CAMS

Impacts of Present and Future Climate Variability on Agriculture and Forestry in the Humid and Sub-humid Tropics

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CAMS Outlines

- Characteristics of Climate of Humid and Sub-humid Tropics
- Features of Agriculture and Forestry in the Humid and Sub-humid Tropics
  - Crops and Livestock
  - Forestry
  - Systems of Agriculture and Forestry
- Climate variability
- Impacts of Climate Variability on Agriculture and Forestry
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  - Impacts on Forestry
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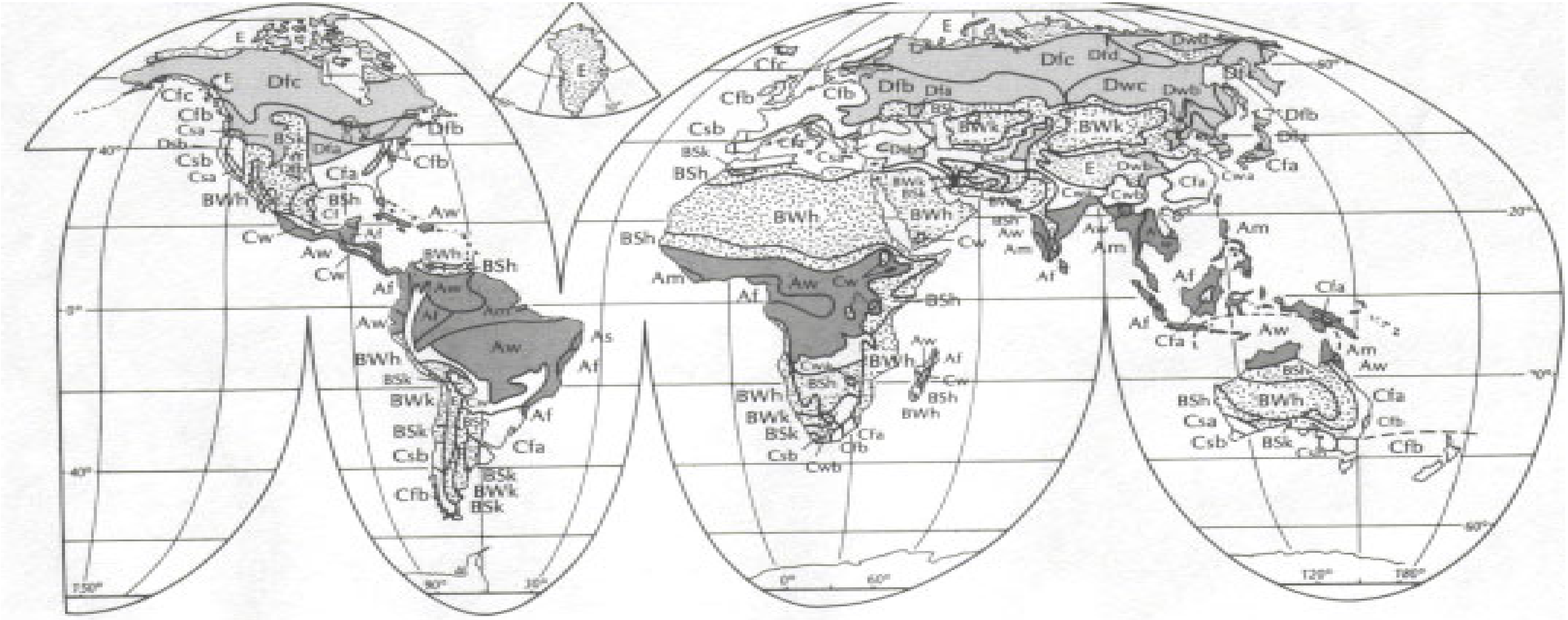
- Conclusions



Koppen classification

Af: Tropical rainy, Aw: Tropical wet-and-dry, Am: Tropical monsoon

Humid and sub-humid tropics:

50 percent of the tropical land mass

20 percent of the earth’s total land

Three principal regions: Central and South America, 45 percent;
Central and Western Africa, 30 percent;
and Tropical Asia, about 25 percent.

62 countries are located within the region.

Characteristics of Climate of Humid and Sub-humid Tropics

Three climate zones:

- ***the tropical rainy climate zone***
  - lowlands within 5° N and 5° S of the equator
  - high temperatures and abundant rainfall
  - the luxurious evergreen forests
- ***the tropical monsoon climate zone***
  - a distinct dry season
  - rainfall totals and temperature conditions similar to those in the tropical rainy climate
  - rainfall regime similar to that of tropical wet-dry climate
- ***the tropical wet-dry climate zone***
  - alternating wet and dry seasons
  - less annual rainfall totals
  - the dry season severe

Characteristics of Climate of Humid and Sub-humid Tropics

Three Principal Regions:

- ***Tropical Asia***
  - two monsoons: summer southwest monsoon, winter northeast monsoon
  - tropical cyclone: two core areas of cyclogenesis (one in the northwestern Pacific Ocean, the other in the northern Indian Ocean
  - El Niño-Southern Oscillation (ENSO) phenomenon
- ***Central and western Africa***
  - heavy rainfall throughout the year in Congo Basin
  - others characterized by wet-dry climate
- ***Central America and the northern part of South America***
  - the Pacific side of Central America dry
  - the Atlantic side wet
  - the east of the Andes Mountains (the Amazon Basin) humid
  - droughts and floods due to the ENSO phenomenon

Features of Agriculture and Forestry in the Humid and Sub-humid Tropics

Crops and Livestock

- Commercial agriculture : perennials, such as rubber, oil palm, bananas, coffee, etc.

- Food crops : roots such as sorghum, sweet potatoes; rice, maize and millet (but differently with different climates, the length of rainy and dry seasons)

- Livestock : mainly pigs and poultry; cattle varies considerably, depending upon the presence or absence of animal diseases and traditional agricultural systems.

Features of Agriculture and Forestry in the Humid and Sub-humid Tropics

Forestry

- Tropical forests represent about 40% of the world's forested area and contain about 60% of global forest biomass.

- Two major types : rainforests and monsoon forests

- Reasons of degradation: no management, logging, farming due to the pressure of increasing population and fire

- Plantation forestry also plays an important role.

Features of Agriculture and Forestry in the Humid and Sub-humid Tropics

Systems of Agriculture and Forestry

- ***Intensive Cropping Systems***

  - Concentrated in lands with adequate water, naturally fertile soils conducive to high agricultural productivity
  - Facing critical challenges: expanding populations, no fallow period

- ***Shifting Cultivation***

  - One of the most widespread farming systems
  - Land use problems: shortening the fallow period and field rotation cycle and consequently, a loss of productivity

Features of Agriculture and Forestry in the Humid and Sub-humid Tropics

- ***Agropastoral System***

  - In Asia: in lowland, rice and buffalo, cattle
    in highland, rice, maize, and swine, poultry
  - In humid Africa: rice, yams, and goats, poultry
  - In Latin America: beans, maize, and cattle, swine

  - Advantages:
    enhancing agroecosystem productivity and stability,
    providing a variety of both crop and livestock products,
    high levels of income

Features of Agriculture and Forestry in the Humid and Sub-humid Tropics

- ***Cattle Ranching***

  - Not important as a economic activity in the humid Africa
  - Common in some countries of Southeast Asia
  - Very common in Latin America, a leading contributor to deforestation and environmental degradation

- ***Agroforestry System***

  - Multiple benefits (agronomic, economic, environmental)
  - Competition for limited resources (nutrients, water, and light)

Climate Variability

- Over the past 100 years, the amount of changes of mean surface temperatures and precipitations has been less in the tropics than the global average, but either in the past climate or in the projected scenarios, climate variability, particularly multidecadal ones, are obvious.

- Based on climate change projections made by IPCC, there is a potential for an increased occurrence of droughts, floods and extreme rainfall events in most of humid and sub-humid tropics (increased variability of precipitation).

- Other recent studies also indicate that the maximum potential intensities of cyclones will remain the same or undergo a modest increase of up to 10–20 percent.

- It also has been suggested that under climate change, more El Niño-like conditions will be experienced, particularly in South America.

Impacts of Climate Variability on Agriculture and Forestry

Impacts on Crop Agriculture

- Negative

- Agriculture, particularly in the sub-humid areas, is vulnerable to many environmental hazards—including frequent floods, droughts, tropical cyclones, storm surges and high temperatures.

- Low-income rural populations that depend on traditional agricultural systems or on marginal lands are particularly vulnerable.

- Agricultural vulnerability to climate change will lead to crop production unsteady, food security is facing great threat.

Table 1: Recent agricultural studies

Study	Scope	Crops	Climate Scenario	Yield impact w/o adaptation	Yield impact w / adaptation	Socio-economic impact	Comments
a. Studies with Explicit Global Economics and/or Global Yields							
Parry et al (1999)	Global	Wheat, Rice, Maize, Soybeans	Transient scenarios: 4 HadCM2 ensemble scenarios, 1 HadCM3 (both assume IS92a forcing)		All cereals by 2080s: NA (-10 to +3%); LA (-10 to +10%); WE (0 to +3%); EE (-10 to +3%); AS (-10 to +5%); AF (-10 to +3%);	By the 2080s: global cereal production (-4 to –2%), cereal prices (+13 to +45), number of people at risk or hunger (+36 to +50%)	Farm-level adaptations (changes in plant date, varieties, irrigation, fertilizer); economic adjustments (increased investment, reallocation of resources, more land in production); no feedback between economic adjustments and yields; CO_2 direct effects included.
Winters et al. (1999)	Africa, Asia, Latin America	Maize, rice, wheat, coarse grains, soybean, "cash crops"	GISS, GFDL, UKMO		Africa [maize (-29 to –23%), rice (0%), wheat (-20 to –15%), coarse grains (-30 to –25%), soybean (-2 to +10%), cash crops (-10 to –4%)]; Asia [maize (-34 to –20%), rice (-12 to-3%), wheat (-54 to 8%), coarse grains (-34 to –22%), soybean (-9 to +10%), cash crops (-13 to +2%)]; Latin America [maize (-26 to –18%), rice (-26 to -9%), wheat (-34 to –24%), coarse grains (-27 to –19%), soybean (-8 to +12%), cash crops (-20 to –5%)];	Africa [total agricultural production (-13 to –9%), GDP per capita (-10 to –7%), agricultural prices (-9 to +56%)]; Asia [total agricultural production (-6 to 0%), GDP per capita(-3 to 0%), agricultural prices (-17 to +48%)]; Latin America [total agricultural production (-15 to -6%), GDP per capita (-6 to -2%), agricultural prices (-8 to +46%)]	Yield impacts based on Rosenzweig and Parry (1994) values for "level 1" (farm level) adaptations and CO_2 direct effects; yield impacts are weighted (by production) average of country-level yield changes; values for total agricultural production and per capita GDP include both yield and price impacts; range for agricultural prices is across food and cash crops, and GCMs
b. Studies with of Yield and Production in Economies-in-Transition and Developing Regions, Nations, and Sub-national Regions							
Matthews et al. (1997)	Asia	Rice	Sensitivity analysis (+1,+2,+4° C); GFDL, GISS, UKMO	+1° C (-7 to 26%) +4° C (-31 to –7%) -8 to +5%	+14 to +27 % (with change in variety)	Change in production: China with change in cropping system (+37% to +44%), region with change in variety (+13 to +25%)	Includes CO_2 direct effects; adaptation (single to double cropping system, planting date shift, change in variety)

Table 1 continued

Study	Scope	Crops	Climate Scenario	Yield impact w/o adaptation	Yield impact w / adaptation	Socio-economic impact	Comments
Smith et al. (1996)	The Gambia Zimbabwe Kazakhstan Mongolia Czech Republic	Maize, millet-early, millet-late, groundnuts Maize Spring wheat, winter wheat Spring wheat Winter wheat	CCC, GFDL, GISS CCC, GFDL CCC, GFDL, incremental scenarios GFDL, GISS Incremental scenarios	-26 to –15% -44 to –29% -21 to –14% +40 to +52% -14 to –12% -70 to –25% -35 to +17% -74 to +32% -3 to +16%	-67 to –5%		CO_2 direct effects considered in all cases but Mongolia; adaptation in Mongolia consists of earlier seeding
Amien et al (1996)	Indonesia	Rice	GISS transient	2050 (-14 to –9%)			Includes direct effects of CO_2
Buan et al. (1996)	Philippines (6 sites)	Rice, Corn	CCC, GFDL, GISS, UKMO	Rice (-13 to +9%), Corn(-14 to –8%)			Includes direct effects of CO_2
Karim et al (1996)	Bangladesh	Rice, Wheat	CCC, GFDL	Rice (-17 to –10%), wheat (-61 to –20%)			CO_2 direct effects not considered
Jinghua and Erda (1996)	China	Maize	GFDL, UKMO, MPI	-19 to +5%		Change in production: -6 to –3%	CO_2 direct effects not considered

Table 3: Assessment of climate change impacts on annual crops in Latin America

Study	Climate Scenario	Scope	Crop	Yield Impact (%)
Downing, 1992	+3° C -25% precipitation	Norte Chico, Chile	Wheat Maize Potato Grapes	Decrease Increase Increase Decrease
Baethgen, 1994	GISS, GFDL, UKMO	Uruguay	Wheat Barley	-30 -40 to –30
De Siqueira et al., 1994	**GISS, GFDL, UKMO**	**Brazil**	**Wheat** **Maize** **Soybeans**	**-50 to –15** **-25 to –2** **-10 to +40**
Liverman, e al., 1994	GISS, GFDL, UKMO	Mexico	Maize	-61 to –6
Sala and Paruelo, 1994	GISS, GFDL, UKMO	Argentina	Maize	-36 to –17
Baethgen and Magrin, 1995	UKMO	Argentina, Uruguay, (9 sites)	Wheat	-5 to –10
Conde et al., 1997a	CCCM, GFDL	Mexico (7 sites)	Maize	Increase-decrease
Magrin et al., 1997a	GISS,UKMO,GFDL,MPI	Argentina (43 sites)	Maize Wheat Sunflower Soybean	-16 to +2 -8 to +7 -8 to +13 -22 to +21

Source: TAR, 2001

Impacts of Climate Variability on Agriculture and Forestry

Impacts on Livestock

- Generally negative

- Heat stress has a variety of detrimental effects on livestock, with significant effects on milk production and reproduction in dairy cows, and swine fertility.

- Pastures and rangelands are vulnerable to the climate variability particularly increased variability of precipitation

- Seasonal water availability and chronically low soil-nutrient availability appear to be the most limiting factors for the pasture in Latin America.

- Livestock distribution and productivity could be indirectly influenced by the changes in the distribution of climate variability-induced livestock diseases in Africa.

Impacts of Climate Variability on Agriculture and Forestry

Impacts on Forestry

- Different impacts :detrimental, beneficial

- Increasing CO2 concentration can increase photosynthesis pronouncedly in C3 plants.

- Prolonged seasonal droughts caused by variability of precipitation affects the survival of some species, particularly dry woodlands and savannas in sub-humid areas.

- For plantation forestry, climate change could reduce silvicultural yields due to changes in water availability and increase the incidence of forest pests and fires.

Impacts of Climate Variability and Climate Change on Agriculture and Forestry in the Humid and Sub-humid Tropics


by

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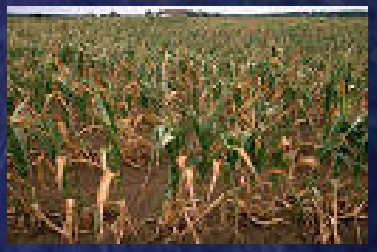
Agriculture and agricultural productivity in Tropical Asia

Present conditions:


Source: CCIC

- Rice is main staple food for Asians
  - Yield decelerated partly due to water scarcity
  - Rapid changes in food supply and demand structures in most developing countries
    - ✓ dramatic declines in self-sufficiency for grains even in countries with advanced economies (Japan, South Korea, Taiwan, Malaysia)
    - ✓ also in Indonesia, the Philippines, Sri Lanka
    - ✓ tighter grain supply and demand

Climate variability and change will seriously endanger sustained agricultural production through:



- moisture stress from prolonged dry spells
- increase in temperature (on crops, pathogens)
- thermal stress from heat wave occurrences
- stress in water availability

Summary of some recent impact studies in South and Southeast Asia

Study	Scenario	Geographic Scope	Crops	Yield impact (%)	Comments
Rosenzweig and Iglesias	GCMs	Pakistan India Bangladesh Thailand Philippines	Wheat Wheat Rice Rice Rice	-61 to +67 -50 to +30 -6 to +8 -17 to +6 -21 to +12	UKMO, GFDL, GISS, and +2, +4°C and +/- 20% precip. Range is over sites and GCM scenarios with direct CO2 effects; scenarios w/o CO2 and w/adaptation also were considered. CO2 effects important in offsetting losses of climate-only effects; adaptation unable to mitigate losses.
Parry *et al.*, 1992	GISS	Indonesia	Rice Soybean Maize	Approx. –4 +10 to –10 -25 to –654	Indonesia: Low estimates consider adaptation; also estimated overall loss of farmer income ranging from $10 to $130 annually.
		Malaysia	Rice Maize Oil Palm Rubber	-12 to –22 -10 to –20 increase -15	Malaysia: Maize yield affected by reduced radiation (increased clouds); variation in yield increase; range is across seasons.
		Thailand	Rice	5 to 8	
Matthews *et al.*, 1995	3 GCMs	India Bangladesh Indonesia Malaysia Myanmar Philippines Thailand	Rice	-12 to +23 -12 to –2 -6 to +22 +21 to +26 -9 to +30 -2 to +12 -20 to -34	GISS, GFDL, UKMO scenarios; included the direct CO2 effects; range is across GCMs; varietal adaptation was shown to be capable of ameliorating detrimental effects of a temperature increase in currently high temperature environments.

Source: Water, Air and Soil Pollution, Vol. 92

- **The positive effects of enhanced photosynthesis (from doubling CO_2) would be more than offset by temperature increases > 2°C (Matthews, et al, 1995)**

Summary of recent current impact studies in East Asia

Study	Scenario	Geographic Scope	Crops	Yield Impact (%)	Comments
Zhan Tao, 1992	2x CO_2; +1°C	China	Wheat, Rice Cotton, Fruits, Oil Crops, Potatoes, Corn	-8 -6 +1 to -4	Agricultural productivity loss, >5%; included direct effects; positive effects in NE and NW; negative in most of the country; no change in SW
Zhang Houxuan, 1993	+1.5°C	South of China	Rice	-7 to –11	Double crop; included CO_2 effect
Jin Zhiquin, et al, 1994	GCMs	South of China	Irrigated Rice	-37 to +15	Range across GISS, GFDL, UKMO scenarios; no consideration of enrichment effects of CO_2

Lou and Lin, 1999

Under elevated CO_2 conditions and associated climate change

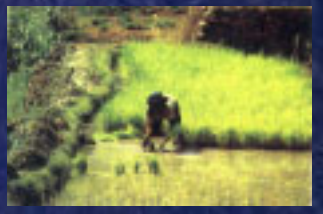
- Increases in crop yield in areas in mid- and high latitudes

- Generally, a decrease in crop yields in areas in the lower latitudes (Lou and Lin, 1999)

Impacts on crop productivity considering both biophysical aspects and socio-economic drivers and consequences

- On world agriculture, economic impacts of climate change is MINOR; decreasing food production in some areas balanced by gains in others (Kane et al, 1991; Tobey et al, 1992; Rosenzweig and Parry, 1993)

- **But in some countries in Asia, projected decline in potential yield and total production of rice because of changes in climate and climate variability would have a significant effect on trade in agricultural commodities. (Matthews et al, 1995)**

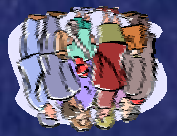


  - **Self-sufficiency in grains would fall further since we could move toward a tighter grain supply.**

  - **Serious impacts of global warming (e.g. considerable reliance on imports) would be felt as early as 2020 (Nakagawa et al, 1997)**

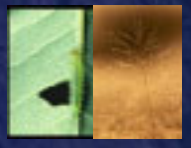
Forestry and forest resources in tropical Asia

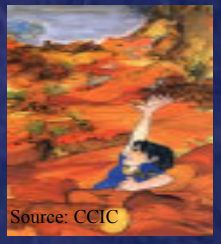
Many of the endangered forest areas in tropical Asia are caused by:

- ✓ Population growth, 
- ✓ ever-increasing demand for agricultural land 
- ✓ poverty, 
- ✓ poor institutional capacity, and 
- ✓ lack of effective community participation

Climate change is expected to affect:

- primary productivity
- species populations and migration
- boundaries of forest types and areas
- occurrence of pests and diseases
- forest regeneration





Climate change will have a profound effect on the future distribution; productivity and health of forests

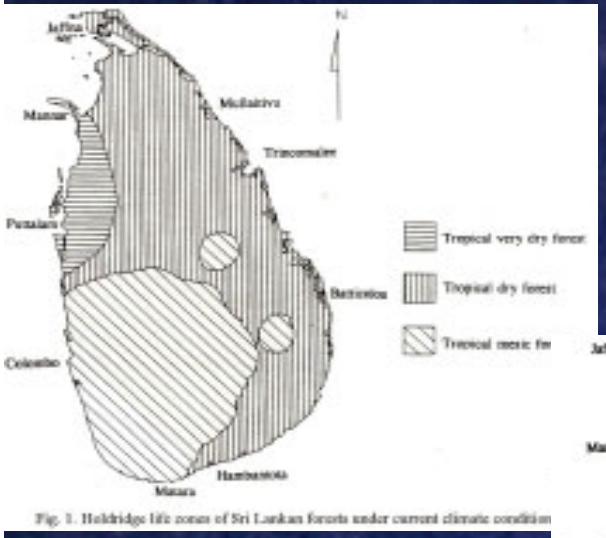


Fig. 1. Holdridge life zones of Sri Lankan forests under current climatic condition

- Holdridge life zones of Sri Lankan forests under current climate conditions

(Samaratne and Dhanapala, 1996)

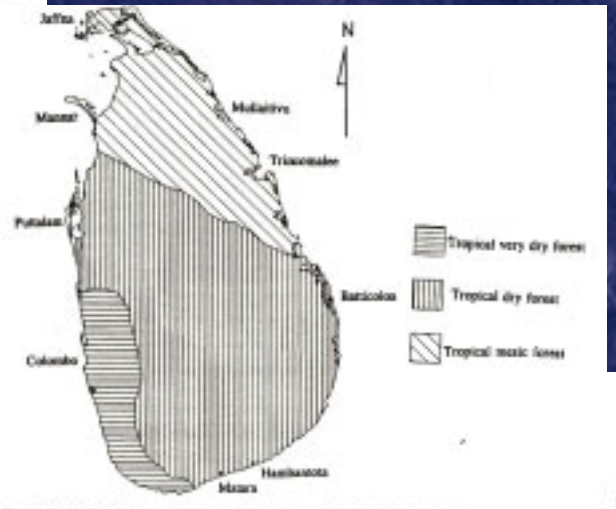


Fig. 2. Holdridge life zones of Sri Lankan forests under CCCM derived climate change scenari

- Holdridge life zones of Sri Lankan forests under CCCM derived climate change scenarios

- **Holdridge life zones of Sri Lankan forests under GFDL derived climate change scenarios**

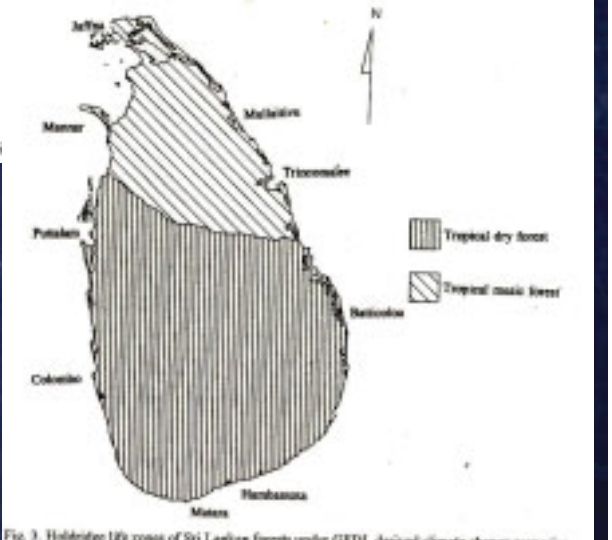


Fig. 3. Holdridge life zones of Sri Lankan forests under GFDL derived climate change scenarios

- **The rich array of plants and animals could be rendered vulnerable by a further fragmentation of their habitat (e.g. changes in environmental conditions related to climate change.**

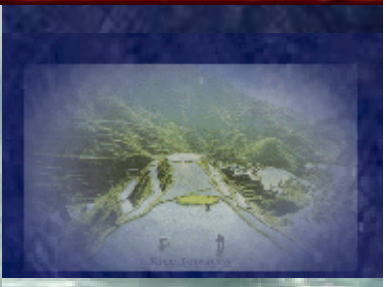
- **Species that live in mountainous areas are at risk of losing habitat as a result of changes in climate**

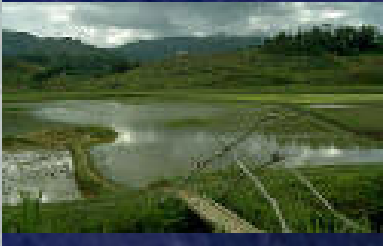
- **Wild species are at risk from changes in environmental conditions that favor forest fires and droughts**

PHILIPPINES

Case Study 1:

Impacts of Climate Variability/Change on Philippine Agriculture





On Agriculture

- Rice dominates the agricultural production in the Philippines

- Rice production growth rate vs population growth rate

2.33% < 2.40%

Irrigated rice

- ✓Increased intensity
- ✓Short-maturing varieties allowing 3 crops/year

Rainfed rice

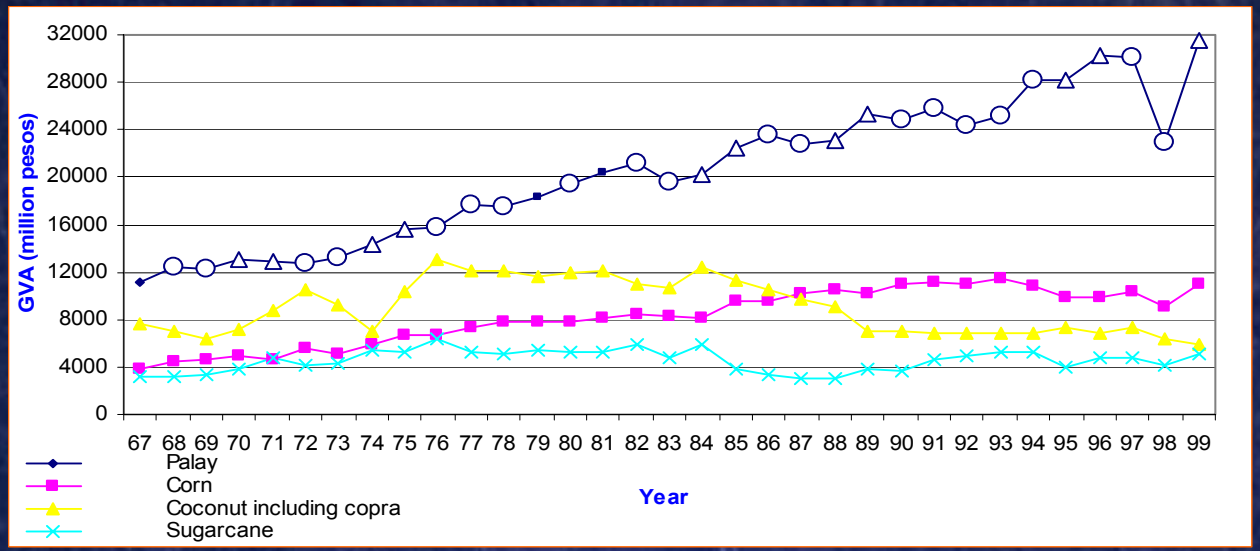
- ✓Gains from crop intensification
- ✓Suffers from uncertain rains
  - drought
  - submergence

Upland rice

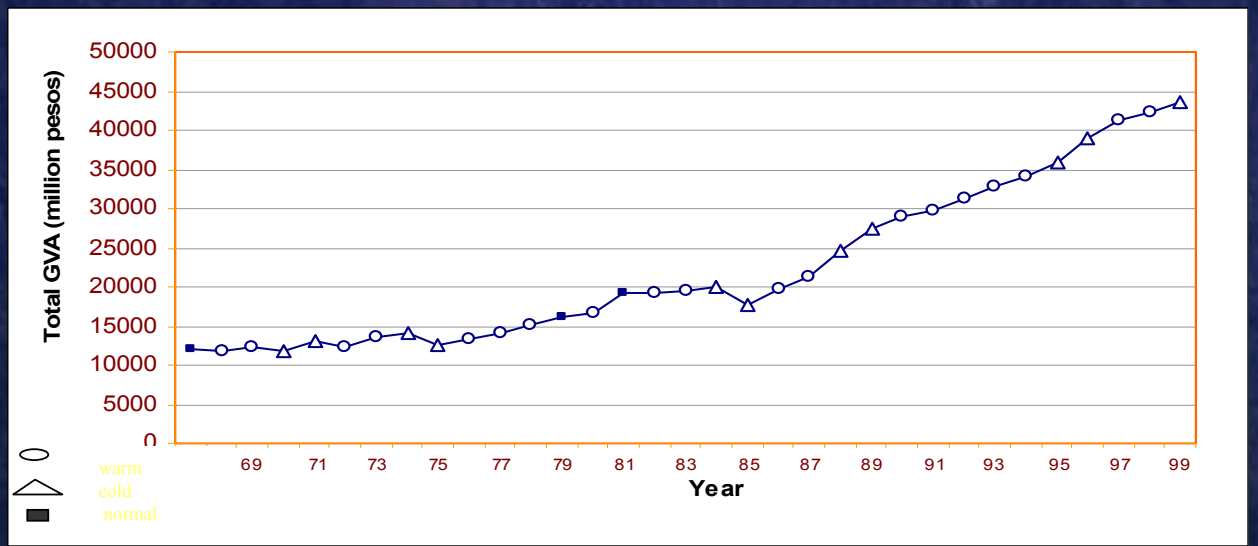
- ✓Major problems
  - acidic soils
  - soil erosion
  - drought
  - weeds/diseases
- ✓least sustainable

Vulnerability to current variability

- high frequency of tropical cyclones and floods
- drought occurrences
- high variability of rainfall
- extreme events



Gross Value Added in 4 principal crops at Constant 1985 Prices



Gross Value Added in Poultry and Livestock at Constant 1985 Prices

Vulnerability to 2 x CO_2 assessments

- **Buendia and Escano**
- **Buan et al**
- **Centeno et al**
- **Matthews et al**

- Results ranged from negative to positive across a range of scenarios.

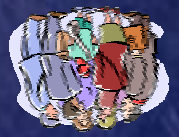
  - but disastrous decreases in yield at 2 x CO_2 and with 4°C increase

- With adaptation options, yields could increase

Impacts of Climate Variability/Change on Philippine Forestry

- 5.88 M ha of forests (50% is residual dipterocarp)
- 120 watersheds (~1.4 M ha)
- home to upland dwellers (e.g. indigenous tribes, lowland migrants)
- diverse gene pool (~ 8,000 plant species)
- provides livelihood to about 9 M

Drivers of change

- population growth 
- resources / demands
- land- use/cover change 
  - → deforestation
  - → conversion to agricultural lands
- climate variability

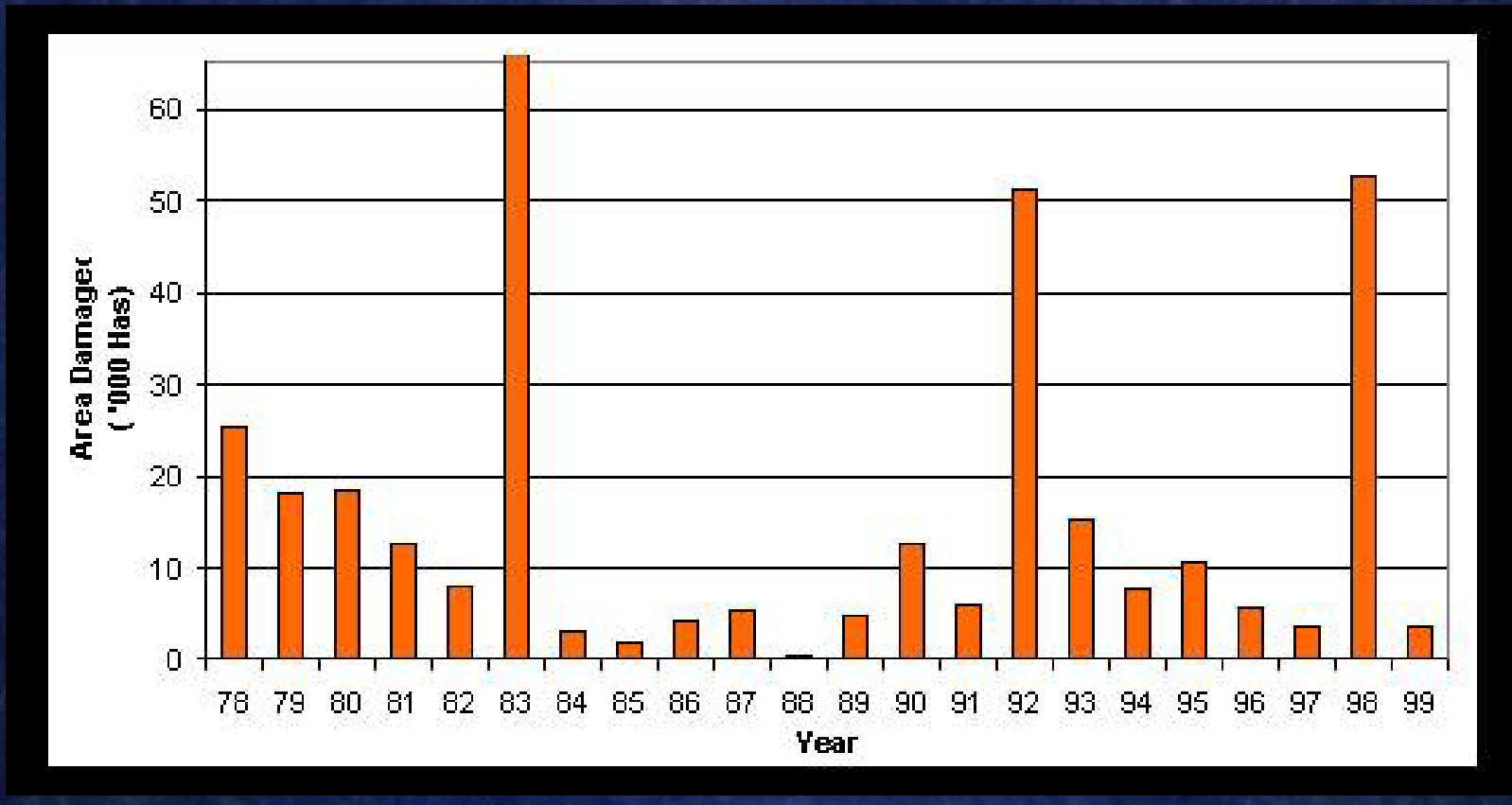
Present vulnerability

- Excessive floodings → soil erosion/ surface runoff → degraded watersheds/ land

- droughts/ prolonged dry spells → Significant damage on productivity → (probable change in forest boundaries)

threatened species → (local biodiversity)

EL-Niño-related droughts → Increased areas of forest fires



Extent of forest fire destruction in the Philippines (1978-1999)

Expected impacts of climate change

- **Rainforests (old growth and residual dipterocarp) will likely expand due to increase in temperature and modest increase in rainfall**

  - migration of species/changed forest boundaries

- **Currently denuded forests and watersheds dominated by grasses will be subjected to more soil erosion if rainfall increases (esp. during wettest months)**

↓

Decline in productivity of watersheds (quantity and quality)

- Changes in temperature/rainfall could result to increased disturbance regimes

  - Grasslands and shrublands could be rendered more vulnerable to forest fires

- Could exacerbate loss of local biodiversity

  - irreplaceable ecological services rendered by threatened species

  - negative impacts on those whose subsistence/cultural/religious practices are dependent on these species (indigenous tribes)

Adaptation strategies are already necessary to arrest further deterioration of the forest ecosystems and to promote sustainable development

Case Study 2:

Impacts of Climate Variability / Change

C H I N A

Land area= 9.6 M km^2

agriculture	3.7%
forests	13.4%
grasslands	41.0%

26% of China is in tropical / subtropical zones

rice production: most important agricultural activity; China is world's largest rice producer

Results of impacts studies in agriculture

- Lin Erda, 1996:

  Projected increase in summer dryness ⟶ more negative impacts in sensitive areas (southern areas of Yunnan Plateau)

- Wang, 1996

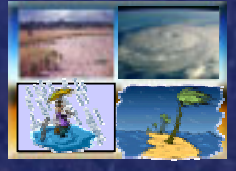
  - for the whole of China, negative impacts on rice and maize
  - increases in rainfall favorable for pests, diseases and weeds in Southern China

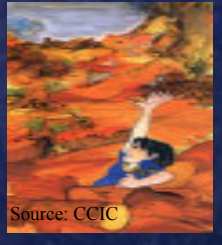
Impacts on forestry

- northward shift of vegetation could happen from a 2°C increase mean temperature (annual) and 20% increase in mean rainfall (Omasa et al, 1996, Tsunekawa et al., 1996)

CONCLUSIONS

- In the developing countries of the humid and sub-humid tropics
  - Current state of agriculture and forestry are characterized by
    - ✓ stagnant yields
    - ✓ recurrent natural disasters (e.g. droughts, floods, tropical cyclones)





    - ✓ deforestation and land degradation
    - ✓ poverty (esp. in rural)

- Most assessments indicate that climate variability/change would have negative impacts on agriculture and forestry:
  - Cereal crop yields would generally decrease even with minimal (Δtemp)s
  - For most crops, extreme events would cause larger damages than changes in mean climate
  - Impacts on animals (heat/disease stresses) and on pasture (forage)
  - Positive and negative impacts on forestry, but impact of deforestation > impact of climate (variability/change)

- **Impacts of climate variability/change are expected to be greatest in the developing world.**

  - ✓ **Current degradation of resources**
  - ✓ **Poor access to technologies**
  - ✓ **Low investments in production**

As a consequence:

- Worsening of food security in most of Africa and tropical Asia
- Low prospects for sustainable development
- Widening inequities between “haves” and “have-nots”