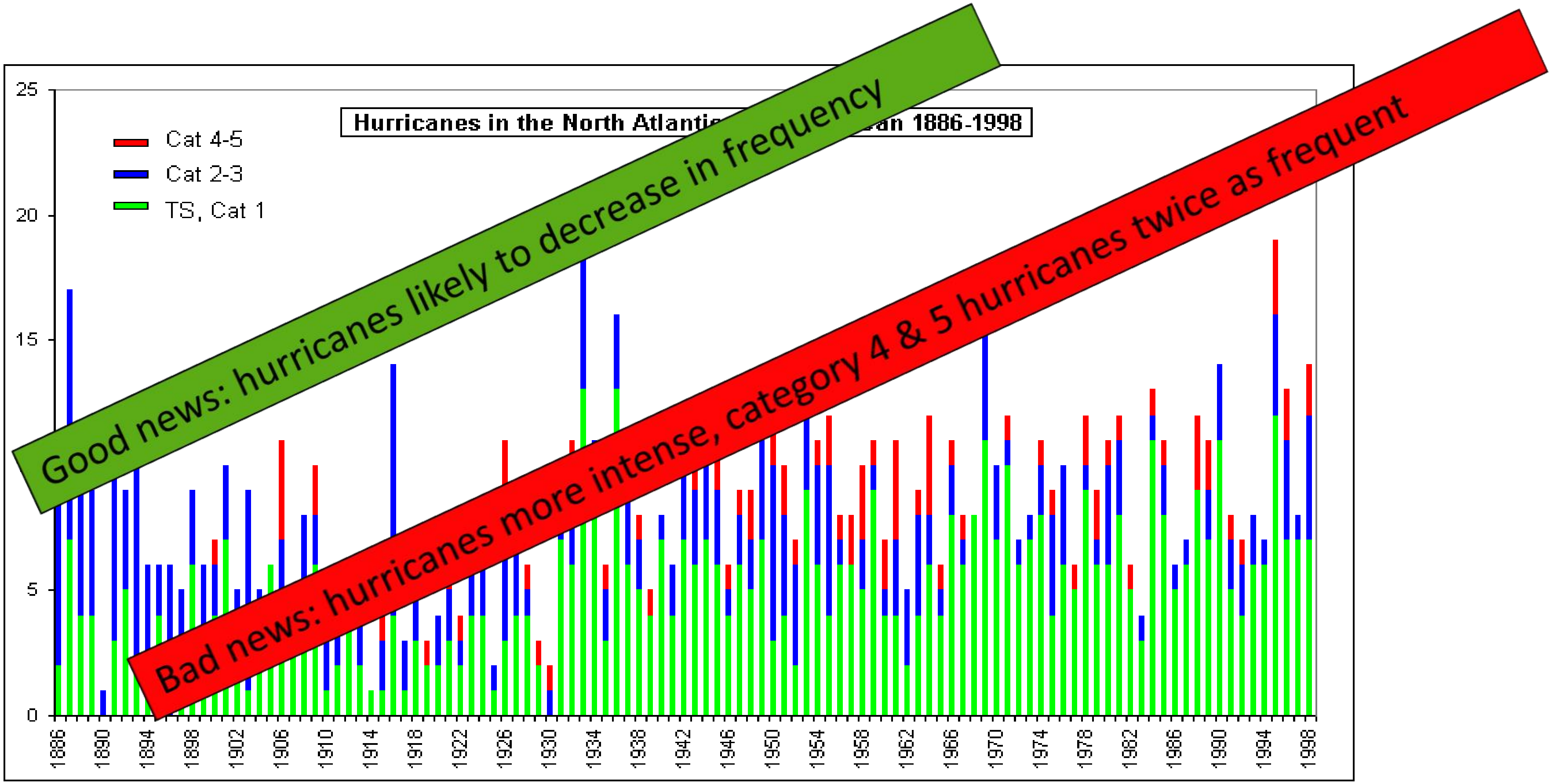


To 2090, taking 14
climate mod

Fou degree rise

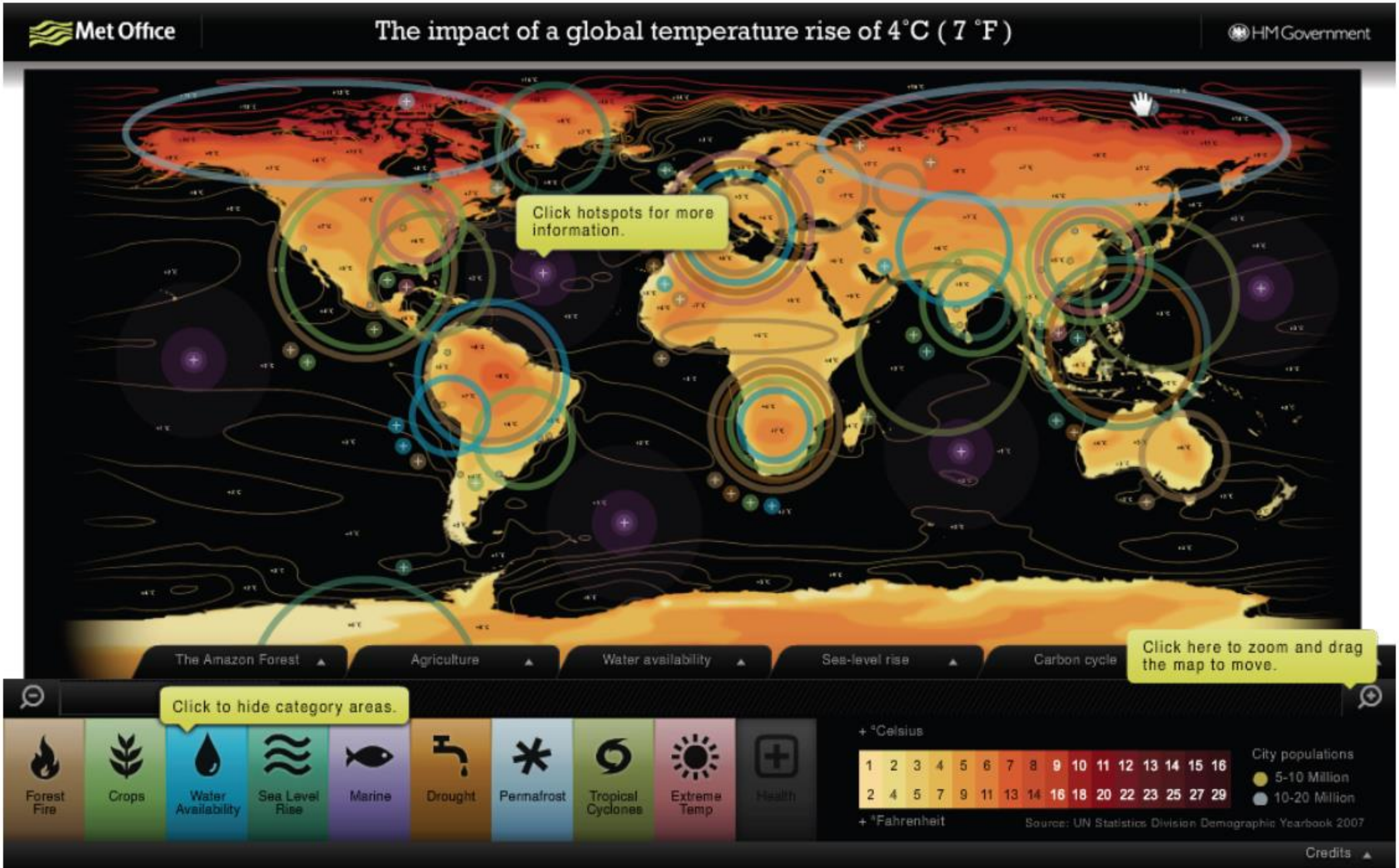
Thornton et al. 2010

Impacts 2: Increasing frequency and intensity of extreme weather events



Pulwaty 2010

4 degrees by 2100 is likely



Impacts 4: Poorest at risk

By 2050, severe childhood stunting by 23% in central Africa and 62% in South Asia

(uses IFPRI IMPACT model + socio-economic models)

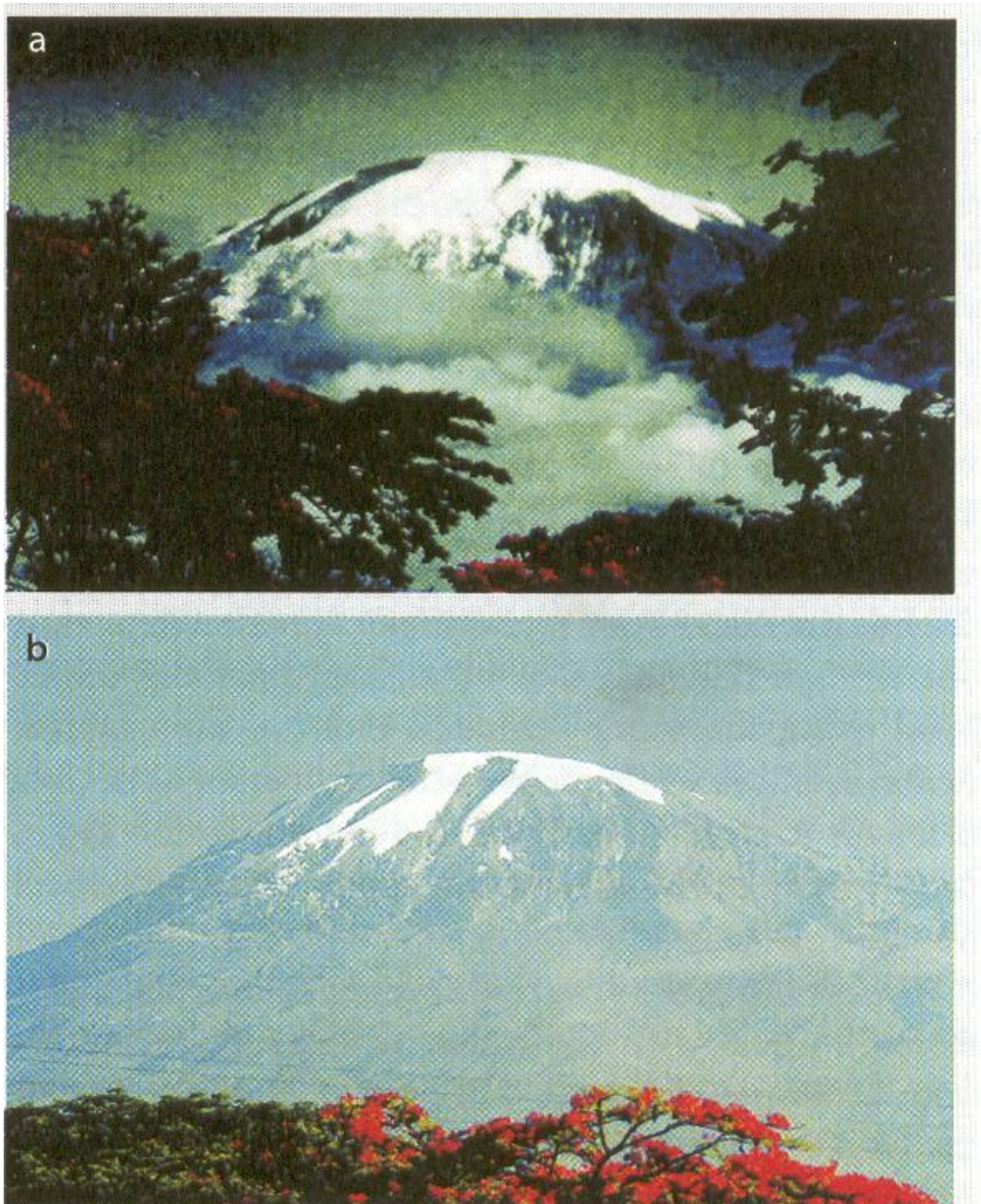
Lloyd et al. 2011
Environmental Health Perspectives

1.3 Evidence of climate change

- Retreating snowlines in mountains (Kilimanjaro, Kenya, Rwenzori)
- Fall in lake levels and river discharges
- Shortages in hydropower production
- Reduced agricultural production, worsening food security
- Increased spread of malaria, frequent outbreak of water-borne diseases (cholera, typhoid, diarrhoea, hepatitis B)
- Increasing incidence of landslides
- Increased conflicts over water, land and other environmental resources
- Loss of biodiveristy
- Loss of coastal land to seal level rise (west Africa)

Climate change indicators in Ethiopia

- Seasonal shifts in rainfall
- Increased frequency of drought
- Expansion of invasive species
- Temperature increase by about 0.2OC in a decade
- Precipitation is stable, but spatial and temporal variability is high
- Generally it is affecting agriculture, water, health, ecosystems and infrastructure



Photographs of ice on the Summit of Kilimanjaro

(a) In 1970

(b) In 2000

1.4. Why climate change is a global issue?

- The effect of climate change is all over the world.
- The effect is transbounadary in nature .
- The earths temperature and precipitation is the cumulative effect from non point sources and affect the earths ecosystem.
- Industrial expansion in developed nations has an influence to alter the climate condition of developing nations .

1.5. Climate change and society

Social Change

- **Civilization goes back 6,000 years**
- **If we picture the total presence of man on earth as one single day then agriculture would have appeared at 11:56 and civilization at 11:57. The development of modern societies would have started start at 11:59 and 30 seconds.**
- **In these last few seconds of human life, there was so much social change that equals all the rest of the history of humans.**

What is social change[1]?

- Heracletus:.. everything flows and no one moment is the same as the previous one in our lives.
- Social change is defined by the subjective structure of an object or a situation at one single time period.
- Modern social change is defined by
  - Changes in culture (e.g. forms of communication, religion, education)
  - Economic Influences (e.g. development of industry technology and science)
  - Political Influences (e.g. Hitler and fascism, communism)
  - Cultural influences (e.g. tradition, norms and values)

Natural environment

- Humans develop their lifestyles according to the climatic conditions of their habitat
- Urban and rural areas lead different lifestyles
- There are still hunters and food-collectors in some areas of the planet
- Development in industry and technology has allowed societies to develop cultivations even in non-hospitable environments
- Humans try to overpower their natural surrounding and circumstances instead of accepting it as given circumstances

Current changes and future prospects

- Post-industrialist society:
  - society of information technology
  - society of services
  - society of knowledge
- Development of services at the cost of the development of labour that produces goods
- Major strategic resource: coded knowledge

Effects of Industrialism and Post-industrialism on natural environment

- Industrial revolution has led to the
  - Greenhouse gas phenomenon
  - Melting of the ice in the arctic regions
  - Rising of temperatures & global warming
  - Extreme weather conditions like flooding, tycoons, droughts etc.
- These phenomena affect the lives of people especially the poorest and the most vulnerable

Effect on developing countries

- Millions of the world's poorest people are already being forced to cope with the impacts of climate change
- These social & cultural impacts go unnoticed in financial markets and in the measurement of world GDP (gross domestic product)
- Increased exposure to drought, to more intense storms, to floods and environmental stress is holding back the efforts of the world's poor to build a better life for themselves and for their children

Who is responsible and who suffers?

- The world's poor suffer the earliest and the most damaging impacts
- Rich nations and their citizens account for the overwhelming bulk of the greenhouse gases locked in the Earths atmosphere
- Poor countries and their citizens pay the highest price for climate change
- Cities like Los Angeles and London may face flooding risks as sea levels rise, but their inhabitants are protected by elaborate flood defense systems

Vulnerability

- **Vulnerability is best defined as an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of potential harmful perturbations[1]**

The most vulnerable

- **Drought**: (e.g. Horn of Africa) crops fail and people go hungry; women and young girls spend more hours collecting water
- **Storms and floods**: in rural communities in the great river deltas of the Ganges, the Mekong and the Nile and in sprawling urban slums across the developing world
- **Neck-deep floods in Thailand's capital Areas**
  - In the north and east of city of 12 million were submerged in filthy water, turning homes into swimming pools and main roads into rivers plied by makeshift rafts and boats.

Risks in developing countries

- High levels of poverty and low levels of human development limit the capacity of households to manage climate risks
- With limited access to formal insurance, low incomes and meager assets, poor households have to deal with climate-related shocks under highly constrained conditions
- Result: millions of people face displacement
- Migration is rising in developed countries which receive millions of migrants from poor vulnerable populations

Impact

- In Ethiopia and Kenya (drought-prone) children 5 years old or less are 36% and 50% respectively more likely to be malnourished if they are born during the drought
- It is noted that Kenya is now receiving masses of displaced people at the border with Somalia, due to drought and civil war in Somalia
- In Niger, children aged 2 or less born in a drought year were 72% more likely to be stunted
- Indian women born during the flood in the 1970s were 19% less likely to attend primary school

Human development reversed with climate change

- ***Agriculture production and food security***: losses in agricultural production undermine efforts to cut human poverty
- ***Water stress and water insecurity***: glacial melt compromises flows of water for irrigation and human settlements. It is estimated that the melt and consequent flooding will be followed by water scarcity
- ***Ecosystems and biodiversity***: global warming is resulting to the possible 20-30% extinction of land species because of the warming seas and the acidity of the oceans
- ***Human health***: Poverty and limited capacity of public health systems to respond are resulting to the expansion of diseases (e.g. malaria)

Adaptation Apartheid

- Inequalities in capacity to adapt to climate change are becoming increasingly apparent
- In the richer part of the world adaptation is a matter of erecting elaborate climate defense infrastructures and of building homes that 'float on' water
- In the other part adaptation means people themselves learning to 'float in' flood water

Gender

- The above mentioned has an even greater impact on women as a social group rather than men as
  - They form the majority of the farmers in poor countries
  - They have less access to environmental resources
  - Gender inequalities exist in terms of access to land, control over resources, ability to command and access paid labour
  - It is usually the men who migrate and women are left behind
  - Women do not participate in political decision making

Conclusion (1/2)

- Humanity in the past two centuries has managed a great industrial and technological development
- Heavy industrialisation with no respect to the environment has led to environmental stress resulting to the change in climate
- The most serious impact of climate change is faced by the most vulnerable people living in developing countries

Conclusion (2/2)

- Inequality among the rich and the poor means that poor populations suffer the injustice of the impact of the environmental stress caused by the rich populations living in the rich developed countries
- Additionally, climate change poses a barrier towards human development and the cut of poverty in developing countries
- Poor populations in the developing world are not in a position to combat the consequences of extreme weather conditions and phenomena such as drought and flooding; thus they are forced to displacement
- Climate change impact affects gender differently, with women suffering the most, because of their lack of access to resources

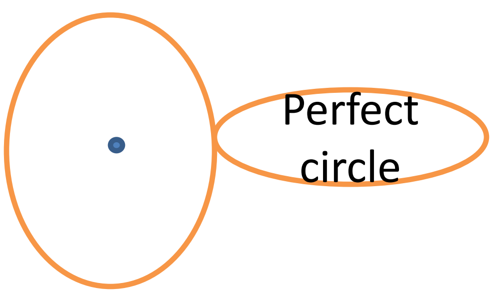
Chapter 2 Drivers of climate change

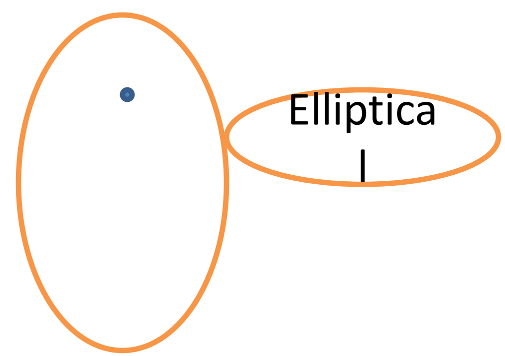
2.1 Natural drivers of climate change

- ✓ The 4 major factors that contribute the climate change are sun, change to Earths orbit, Ocean cycle and volcanoes.
- ✓ the sun is obviously Sun:-the largest external source of energy for the earth.
- ✓ Our planet would not be inhabitable without warmth from the sun.
- ✓ The sun brightness is changes through time.
- ✓ When the sun emit more energy the sun is warms up and the reverse is true
- ✓ When the sun has lots of sun spots(dark area)and bright spots (called faculae)solar energy out puts increase overall.
- ✓ When few sun spots and faculae are present the solar energy out puts decreases.

2.1 natural drivers of cc---

- During most of 20th century the sun demonstrates a gradual increase in its intensity.
- Longer term solar trend favored slight warm of the earth.
- Changes to earths orbit :-   the earths orbits characteristics determines how solar energy gets distributes across the surface of the planet.
- For starters the shape of the earths orbits changes very slowly
- With time various between elliptical and nearly perfect circle as indicated hear but the cycle that last bout 100,000 years.
-





2.1---

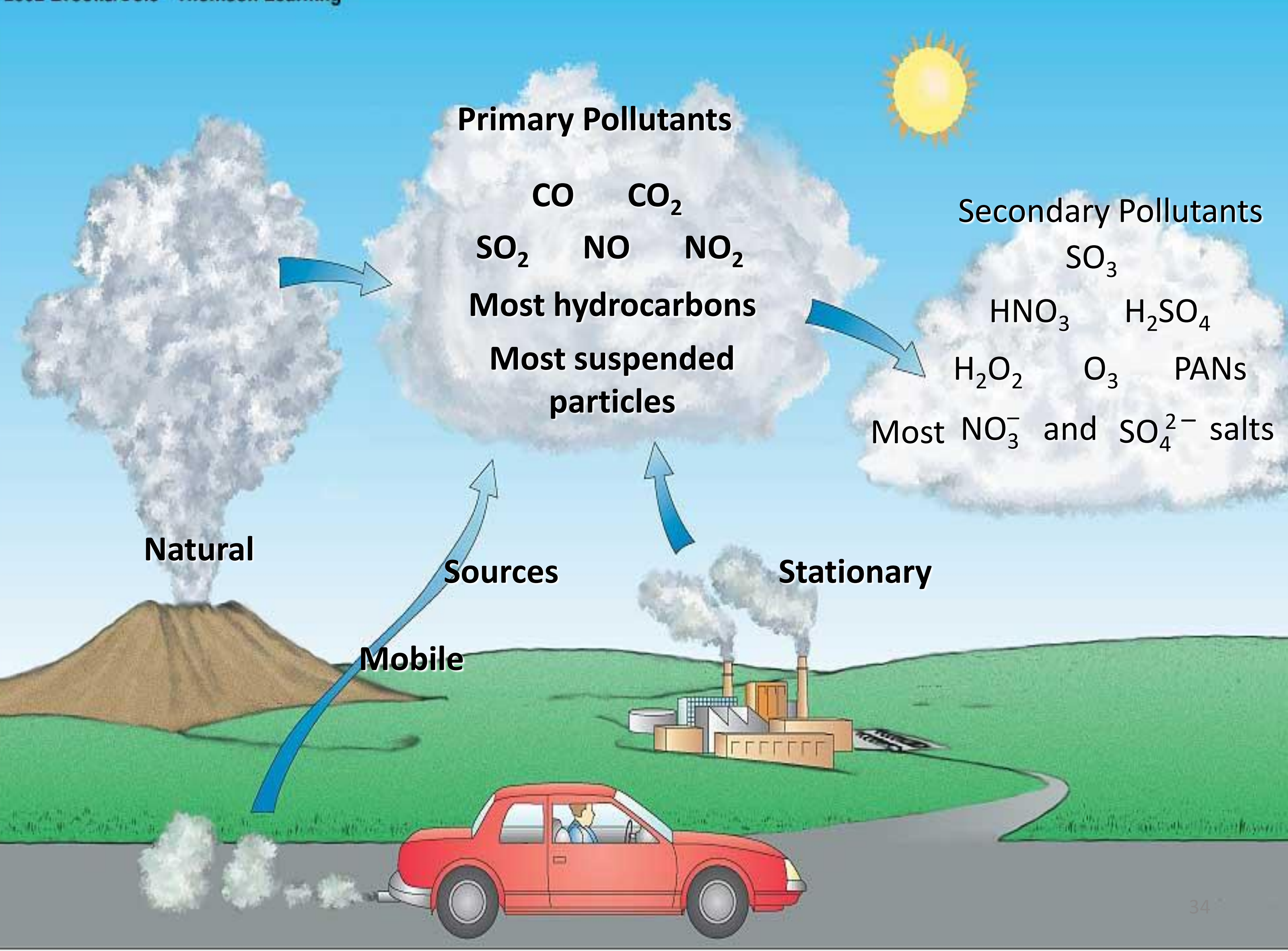
- Earths tilt on its axis is not perfect constant.
- Earths tilts on its axis is the reason for the season.

2.1--

- Ocean cycle : -earths oceans are not static, various portions of the oceans have their own warming and cooling cycles.
- El nino and la Nina are the result of this
- Because of ocean exchange moisture and energy with the atmosphere these oceanic cycles affect the atmosphere too.
- It is important that the ocean cycle do not add or subtract energy from the earths atmosphere, instead redistribute energy with in the system.

2.1---

- Volcanic and geological activities :-very powerful volcanic eruption spew ashes, dusts sulfur particles in to the stratosphere they can linger for months and drift around the entire globe, sulfur react with water to form sulfuric acid . The emission blocks the incoming solar radiation which temporarily cool the earth.
- Volcanic eruption also emits the earths green house gases like CO2,CH4
- These gases absorb and emit infrared radiation contributing greenhouse effect, which warms the earth.
- Other geological activities like burning of fossil fuel also contribute to global warming


Primary Pollutants
CO CO2
SO2 NO NO2
Most hydrocarbons
Most suspended particles
Secondary Pollutants
SO3
HNO3 H2SO4
H2O2 O3 PANs
Most NO3- and SO4 2- salts
Natural
Sources
Stationary
Mobile

2.2 Anthropogenic drivers of climate change

2.2.1 Technological development and transportation

- ✓ Burning of fossil fuel like gasoline and diesel release carbon dioxide into the atmosphere
- ✓ The building up of CO2,CH4,NO2 and HFCs is causing the Earths atmosphere to warm, resulting in changing to the climate
- ✓ Greenhouse gas emission from transportation accounts 29 % of US greenhouse gas emission, making it the largest contribution between 1990-2017.
- ✓ United nation environmental protection agency is addressing climate change by decreasing fuel consumption can reduce our dependence on foreign oil.
- ✓ Setting GHG emission standards for cars and trucks.
- ✓ Improve fuel efficiency while protecting consumers choice.
- ✓ Increase the use of renewable fuel
- ✓ Taking first step to set a greenhouse gas standard for aircraft.

2.2.2. Increased world industrial activities

- Industry is the key to wealth and better living
- On the other hand it affects the environment and ultimately contribute to climate change.
- It has been shown that human activities has lead to increase global temperature causing climate change
- these activities use available and abundant natural resources and process them in to products in order to improve quality of life.
- The industrial expansion started in 1750 in UK.
- The industries release large amount of GHG emission in to the atmosphere.
- The population growth w/c accompanied the industrial revolution give rise to the need for more land for agriculture and urban development, leads to massive deforestation and changing the environment.
- About 98 % of CO_2 emission, 24 % CH_4 and 18% NO_2 are due to fossil fuel burned to run cars and trucks, heat home and business and power factories.
- US remain the largest emitter and accounts for 40% of industrialized country emission.

- To date , industrialized countries accounts for about 80% of the CO_2 build up in the atmosphere.
- Annually more than 60% of global industrial CO_2 emission originate in industrial

Where only about 20% of the world population resides.

Industry ---

- Much of the growth in emission in developing countries result from the provision of basic human need for growing population, while emission in industrialized countries contribute to growth the standard of living that is already far apart average person world wide.
- impacts of industrialization includes:- release of waste, health problems, imbalance in wealth distribution, change lifesyle,destruction of arable land over exploitation of NRs

2.2.3. Land use change and deforestation

- Greenhouse gas emission from growing crops and raising livestock are higher than deforestation and land use change
- On average cutting down trees and clearing land contributed the equivalent of 6.4 Gt of CO_2 to the atmosphere each year of 1990 .
- This fells 5.4 Gt in 2000 and 4.9 Gt in 2010 .
- In comparison , global emission from crop and livestock production rose from 4.8 Gt in 1990, to 5.2 Gt in 2000 and 5.4 Gt in 2010.

Chapter 3.**Vulnerability,**

Outlines

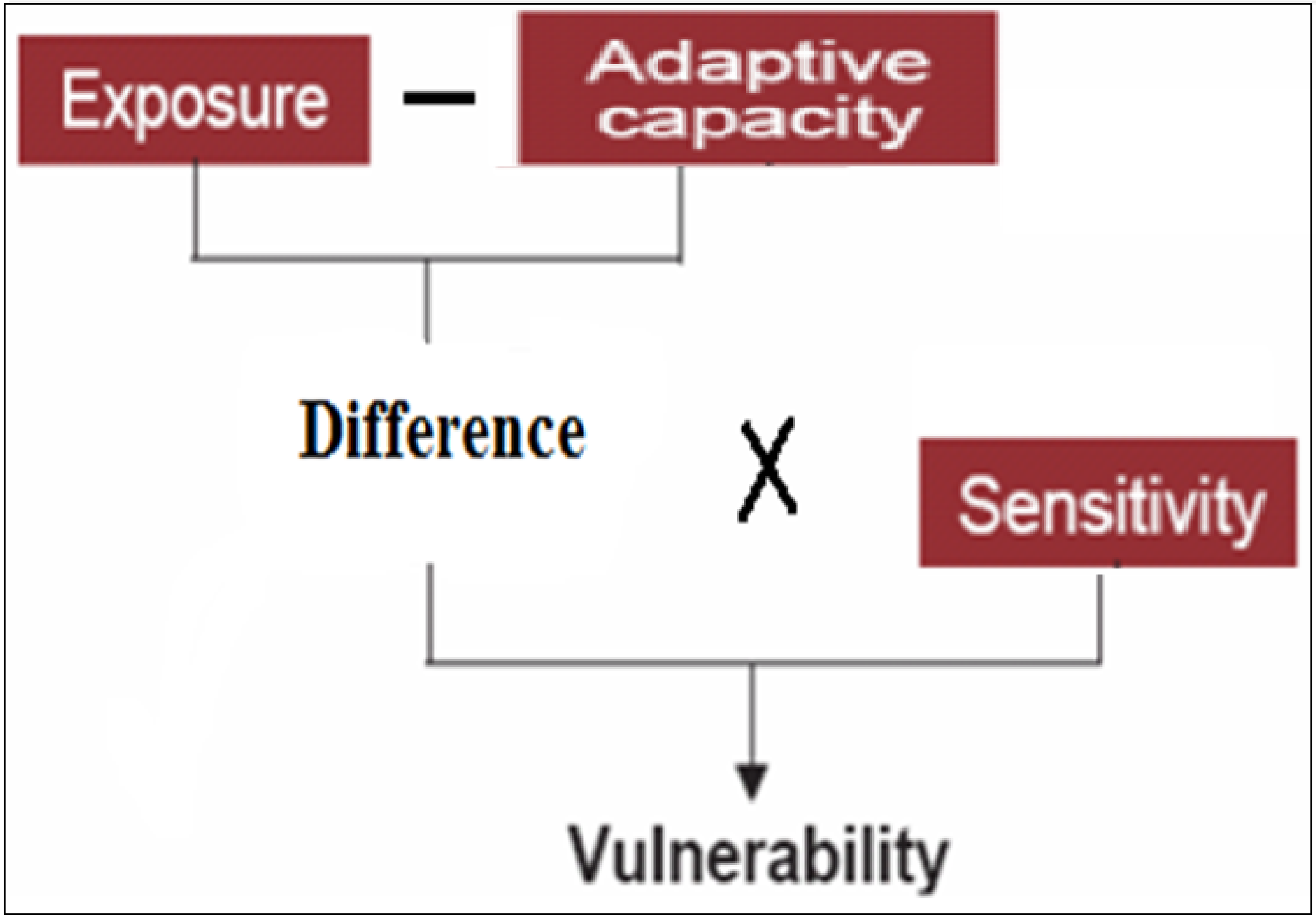
- 3.1. Vulnerability
- 3.2. observed and projected impacts on natural ecosystem
- 3.3. Impacts of climate change on agricultural system
- 3.4. Impacts of climate change on human health
- 3.5. Climate change impacts on sustainable development

. 3.6. Climate change adaptation and mitigation

Two approaches:

- IPCC approach ...global
- Pragmatic approach ...local

3.1. Vulnerability



Exposure

- Exposure is defined as the degree of climate stress upon a particular unit analysis; it may be represented as either long-term changes in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events (IPCC, 2001).
- There are two main elements to consider in exposure.
- Things that can be affected by climate change (populations, resources, property, and so on)
- The change in climate itself (sea level rise, precipitation and temperature changes, and so on)

Sensitivity

- Sensitivity is the degree to which a system will be affected by, or responsive to climate stimuli (Smith et al., 2001).
- Sensitivity is basically the biophysical effect of climate change; but sensitivity can be altered by socio-economic changes. For example, new crop varieties could be either more or less sensitive to climate change.

Adaptive Capacity

- Adaptive capacity refers to the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences (Smit and Pilifosova, 2001). As the name suggests, adaptive capacity is the capability of a system to adapt to impacts of climate change. Smit et al., 2001, have identified the following seven factors that determine adaptive capacity.
  - Wealth
  - Technology
  - Education
  - Institutions
  - Information
  - Infrastructure
  - Social capital

Table 3. Key Factors for Adaptive Capacity[17]

Factors	Examples
Economic resources	Wealth of individuals and localities.
Technology	Localized climate and impact modeling to predict climate change and variability; efficient irrigation systems to reduce water demand.
Information/awareness	Species, sector, and geographic-based climate research; population education and awareness programs.
Skills/human resources	Training and skill development in sectors and populations; knowledge-sharing tools and support.
Natural resources	Abundant levels of varied and resilient natural resources that can recover from climate change impacts; healthy and inter-connected ecosystems that support migration patterns, species development and sustainability.
Infrastructure	Systems that provide sufficient protection and enable efficient response (e.g., wireless communication, health systems, air-conditioned shelter).
Institutional support/governance	Governmental and non-governmental policies and resources to support climate change adaptation measures locally and nationally.

Source: Pew Center on Global Climate Change. 2009. *Climate Change 101: Understanding and Responding to Global Climate Change*. Arlington, VA.

Vulnerability = f (Exposure, Sensitivity, Adaptive Capacity)

- In other words, the greater the exposure or sensitivity, the greater is the vulnerability. However, adaptive capacity is inversely related to vulnerability. So, the greater the adaptive capacity, the lesser is the vulnerability.
- Therefore, reducing vulnerability would involve reducing exposure through specific measures like building a dyke in case of sea level rise, or increasing adaptive capacity through activities that are closely aligned with development priorities.
- The table below is an example of the effect of climate change on livelihoods, and illustrates how interplay of these impacts affects the vulnerability of the system.

Changes in mean climate, variability, extreme events and sea level rise	Effects on livelihoods	Impact on vulnerability
Increased temperature and changes in precipitation reduces agricultural and natural resources Changes in precipitation run-off and variability leads to greater water stress Increased incidence or intensity of climate related extremes such as water stress Temperature, water and vegetation changes resulting in increasing prevalence of disease	Direct impacts of climatic shocks and stresses such as livelihood assets, health, food and water security Increased pressure on Coping strategies and social protection measures Reduced ability recover due to increased frequency of climatic shocks or increased intensity of climatic stresses	Increased vulnerability due to: • Lower capacity to prepare; • Lower capacity to cope; and • Lower capacity to recover from climatic and non-climatic shocks and stresses

- Where are the areas of food insecurity/vulnerability?
- What physical/human characteristics and features of the location are related to food insecurity?
- What geographic characteristics of the area - compact/dispersed, close/far, accessible/remote - should be considered in development and aid strategies?
- What are the key spatial relationships involved in the food security problems and their possible solutions: linkages between ports and roads, stocks and delivery points, barriers or administrative boundaries? (UNWFP 2005)

FDA's Vulnerability Assessment Software tool

- The FDA's Vulnerability Assessment Software tool uses the CARVER + Shock methodology.
- The software tool is a user-friendly, interactive application developed by the **Food and Drug Administration's Centre for Food Safety and Applied Nutrition**

CARVER is an acronym for the following six attributes used to evaluate the attractiveness of a target for attack

- **Criticality**: Assesses the public health and economic impacts of an attack.
- **Accessibility**: Ability to physically access and egress from a target undetected.
- **Recoverability**: Ability of a system to recover from an attack.
- **Vulnerability**: Ability to accomplish a successful attack.
- **Effect**: Amount of direct loss from an attack as measured by loss of production.
- **Recognisability**: Ease of identifying a target.

Risk = ***probability of failure*** x ***cost of failure***

Can we assess probabilities of failure and costs of failures?

Vulnerable : =

- capable of being physically wounded

- open to attack or damage

Source: ***Webster's New Collegiate Dictionary***

Vulnerability – degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change.

Adaptation – adjustment in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Based on: ***IPCC TAR Glossary***

Adaptive capacity – ability of the system to adapt

- **to curb potential damages,**
- **to cope with consequences,**
- **to take advantage of opportunities.**

(function of wealth, organization, legislation, education, awareness…)

Vulnerability depends on exposure to climatic stimuli (character, magnitude, and rate of climate change); sensitivity, and adaptive capacity of the system.

Based on: ***IPCC TAR Glossary***

Vulnerability – expected cost of failure if there is a failure

Conditional expected value

Probability of failure may be low

Safe-fail, safe in failure

Exposure to extreme climate events:
Droughts and floods

- **Increasing summer drying** over mid-latitude continental interiors (increase in temperature and potential evapotranspiration not balanced by precipitation, hence decrease in soil moisture)
- Less snow pack as spring arrives, earlier snowmelt runoff, and less soil moisture and water in the summer. Decrease in snowmelt and ice-jam flooding
- More frequent, intense and pronounced **El Niño** is accompanied by droughts in several areas and floods in other areas
- Increasing intense precipitation
- Increasing winter precipitation (rain more often)

Water storage against floods and droughts

* **Enhancing water storage** for both floods and droughts - Catching water when abundant and storing it for the times of need

KEEP WATER WHERE IT FALLS

***Achieve more with less resource use – receipt for the era of water scarcity** Dramatic improvement of effectivity of water use is urgently necessary! Von Weizsäcker et al. (1997): Search of **negaliters and negawatts** rather than **megaliters and megawatts**.

Save water! Avoid wastage!

Change water allocation!

Develop virtual water trade!

Vulnerability varies

- If person/country does nothing, how large is harm?
  - "Vulnerability is greater for those who have few resources and few choices"
  - Structural and infrastructural choices
    - Dense population, near ocean
- Knowledge of impending climate outputs and of how to respond can reduce vulnerability
  - Privileged vs. marginalized matters: those with many resources/already advantaged socially are less vulnerable
- Community resources

Adaptive capacity varies

- What resources does person/country have to do something that reduces their exposure?
- Can they "get out of the way" (e.g., migration)
- More resources is better
- How big is the adaptation "task"? Redesign a city?
- Different types of resources (next slide)
- Privileged vs. marginalized matters here too
  - "Adaptive capacity is intimately connected to social and economic development but is unevenly distributed" (IPCC, 15).
  - "Structural" vulnerabilities: NOT their fault but due to colonial history and current world economic structure
- Some outputs cannot be adapted to: small-island states

Exposure varies

- Is person/country likely to experience a given impact?
  - "Small islands: … high exposure of population and infrastructure" (IPCC Summary, p. 9)
  - "Asian and African megadeltas: high exposure to sea level rise, storm surges and river flooding." (IPCC Summary, p. 9)
- Geographic location
  - Switzerland/Austria: no sea level rise
  - Tahiti: no glacial retreat
  - Droughts/floods increase in some regions, decrease in others
- Existing material infrastructure
  - Seawalls; Dutch polders
  - Reliance on rainfall vs. ground water

Resilience varies

- How capable is person/country to absorb such damage as they can’t avoid, and adapt to the new status quo?

3.2. observed and projected impacts on natural ecosystem

What impacts have occurred and are predicted to occur from global warming?

- ***Key changes associated with an increased concentration of greenhouse gases in the atmosphere and the resulting changes in climate) include:***

A. ***Changes in the seasonal distribution and amount of precipitation.***
B. ***An increase in precipitation intensity under most situations.***
C. ***Changes in the balance between snow and rain.***
D. ***Increased evapotranspiration and a reduction in soil moisture.***
E. ***Changes in vegetation cover resulting from changes in temperature and precipitation.***
F. ***Consequent changes in management of land resources.***
G. ***Accelerated melting glacial ice.***
H. ***Increases in fire risk in many areas.***
I. ***Increased coastal inundation and wetland loss from sea level rise.***
J. ***Effects of CO_2 on plant physiology, leading to reduced transpiration and increased water use efficiency (Goudie 2006).***
K. ***threats to biodiversity***
L. ***Invasive species***

Agriculture

- Shifts in food-growing areas
- Changes in crop yields
- Increased irrigation demands
- Increased pests, crop diseases, and weeds in warmer areas

Water Resources

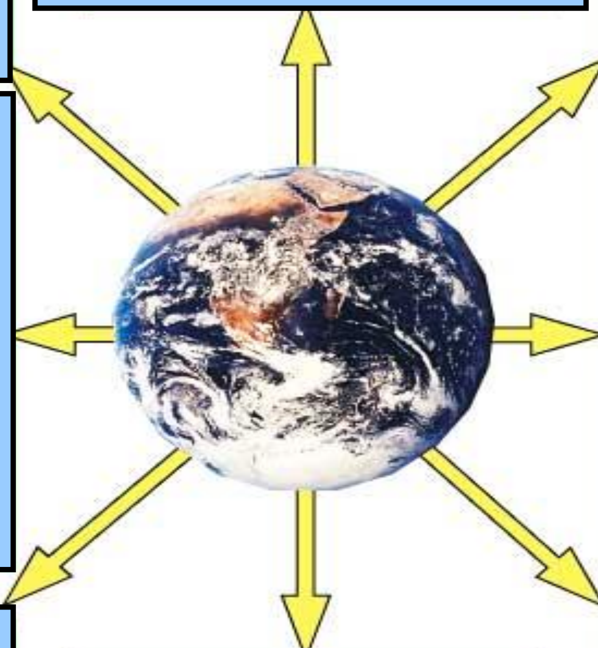
- Changes in water supply
- Decreased water quality
- Increased drought
- Increased flooding

Forests

- Changes in forest composition and locations
- Disappearance of some forests
- Increased fires from drying
- Loss of wildlife habitat and species

Biodiversity

- Extinction of some plant and animal species
- Loss of habitats
- Disruption of aquatic life



Sea Level and Coastal Areas

- Rising sea levels
- Flooding of low-lying islands and coastal cities
- Flooding of coastal estuaries, wetlands, and coral reefs
- Beach erosion
- Disruption of coastal fisheries
- Contamination of coastal aquifiers with salt water

Weather Extremes

- Prolonged heat waves and droughts
- Increased flooding
- More intense hurricanes, typhoons, tornadoes, and violent storms

Human Population

- Increased deaths
- More environmental refugees
- Increased migration

Human Health

- Increased deaths from heat and disease
- Disruption of food and water supplies
- Spread of tropical diseases to temperate areas
- Increased respiratory disease
- Increased water pollution from coastal flooding

Direct manifestations

i. Heat waves and periods of unusually warm weather

ii. Sea level rise and coastal flooding

- ✓ *If all the ice on Greenland melted, world sea levels would rise about six metres (20 feet)*
- ✓ *If all the ice on the Antarctic continent melted, sea levels would rise over 70 metres (230 feet)*

iii. Glaciers melting

Iv. Arctic and Antarctic warming with ice shelves breaking up

v. Increase severity of weather

vi. Zooplankton are dying in the Pacific Ocean

➢ *Other Possible Consequences*

a) ***Spreading disease*** */ Mosquitoes and insects are moving north in the Northern Hemisphere/*

b) ***Earlier spring arrival*** */ For example, the Japanese keep very detailed records on the blossoming of their Tokyo cherry trees, so they know they are blooming 5 days earlier on average than they were 50 years ago/*

c) ***Plant and animal range shifts and population declines*** */plant, birds, and animal species are moving north in the Northern Hemisphere/*

d) ***Coral reef bleaching***

e) ***Downpours, heavy snowfalls, and flooding***

f) ***Droughts and fires***

Impacts vary by region

- Climate changes will vary by region
  - Some areas warm more, others warm less
  - Some areas get wetter, some dryer
- Vulnerability varies by region
  - Coastal vs. inland
  - Rainfall vs. aquifer dependent
- Adaptive capacity varies by region
  - Poor vs. rich
  - Ease of adaptation (e.g., small island states vs. US)

Who and what gets harmed?
What determines how bad it will be?

- Non-human impacts
- Climate outputs: how does climate respond to human-induced changes?
- Exposure: is person likely to experience the impact?
- Vulnerability: if person does nothing, how likely and how large is harm?
- Adaptive capacity: what resources for reducing exposure vulnerability?
- Resilience: can unavoidable damage be absorbed and new status quo established?
- Harm experienced

Non-human impacts

- Many plants and animals cannot adapt or mutate quickly enough
- Plants can’t “migrate” fast enough
- Animals can migrate but their ecosystem partners (their predators and prey) are unlikely to migrate at same speed, upsetting ecosystem balances
- Ocean acidification

Non-human impacts

- Forest degradation due to pests, precip, and temp
- Invasive species changes
- Coral reef bleaching
- Habitat change and loss
- Species and biodiversity loss
- Killing off some species while making better niches for others, particularly disease vectors

Ocean acidification

- The other side of the CO_2 coin
- CO_2 “absorbed” into ocean waters
- Ocean acidifying, causing breakdown of shells of animals at bottom of food chain
- Evidence that this is already occurring

Source: IPCC, 2013

Examples

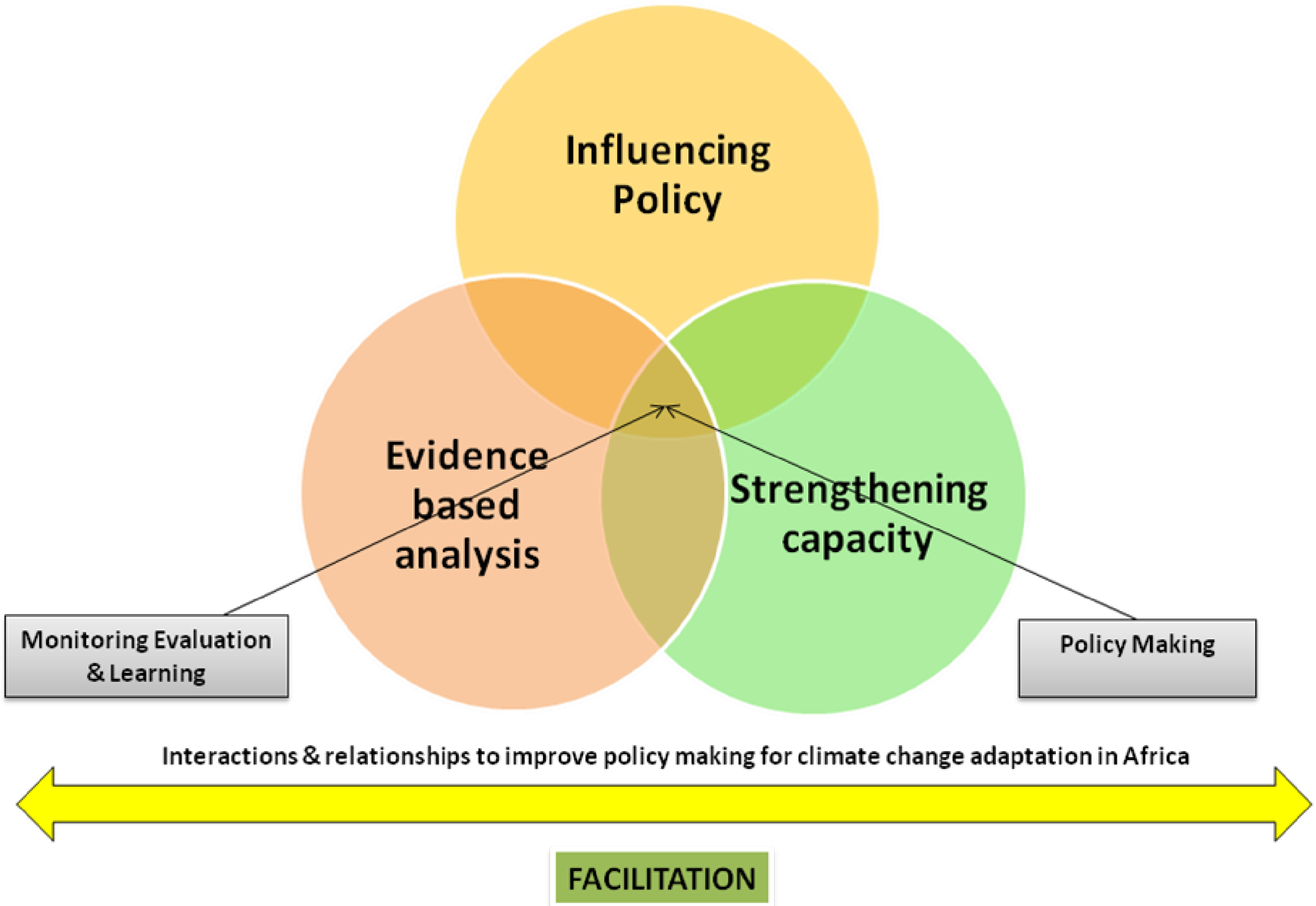
- Shelter and location
- Food and water
- Health
- War and conflict

3.3. Impacts of climate change on agricultural system

Vulnerability of Africa to climate change

- Significant areas of the region are desert or dry land
- High exposure to drought and flood
- Economies largely dependent on natural resources
- Biomass provides 80% of domestic primary energy supply
- Rain fed agriculture contributes 30% of GDP and employs 70% of population
- Inadequate infrastructure

Model for facilitating interactions



Invasive Alien Plant Species in Ethiopia:
Impacts, Challenges and Responses

- Invasive Alien Species (IAS) are of a great concern in Ethiopia, posing particular problems on:

A. Biodiversity of the country,
B. Agricultural lands,
C. Range lands,
D. National parks,
E. Water ways,
F. Lakes, rivers, power dams,
G. Roadsides and
H. Urban green spaces with great economic and ecological consequences.

- **Foremost among these invasive species are:**

a) parthenium weed (Parthenium hysterophorus),

b) prosopis (Prosopis juliflora),

c) water hyacinth (Eichhornia crassipes),

d) cactus (Euphorbia stricta) and

e) lantana weed (Lantana camara).

- ✓ They have been identified by the Environmental Policy and the National Biodiversity Strategy and Action Plan as a major threat to biodiversity of the country and economic well being of its people

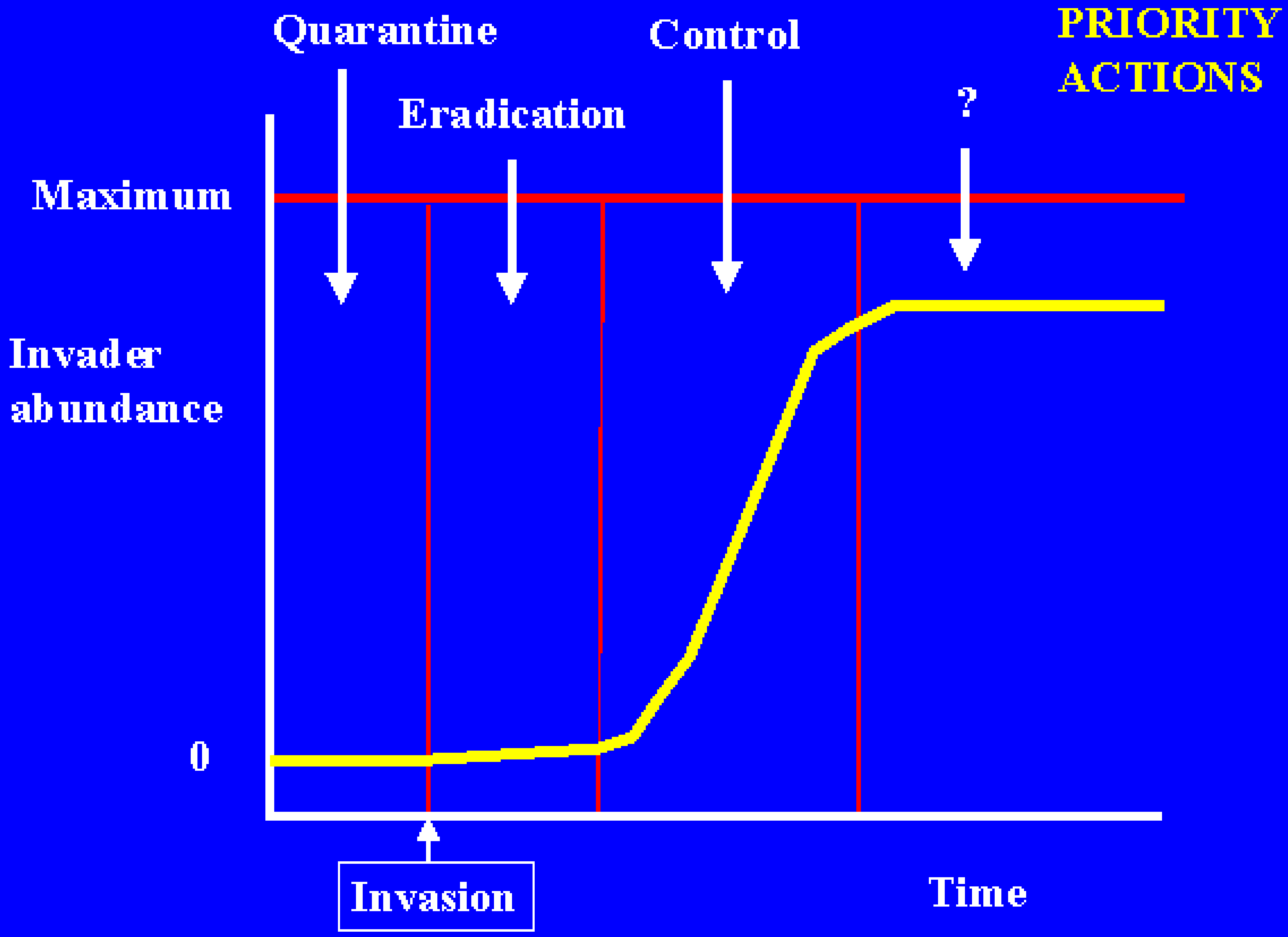
- ✓ Challenges to their management in Ethiopia are:

i. Their high seed production capacity and spread,

ii. Their adaptation to wide climatic and soil conditions,

iii. Their spread by animal movement and their association with pastoralists way of life and

iv. Overgrazing


PRIORITY ACTIONS
Quarantine
Eradication
Control
?
Maximum
Invader abundance
0
Invasion
Time

Their Impacts:

1. Health Impacts

- ✓ **Manual control of parthenium by farmers resulted in some of them developing skin allergies, itching, fever, and asthma.**

2. Socio-economic Impacts

- ✓ **Prosopis *form impenetrable thicket that prohibits free movement of people and animals* and *its thorns damage eyes and hooves of animals.***

- ✓ The social cost of parthenium in Ethiopia was measured by **Disability Adjusted Life Years** and its equivalence in terms of monetary value was estimated at *2,535,887–4,365,057 USD*.

Costs to Society of Climate Variability

- 1998 Ice Storm – 600 000 people evacuated, 28 deaths, 945 injuries, $7 billion in damages

- 1997 Red River Flood – 25 000 people evacuated, $815 million in damages

- From 1991 - 2001, natural disasters cost Canadian governments over $13 billion to repair infrastructure and properties after natural disasters

- Contamination of drinking water and recreational water costs Canadian communities approximately $300 million annually –

- climate change is expected to impact on the quality of drinking water

Public Health Implications in Local Communities

- food security and nutrition
- water quality/air quality
- disease monitoring and surveillance
- disaster preparedness and relief
- housing and shelter
- education and awareness (sun protection)
- healthy child development
- emergency services (community health centres)
- mental health

The Need for a Public Health Response

What can be done to protect public health in a changing climate?

- Mitigate – reduce emissions of greenhouse gases that cause climate change and variability (I.e., Kyoto Protocol is first step)
- Build Knowledge – be informed of health impacts of climate change and relevance to public health programs
- Plan and Adapt – adjust public health policies to account for climate changes and minimize the impact on health

Current changes and future prospects

- **Post-industrialist society:**
  - society of information technology
  - society of services
  - society of knowledge
- **Development of services** at the cost of the development of labour that produces goods
- **Major strategic resource:** coded knowledge

Effects of Industrialism and Post-industrialism on natural environment

- Industrial revolution has led to the
  - Greenhouse gas phenomenon
  - Melting of the ice in the arctic regions
  - Rising of temperatures & global warming
  - Extreme weather conditions like flooding, tycoons, droughts etc.
- These phenomena affect the lives of people especially the poorest and the most vulnerable

Effect on developing countries

- Millions of the world's poorest people are already being forced to cope with the impacts of climate change
- These social & cultural impacts go unnoticed in financial markets and in the measurement of world GDP (gross domestic product)
- Increased exposure to drought, to more intense storms, to floods and environmental stress is holding back the efforts of the world's poor to build a better life for themselves and for their children

Who is responsible and who suffers?

- The world's poor suffer the earliest and the most damaging impacts
- Rich nations and their citizens account for the overwhelming bulk of the greenhouse gases locked in the Earths atmosphere
- Poor countries and their citizens pay the highest price for climate change
- Cities like Los Angeles and London may face flooding risks as sea levels rise, but their inhabitants are protected by elaborate flood defense systems

Risks in developing countries

- **High levels of poverty and low levels of human development limit the capacity of households to manage climate risks**
- **With limited access to formal insurance, low incomes and meager assets, poor households have to deal with climate-related shocks under highly constrained conditions**
- **Result:** millions of people face displacement
- **Migration is rising in developed countries which receive millions of migrants from poor vulnerable populations**

Impact

- In Ethiopia and Kenya (drought-prone) children 5 years old or less are 36% and 50% respectively more likely to be malnourished if they are born during the drought
- It is noted that Kenya is now receiving masses of displaced people at the border with Somalia, due to drought and civil war in Somalia
- In Niger, children aged 2 or less born in a drought year were 72% more likely to be stunted
- Indian women born during the flood in the 1970s were 19% less likely to attend primary school

Human development reversed with climate change

- ***Agriculture production and food security***: losses in agricultural production undermine efforts to cut human poverty
- ***Water stress and water insecurity***: glacial melt compromises flows of water for irrigation and human settlements. It is estimated that the melt and consequent flooding will be followed by water scarcity
- ***Ecosystems and biodiversity***: global warming is resulting to the possible 20-30% extinction of land species because of the warming seas and the acidity of the oceans
- ***Human health***: Poverty and limited capacity of public health systems to respond are resulting to the expansion of diseases (e.g. malaria)

Climate change impacts on sustainable development

Sustainable Development Context: Sorry State of the Environment Today

- Atmospheric Pollution
- Pollution of Water Bodies
- Loss of Forest Cover
- Depletion of Ground Water
- Extinction of Species
- Reduced Soil Fertility
- Desertification
- Acid Rain
- Depletion of Ozone Layer
- Greenhouse Effect
- Global Warming
- Climate Change

Sustainable Development

- "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland Commission)
- Sustainable development integrates economic development, social development and environmental protection.
- Sustainable development has three overarching objectives and essential requirements:
  - Poverty reduction;
  - Changing unsustainable patterns of production and consumption;
  - Protecting and managing the natural resource base of economic and social development.

Indicators of Sustainable Development

- Indicators of sustainable development can have multiple functions:
  - Simplifying, clarifying and making aggregated information and scientific knowledge available to policy-makers
  - Measuring progress towards sustainable development goals
  - Identifying critical issues for sustainable development
  - Communicating the concept of sustainable development to policy-makers and the public

- Indicators of sustainable development often integrate economic, social and environmental statistics, e.g.
  - Resource efficiency indicators integrate economic and environmental statistics;
  - Gender employment indicators integrate economic and social statistics;
  - Air pollution indicator integrate social and environmental statistics;
  - Indicator on sustainable resource management integrate all three dimensions, but are often not fully developed.

- Indicators of sustainable development can use different frameworks.
  - Frameworks determine what to measure and why
  - Policy-oriented frameworks
    - Guaranteed policy relevance, flexible, buy-in form stakeholders
    - Prone to change with change in government, sometimes theoretically weak
  - Theory-based frameworks
    - More stable across time, more commonalities across countries, less subject to political change
    - Need to agree on theory, validity and relevance of theories varies across time and space, less buy-in from stakeholders, policy relevance can be low
    - Extended capital theory advocated by some (see e.g. Joint ECE/OECD/Eurostat Working Group on Statistics for Sustainable Development)
  - Other frameworks: Indices (theory-based or theory-free), Pressure-state-response frameworks

Climate Change evaluates adaptation options

Bottom Line

- Climate is changing
- Rate of change is more rapid than previously experienced
- Will result in profound ecosystem changes
- Will favor species with high genetic plasticity
- Likely to have major implications for controlling aquatic invasive species

Chapter 4&5

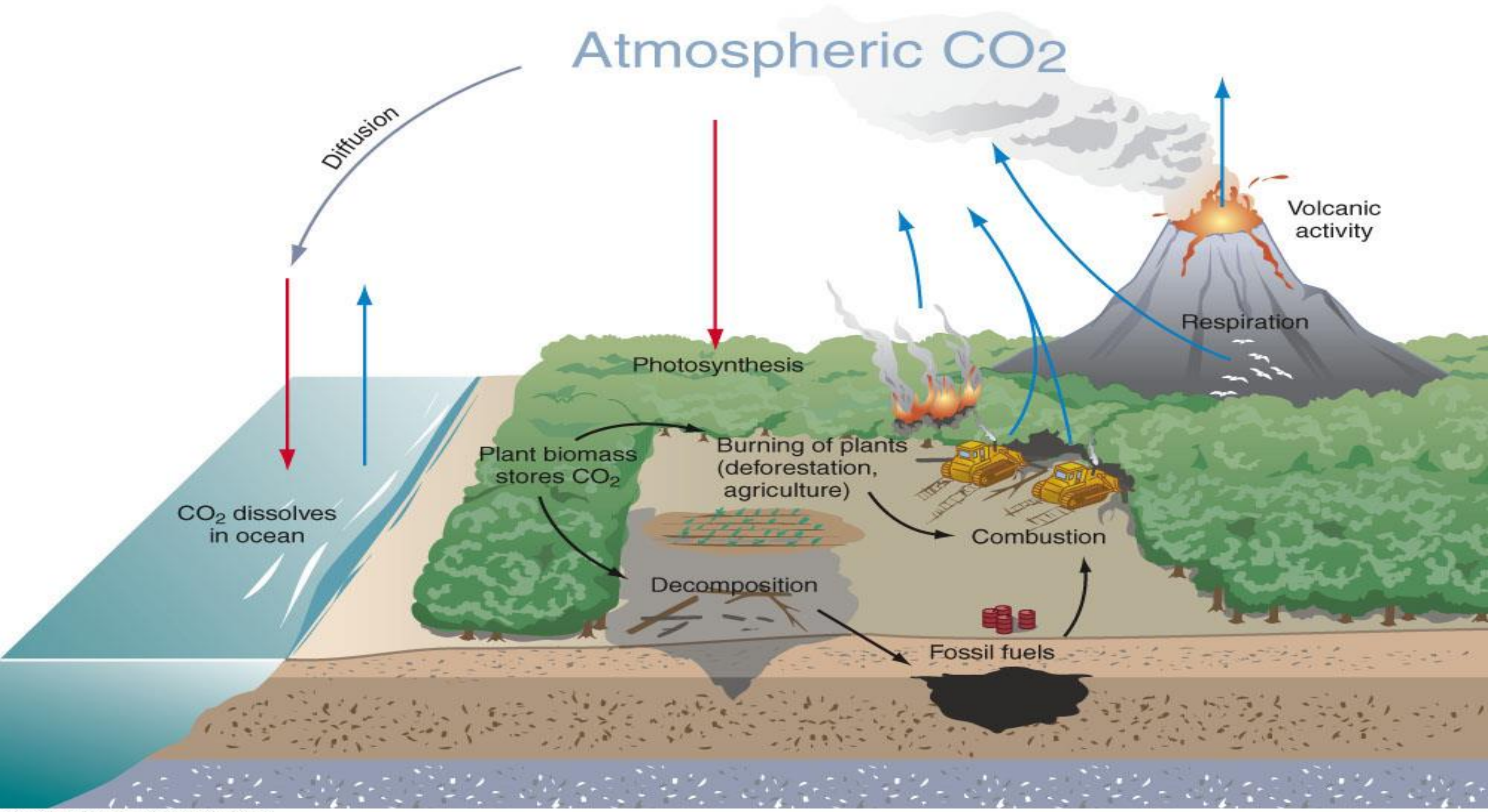
Climate change mitigation strategies

chapter 5. Climate change mitigation strategies

Outlines

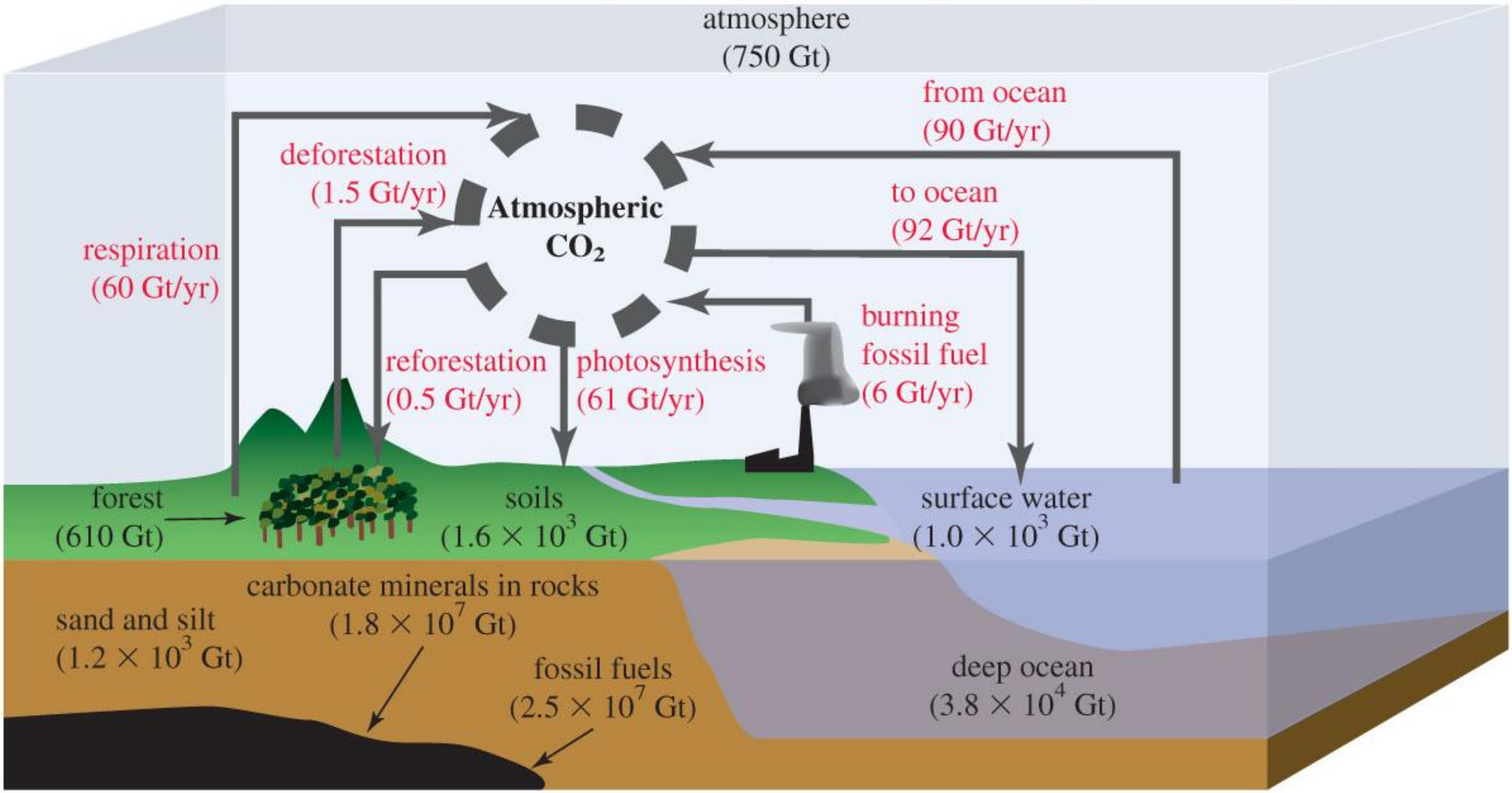
A. **Carbon sequestration**
B. **Reduced emission**
C. **Carbon trading**

A . Carbon sequestration



Atmospheric CO_2
Diffusion
Volcanic activity
Respiration
Photosynthesis
Burning of plants (deforestation, agriculture)
Plant biomass stores CO_2
CO_2 dissolves in ocean
Combustion
Decomposition
Fossil fuels

Earth's carbon cycle



A. Carbon sequestration

- Stores CO_2 removed from the atmosphere or captured from emissions and stores it in another form somewhere else (a ‘carbon sink’)
- Occurs naturally: oceans and plants are already absorbing much of what we emit
- We can speed the process along or deposit CO_2 in sinks that it wouldn’t have entered before
- Possible sinks: plants and soils, carbonate minerals, geologic formations, ocean

…count

- **Carbon capture and storage** (**CCS**) is an approach to mitigating global warming by capturing carbon dioxide (CO_2) from large point sources such as power plants and subsequently storing it instead of releasing it into the atmosphere.

- Technology for capturing of CO_2 is already commercially available for large CO_2 emitters, such as power plants; however, **capture** is meaningless without **storage**.
- Storage of CO_2, on the other hand, is a relatively untried concept and as yet (2007) no power plant operates with a full carbon capture and storage system.

Worldwide large stationary sources of CO2

Profile by process or industrial activity of worldwide large stationary CO_2 sources with emissions of more than 0.1 million tonnes of CO_2 ($MtCO_2$) per year.

Process	Number of sources	Emissions ($MtCO_2\ yr^{-1}$)
Fossil fuels		
Power	4,942	10,539
Cement production	1,175	932
Refineries	638	798
Iron and steel industry	269	646
Petrochemical industry	470	379
Oil and gas processing	Not available	50
Other sources	90	33
Biomass		
Bioethanol and bioenergy	303	91
Total	**7,887**	**13,466**

CO2 storage

- Various forms have been conceived for permanent storage of CO2. These forms include gaseous storage in various deep geological formations (including saline formations and exhausted gas fields), liquid storage in the ocean, and solid storage by reaction of CO2 with metal oxides to produce stable carbonates

Geological storage

- Also known as *geo-sequestration*, this method involves injecting carbon dioxide directly into underground geological formations. Oil fields, gas fields, saline formations, unminable coal seams, and saline-filled basalt formations have been suggested as storage sites. Here, various physical (e.g., highly impermeable cap rock) and geochemical trapping mechanisms would prevent the CO2 from escaping to the surface.

- CO2 is sometimes injected into declining oil fields to increase oil recovery (enhanced oil recovery). This option is attractive because the storage costs are offset by the sale of additional oil that is recovered.

- Disadvantages of old oil fields are their geographic distribution and their limited capacity.

……Storage

- Unminable coal seams can be used to store CO_2 because CO_2 adsorbs to the surface of coal. However, the technical feasibility depends on the permeability of the coal bed.
- In the process of absorption the coal releases previously absorbed methane, and the methane can be recovered (Enhanced Coal Bed Methane recovery).

….. Storage

- **Saline aquifers** have been used for storage of chemical waste in a few cases. The main advantage of saline aquifers is their large potential storage volume and their common occurrence. This will reduce the distances over which CO2 has to be transported.
- The major disadvantage of saline aquifers is that relatively little is known about them, compared to oil fields. To keep the cost of storage acceptable the geophysical exploration may be limited, resulting in larger uncertainty about the aquifer structure. Unlike storage in oil fields or coal beds no side product will offset the storage cost.
- Leakage of CO2 back into the atmosphere may be a problem in saline aquifer storage.

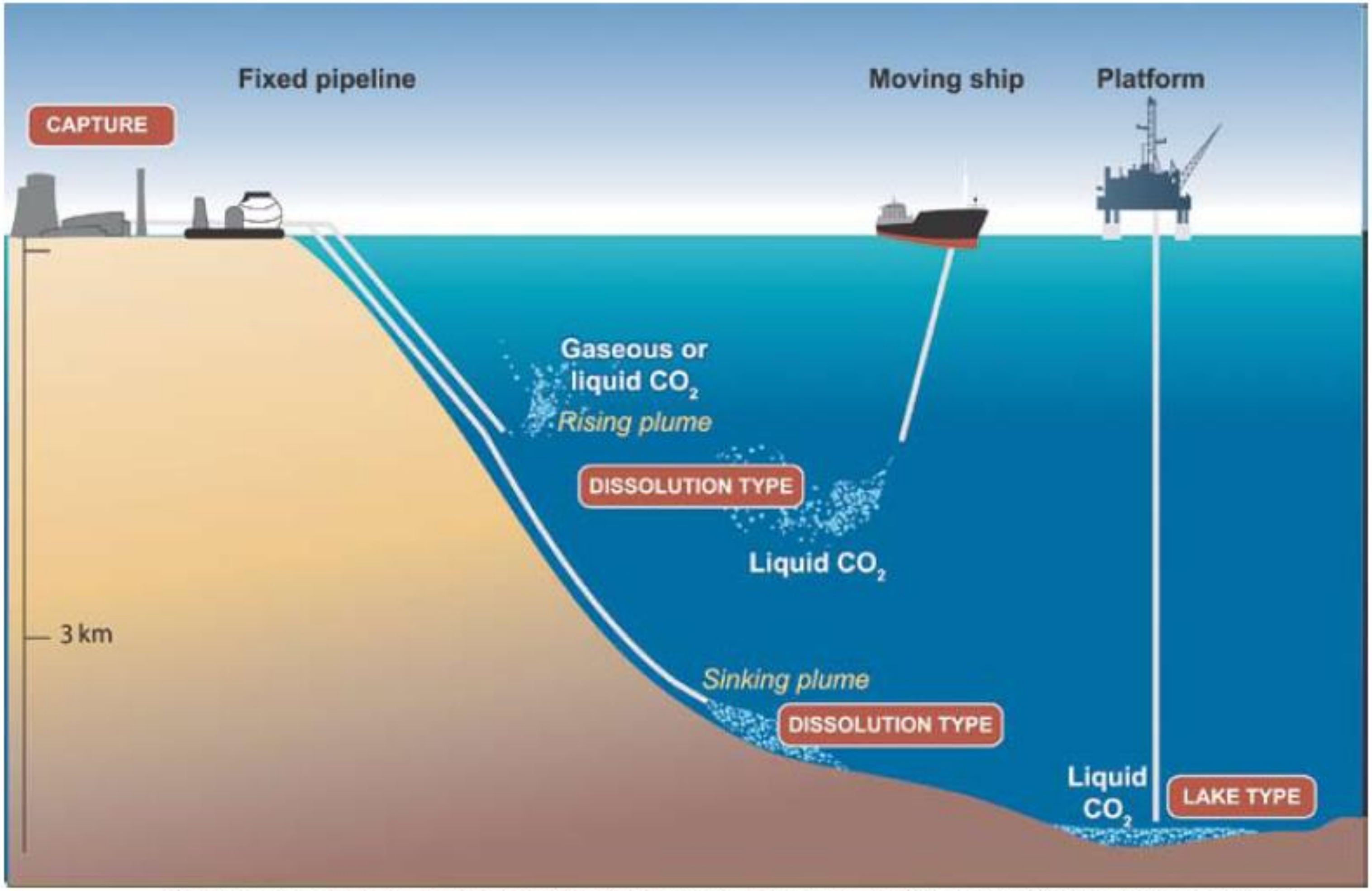
….. Storage

- For well-selected, designed and managed geological storage sites, IPCC estimates that CO2 could be trapped for millions of years, and the sites are likely to retain over 99% of the injected CO2 over 1,000 years.

….. Storage

- **Ocean storage**
- Two main concepts exist. The 'dissolution' type injects CO_2 by ship or pipeline into the water column at depths of 1000m or more, and the CO_2 subsequently dissolves. The 'lake' type deposits CO_2 directly onto the sea floor at depths greater than 3000m, where CO_2 is denser than water and is expected to form a 'lake' that would delay dissolution of CO_2 into the environment.

Dissolution and lake type storages



Overview of ocean storage concepts. In "dissolution type" ocean storage, the CO_2 rapidly dissolves in the ocean water, whereas in "lake type" ocean storage, the CO_2 is initially a liquid on the sea floor (Courtesy CO2CRC).

CCS v non-CCS

- CCS applied to a modern conventional power plant could reduce CO_2 emissions to the atmosphere by approximately 80-90% compared to a plant without CCS.
- Capturing and compressing CO_2 requires much energy and would increase the fuel needs of a plant with CCS by about 10-40%.
- These and other system costs are estimated to increase the cost of energy from a power plant with CCS by 30-60% depending on the specific circumstances.

- Storage of the CO_2 is envisaged either in deep geological formations, deep oceans, or in the form of mineral carbonates. In the case of deep ocean storage, there is a risk of greatly increasing the problem of **ocean acidification**, a problem that also stems from the excess of carbon dioxide already in the atmosphere and oceans.
- Geological formations are currently considered the most promising sequestration sites, and these are estimated to have a storage capacity of at least 2000 Gt CO_2.
- IPCC estimates that the economic potential of CCS could be between 10% and 55% of the total carbon mitigation effort until year 2100.

Cost of CCS (carbon capture storage)

- Capturing and compressing CO_2 requires much energy, significantly raising the running costs of CCS-equipped power plants.
- In addition there are added investment or capital costs. The process would increase the energy needs of a plant with CCS by about 10-40%. The costs of storage and other system costs are estimated to increase the costs of energy from a power plant with CCS by 30-60%, depending on the specific circumstances.

.....Cost

- For the world scale, estimates are commonly about 2% of Global Domestic Product. That is one year of normal growth.

CO2 transport

- After capture, the CO_2 must be transported to suitable storage sites.
- This is done by pipeline, which is generally the cheapest form of transport, or by ship when no pipelines are available.

Environmental effects

- A third concept is to convert the CO_2 to bicarbonates (using limestone) or hydrates.
- The environmental effects of ocean storage are generally negative, but poorly understood.
- Large concentrations of CO_2 kills ocean organisms, but another problem is that dissolved CO_2 would eventually equilibrate with the atmosphere, so the storage would not be permanent.

….Environmental effects

- The time it takes water in the deeper oceans to circulate to the surface has been estimated to be on the order of 1600 years, varying upon currents and other changing conditions.

- The bicarbonate approach would reduce the pH effects and enhance the retention of CO_2 in the ocean, but this would also increase the costs and other environmental effects.

- Also, as part of the CO_2 reacts with the water to form carbonic acid, H_2CO_3, the acidity of the ocean water increases. The resulting environmental effects on benthic life forms are poorly understood.

- Even though life appears to be rather sparse in the deep ocean basins, energy and chemical effects in these deep basins could have far reaching implications.

- Much more work is needed here to define the extent of the potential problems.

….Environmental effects

- **Leakage**
- A major concern with CCS is whether leakage of stored CO2 will compromise CCS as a climate change mitigation option. For well-selected, designed and managed geological storage sites, IPCC estimates that CO2 could be trapped for millions of years, and are likely to retain over 99% of the injected CO2 over 1000 years.
- For ocean storage, the retention of CO2 would depend on the depth; IPCC estimates 30-85% would be retained after 500 years for depths 1000-3000 m. Mineral storage is not regarded as having any risks of leakage.
- The IPCC recommends that limits be set to the amount of leakage that can take place.

Norway’s Sleipner gas field

- To further investigate the safeness of CO_2 sequestration, we can look into Norway's Sleipner gas field, as it is the oldest plant that sequesters CO_2 in an industrial scale.
- According to an environmental assessment of the gas field which was conducted after ten years of operation, the author affirmed that geographic sequestration of CO_2 was the most definite way to store CO_2 permanently.
- *"Available geological information shows absence of major tectonic events after the deposition of the saline reservoir. This implies that the geological environment is tectonically stable and a site suitable for carbon dioxide storage.*

…Example CCS projects

- As of 2005, three industrial-scale storage projects are in operation. Sleipner is the oldest project (1996) and is located in the North Sea where Norway's Statoil strips carbon dioxide from natural gas with amine solvents and disposes of this carbon dioxide in a saline formation.
- The carbon dioxide is a waste product of the field's natural gas production and the gas contains more (9% CO2) than is allowed into the natural gas distribution network. Storing it underground avoids this problem and saves Statoil hundreds of millions of euro in avoided carbon taxes.
- Sleipner stores about one million tonnes CO2 a year.

Statoil

•The Sleipner A project injects carbon dioxide into saltwater aquifers deep beneath the sea floor off the Norwegian coast. The project turns a profit due to the presence of Norway's high carbon taxes.

...Example CCS projects

- The Weyburn project Weyburn started in 2000 and is located in an oil reservoir discovered in 1954 in Weyburn, Southeastern Saskatchewan, Canada.
- The CO_2 for this project is captured at the Great Plains Coal Gasification plant in Beulah, North Dakota which has produced methane from coal for more than 30 years.
- At Weyburn, the CO_2 will also be used for enhanced oil recovery with an injection rate of about 1.5 million tonnes per year.

…Example CCS projects

- The third site is In Salah, which like Sleipner is a natural gas reservoir located in In Salah, Algeria.

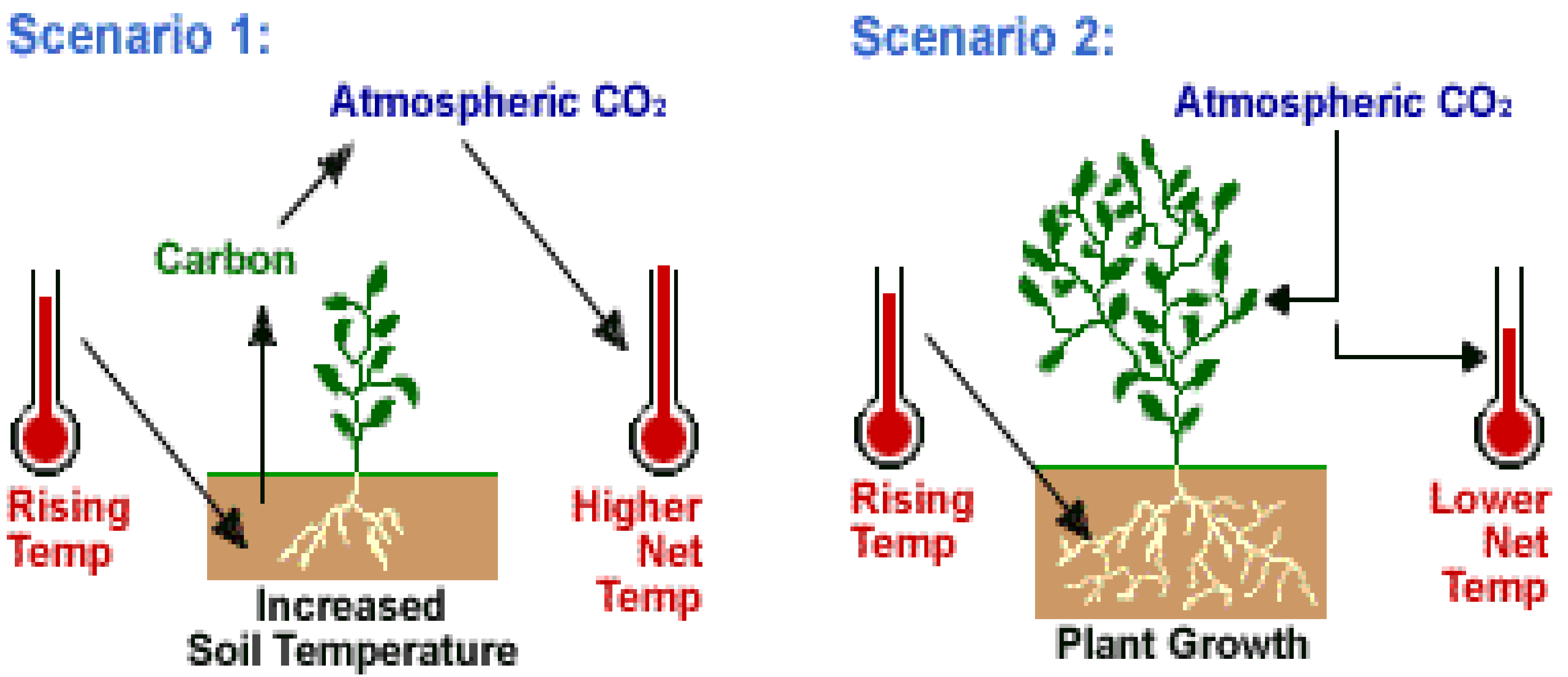
- The CO2 will be separated from the natural gas and re-injected into the subsurface at a rate of about 1.2 million tonnes per year.

…Example CCS projects

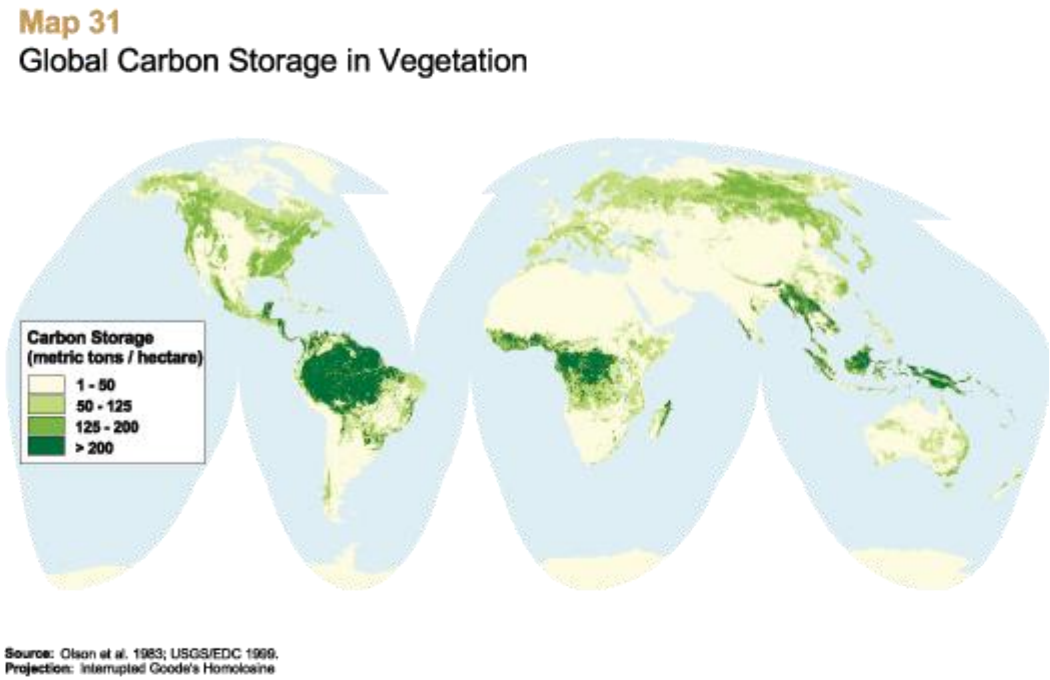
- A major Canadian initiative called the Integrated CO2 Network (ICO2N) is a proposed system for the **capture**, **transport** and **storage** of carbon dioxide (CO2).

- ICO2N members represent a group of industry participants providing a framework for carbon capture and storage development in Canada.

- Currently, the United States government has approved the construction of what they claim to be the world's first CCS power plant, FutureGeneration.


Scenario 1:
Atmospheric CO_2
Carbon
Rising Temp
Higher Net Temp
Increased Soil Temperature
Scenario 2:
Atmospheric CO_2
Rising Temp
Lower Net Temp
Plant Growth

Global C storage in vegetation



In terms of quantity of carbon stored, tropical and boreal forests are visibly outstanding. The values for carbon storage in vegetation in the tropics reach a maximum of 250 metric tons per hectare.

Temperate forests and tropical savannas store less than the tropical and boreal forests. Non-woody grasslands and drylands store less than the forested areas, and sparsely vegetated and bare desert areas have the least carbon storage potential.

Capturing carbon dioxide from small, mobile sources, such as cars, would be more difficult.

But with power plants comprising 40 percent of the world's fossil fuel-derived carbon emissions, the potential for reductions is significant. Estimates of worldwide storage capacity range from 2 trillion to 10 trillion tons of carbon dioxide, according to the Intergovernmental Panel on Climate Change (IPCC) in its report on carbon capture and storage.

Global emissions in 2004 totaled 27 billion tons, according to the U.S. Department of Energy's Energy Information Administration.

If all human-induced emissions were sequestered, enough capacity would exist to accommodate more than 100 years' worth of emissions, - IPCC.

Safety smarts

- The goal of carbon sequestration is to store the carbon dioxide permanently, i.e. very, very long-term, geological time periods.
- The greatest concern surrounding carbon dioxide storage is the potential for it to leak. The obvious worry is that leakage would lead to more global warming, defeating the purpose of storage in the first place. But studies have shown that leakage, if it happened at all, would be insignificant.
- The IPCC reported that 99% retention of the carbon dioxide that is stored would be ''very likely'' over 100 years and ''likely'' over 1,000 years. If done right, selecting the site correctly and monitor, it can be near permanent.

.....Safety smarts

- Of greater concern to the researchers are the potential risks of carbon sequestration to human health, mainly through **asphyxiation/ suffocation** and **groundwater contamination**.

- The threat of asphyxiation-or suffocation due to carbon dioxide displacing oxygen-is very low, because of the unlikelihood of a rapid leakage, which would have to occur to cause a problem.

…..Safety smarts

- Drinking water contamination is the more probable danger. For example, if carbon dioxide enters the groundwater somehow, it can increase the water's acidity, potentially leaching toxic chemicals, such as lead, from rocks into the water.
- To address these risks, scientists are studying reservoir geology to better understand what happens after injecting carbon dioxide underground.

…..Safety smarts

- Carefully selecting places that will not leak, and doing a good job of engineering the injection systems and paying attention to where the carbon dioxide is actually going required.
- While a thorough technical understanding of the risks will reveal best practices, the scientists also stressed the need for good management to see that proper procedures are followed.

'A family of solutions'

- **'A family of solutions'**
- Critics of carbon sequestration argue that the technology will divert attention from research on long-term clean energy options, such as renewable power. Worse, they fear it will prolong fossil fuel use, if fossil fuels from some stationary sources can be used more cleanly.

- Continual emphasis on the need to adopt other technologies in addition to carbon sequestration needed
- Geological sequestration be one of a family of solutions for addressing the greenhouse gas issue.
- Energy efficiency and renewable energy are already feasible today and also can define the long-term energy picture.

- Carbon dioxide sequestration is only a bridge technology.

What if we do nothing?

- The longer we wait, the worse it gets. Most scientists believe that the evidence of high CO_2 levels and hot climates in the past is compelling.
- Like all preventive medicine, it's easier to put off the fateful day. But when that day arrives, it causes you more pain, and costs more, compared to early actions. Its important to realise that, even if we act now, the climate will carry on warming for another 3 or 5 degrees Centigrade. Potential for areas to dry and heat up to become uninhabitable desert.
- By acting now, we have a chance to limit that rise to less than 5 Centigrade, by keeping atmospheric CO_2 less than 550 parts per million.

Overview

- Carbon capture and storage (CCS) in geological structures is technically feasible, although further development is needed to optimise it.
- CCS potentially offers carbon emissions reduction at costs similar to offshore wind and nuclear power.
- CCS offers a low-carbon way to use fossil fuels to ensure security of electricity supply.
- Enhanced oil recovery in the North Sea could reduce the cost of CCS and could also act as a lesson.
- Under present economic conditions CCS may not be financially viable. Creating incentives for CCS forms part of the wider debate on economic strategies to reduce CO2 emissions.
- CCS could play a key role in reducing future emissions from the developing world like South Africa

Acknowledgements

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Global carbon cycle

The big picture

- During geological history, the emergence of plants on earth has led to the conversion of carbon-dioxide (CO2) that was in the atmosphere and oceans, into innumerable inorganic and organic compounds on land and in the sea.
- Natural exchange of carbon (C) compounds between the atmosphere, the oceans and terrestrial ecosystems is now being modified by human activities that release CO2 from fossilized organic compounds ('fossil fuel') and through land use changes.
- The earth is returned to a less vegetated stage of its history, with more CO2 in its atmosphere and a stronger greenhouse gas effect trapping solar energy.

- The figure below shows the global C cycle between C-stocks and flows in the reservoirs and in the atmosphere.

- By far the greatest proportion of the planet's C is in the oceans; they contain 39000 Gt out of the 48000 Gt of C shown (1 Giga ton (Gt) = 109 t = 1015 g).

- The next largest stock, fossil C, accounts for only 6000 Gt.
- Furthermore, the terrestrial C stocks in all the forests, trees and soils of the world amount to only 2500 Gt, whilst the atmosphere contains only 800 Gt.

- The use of fossil fuels (and cement) releases 6.3 Gt C yr-1, of which 2.3 Gt C yr-1 is absorbed by the oceans, 0.7 Gt C yr-1 by terrestrial ecosystems, and the remaining 3.3 Gt C yr-1 is added to the atmospheric pool.

- Fossil organic C is being used up much faster than it is being formed, as only 0.2 Gt C yr-1 of organic C sediments into seas and oceans, as step towards fossilization.

- The net uptake by the oceans is small relative to the annual exchange between atmosphere and oceans: oceans at low latitudes (in the tropics) generally release CO_2 into the atmosphere, while at high latitudes (temperate zone and around polar circles) absorption is higher than release.

- Similarly, the net uptake by terrestrial ecosystems of 0.7 Gt C yr-1 is small relative to the flux: about 60 Gt C yr-1 is taken up by vegetation, but almost the same amount is released by respiration and fire.
- The global C-cycle showing C-stocks in reservoirs (in Gt = 109 ton) and C-flows in Gt yr-1) relevant to anthropogenic disturbance, as annual averages over the decade from 1989- 1998 (Shimel et al., 1996)

Special roles of forest in global carbon cycle

- Forests play an important role in the global carbon balance. As both carbon sources and sinks, they have the potential to form an important component in efforts to combat global climate change. FAO (2010) estimated that the world's forests store 289 Gt of carbon in their biomass alone (http://www.fao.org/forestry/fra/en/).
- While sustainable management, planting and rehabilitation of forests can conserve or increase forest carbon stocks, deforestation, degradation and poor forest management reduce them.
- For the world as a whole, carbon stocks in fores biomass decreased by an estimated 0.5 Gt annually during the period 2005–2010, mainly because of a reduction in the global forest area.

- The vegetation of tropical forest is a large and globally significant storage of C, because tropical forest contains more C per unit area than any other land cover. About two-third of the global terrestrial C, exclusive of that sequestered in rocks and sediments, is sequestered in forest ecosystems (Sedjo, 2006).
- The main carbon pools in tropical forest ecosystems are the living biomass of trees and understorey vegetation and the dead mass of litter, woody debris and soil organic matter. About 50% of plant biomass consists of C.
- The carbon stored in the aboveground living biomass of trees is typically the largest pool and the most directly impacted by deforestation and degradation.

B. Reduced emission

- Use of alternative sources of Energy
- Conventional sources of Energy (coal, N.gas and oil) should be replaced by:
  - Solar
  - Wind
  - Geothermal
  - HEP
  - Nuclear plant
  - Etc

5.3.Carbon trading

What is carbon market?

- There is **no single carbon market**, defined by a single commodity, a single contract type or a single set of buyers and sellers.

- What we call "carbon market" is a **loose collection of diverse transactions** through which quantities of greenhouse gas (GHG) emission reductions are exchanged.

- Information is limited, **especially on prices**, since there is no central clearinghouse for carbon transactions. As such, it is **difficult to compare prices/quantities over whole market**

1. **By commodity traded**
   - **Project-based GHG emission reductions** (ERs), created and exchanged through a given project or activity

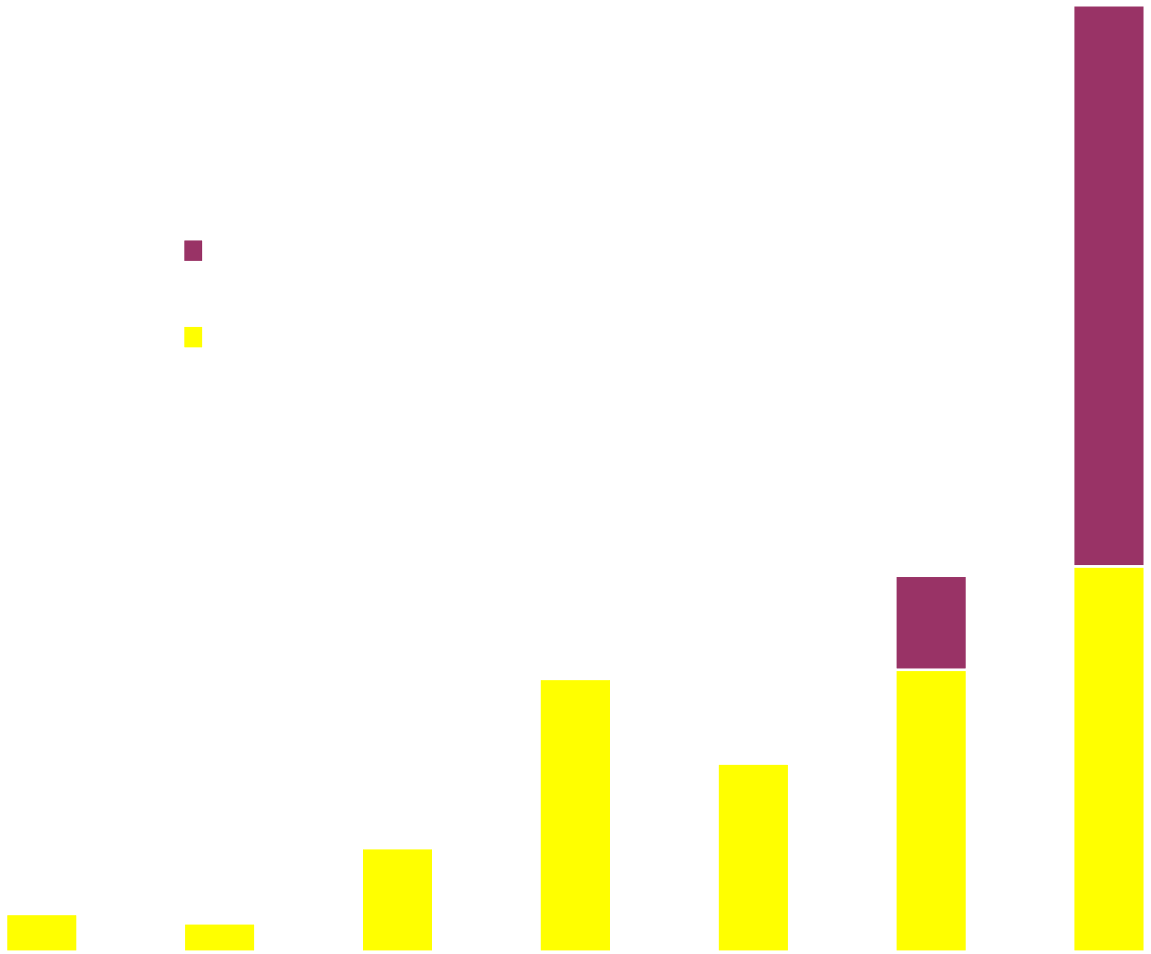
   - **GHG Emission Allowances**, as defined, or expected to be defined under international, national, regional or firm-level regulations

     Examples: UK trading system,
2. **By volumes**
   - **Wholesale**: Large transactions, usually > 1 MtCO2e

     Examples: most projects to date
   - **Retail**: Deals are in the '000s of tons

     Examples: Carbon-neutral events, non-carbon intensive corporations, etc.
3. **By types of contracts** (*e.g. spot, forward, options,*)
4. **By timeframes** (most contracts: 10-14 years; some 50+ years)

Number of trades 1996-2002



Chapter 6

Global policies, Conventions and protocols on climate change

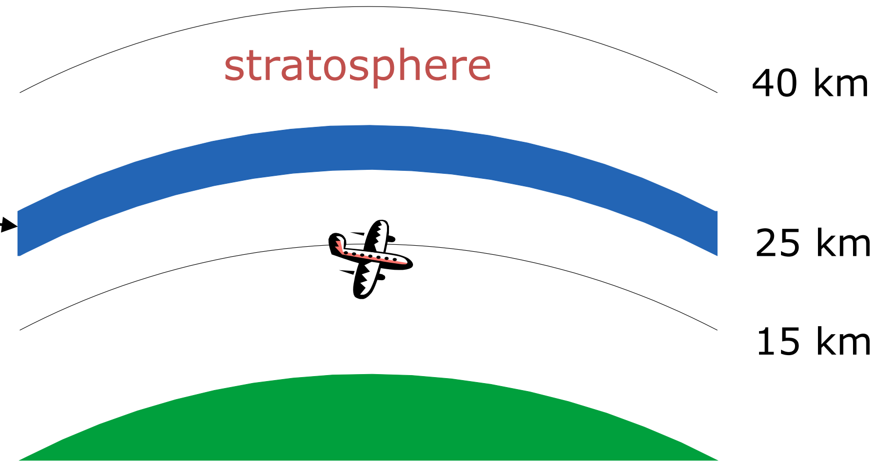
6.2. Montreal

Montreal Protocol Gases

- CFC – chloro fluoro carbon
- HCFC – hydro chloro fluoro carbon

CFCs and HCFCs

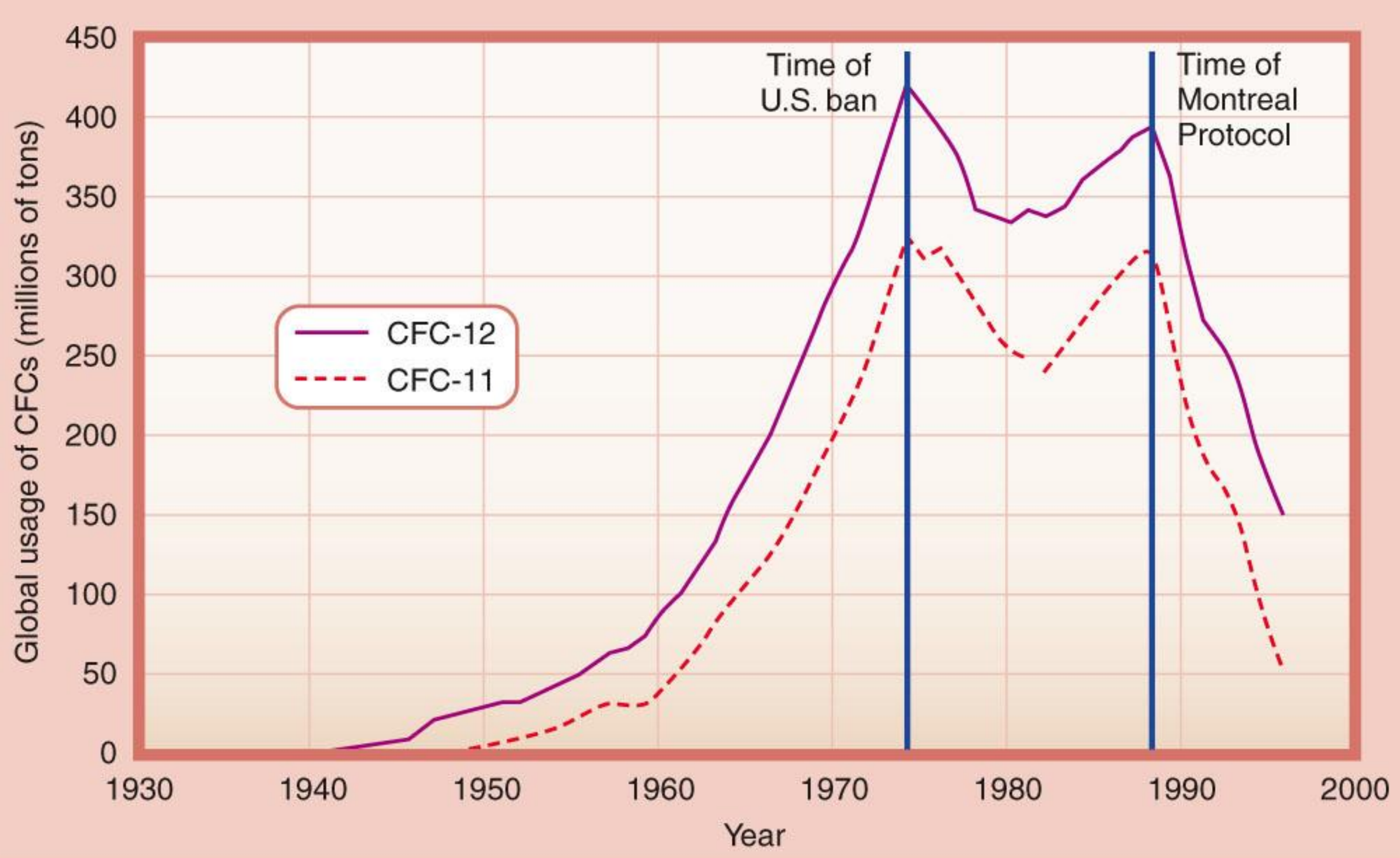
Deplete stratospheric ozone



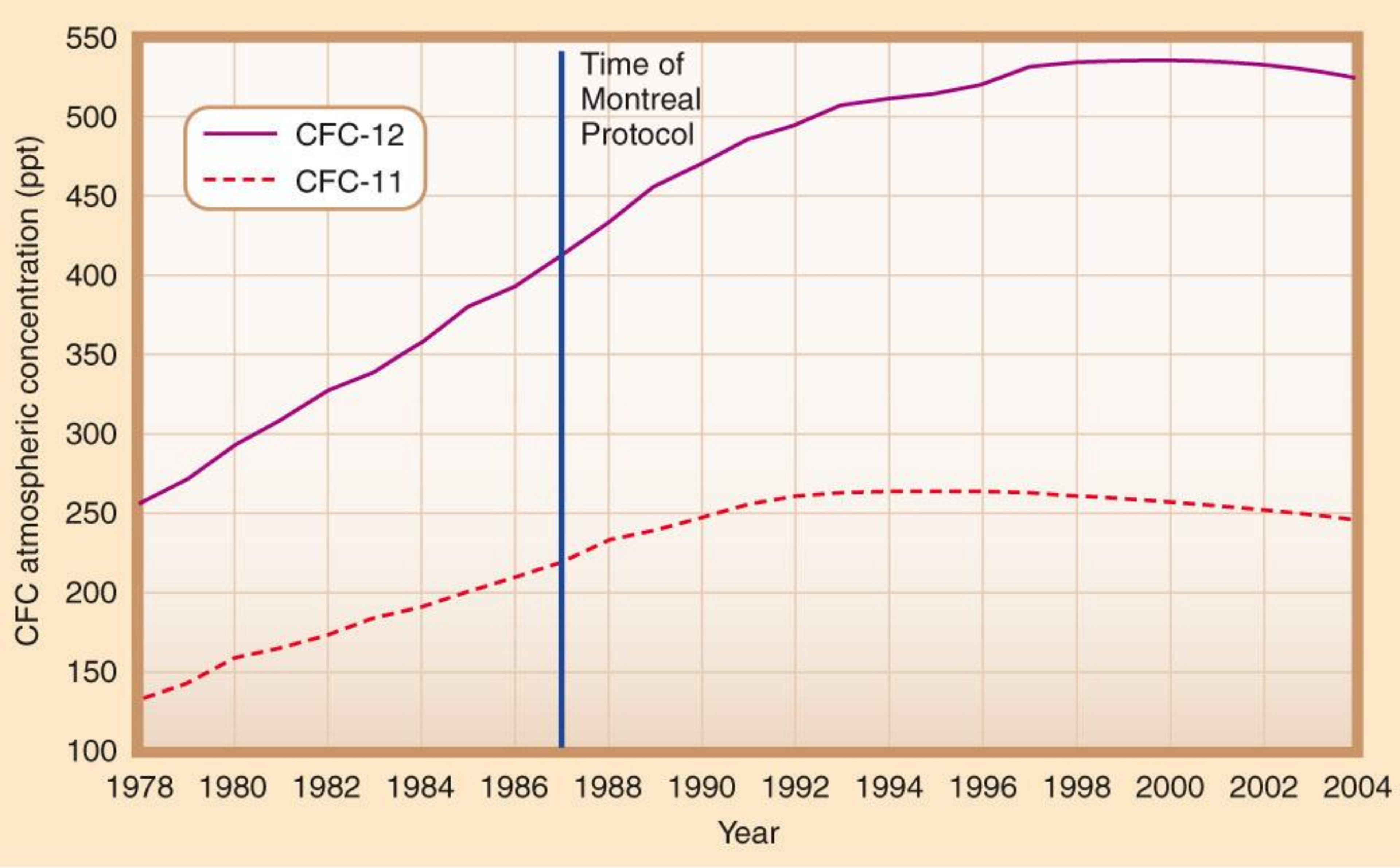
Are Greenhouse Gases

Production and Consumption are controlled by the Montreal Protocol. Emissions are not controlled.

Stratospheric Ozone Depletion and Climate Change can be addressed separately, even though they have scientific interconnections.



CFCs: global production



CFCs: global concentration

- **6.5. Issues of concern: sharing responsibility, policy response**

The UN Framework Convention on Climate Change

- 192 Parties – near universal membership
- **The ultimate objective of the Convention:** change is inevitable, but pace and intensity must be managed so that people and ecosystems can adapt.
- Principle of common but differentiated responsibilities and respective capabilities: **developed countries must take the lead**

Key commitments under the UNFCCC

- All Parties shall "Cooperate in preparing for adaptation to the impacts of climate change; **develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas,** particularly in Africa, affected by drought and desertification, as well as floods."

  – Article 4.1 (e)

Key commitments under the UNFCCC

All Parties shall "Take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions, and employ appropriate methods, **for example impact assessments, formulated and determined nationally, with a view to minimizing adverse effects on the economy, on public health and on the quality of the environment**, of projects or measures undertaken by them to mitigate or adapt to climate change."

– Article 4.1 (f)

Key commitments under the UNFCCC

"The **developed** country Parties … shall also assist the **developing** country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects."

- Article 4.4

Key commitments under the UNFCCC

"The Parties shall take full account of the **specific needs and special situations** of the least developed countries in their actions with regard to funding and transfer of technology."

– Article 4.9

6.4. Kyoto protocol

Greenhouse Gases

Carbon dioxide - CO_2
Methane - CH_4
Nitrous oxide - N_2O
The F-gases:
- HFC - hydrofluorocarbon
- PFC - perfluorocarbon
- SF_6 - sulphur hexafluoride

The Kyoto Protocol

- 1990 IPCC certified the scientific basis for global climate change.
- Kyoto Conference in 1997 - 161 countries were represented.
- **Binding** emissions targets were set for six greenhouse gases for 38 countries; the goal was to reduce emissions by 5% around 2010.
- Emissions credit trading was established.
- Emissions credit could also be given by helping developing nations reduce emissions through improved technology.

The Kyoto Protocol - where are we?

- New agreements reached in 2001 in Bonn
- The U.S. did not participate.
- 84 countries signed and 37 countries have ratified the treaty, including the European Union, and Japan.
- The sticking point for the U.S. has been (starting with the Clinton administration) the failure to agree on limits for key developing countries.
- Russia signed in 2004

Copenhagen accord

- China wants it both ways
- \$ 100B yr^{-1} promised to developing nations
- Targets for reductions submitted by 38 countries January 31, 2010
- Reducing intensity (emissions per unit of GDP) seems like an end around to me
- If US and BRIC could reach consensus that’s maybe 80% of the problem

- Chapter 7. **An overview of climate change adaptation strategy of Ethiopia**

- The two ***strategies necessary*** ***to reduce the risks of climate change are adaptation and mitigation***

- ***Adaptation:*** ***the latest IPCC assessment report gives the following definition:*** 'Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2007b, WG II, p. 869).

- ***Mitigation: -'It is just the reduction of greenhouse*** gases'.
- In mitigation, the primary purpose is to avoid the unmanageable – the causes of climate change are removed by reducing GHG emissions.
- Whereas in adaptation, the effects of climate change are dealt with by coping with their negative impacts: it is about managing the unavoidable.

- The two strategies are interlinked: the more successful the mitigation is, the less adaptation is required.

- Political leaders around the world negotiate on the level of GHG emissions that can be allowed without affecting the integrity of the earth.

- There is increasing agreement that if temperatures rise by no more than $2^{O}C$ the earth's integrity can be preserved and many of the potentially grave consequences of climate change could be avoided. This threshold is associated with per capita emissions of approximately 2 tons of CO2 equivalents each year.

Developed countries, which currently have per capita emissions of about 16 tons per year, need to sharply reduce their missions (Kropp and Scholze, 2009).

Most important climate change related ***stimuli are:***

- Increased temperature (including seasonal changes),
- more intensive and frequent storms,
- sea level rise,
- more heat waves,
- more cold spells,
- more droughts,
- more flooding
- more extreme rain (including seasonal changes, change in annual and seasonal water availability,
- accelerated melting of glaciers, and
- melting of permafrost.

6.6.1 Adaptation

- **Adaptation**

  Adjustment in natural or human systems in response to actual or expected climatic *stimuli* or their effects, which moderates harm or exploits beneficial opportunities. Types of adaptation include anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation

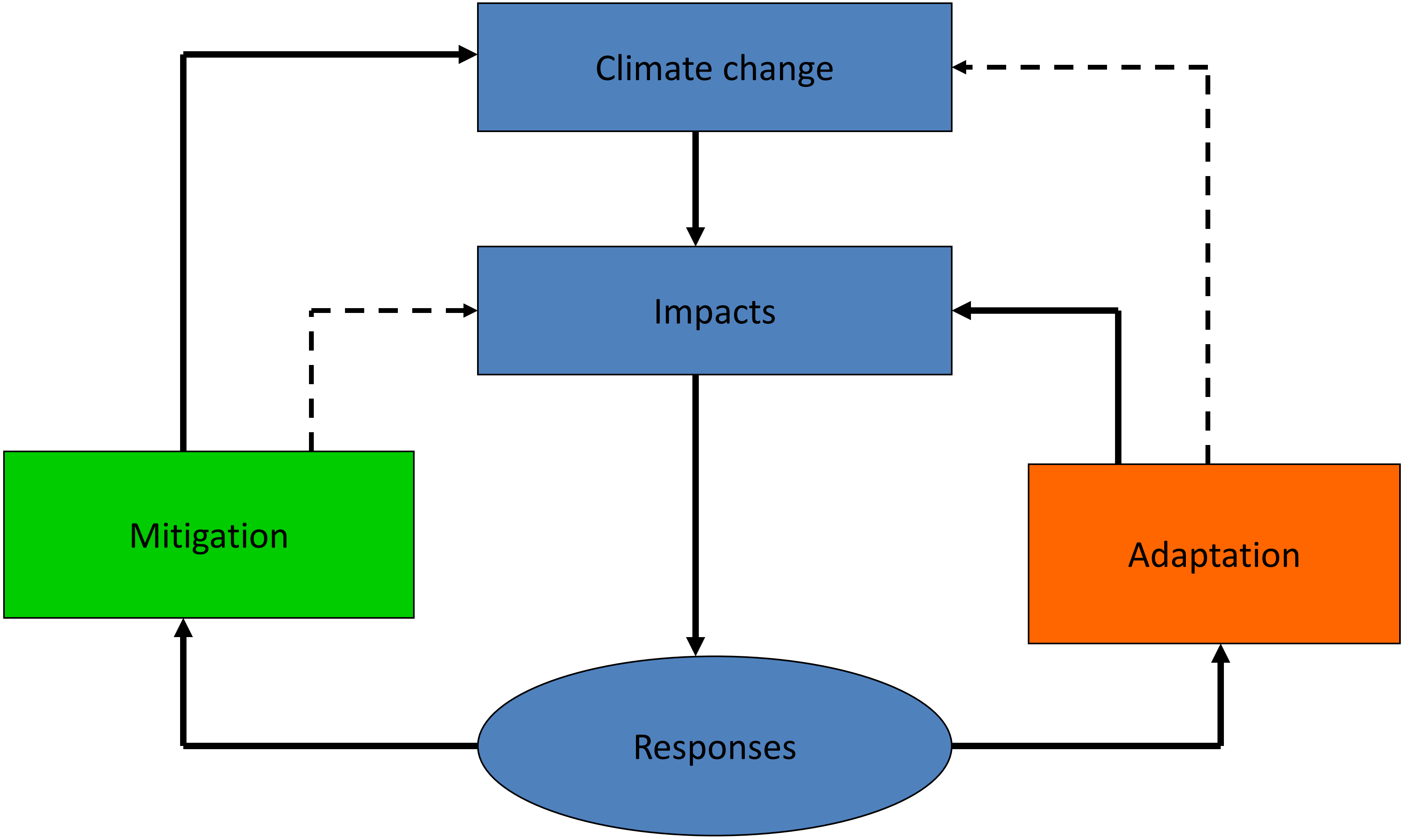
Who are vulnerable?

Geographical space: "people who live on arid or semi-arid lands, in low-lying coastal areas, in water limited or flood-prone areas, or on small islands……"

Social space: "developing countries… have lesser capacity to adapt and are more vulnerable to climate change damages, just as they are to other stresses. This condition is more extreme among the poorest people" (double-exposure).

Source: Olmos, "Vulnerability and Adaptation to Climate Change: Concepts, Issues, Assessment Methods", *Foundation Paper*, Climate Change Knowledge network, 2001.

Dealing with Climate Change:
Mitigation and Adaptation



The need for adaptation

- Mitigation will not work, So it is necessary to organize in order to take advantage of the new opportunities (longer growing season) and avoid some of the negative impacts (extreme weather variability, drought).

Adaptation strategies for Ethiopian farmers

- diversification of income
- growing of drought and heat resistance crops
- use of small scale irrigation
- increased agro forestry practices
- shifting in different seasons
- reduction in herd and farm size
- diversification of animal and plant varieties

- Use of vaccination
- herd supplementation
- selling of assets at the time of difficulties
- Use of indigenous early warnings and forecasting systems
- Cropping intensity
- Inter cropping
- Farm input)

- Planting date adjustment
- Zoning
- Increasing off-farm income
- tree planting
- Soil and water conservation
- Proper utilization of Commercial fertilizer
- Compost preparation and utilization
- Manure preparation and utilization

- Develop Saving Practices
- Use of money deposited at the time of difficulties
- Obtaining aid from the government
- Evacuation at the time of difficulties
- Develop remittance
- Land rents
- Using insurance service

- Adjustment of clothing styles
- diet adjustment
- Use health center
- Use pure water
- Rain water harvesting

- The recent IPCC report estimated that the global forestry sector represents over 50% of global greenhouse mitigation potential. On the other hand, the forest sector can also be a source of greenhouse gases. Consequently, global climate change policy focuses on the forest sector, and holds a key position in international climate treaties.

- Deforestation and forest degradation represents about 17% of the global GHG emissions.
- Cutting down trees in the forest releases carbon to the atmosphere. Although selective logging may only remove a few big trees per ha (and damage surrounding ones), it can lead to a substantial decrease in total biomass and carbon stock. When forests (250 tons carbon ha-1) are transformed into agriculture, the subsequent land use systems implemented determine the amount of potential carbon restocking that takes place.

- Annual crop systems will on average contain only 3 tons C ha-1, intensive tree crop plantations 30-60 tons carbon ha-1, which is 1 and 10-25% of the forest biomass and carbon stock.
- The annual C sequestration rate (increment of standing stock) may be the same for these three of vegetation types (annual crop, tree plantation and forest) about 3 tons carbon ha-1 yr-1, but the mean residence time differs from 1, 10 to 83 years.
- Changes in carbon stock between vegetation and land use types relate primarily to this ‘mean residence time’.

International climate agreements and climate finances
UNFCCC, Kyoto Protocol

- A total of 192 countries of the world have joined an international treaty - the United Nations Framework Convention on Climate Change (UNFCCC) - to begin to consider what can be done to reduce global warming and to cope with whatever temperature increases are inevitable.
- Most, but not all, nations have also approved an addition to the treaty: the Kyoto Protocol, which entered into force on 16 February 2005 and which has more powerful (and legally binding) measures, focused on the ‘first commitment period’ of 2008-2012.

- The Convention places the heaviest burden for fighting climate change on industrialized nations, since they are the source of most past and current greenhouse gas emissions.
- For the most part, these developed nations, called "Annex I" countries (because they are listed in the first annex to the treaty) belong to the Organization for Economic Cooperation and Development (OECD).
- These advanced nations, as well as 12 "economies in transition" (countries in Central and Eastern Europe, including some states formerly belonging to the Soviet Union) were expected by the year 2000 to reduce emissions to 1990 levels.

- Industrialized nations agreed under the Convention to support climate-change activities in developing countries by providing financial support above and beyond any financial assistance they already provide to these countries.
- Because economic development is vital for the world's poorer countries - and because such progress is difficult to achieve even without the complications added by climate change - the Convention accepts that the share of greenhouse gas emissions produced by developing nations will grow in the coming years.

- It nonetheless seeks to help such countries limit emissions in ways that will not hinder their economic progress. The Convention acknowledges the vulnerability of developing countries to climate change and calls for special efforts to ease the consequences.
- Developing countries have an obligation to report their emissions and C stocks to assist in the global book keeping of emissions and drivers of climate change.
- Developing countries that want to participate in other mechanisms of the Convention will need to provide such data, as part of global transparency.

- To achieve required carbon reduction, carbon emissions are commoditized under a number of flexible mechanisms.
- The Kyoto protocol introduces three market-based mechanisms to allow Annex I countries to reduce emissions beyond their national boundaries yet include reductions in their national level target.
- The three mechanisms are: The International Emissions Trading, The Joint Implementation and the Clean Development Mechanism (CDM).
- International Emissions Trading (Article 17) allows
- Annex I countries to trade part of their assigned cap. Joint Implementation (Article 6)
- functions at sub-national level so that project activities can be sponsored and
- implemented in Annex I Party to meet reduction requirements in a second Party.

- The Clean Development Mechanism (Article 12) allows the sponsorship and implementation of project activities in non-Annex I Parties.
- The forest C sinks were included in the Kyoto Protocol as a mechanism to mitigate global climate change.
- According to the Protocol, the net sink of C arising from land use changes and forestry over the period of 2008-2012 can be credited and may substitute the reduction of GHG emissions and to fulfil the reporting requirements of international agreements of Annex I countries. Consequently, there has been a proliferation of climate-related financial mechanisms in the last few years.

- Within the existing instruments of climate (and carbon) finance, the Clean Development Mechanism (CDM) and the Reduced Emissions from Deforestation in Developing Countries (REDD) are usually linked with efforts to mitigate the impacts of climate change.
- By creating a market for emission reductions, in effect paying people and business to reduce greenhouse gas emissions, they argue that the carbon market provides a financial incentive to invest in clean energy projects, in energy efficiency, in fuel-switching, in waste management and in forestry.
- The carbon market is estimated to be worth about $64 billion according to the World Bank.

- The CDM was introduced for industrialized countries to achieve their emission reduction targets in a cost effective manner while contributing to sustainable development in developing countries (UNEP, 2002). However, CDM investments have been rather skewed with hardly any investments in the least developed countries

(LCDs), particularly in Africa (Capoor and Ambrosi, 2006).

- The World Bank has attempted to improve the distribution of carbon investments in Africa through its Community Development Carbon Fund and BioCarbon Fund.
- However, all these investments in Africa still comprise less than 10% of the US$629 million worth of global carbon portfolio managed by the World Bank's carbon finance unit. There is thus a need for other multilateral donors to push for more carbon investments in African countries.

- An encouraging start in this regard is the creation of international funds that focus on carbon projects in poor countries. Examples include the International Union forConservation of Nature (IUCN) Climate Fund and the Finnish CDM Program that are mandated to support carbon projects in Africa (UNEP and IETA, 2005). The UNDP's
- Millennium Development Goals Carbon initiative also seeks to redress this imbalance.

- Ethiopia will benefit from such initiatives.

The Bali RoadmapRE(D)i+j

- At the 13th Conference of Parties in Bali in December 2007 a “Bali Road Map’ was agreed

upon which includes efforts to include a new mechanism for Reducing Emissions from Deforestation and (forest) Degradation (REDD) in the agreements that are to define the successor of the Kyoto protocol, culminating in the 15th COP in Copenhagen, December 2009.

- Earning carbon credits through avoided deforestation (REDD) could be particularly relevant for Africa, where many countries have very high deforestation rates. These high deforestation rates are often accompanied by rapid loss of species, reduction in land productivity and other adverse environmental impacts.
- Many African countries, however, lack adequate financial or technical means to conserve their forests. Carbon investments for emission reduction through avoided deforestation could therefore provide direct economic incentives for these countries to take up conservation.
- FAO (2007) estimates that the total carbon mitigation from avoided deforestation in Africa from 2003–2012 could be 615.8 million tons CO2. A sale of even a small proportion of these carbon offsets to international investors will provide significant economic returns
- to local communities and to host governments in Africa to invest in forest conservation.

VALUES OF FOREST CARBON IN THE INTERNATIONAL MARKET ANDCOSTS OF CARBON FORESTRY

- On the world market, carbon is currently valued at between $10 and $20 per ton. The forest management costs (that is, overheads incurred by the Forest Department) vary according to management activity but range from $1 per ha to $100, so at the lower end of the scale the management activities could in fact be financed entirely out of the carbon income.
- This does not however take into account the transaction costs (which include development of a CDM project proposal, creating the baseline, making the necessary carbon measurements of changes in vegetation on a periodic basis, reporting on these, etc).
- If such activities are carried out by experts there is likely to be little margin of gain to the communities themselves. As Landell- Mills and Porras (1999) have pointed out, it is the transaction costs that are likely to be the key factor in determining whether or not such forest management is financially feasible.

- Unfortunately transaction costs for small projects which involve community groups under community based forest management (CBFM) are thought to be relatively higher than for industrial plantations which are more uniform in nature and under one owner, as well as having the advantage of economies of scale (Smith and Scherr, 2002).

Chomitz concludes that the cost per ton of measuring carbon stored in biomass will be approximately inversely proportional to the size of the carbon sink (this follows from standard statistical theory).

- The cost for small, heterogeneous forest management projects could be exorbitant if done by fieldwork, especially if high levels of accuracy (e.g. 5% rather than 10% as in the case described above) are demanded. He suggests therefore that such projects might have to rely on standardized, benchmarked (so-called ‘default’) values (Chomitz, 2002).

CDM AND REDD ACTIVITIES IN ETHIOPIA
CDM supported reforestation projects in Ethiopia

- There is one project registered under the Clean Development Mechanism (CDM) located in the Humbo area (UNFCCC registration Dec 2009, area of 2 728 ha); and there are three further projects, in the Abote, Ada Berga, and Sodo areas, that are mentioned as potential CDM projects (currently not registered at UNFCCC).
- An additional CDM project, covering an area 20,000 ha earmarked for afforestation/ reforestation in the Amhara National Regional State is under discussion

REDD+ Pilot Projects in Ethiopia

- REDD+ pilots are in preparatory stages in Ethiopia, and they exist in the Bale eco-region (500,000 ha) (which is expected to generate over 320 m illion USD during the contract period of 21 years), in the The Yayu and Gedo forests (190,000 ha), and in the Baro- Akobo area (7,610,300 ha), as well as in the south west of the country (Tsegaye Tadesse,2010).
- These pilots are generally designed to feed into both PFM programmes and protected area programs that are developing PFM buffer zones. They are pioneering the development of REDD+ implementation in the country (developing carbon accounting, benefit sharing mechanisms), and will be essential sources of information for up-scaling of REDD+ projects in the country.

- **Aboveground biomass**

The AGB carbon pool consists of all living vegetation above the soil, inclusive of stems, stumps, branches, bark, seeds and foliage.

- **Basal area**
- Basal are of a tree is the cross-sectional area of a tree at breast height.
- **Belowground biomass**
- The BGB carbon pool consists of the biomass contained within live roots.
- In some text books, the below-ground biomass comprises living and dead roots, soil
- fauna, and the microbial community.

- **Biomass**
- Biomass is a quantity of living matter in a given ecosystem expressed in terms of its
- mass. Alternative definition: The total mass of living organisms including plants and
- animals for a given area usually expressed as dry weight in g m-2 or kg ha-1.
- Broadly, forest biomass is organic matter expressed as oven-dry tons per unit area: it
- can be referred to as biomass density when expressed as mass per unit area.
- Approximately 50% of dry forest biomass is carbon.

- **Carbon dioxide equivalent**
- A measure used to compare different greenhouse gases based on their contribution to radiative forcing. The UNFCCC currently (2005) uses global warming potentials (GWPs) as factors to calculate carbon dioxide equivalent.
- **Carbon pool**
- Carbon pools are major components of an ecosystem that can either accumulate or release carbon.

Carbon stocks

- Total carbon stored (absolute quantity) in terrestrial ecosystems at specific time, as living or dead plant biomass (above and below-ground) and in the soil, along with usually negligible quantities as animal biomass. The unit is Mg ha-1.
- The value expressed in terms of unit area is known as ***carbon density, which is used to compare the potential*** of different land uses for carbon storage.
- Aboveground plant biomass comprises all woody stems, branches, and leaves of living trees, creepers, climbers, and epiphytes as well as understorey plants and herbaceous growth.

Carbon stock accounting

- Stock accounting assesses the magnitude of carbon stored in forest ecosystems at a single point in time.

Breast height diameter (DBH)

- It is the thickness of the stem at 1.3 m above the ground level.

Emissions

- The release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time.

Emission reductions accounting

- Emission reductions accounting assesses the decrease in emissions from project or policy activities, often so that they can be traded.

Emissions accounting

- Emissions accounting assesses the net greenhouse gas emissions to the atmosphere resulting from forests.

Forest

- According to the IPCC forest is a minimum land area of 0.05-1 hectare with tree crown cover more than 10-30% and tree height of 2-5m at maturity.

- **Global Warming Potential (GWP)**
- Used to enable the comparison of the six common GHG, it is the cumulative radiative forcing effects of a unit mass of gas over a specified time horizon relative to CO_2.

- It is expressed in terms of carbon dioxide equivalents (CO_2e). Of relevance to forest carbon accounting: $GWP_{CO2} = 1$, $GWP_{CH4} = 21$, $GWP_{N2O} = 310$.

- **Greenhouse Gas (GHG)**
- There are six recognised major greenhouse gases; CO2 (carbon dioxide), CH4 (methane), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons), N20 (nitrous oxide) and SF6 (sulphur hexafluoride).
- Carbon accounting often refers to the accounting of all major GHGs using a carbon dioxide equivalent (CO2e) that standardise these gases based on their global warming potential.

Sequestration

- The process of increasing the content of a carb on pool other than the atmosphere.

Shrub land

- Land supporting a stand of trees, usually not exceeding 6m in height , with a canopy cover greater than 20%. The ground cover is often poor as fire is very frequent, and there may exist scattered and rare trees.

Sink

- Any process, activity or mechanism which removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas from the atmosphere.
- Or a carbon sink is a carbon pool from which more carbon flows in than out: forests can act as sink through the process of tree growth and resultant biological carbon sequestration Notation in the final stages of reporting is the negative (-) sign.

Site index

- Site index is a site quality indicator that uses dominant height of a stand at a certain age.

Source

- Any process or activity which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere. Or a carbon source is a carbon pool from which more carbon flows out than flows in: forests can often represent a net source of carbon due to the processes of decay, combustion and respiration Notation in the final stages of reporting is the positive (+) sign.

- **Stocking**
- A qualitative expression of the adequacy of woody plant cover on an area in terms of crown closure, number of woody plants, basal area or volume in relation to a pre established norm.

Stock table

- A summary table showing the volume of woody plants per unit area by species and diameter classes, for a stand, a forest type or land cover type.

Volume equation

- It is a statistically derived expression of the relationship between volume and other woody plant or stand variables.
- It is used to estimate volume from easily measured variables such as diameter at breast height, woody plant or stand height and crown closure.

Weight (Biomass) table

- A summary table showing the weight of woody plants per unit area by species and diameter classes, for a stand, a forest type or land cover type.

Woodland

- Lands dominated by trees, which are heavily branched and have a height of up to 20 m.
- The flat crowns do not form a closed canopy, but cover more than 20 per cent of the ground and are leafless during some parts of the year. The ground is covered with grasses, herbs and shrubs.

Yield table

- A summary table showing characteristics at different ages or development stages for stands or land cover types of one or more species on sites of differing qualities. It shows the development of the most important stand characteristics, such as dominant height, average diameter, stocking, volume or weight (mass) per ha, and removal.

- It is the simplest tool for predicting the future development of a stand. Because site, tree species, rotation (seedling or coppice), thinning, fertilization and other treatments affect growth and stand characteristics, there should be a separate yield table for each site class, species, rotation and for each treatment regime.