Sustainable Development

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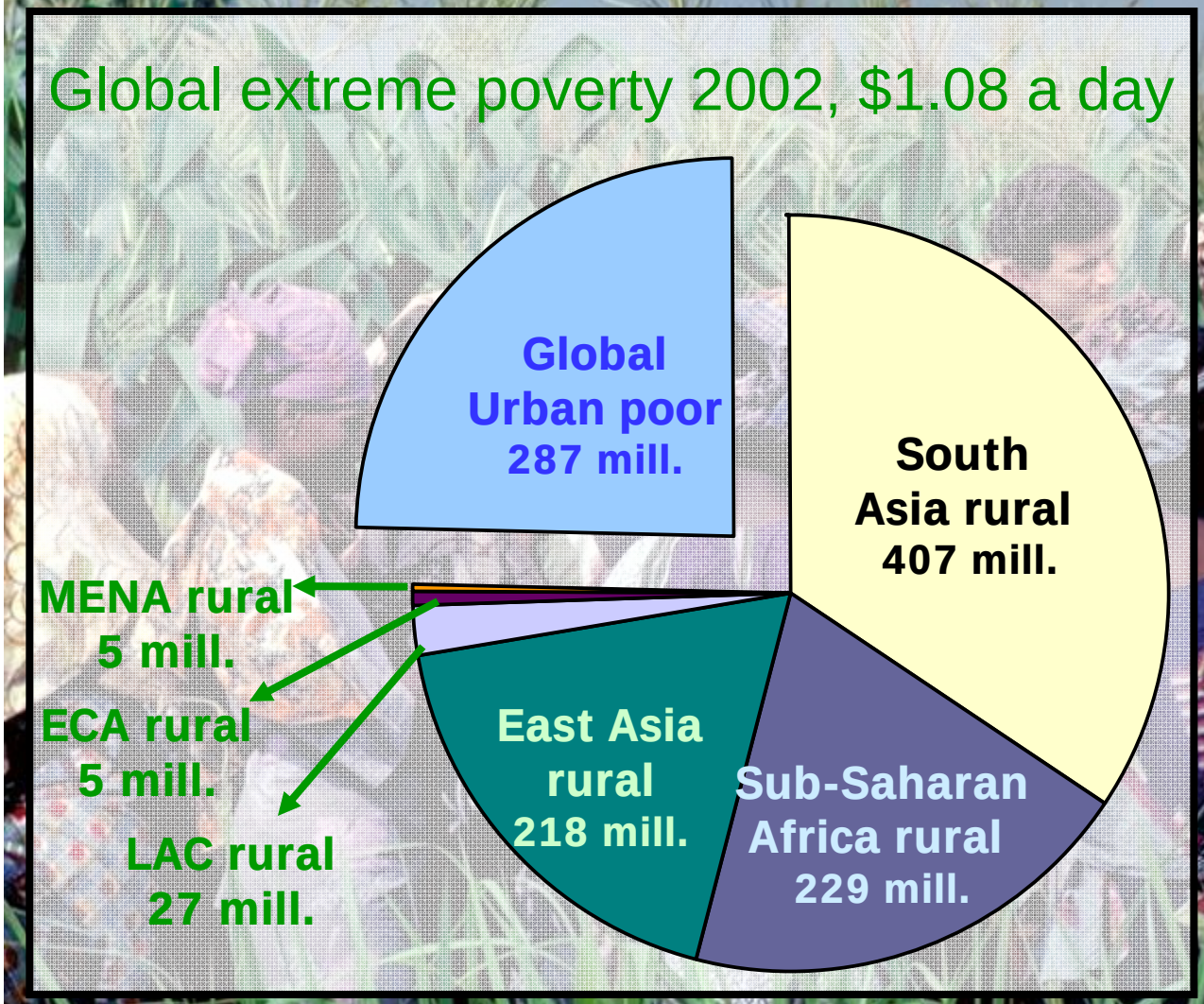
1. Agriculture – food, fiber, fuel & ecosystem services

75% of the world's poor are rural and most are involved in farming

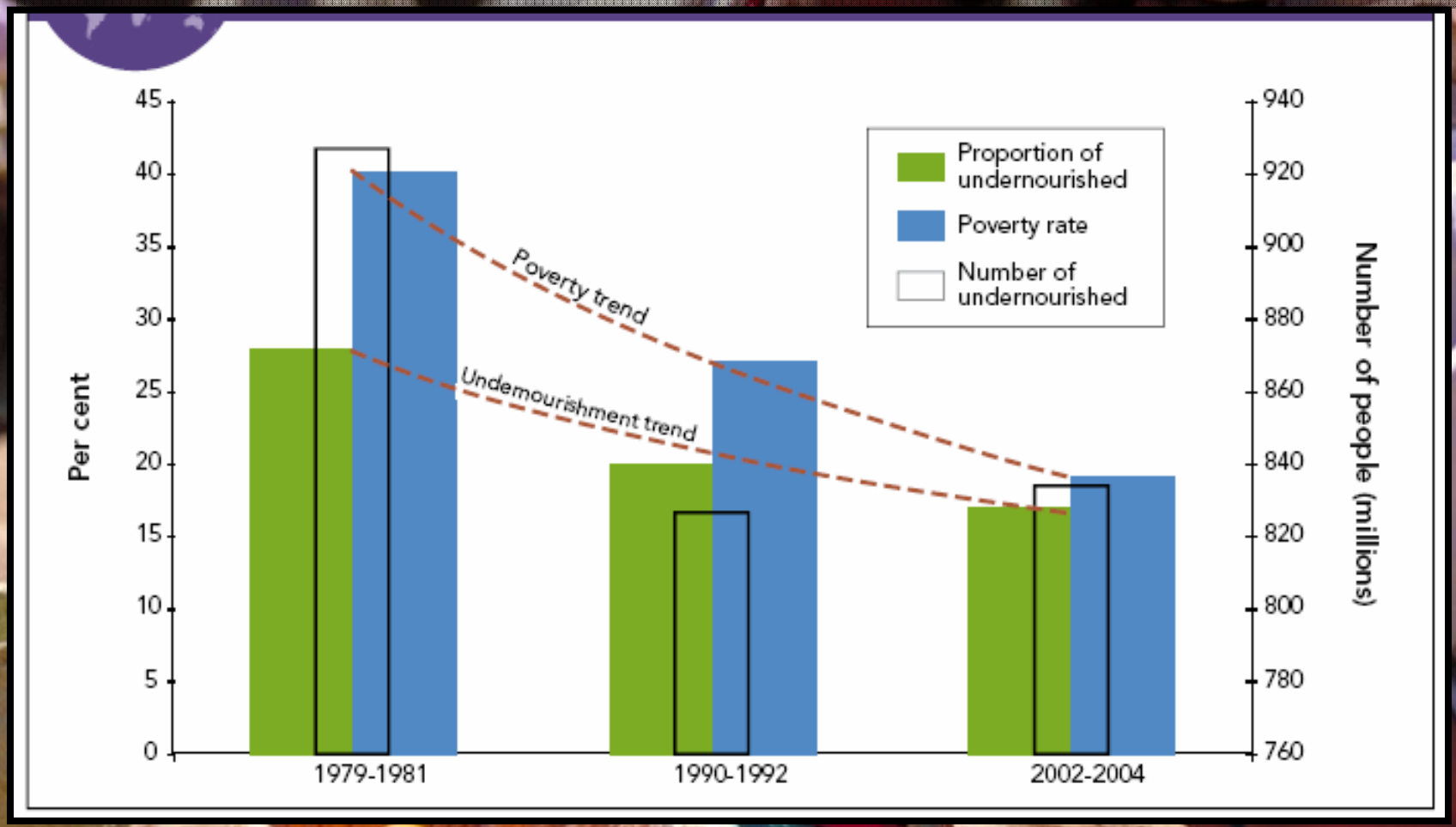
In the 21st century, agriculture remains fundamental for poverty reduction, economic growth, and environmental sustainability

2. A source of livelihoods



- 2.5 billion people depend directly on agriculture
- 800 m smallholders
- 75% of poor are rural and the majority will be rural to about 2040

Lower Poverty and Less Undernourishment



Source: Poverty rates—Ravallion, Chen and Sangraula (2007); undernourishment rates— FAO (2006).

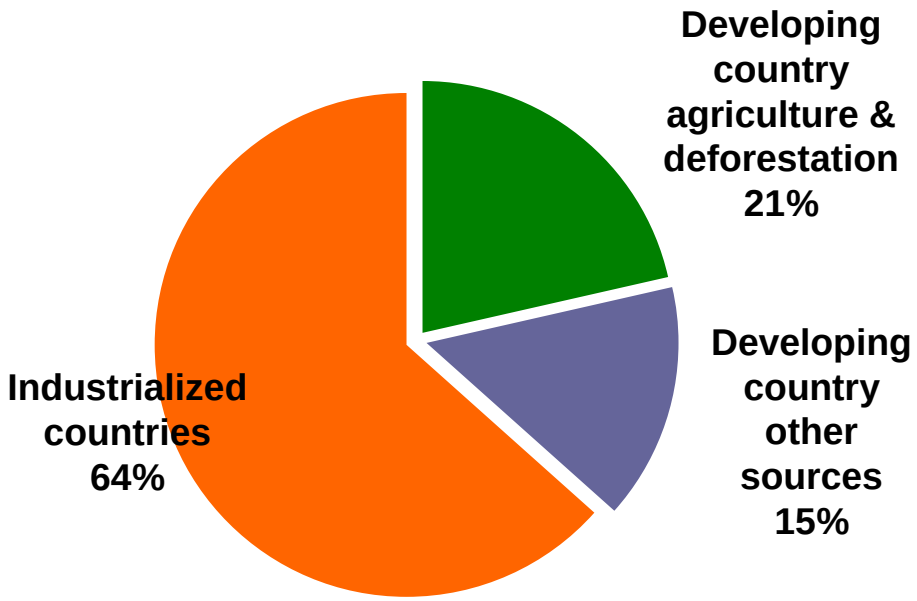
Note: Dotted lines are logarithmic trends in poverty and undernourishment rates.

3. Better natural resource management

Important user of natural resources:

- 80% of fresh water resources
- 40% of land area
- 21+ % of greenhouse gas emissions

Contributions to greenhouse gas emissions



Many Opportunities:
Sustainable farming systems and environmental services (conservation farming, agroforestry, managing landscapes for climate resilience)

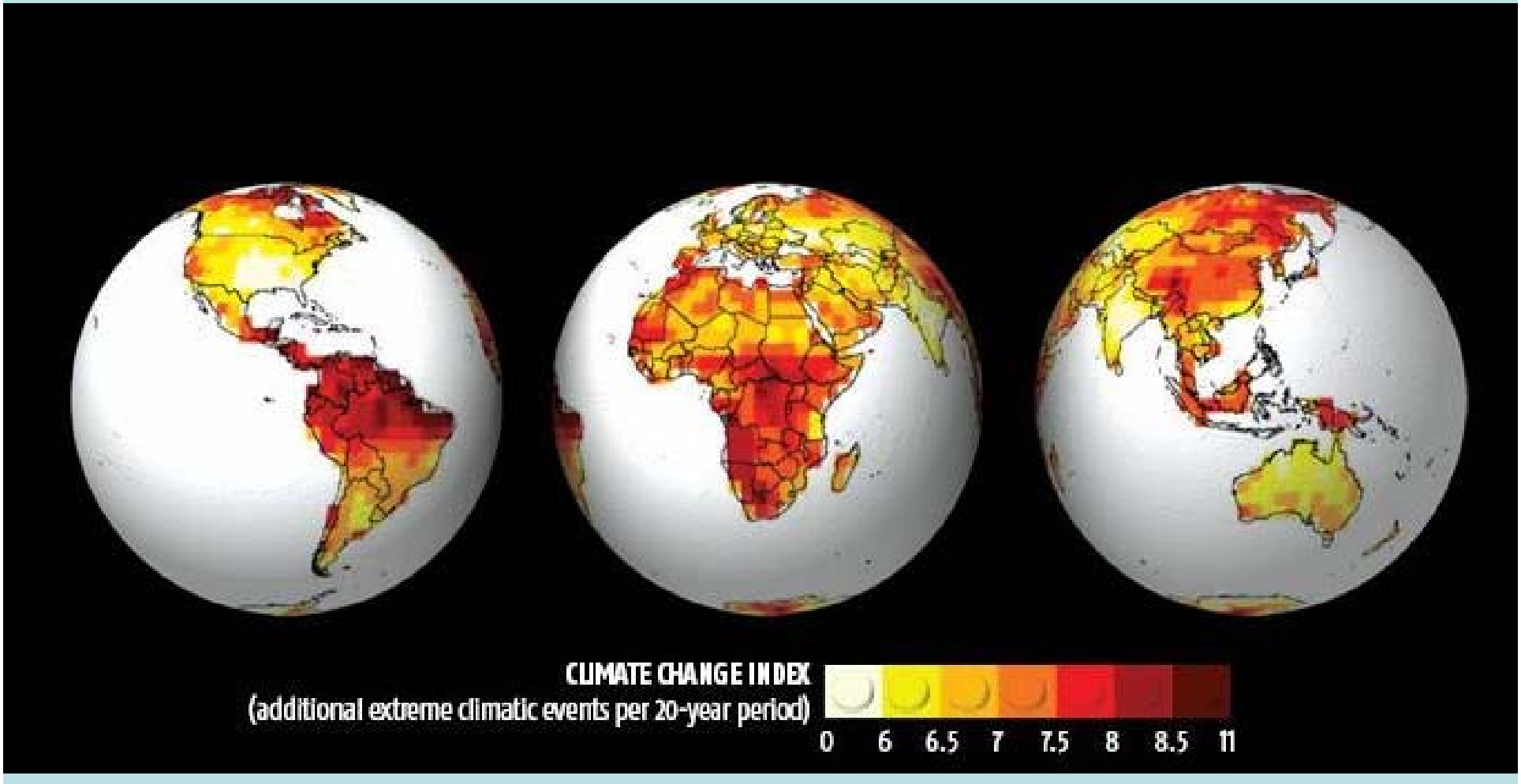
Climate Change

- Climate change presents an urgent challenge to the well-being of all countries...
- ….and particularly to the poorest countries and the poorest people (especially women and children) in vulnerable regions.
- Addressing climate change is central to the development and poverty reduction agenda.
- Tackling climate change is feasible…
- …but who bears how much of the costs remains the key issue [UNFCCC estimates $100b for mitigation + ~$40b for adaptation in addition to ODA]

Climate Variability & Weather

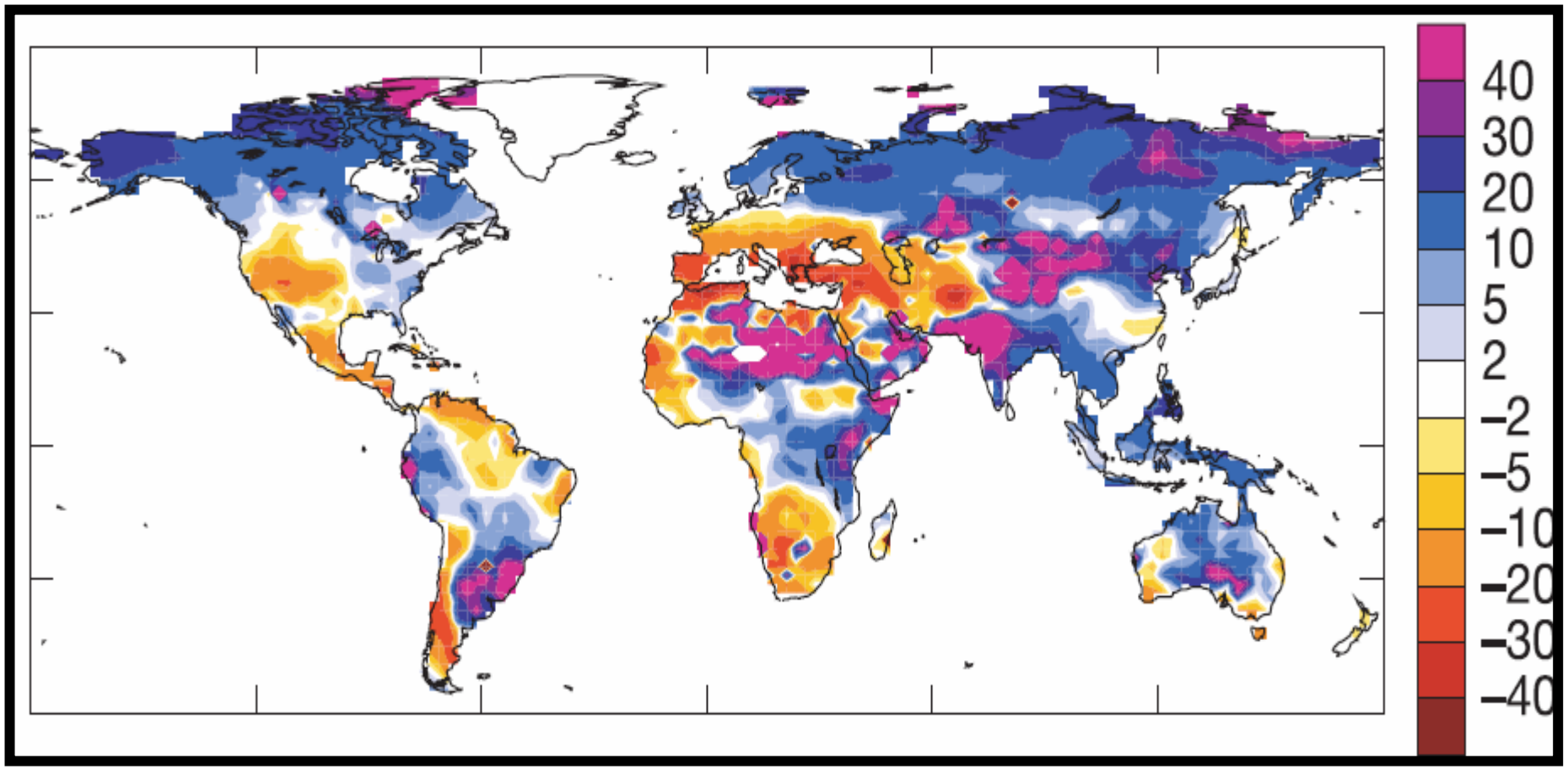
- Erratic Patterns Result in: Flooding, Drought, Increased Desertification, Tropical Storms, etc.
- Consequences of poor risk management—Socio-economic costs, greater risks for communities:
  - Unpredictable crop yields
  - Displacement of communities
  - Flooding, storms, etc. results in excess water, whereas drought results in water deficits.

Projected Change in Frequency of Extreme Events



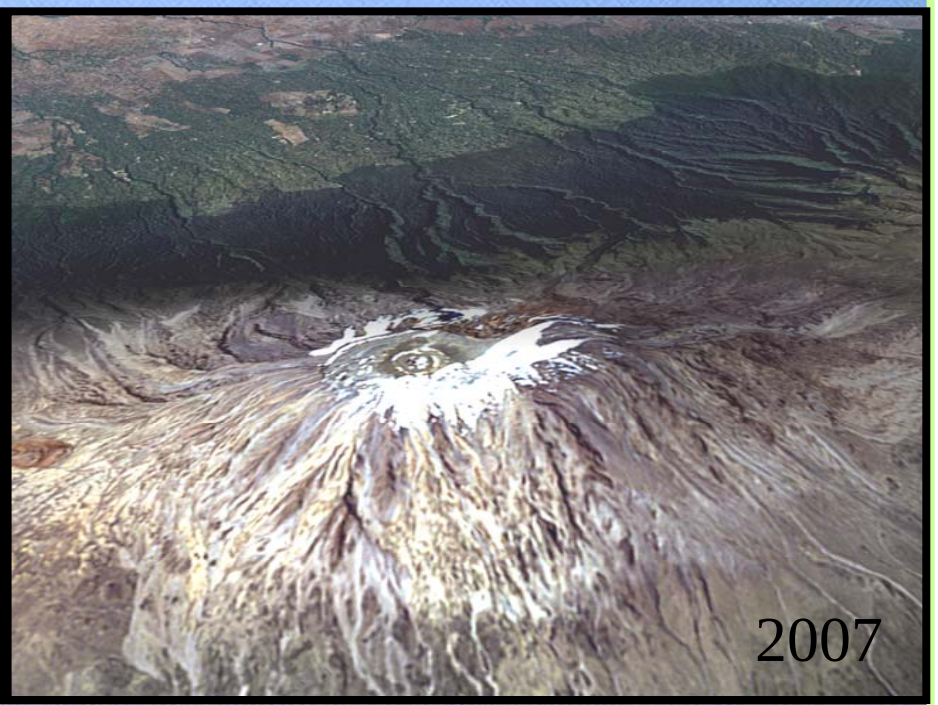
Baettig, M. B., M. Wild, and D. M. Imboden (2007), A climate change index: Where climate change may be most prominent in the 21st century

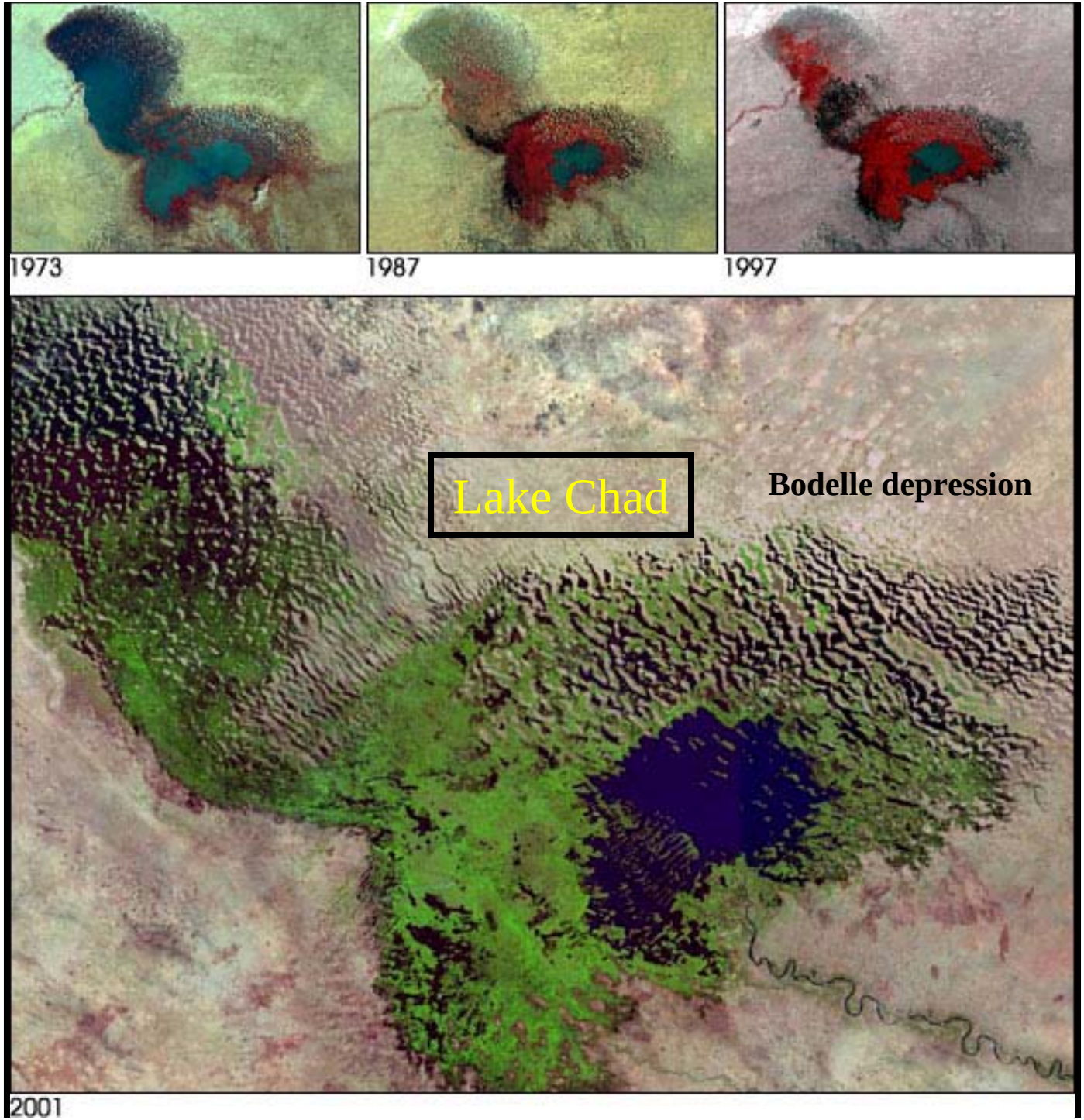
% change in runoff by 2050

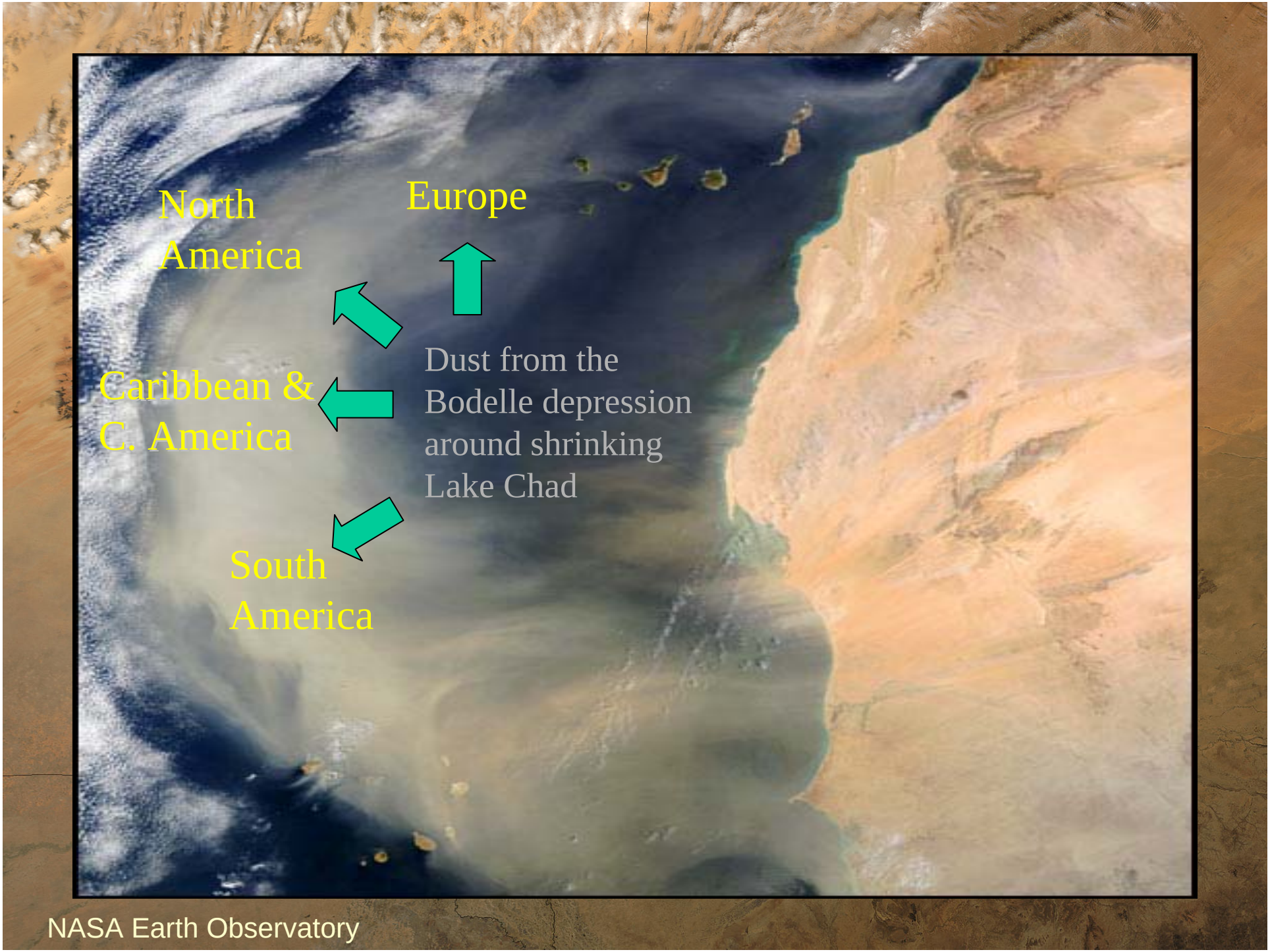


- Many of the major “food-bowls” of the world are projected to become significantly drier
- Globally there will be more precipitation
- Higher temperatures will tend to reduce run off
- A few important areas drier (Mediterranean, southern South America, northern Brazil, west and south Africa)

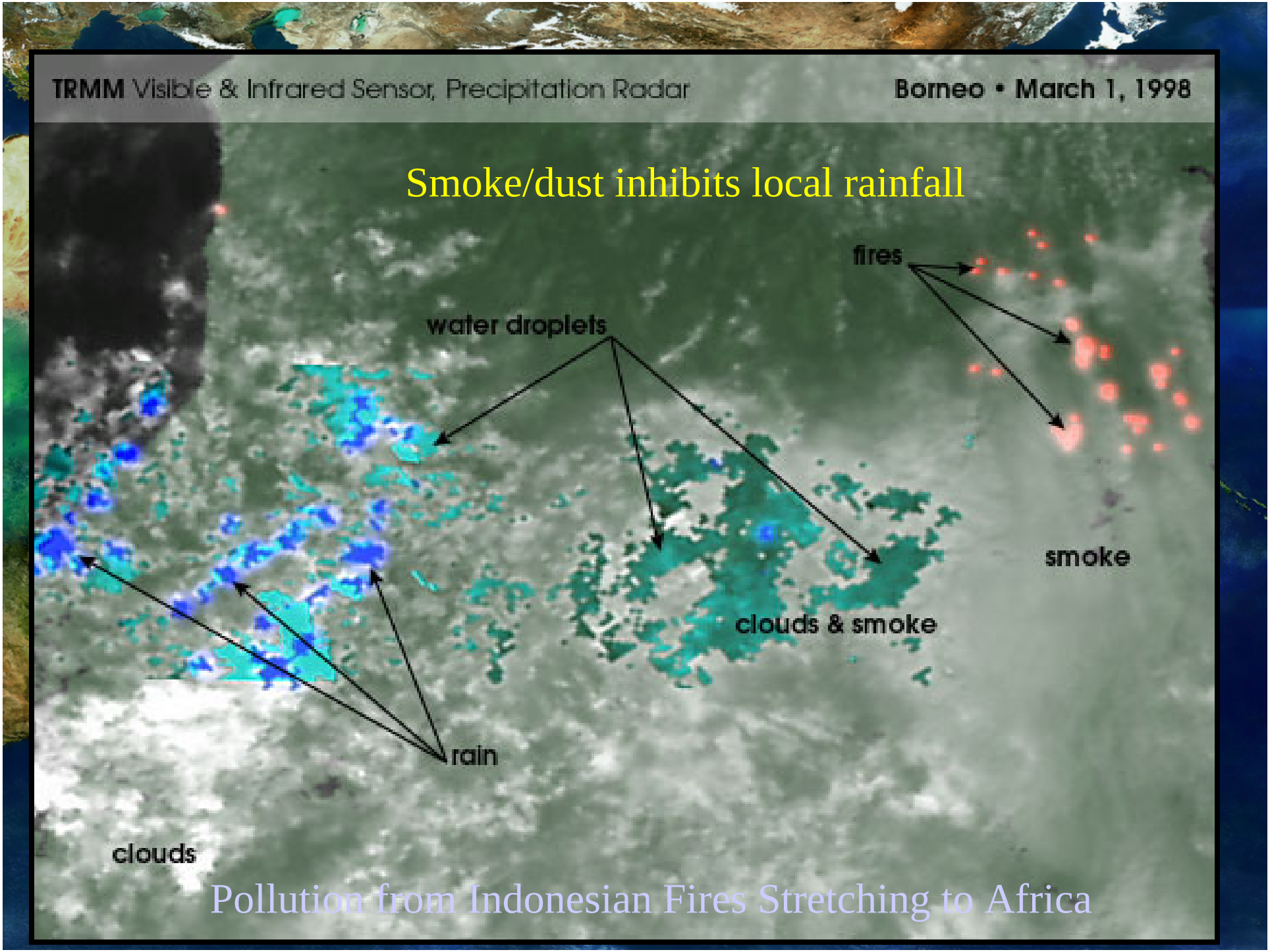
Since Kili’s glaciers and snow fields were first mapped in 1914, 85% of the snow cap has been lost. Current estimates suggest total loss by 2015

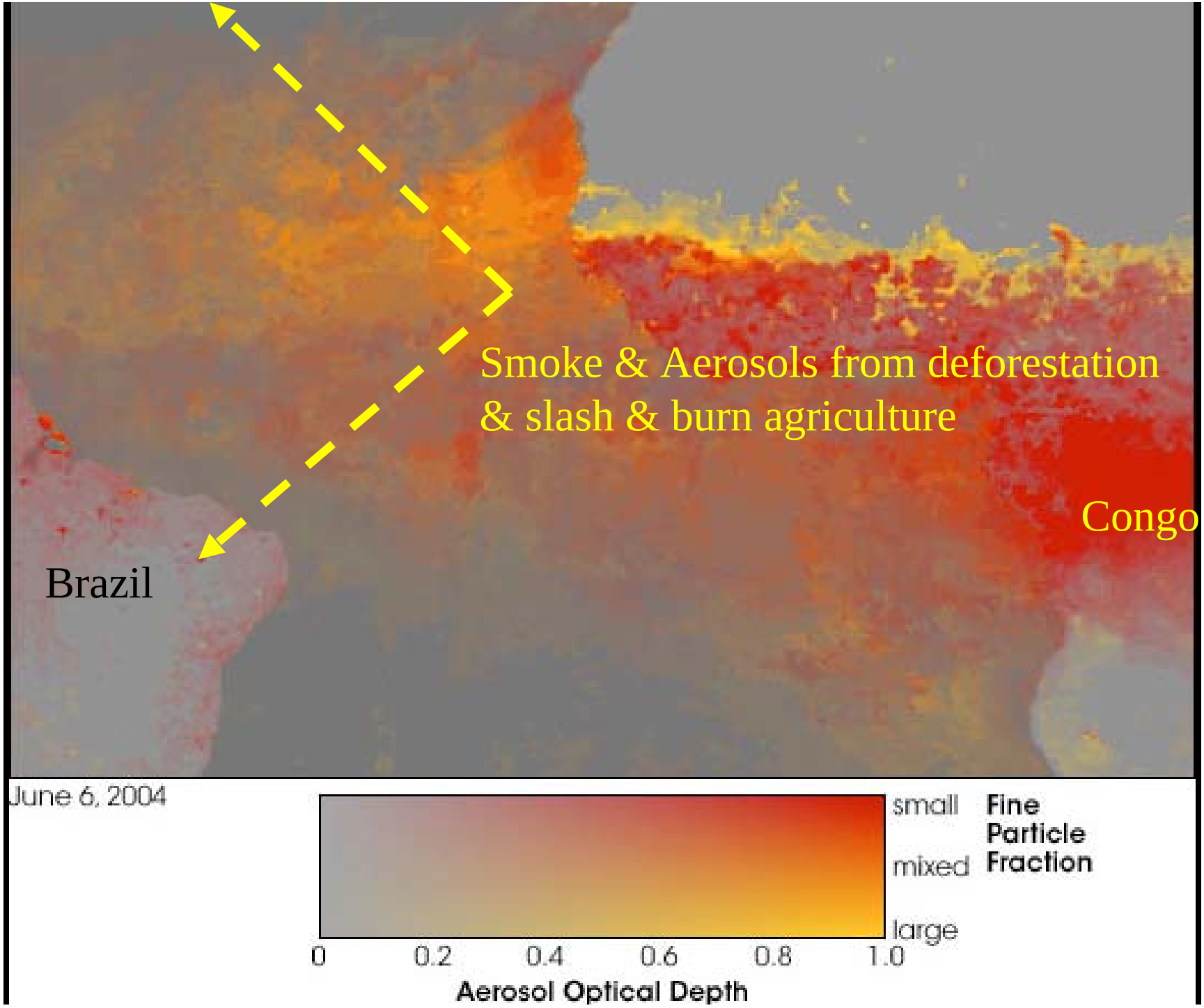


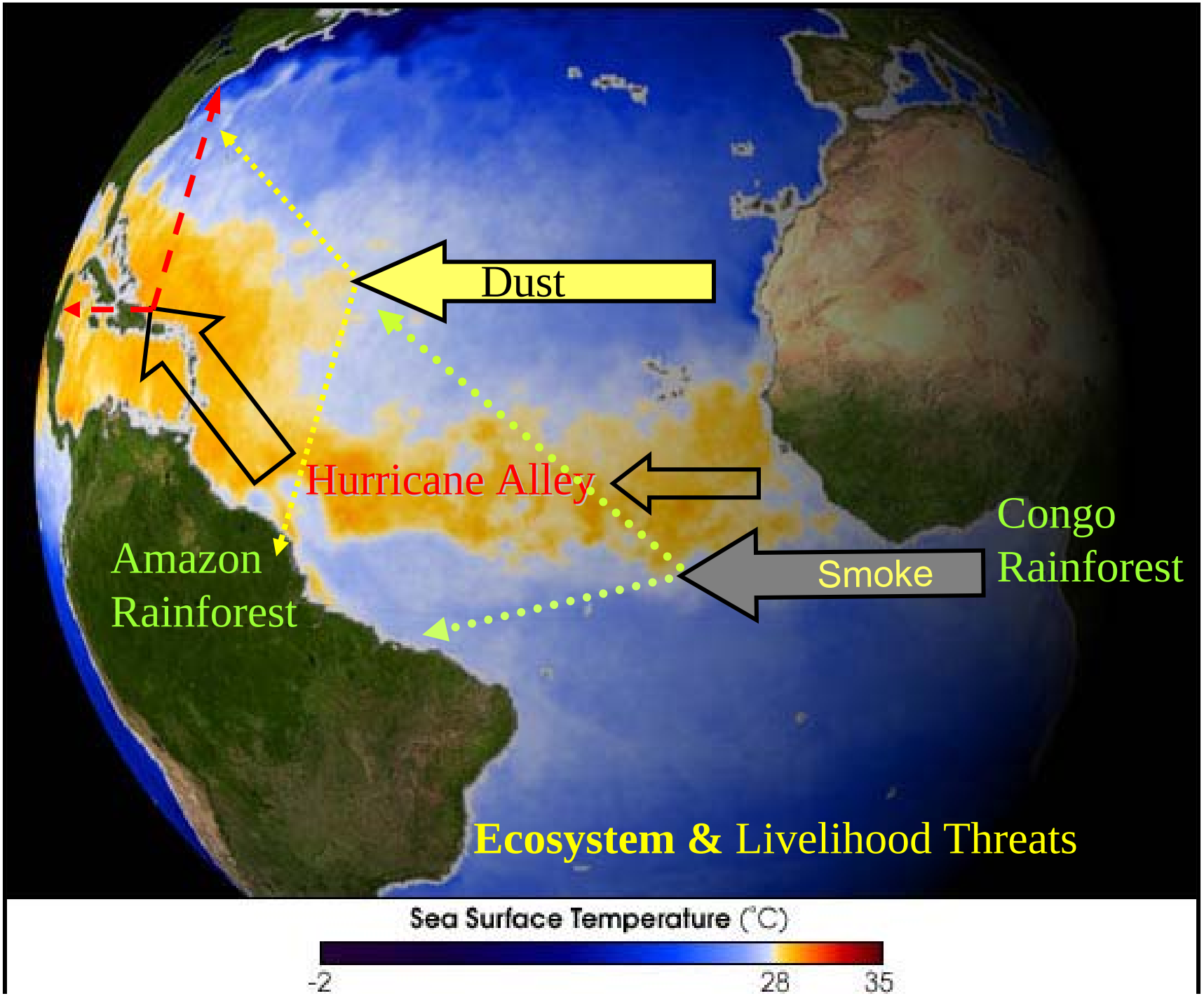

1973
1987
1997
Lake Chad
Bodelle depression
2001



NASA Earth Observatory


TRMM Visible & Infrared Sensor, Precipitation Radar
Borneo • March 1, 1998
Smoke/dust inhibits local rainfall
fires
water droplets
smoke
clouds & smoke
rain
clouds
Pollution from Indonesian Fires Stretching to Africa


Smoke & Aerosols from deforestation
& slash & burn agriculture
Congo
Brazil
June 6, 2004
small
mixed
large
Fine
Particle
Fraction
0
0.2
0.4
0.6
0.8
1.0
Aerosol Optical Depth


Dust
Hurricane Alley
Amazon
Rainforest
Smoke
Congo
Rainforest
Ecosystem & Livelihood Threats
Sea Surface Temperature (°C)
-2
28
35

Climate Change,Poverty Reduction & Livelihood Impacts – Africa

Poverty and water scarcity:

- 14 countries are already experiencing water stress, another 11 countries are expected to join them by 2025 at which time nearly 50% of Africa's predicted population of 1.45 billion people will face water stress or scarcity.

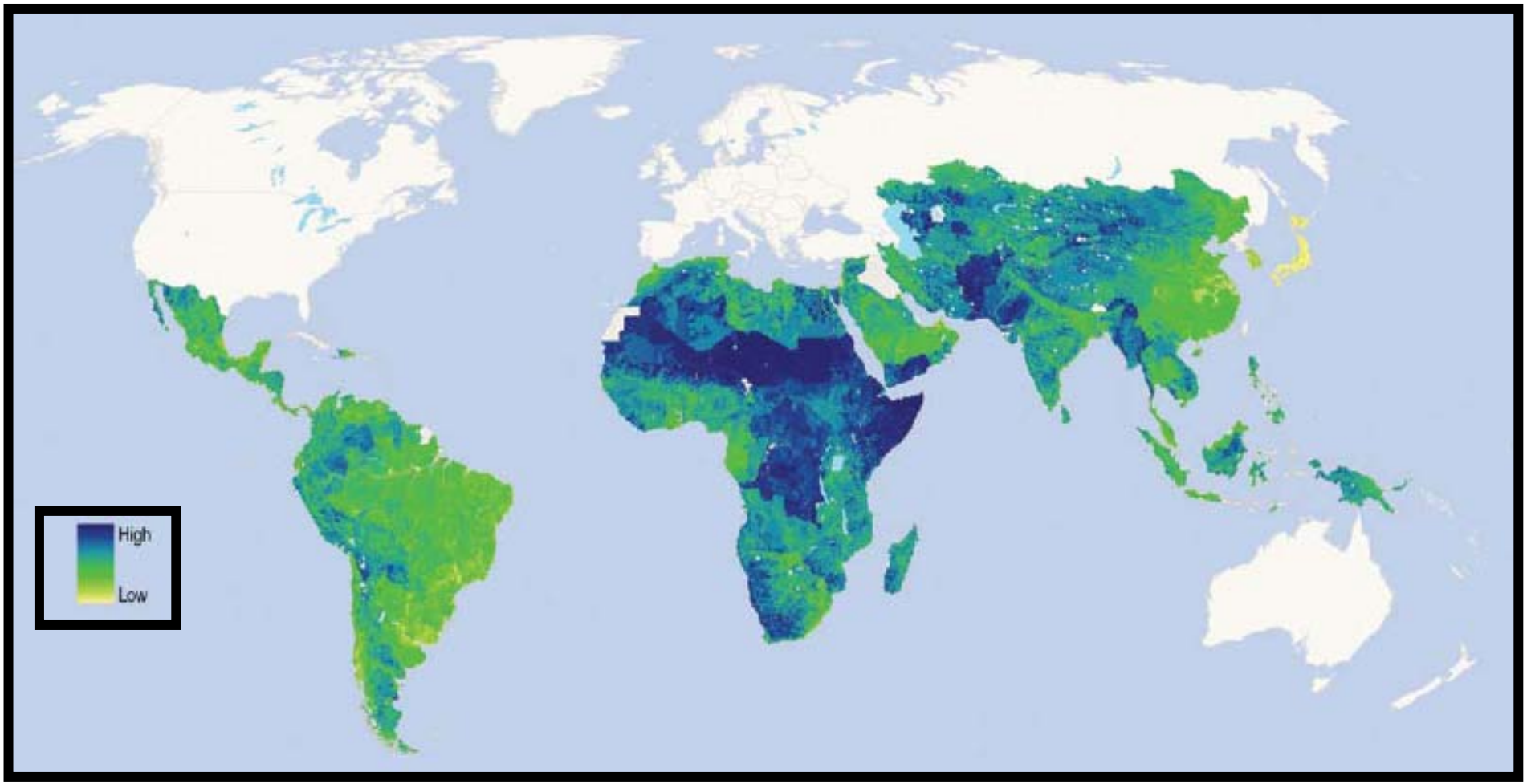
- Nearly 51% (300 million) of people in sub-Saharan countries lack access to safe supply and 41% lack adequate sanitation.

Health:

- Almost half of the African population (778 million in 1997) suffers from one of the six major water related diseases.

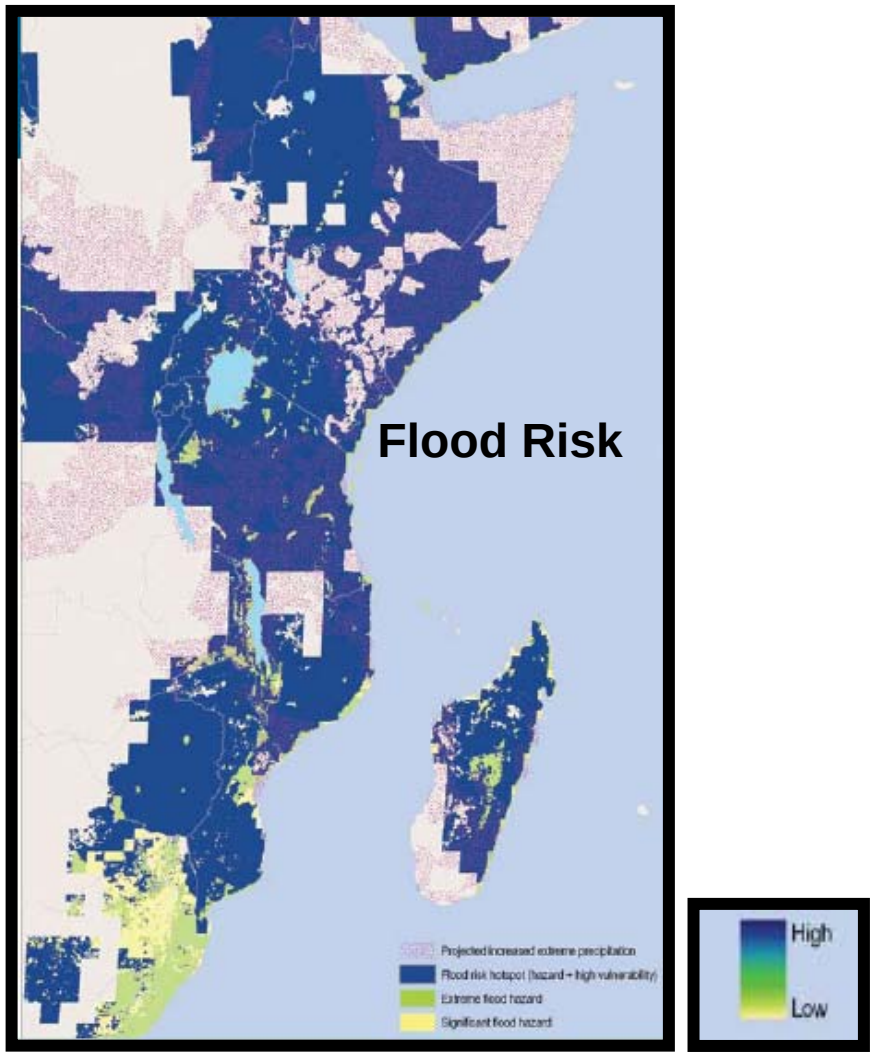
Human Vulnerability, World

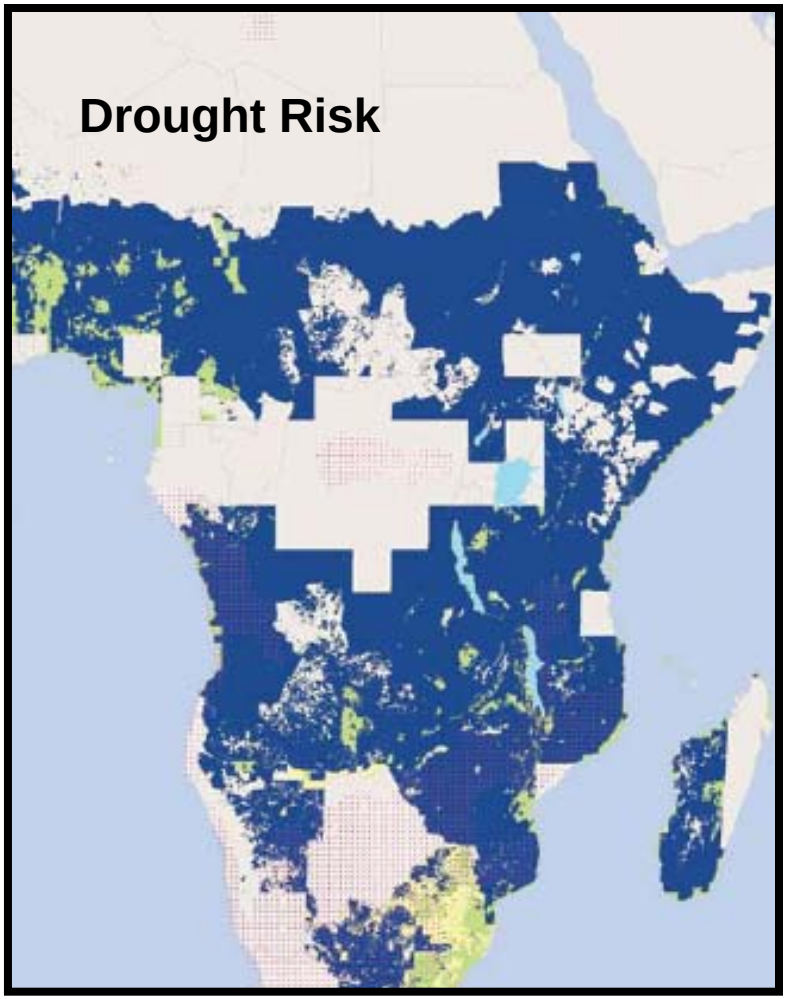
This map shows overall human vulnerability based on a combination of natural, human, social, financial and physical factors. Areas shown in darkest blue are likely to be most at risk if exposed to extreme weather, such as floods, cyclones and droughts, or other impacts of climate change.



Source: CARE, 2008

Increased Flood and Drought Risk





Source: CARE, 2008

Adaptation to Climate Variability & Change

Zambezi Floods

- **Loss of Assetts, homes, crops, livestock**
- **Destruction of critical infrastructure**

Zambezi Droughts

Mozambique:
Impact of 2000 floods on the economy

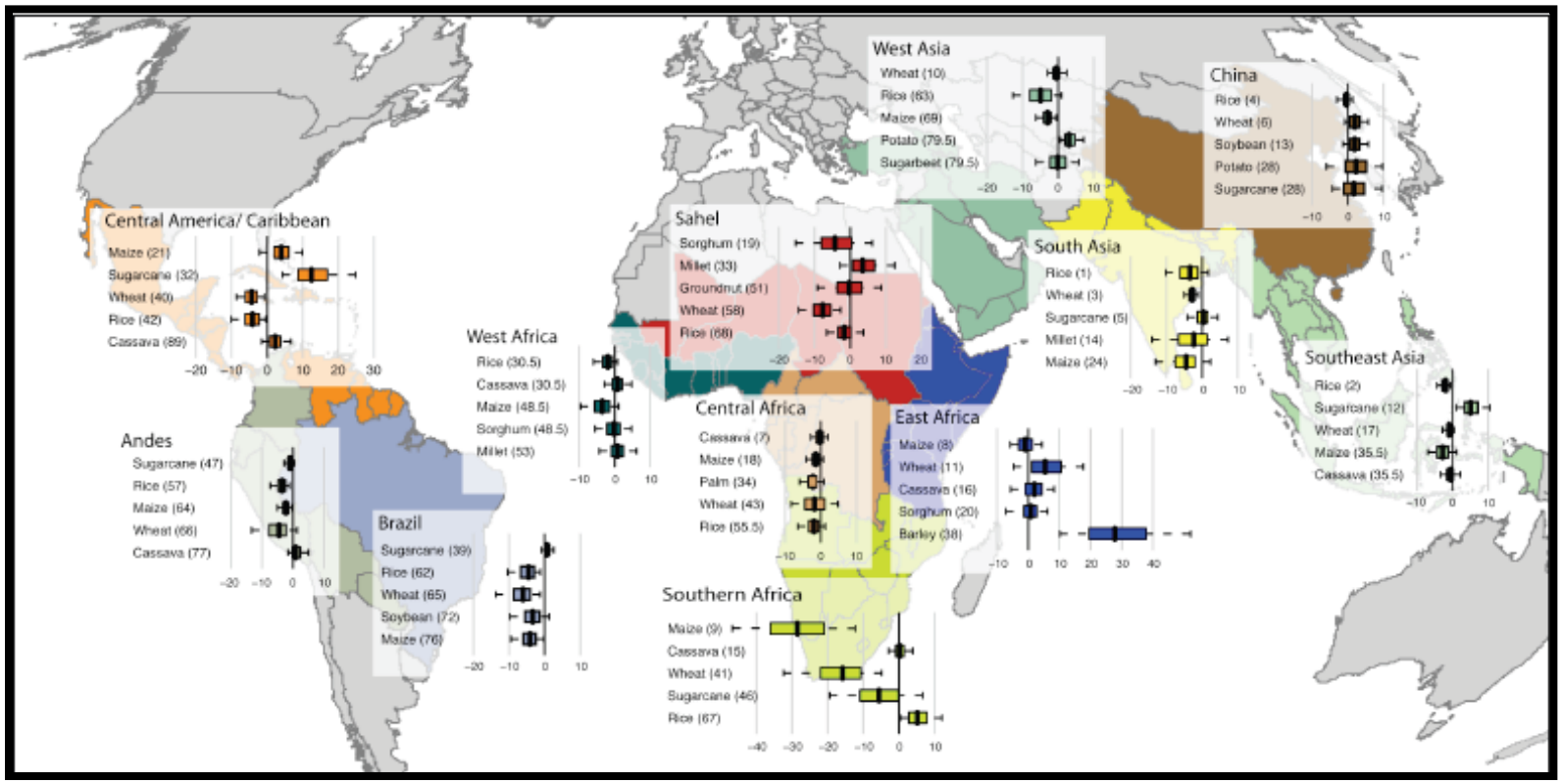
	Actual		Projection			
			Before the Floods		After the Floods	
	1998	1999	2000	2001	2000	2001
Real GDP (ann. Growth rate)	12.0	9.0	7.0	7.2	5.4	7.9
Inflation (ann. average, %)	0.6	2.0	6.6	5.0	9.5	5.0
External current account:						
Before grants	-20.5	-31.7	-23.0	-15.7	-31.5	-18.4
After grants	-12.4	-21.5	-16.3	-9.1	-19.7	-11.0
Fiscal Balance:						
Before grants	-10.7	-12.1	-12.1	-10.7	-16.0	-11.5
After grants	-2.4	-1.2	-5.2	-4.4	-7.0	-5.1
Memorandum: GDP (Mt billion)	46,134	52,913	60,177	67,790	61,471	69,673

Source: Staff estimates, IMF and Government of Mozambique

-23%

+44%

Projected impacts of climate change by 2030 for five major crops in each region



(2008) DAVID LOBELL, MARSHALL BURKE, CLAUDIA TEBALDI , MICHAEL MASTRANDREA,WALTER FALCON, AND ROSAMOND NAYLOR

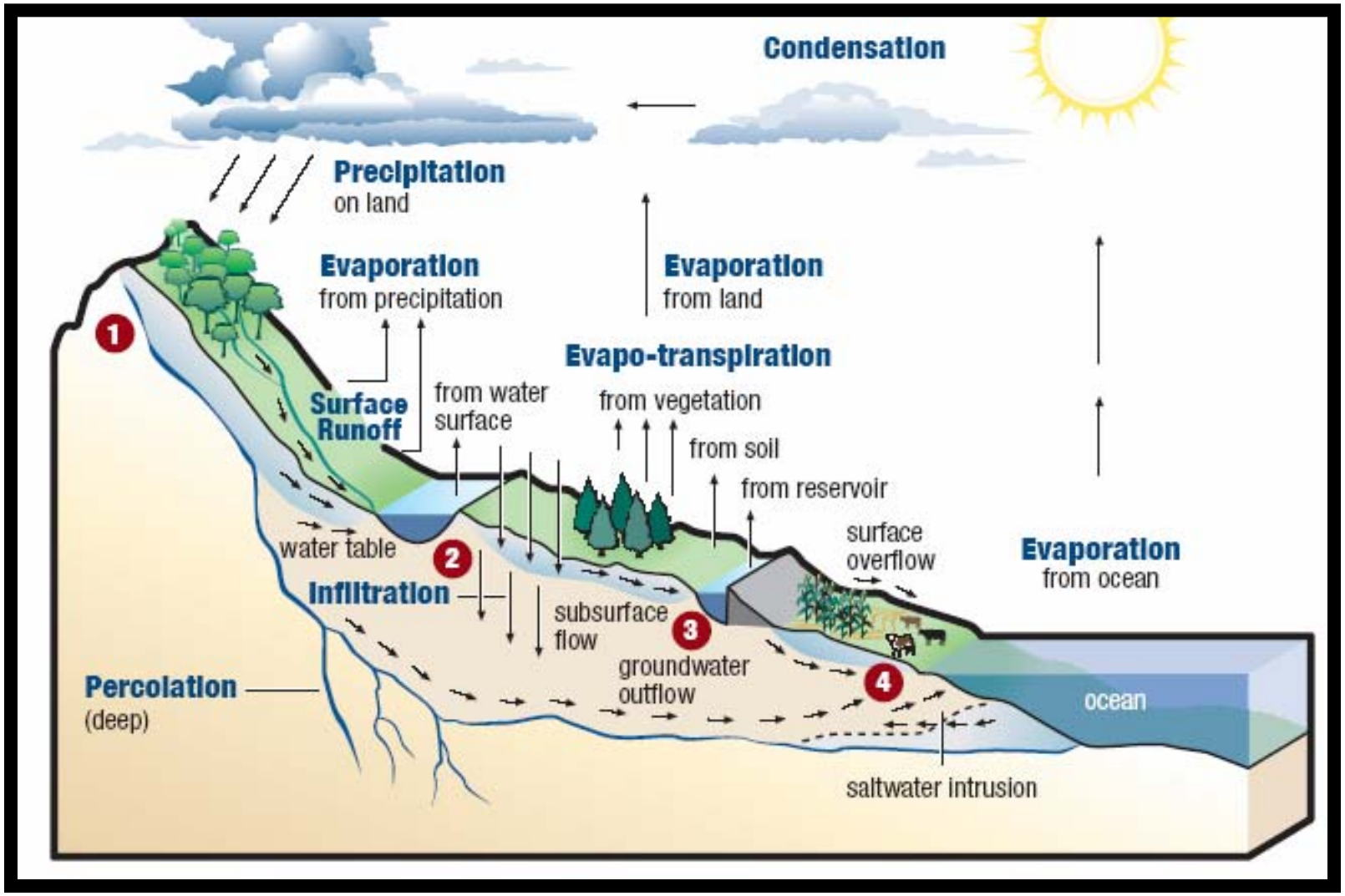
Vision for Climate Resilient and Productive Landscapes

- Existing forests/woodlands protected from further deforestation and local communities rewarded for reduced deforestation (opportunity costs, incentives, payments, penalties).
- State-of-the-art, science+knowledge based aquaculture, crop, horticulture, pasture, and timber systems (varieties, inputs, best management practices on already cleared land) implemented.
- Landscapes with diverse mosaics of food and fibre systems that provide nutritious foods, protect crop and urban areas, and maintain a diverse range of ecosystem functions (hydrology, C sequestration, biodiversity conservation).
- All degraded lands rehabilitated for optimal productive and/or ecosystem services (riparian zones, landscape connectivity, forest buffers, fire breaks).
- Legal frameworks in place and enforced, local institutions strengthened, governance and equity issues ensured.

Guiding Principles

- Protect existing forests from further fragmentation
- Drastically reduce the use of fire in agriculture and forestry and couple with early-warning for dry years.
- Harness the N-fixing capabilities of native legumes. Supplement with inorganic P, especially in low P soils.
- Multiple cropping and agroforestry rather than monocrops to support biodiverse and multifunctional habitats/niches.
- Protect riparian vegetation to reduce the loss of terrestrial carbon pools to aquatic systems thereby reducing outgasing?
- Assess the spatial issues (landscape connectivity, environmental flows, reduced fire vulnerability) associated with degraded lands and prioritize the locations and product/service functions to guide system design and rehabilitation process.

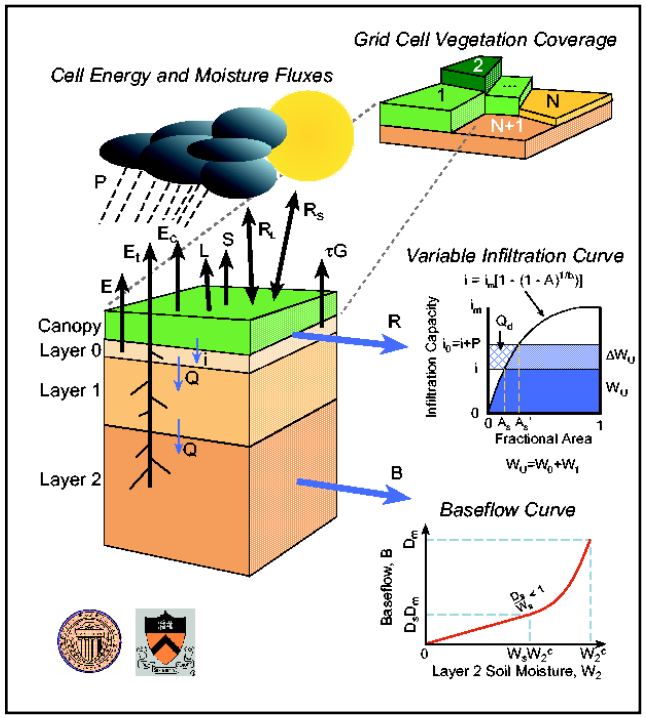
Understanding and Using Spatial & Scale – based Processes



Bring it to life: Science for Society

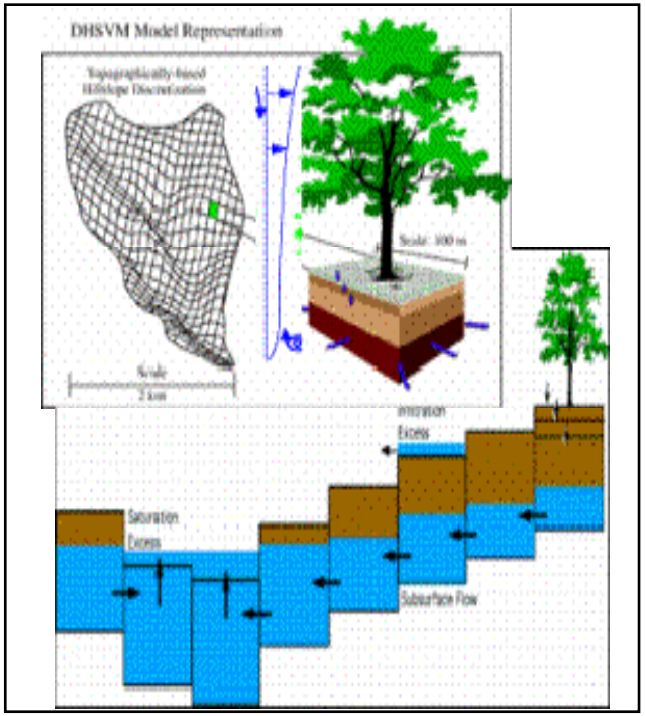
Large Scale

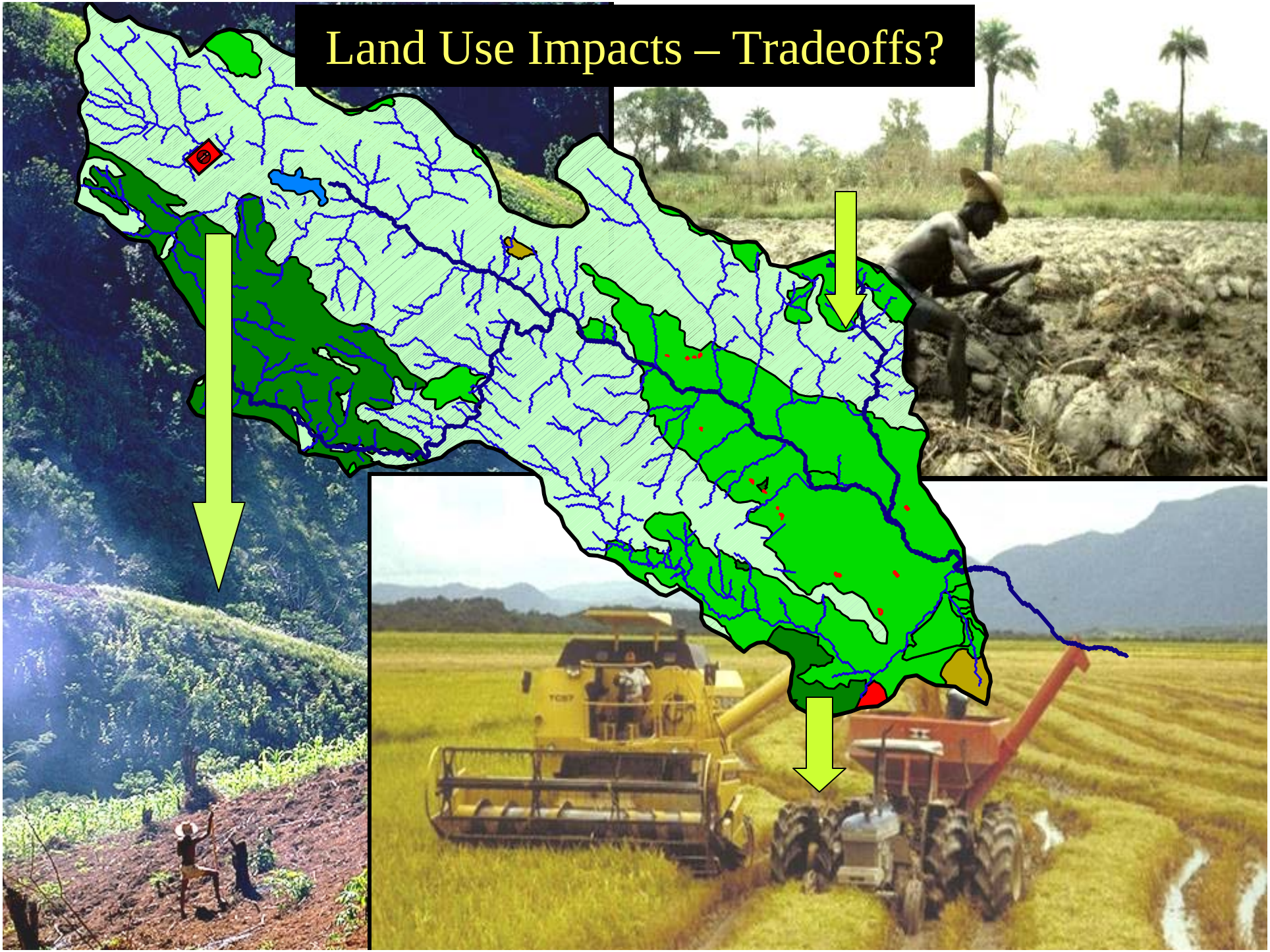
e.g. VIC (Variable Infiltration Capacity) Meso/Macroscale Landscape/Hydrologic Model. (moderate to large-scale resolution)



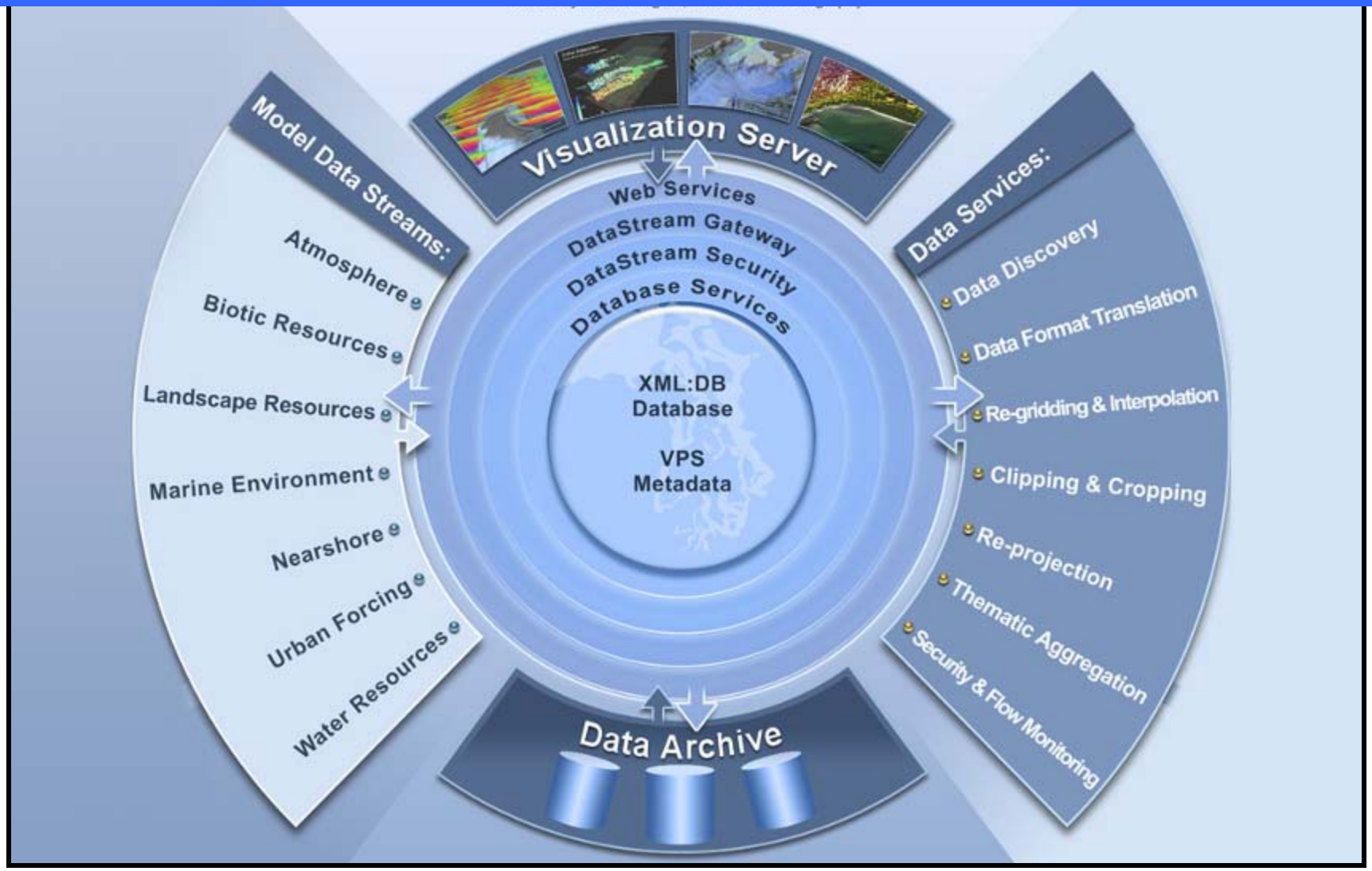
Small-Scale

e.g., DHSVM (Distributed Hydrology Soil Vegetation Model) Micro/Mesoscale Landscape/Hydrologic Model (high to moderate resolution)




Land Use Impacts – Tradeoffs?

User-Friendly, Decision Support Systems: Responding to Policy Makers



Development and Climate Change A Strategic Framework (DCCSF)

Climate change "is a development, economic, and investment challenge. It offers an opportunity for economic and social transformation that can lead to an inclusive and sustainable globalization. That is why addressing climate change is a critical pillar of the development agenda."

Robert Zoellick - United Nations Climate Change Conference in Bali, Indonesia, December 2007

Link to DCCSF

Example of GoM + WBG + GEF
Climate – Landsurface – Water Cycle
Multisector: Ag, Biodiversity, Energy, Infrastructrue, Water

Suggested Investments & Actions

1. **Greater investment in disaster preparedness and response.**
   - At Regional, National and Local levels.
   - International humanitarian community
     - Need for more flexible disaster response capacity since climate change increases the uncertainties of where, when and how disasters unfold.
     - The results need to be assessed in terms of response-time, but also improvements in quality and accountability.

Suggested Actions II

2. **Action to reduce disaster risks and strengthen disaster resilience, especially in high risk 'hotspots' to reduce vulnerability**.
   - *Increasing access to essential services* (like health and education) and long-term social protection systems.
   - *Strengthening the capacity of local actors*, particularly government at all levels, to better understand the nature of risks they may face and to take appropriate action to reduce vulnerability.
   - *Empowering local populations* to have a strong role and voice in emergency preparedness, response to disasters and subsequent recovery and rehabilitation.
   - *Improving the accountability of governments and service providers* to populations affected by disasters.

Protect Existing Forests/ Woodlands

- REDD (Reducing Emissions from Deforestation and Forest Degradation)
  - REDD was first proposed by the governments of Papua New Guinea and Costa Rica at an international climate meeting in 2005.
  - Stern (2006) identified avoided deforestation as the cheapest means of stemming carbon dioxide emissions. A two-thirds cut in emissions from deforestation could be done for around US$5–10 billion a year—roughly half the price of preventing a similar loss of emissions from western power generation.
  - With almost one-fifth of global carbon emissions coming from forest loss, the benefit for both the world's climate and rainforests could be major.
  - REDD could form a key part of the package of measures that will replace the Kyoto Protocol in 2013.

Harnessing “Green Markets”

- Carbon sequestration, Avoided Deforestation (REDD), Proactive Investments in Natural Capital (PINC), Biochar (Soil Carbon + Bioenergy)
- Domesticated & cultivated wild plant species for nutraceuticals to rapidly emerging markets for “Functional Foods”
- Payments for Ecosystem Services (PES) e.g.Environmental flows, Biodiversity Offsets

REDD "Opportunity Costs"

- **On-going studies by Daniel Nepstad, Claudia Stickler, Nadine Laporte – Woods Hole Research Center)**
  - Brazil: ~ US$5/ton enough to compensate ranchers and to double the income of smallholders and rubber tappers. Total cost to reduce deorestation to zero in 10 years ~US$1.5 billion per year.
  - Central Africa: ~US$ 20-65 per ton to stop slash and burn agriculture
  - Highest cost in SE Asia due to population density and higher value, land uses e.g. rubber, palm oil.
  - Still need to resolve (1) how to protect really vulnerable forests (not cheapest!); (2) Prevent leakage (national baselines); (3) Ensure local people's needs and concerns are considered and accounted for in managing the forests, (4) how to reward countries who have very little deforestation.

Protect Existing Forests where there is currently little deforestation

Proactive Investment in Natural Capital PINC (vs REDD)

- Guyana model - Ecosystem Services (rainfall seeding, environmental flows, biodiversity): 20 yr instrument
- Coupon adjusted every 5 yrs based on atmospheric ppm
- Incentives for (1) rich countries to reduce emissions ; (2) recipient nations to conserve forests; and (3) private investors to invest
- Pension fund interest in long term assets

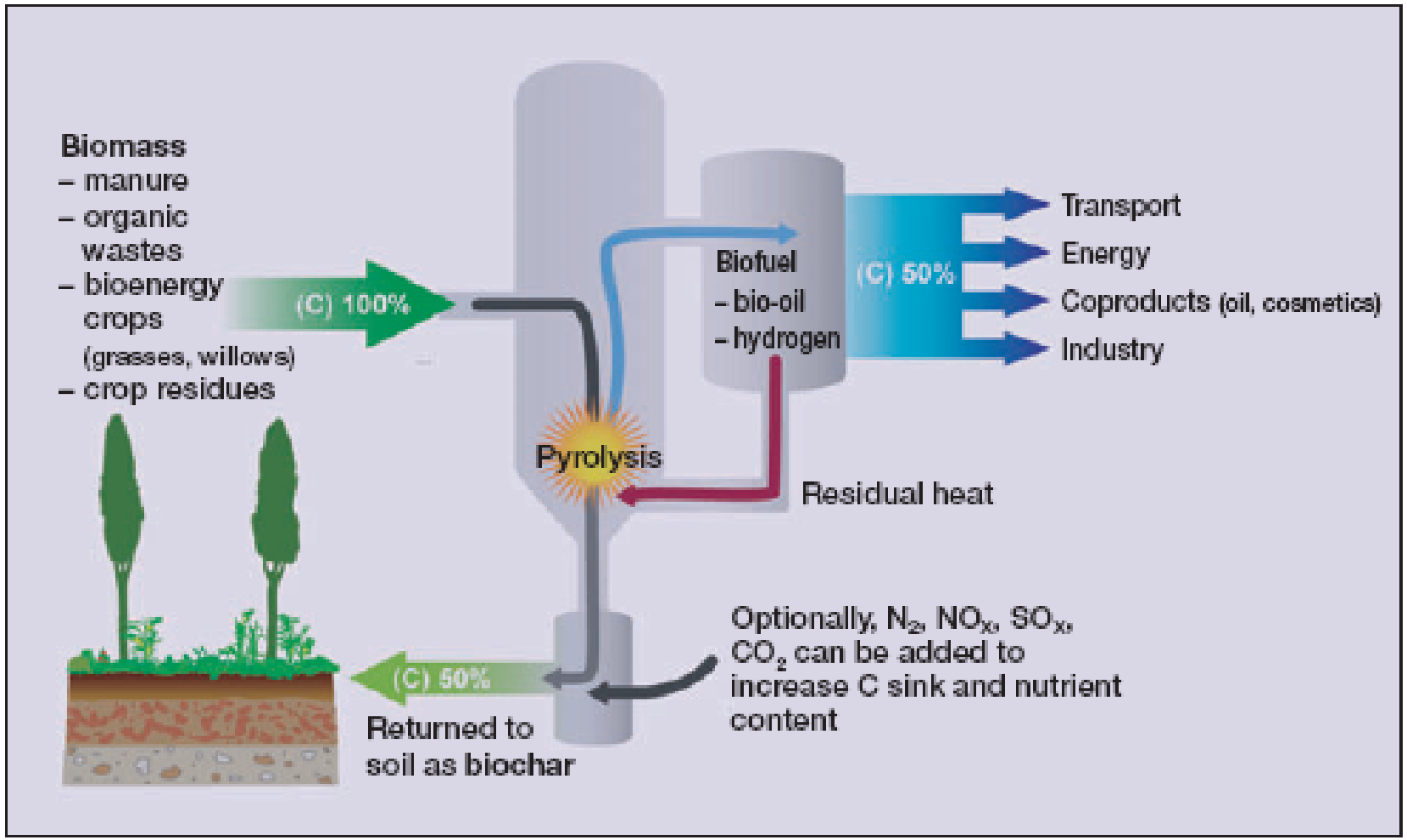
Source: Canopy Capital

“Biomass to Biochar”

Bioenergy + C sequestration + Improved Land & Water Productivity

- Biochar is the residue of biomass pyrolysis at 400-500 C and sold as charcoal briquettes.
- A novel approach is to couple rural biomass production systems with the “green” value of this by-product when added to soil.
- Two aspects of biochar make it valuable for this purpose:
  - high stability against decay, and
  - superior ability to retain nutrients as compared to other forms of soil organic matter.
- Three environmental benefits arise from these properties:
  - mitigation of climate change,
  - improvement of soils, and
  - reduction of environmental pollution.

Low Temp (500 C) Pyrolisis of Biomass for Biochar (soil carbon), Energy, Biodiesel



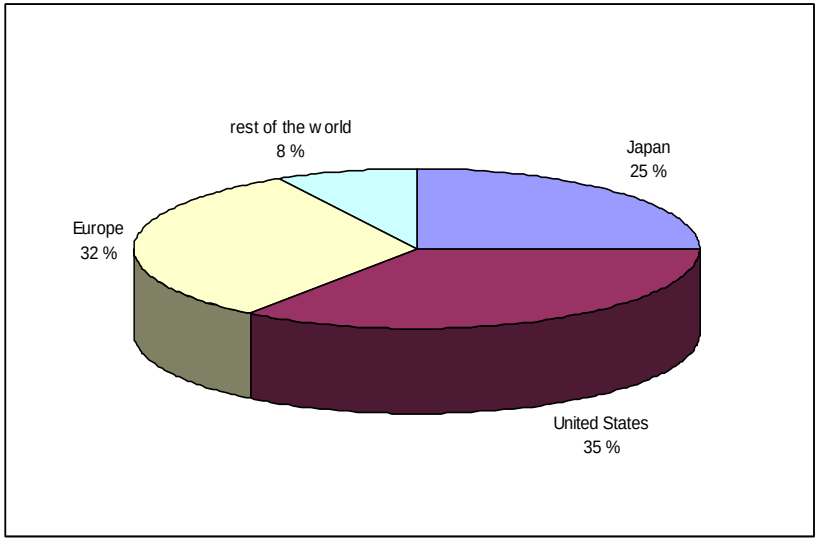
Source: Lehmann Front Ecol Environ 2007; 5(7): 381–387

Health Enhancing – Functional Foods:

Opportunity for Diversifying Ag Systems, Farm Income & Enhancing Resilience

Functional Foods – Promising Markets

- Global: past annual growth rate of about 10 % (value)
- The current market value estimate: from US$31 billion to nearly US$61 billion



- Expected to grow to US$ 167 billion by 2010 – 13% a year
- Overall food sector: 2% annual growth rate

Japan:
- Market share: US$4-15 billion
- Expected growth rate: 12%

EU:
- The market share about 1% - more than US$15 billion (of US$1-1.5 trillion)
- Expected growth rate: 15%

US:
- About 3% - US$15-19 billion (of US$500 billion)
- Expected growth rate: >6%

Global organic market:
- US$36 billion (2005)
- Growth rate: past 15%, expected to continue at nearly 13%

Click Source: The World Bank, 2007

Optimize Tradeoffs

- Quantitative and semi-qualitative, cross-sector analysis.
- Compare and contrast a range of land use models/systems.
- Possibility of coupling such analyses to spatial tools to test scaling-up/down hypotheses.

Food & Ecosystem Services

- Well nourished, healthy populations
- Robust and resilient agroecosystems in stable landscapes
  - Hilltops & riparian areas protected
  - Native biodiversity conserved & enhanced
  - Invasive species controlled & removed
  - Landscape hydrological functions restored
- Plant productivity enhanced to fix and sequester C and augment sinks for other GHGs

Ecosystem Services Valued

- State of the art cropping systems (varieties, inputs, best management)
- Diverse food and fiber systems that also provide nutritious foods, protect high potential crop lands and maintain a diverse range of ecosystem functions (hydrology, C sequestration, biodiversity conservation)
- Rehabilitated productivity of degraded lands for diverse food and fiber systems and ecosystem services

“Biodiverse Bioengineering”
Field to watersheds and beyond!
Quantify, Value, Reward
Agricultural Carbon!!

- Complex Agroforestry Systems
- Crops, livestock, trees, bioenergy, biodiversity, carbon sequestration

Agrosilviculture 1

1991


1992


1992


1994


1998


2002

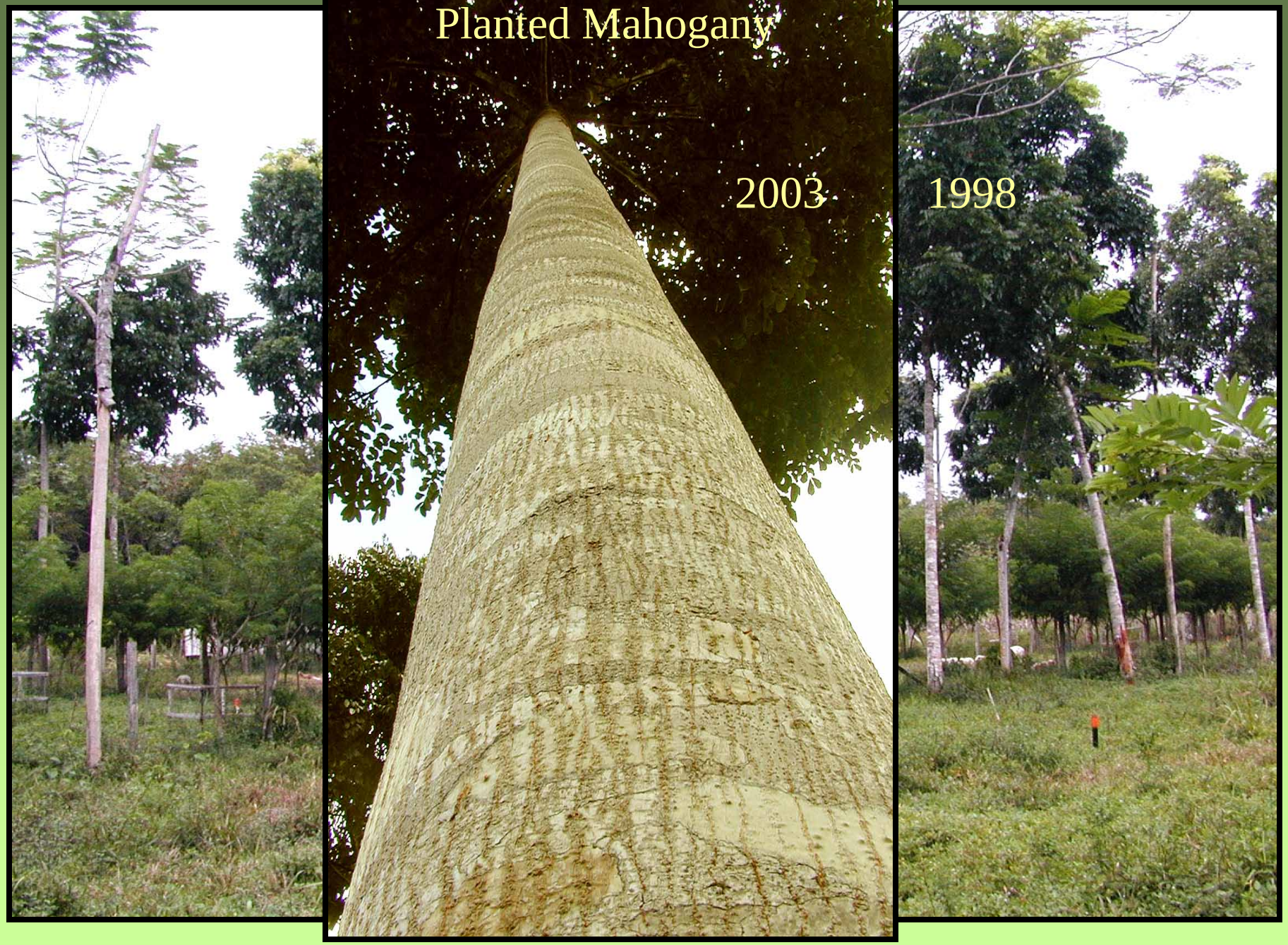

2003
2002

Agrosilvopastoril 1

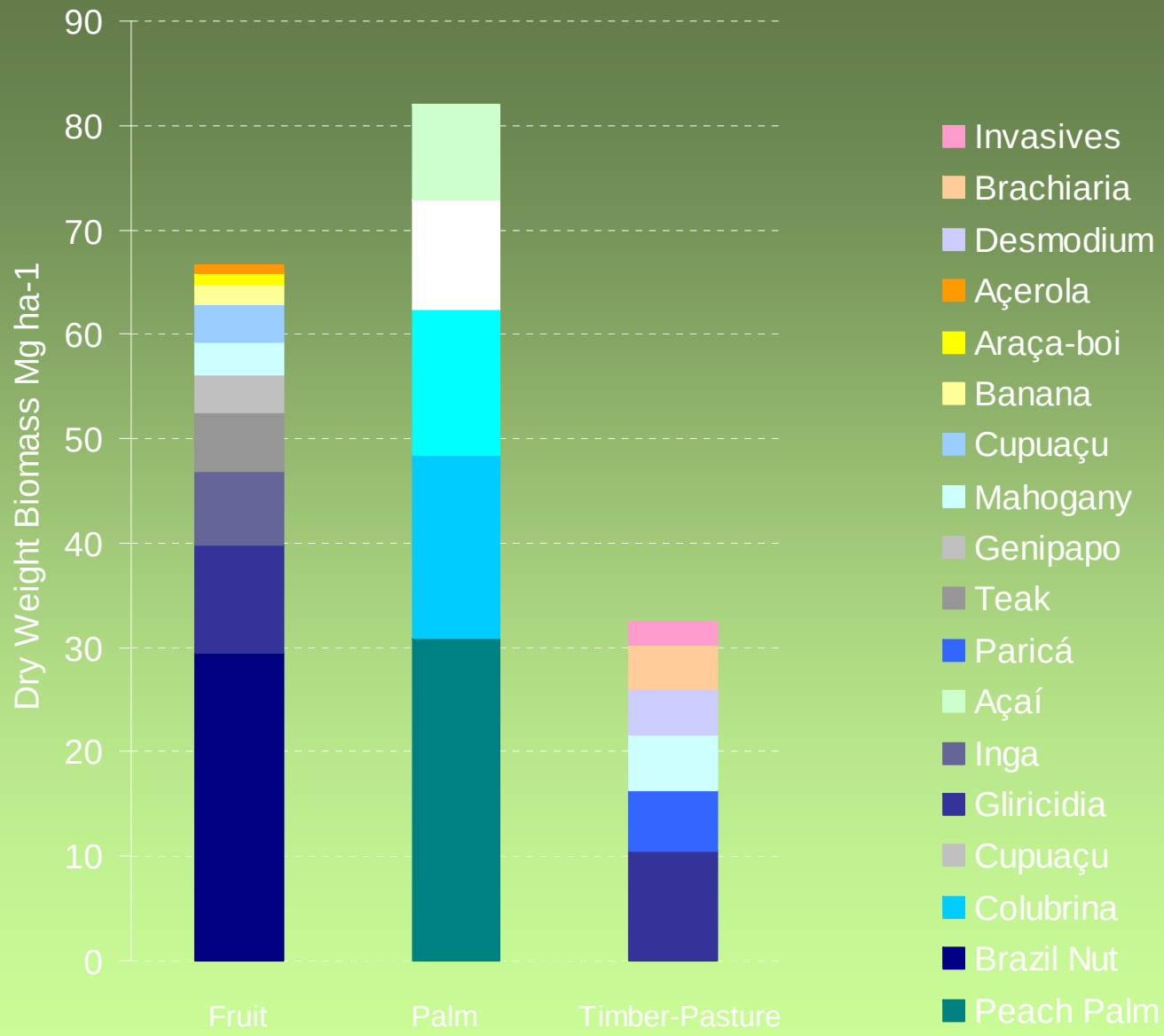
10 years later

Ten years later


Planted Mahogany
1998


Planted Mahogany
2003
1998

Aboveground Biomass in 9-yr-old Agroforests



Wandelli, McCaffery, Rondon, Fernandes (submitted)

Biomass and Carbon Stocks

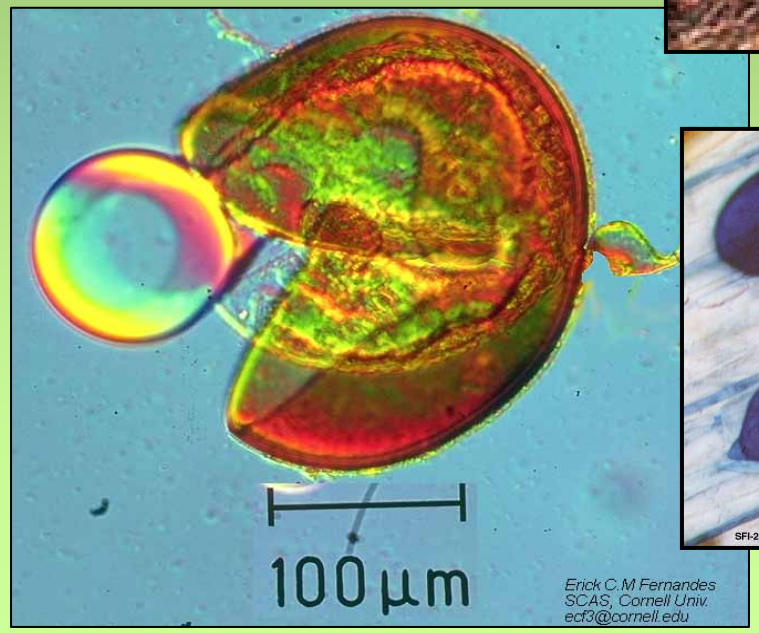
System	Biomass Mg ha^{-1}	Rate Mg ha^{-1} yr^{-1}	Carbon Mg ha^{-1}	Carbon Mg ha^{-1} yr^{-1}
Palm	82.0	9.1	41.7	4.6
Fruit	66.7	7.4	34.3	3.8
Timber-Pasture	32.5	3.6	16.0	1.8
Secondary Forest	111.9	12.4	53.8	6.0

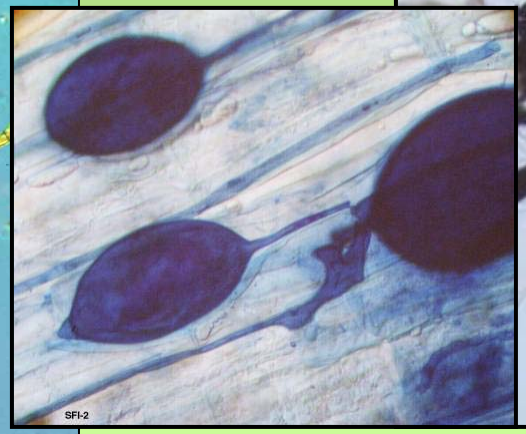
*Simple AFS	5.0 – 9.0
*Complex AFS	2.0 - 4.0
*Pastures	-0.2 - -0.6

Florestas 0.55-0.85 Mg/ha C/yr – Y. Mahli

*Source: Sanchez 2000

Belowground Biodiversity

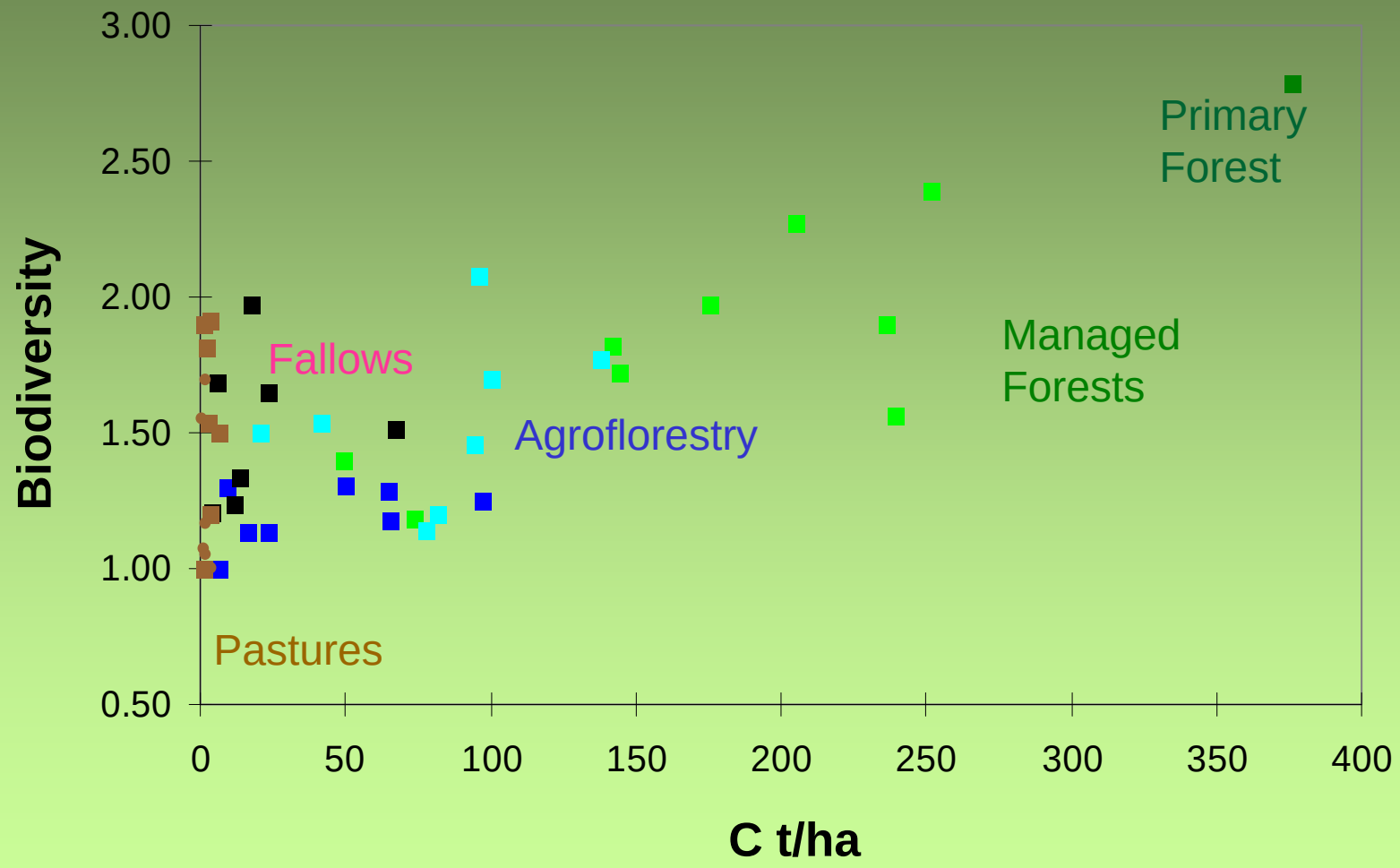




Tradeoffs Analysis

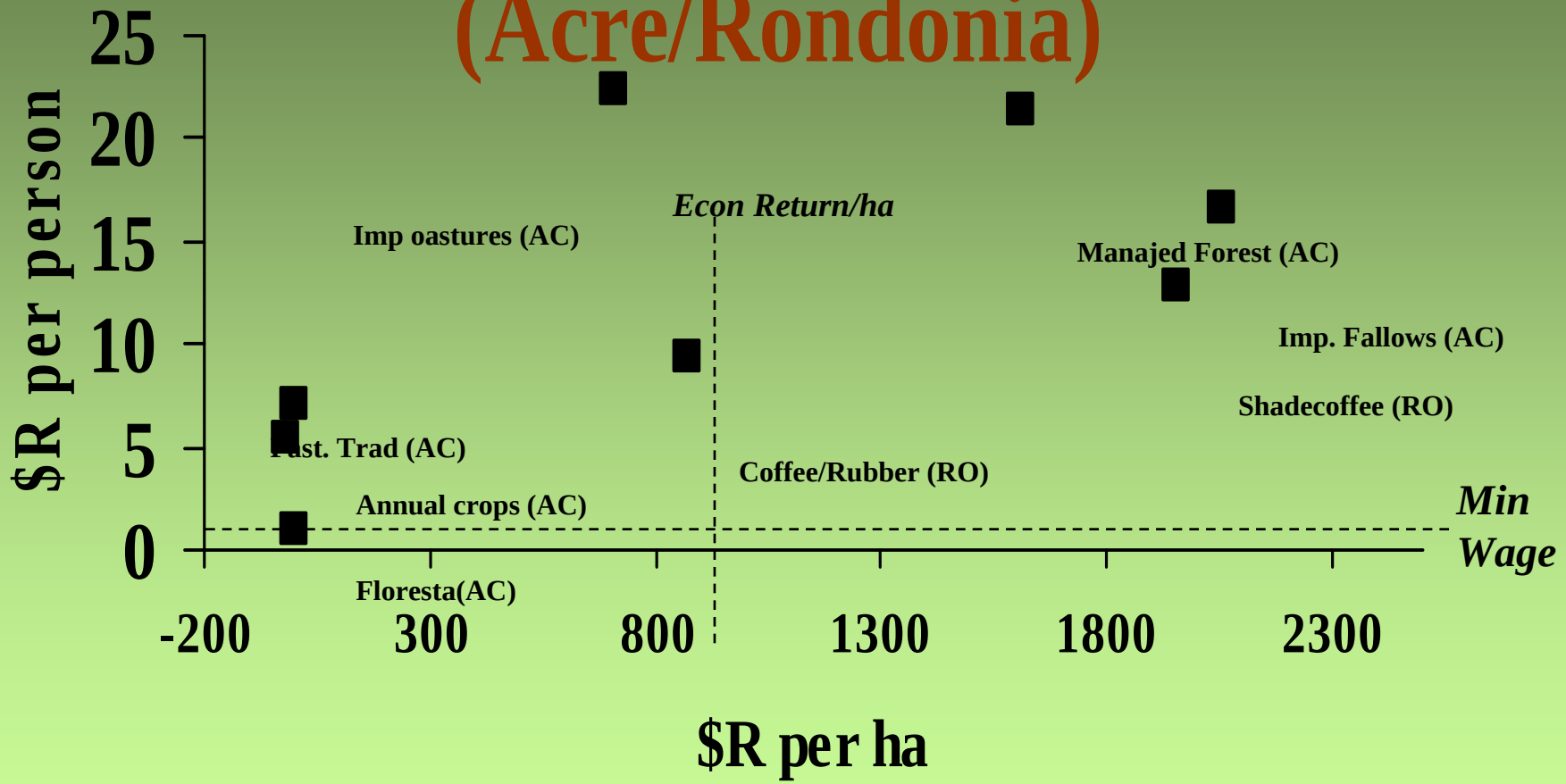
- Quantitative and semi-qualitative, cross-sector analysis.
- Compare and contrast a range of land use models/systems.
- Possibility of coupling such analyses to spatial tools to test scaling-up/down hypotheses.

Carbon & Biodiversity



Gillison and Palm, 1998

Economic Return (Acre/Rondonia)



Vosti, Witcover, and Carpentier 1998.

Some Concluding Thoughts

- A significant science and natural resource management knowledge base already exists.
- Organize it to provide Decision Support to Policy Makers
- Increase food productivity on the "best" land and protect the existing forest, woodlands, and wetlands against fragmentation.

- Diversify agroecosystems to protect food systems, improve diets, minimize risks, diversify incomes, and conserve agrobiodiversity
- Rehabilitate productivity and ecosystem functions of degraded lands to enhance environmental roles (C sequestration, environmental flows, biodiversity habitats)
- Strengthen local institutions and community-driven natural resource management for managing the expanding scale of shocks, stresses, and global trade

Thank you!

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The Zambezi River near Tete in Mozambique