The Science of Climate Change and Climate Change Vulnerability and Adaptation

ADAPTATION FOR COASTAL ECOSYSTEMS IN THE CARIBBEAN

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OUTLINE

- Definition
- Role and purpose of Coastal Ecosystems
- Impacts on Coastal Ecosystems
- Adaptation

What is the Coastal Ecosystem?

- Interface of land and water – creating environments with distinct structure, diversity, and energy flow.

- Include :

Coral Reefs	Seagrasses	Salt marshes
Mangroves	Wetlands	Estuaries
Bays	Sand dunes	Coastal Forest

- Sensitive to changes in the environment.

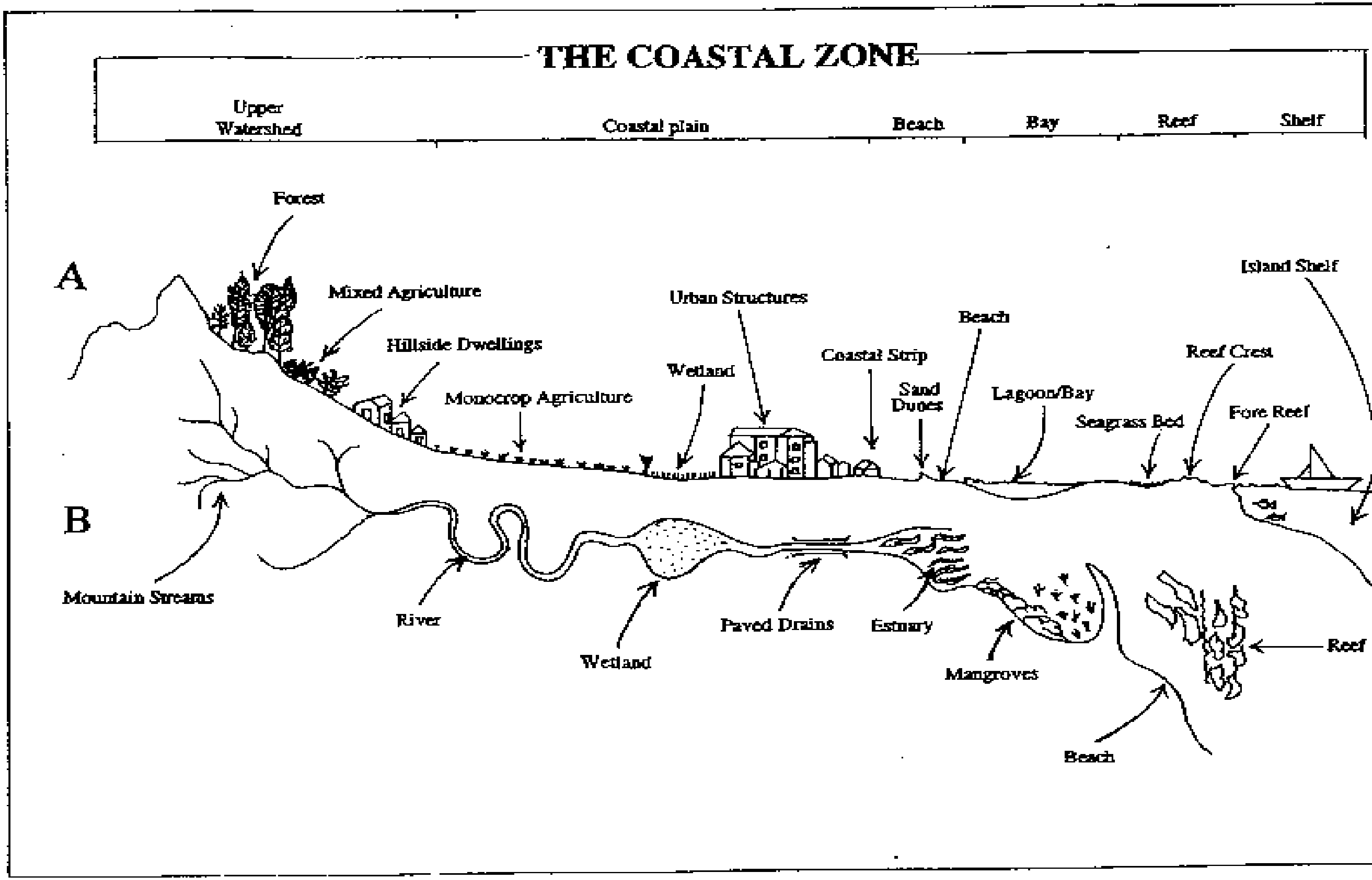


FIGURE 8.1 Schematic representation of the Caribbean coastal zone.

The Coastal Ecosystem

- Provide a wide array of goods and services eg. fish, fertilizer, pharmaceuticals, cosmetics, household products and construction materials.

- Store and cycle nutrients, filter pollutants from inland freshwater systems.

- Protect shorelines from erosion and storms.

- Oceans regulate global hydrology and climate.

MANGROVE FOCUS

Value of mangroves:

- Prevent coastal erosion
- Provide food and shelter

for juvenile fin and shell fish

- Provide habitat and

substrate for marine plants & animals-

HIGH BIODIVERSITY

Biodiversity-Rare/Endemic

Protection of animals and their Habitat

American croc

crabs

Magnificent Frigate bird

Queen conch

White Ibis

Spotted eagle ray

Dolphin

Prop root habitat- Large # of species (high biodiversity)

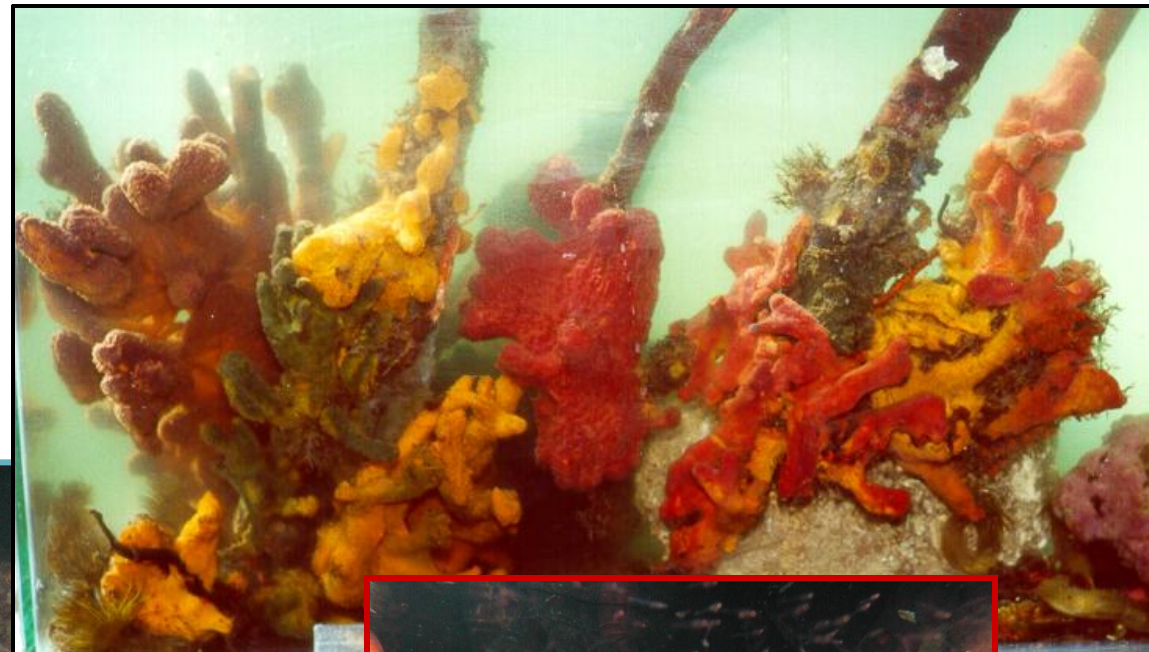
- A mangrove Root with high diversity marine animals.
- Water cleaning filter feeders
- Number of species ~ 50 with a wet biomass of ~2 kg.

Exploitable resources.

- “Flat Oyster” collected by oyster fishermen for food.

- Orange sea squirt, *Ecteinascidia turbinata* from which the anti tumor drug Ecteinascidin has been extracted.
- Recently approved in Europe for the treatment of soft tissue sarcomas.

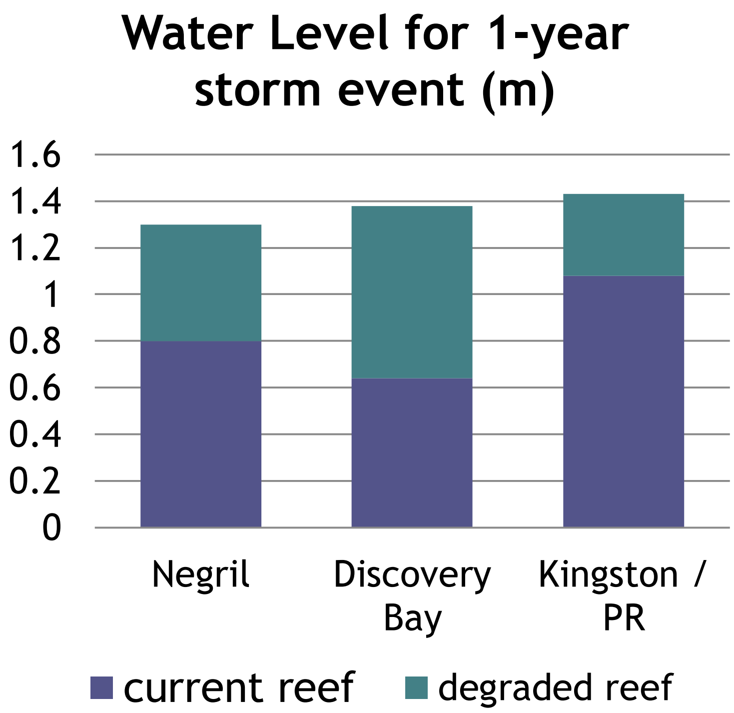
New species of Mangrove sponge-
Haliclona portroyalensis (Jackson, DeWeerdt & Webber, 2006)

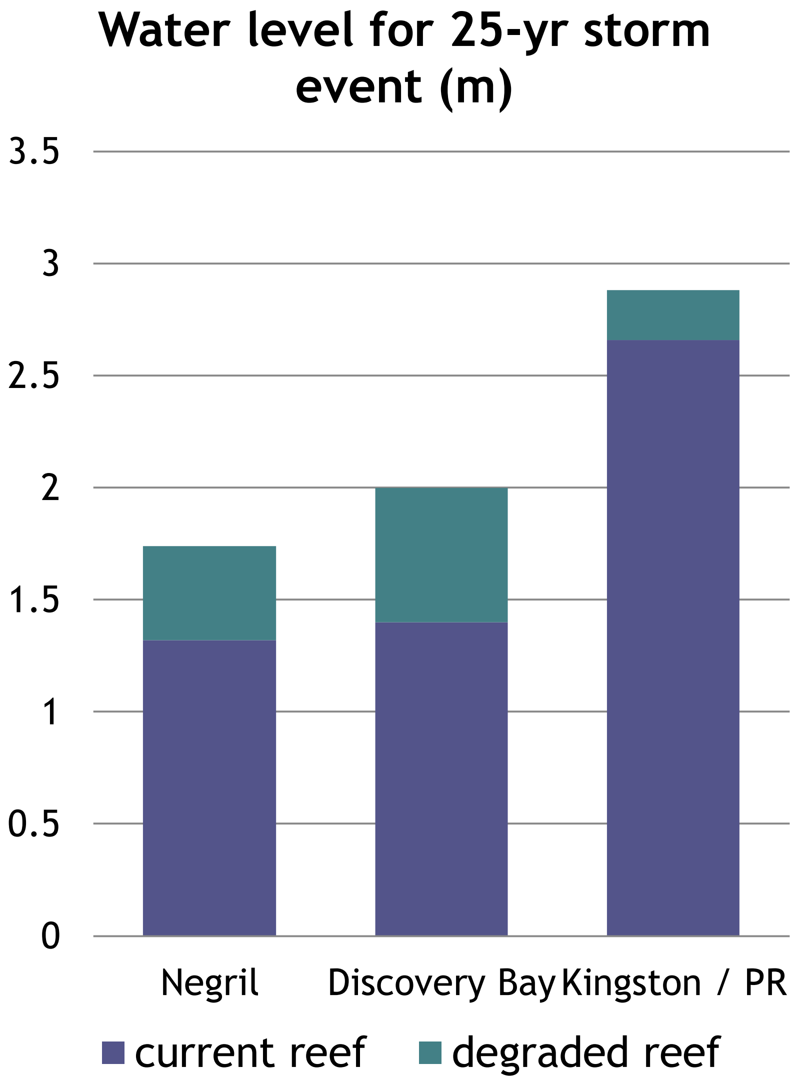


Ecosystem Services from Coral Reefs

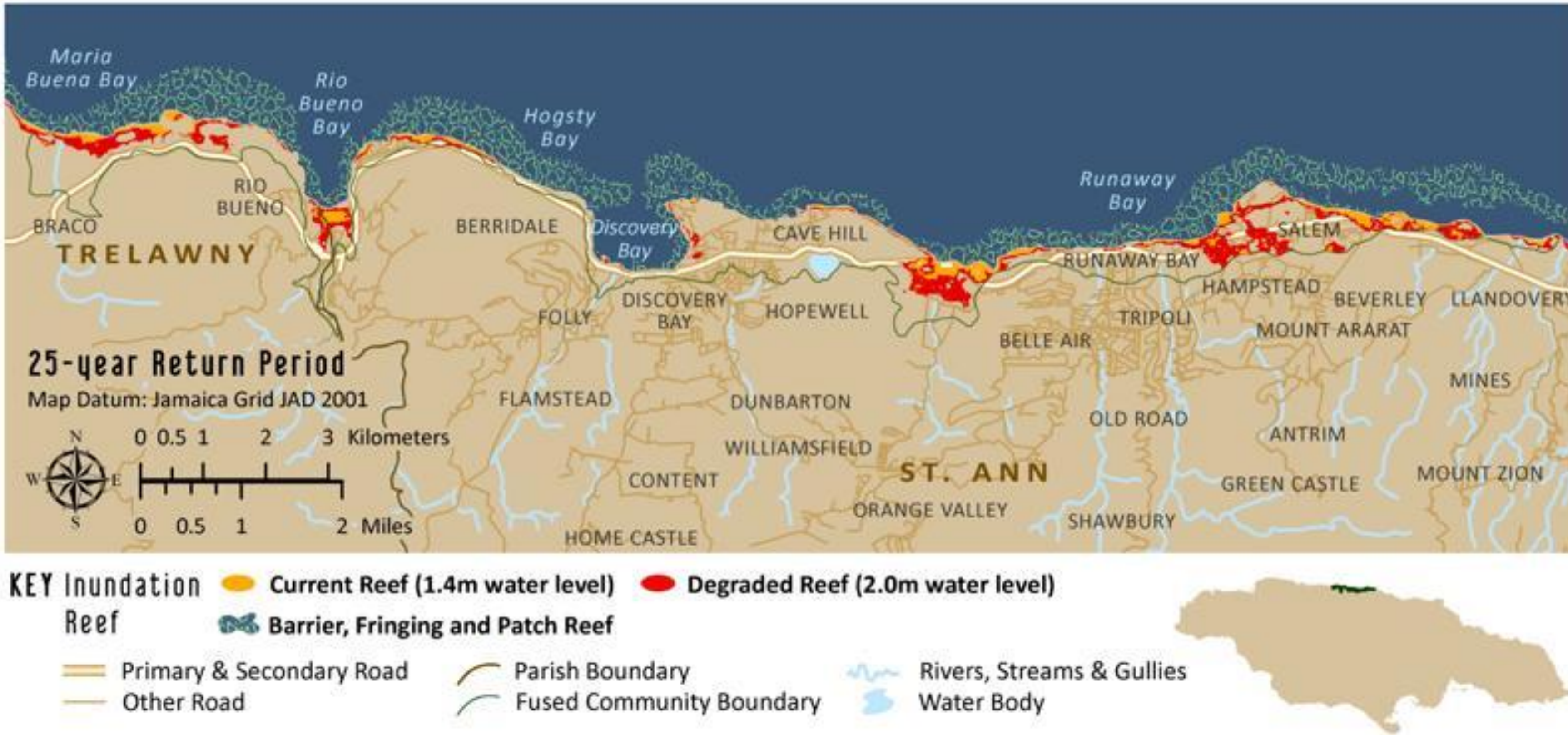
Provisioning Services	Regulating Services	Cultural Services
• fish and shellfish • medicines and pharmaceuticals • ornamental resources • building materials	• erosion control • storm protection **Supporting Services** • sand formation • primary production	• inspiration • aesthetic values • social traditions • spiritual values • recreation & tourism

Change in water level at shore due to reef degradation





25-year storm scenario



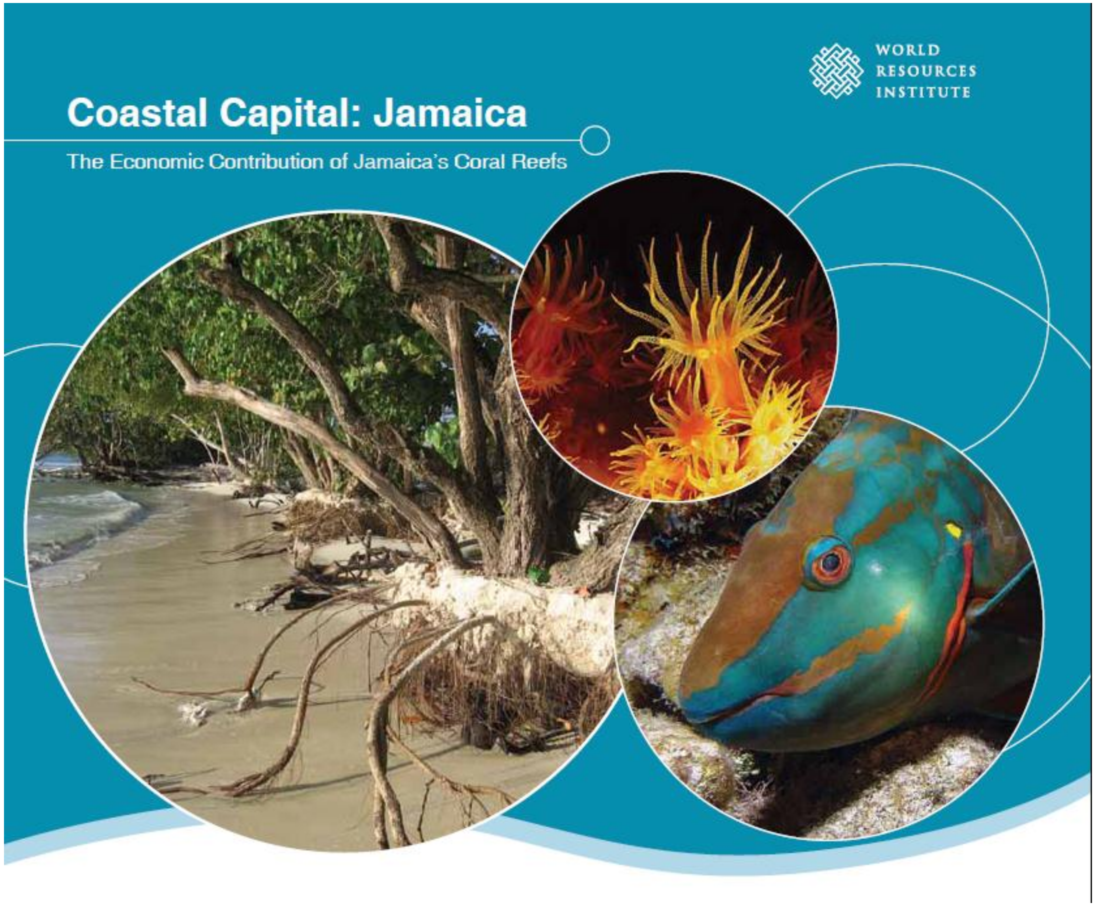
Property Affected:
Current reef – 39 buildings
Degraded Reef – 154 buildings,
including 2 hotels, church, airfield

Coastal Inundation Map Series

WORLD RESOURCES INSTITUTE


Photo credit: Steve Lindfield

Coastal Capital: WRI



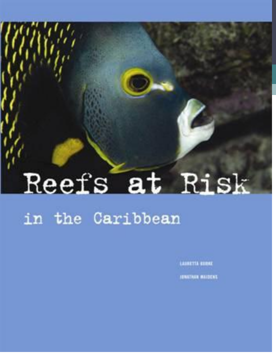
WRI

The Nature Conservancy
Protecting nature. Preserving life.™

The Marine Geology Unit
UWI, Mona

MONA
GeoInformatics

MacArthur
The John D. and Catherine T. MacArthur Foundation



Regional Valuation – Reefs at Risk in the Caribbean (2004)

- Value = US$ 3.0 – 4.6 billion / year
- Losses of US$ 350 – 870 million / year estimated to result from degradation

3 Goods and Services Evaluated

Fisheries

Tourism

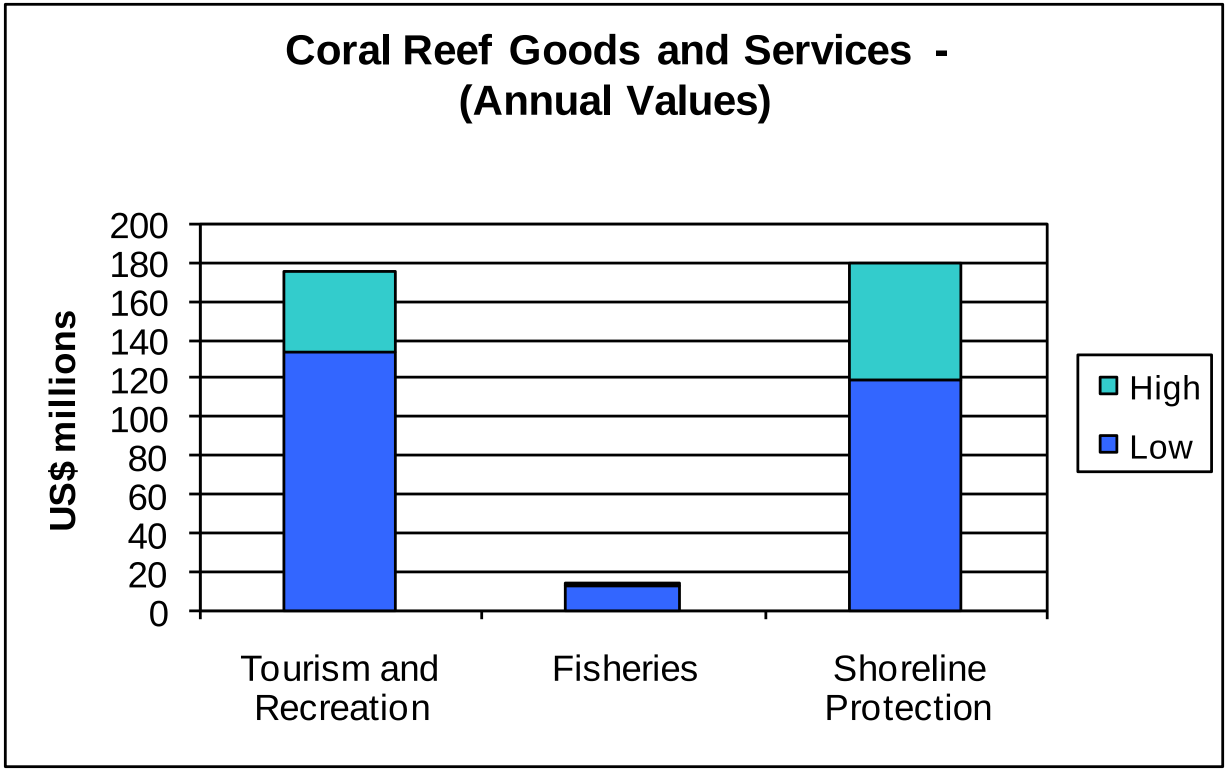
Shoreline Protection

Benefits:

- *Tangible*
- *Relevance to national and local economies*
- *Data available*

Coastal Capital: study locations

Belize: Annual economic contribution of **coral reefs** was between US$270 and $370 million in 2007



Source: Cooper et al, 2008.

Environmental stresses/ Human induced impacts

- Injection of wastes
- Alterations in coastal morphology and ecology & poor land-use practices
- Tourism, housing, recreation
- Industry (manufacturing/shipping/mining)
- Petroleum & refinery processes
- Run-off pollution
- Point and non point source pollution


STATION CODES
HBV Sewage outfall at Harbour View
TML Thermal discharge from cement Co.
SS Discharge from Cement Co.
CWE Discharge from Cement Co.
CWW Spring west of Cement Co.
SHC Rockfort Creek
MTN Mountain view Gully
BEL Discharge from Belview Hospital
RAE Franklin Town Gully
GPW Barnes Gully
JPS Gully east of JPS Power Station
PET Gully east of PETAROJAM Ltd
JEW Jew Gully
D&G Gully west of D&G Brewery
TIA Gully west of Tia Maria Ltd.
SAN Sandy Gully
CON Constant Spring gully
6MI Duhaney River
FRE Fresh River
RIO Rio Cobre
JAM Sewage Outfall at the Jam World Entertainment Centre
SOU Sewage Outfall at Germain Road Portmore
FRE
6MI
CON
SAN
TIA
D&G
RIO
JEW
JAM
PET
JPS
SOU
GPW
RAE
BEL
MTN
SHC
CWW
CWE
SS
TML
HBV
ST. ANDREW
KINGSTON
LIGUANEA PLAIN
Hunts Bay
KINGSTON HARBOUR
PORTMORE
MAP SHOWING SAMPLE SITE LOCATIONS FOR
DEC 1994-DEC 1995 STUDY

Threat: Coastal Development

Photo credit: Wolcott Henry

Threat: Sediment and pollution

Threat: Marine pollution and damage

Photo credit: Chad King/NMS


Photo credit: Wolcott Henry

Threat: Overfishing

Photo credit: Steve Lindfield

Threat: Destructive Fishing

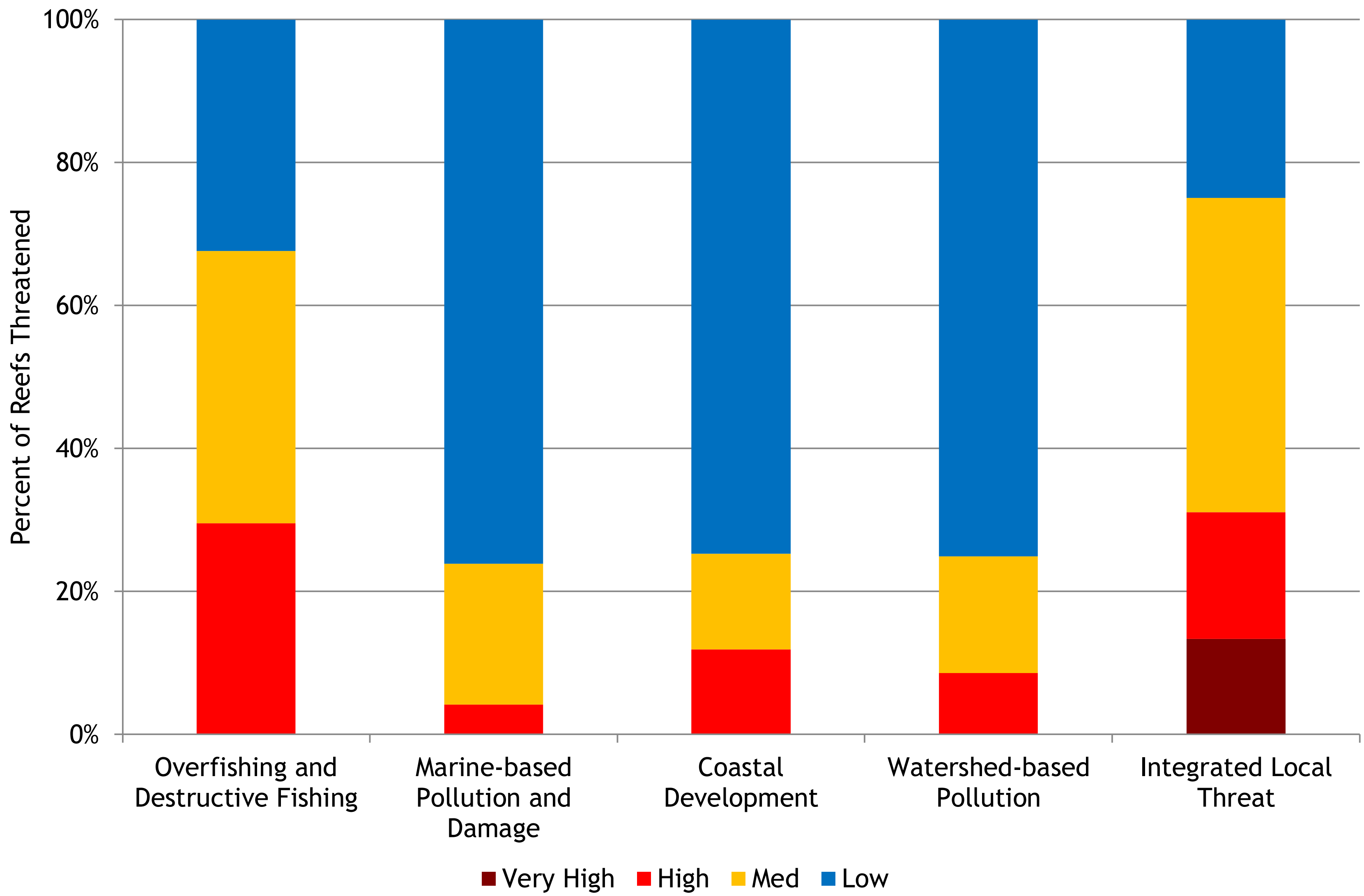
Photo credit: Lynn Funkhauser

Photo credit: Wolcott Henry

Integrated local threats to coral reefs

Low Medium High Very High

In the Caribbean, more than 75% of reefs are threatened by local activities



Potential Impacts of Climate Change on Coastal Systems

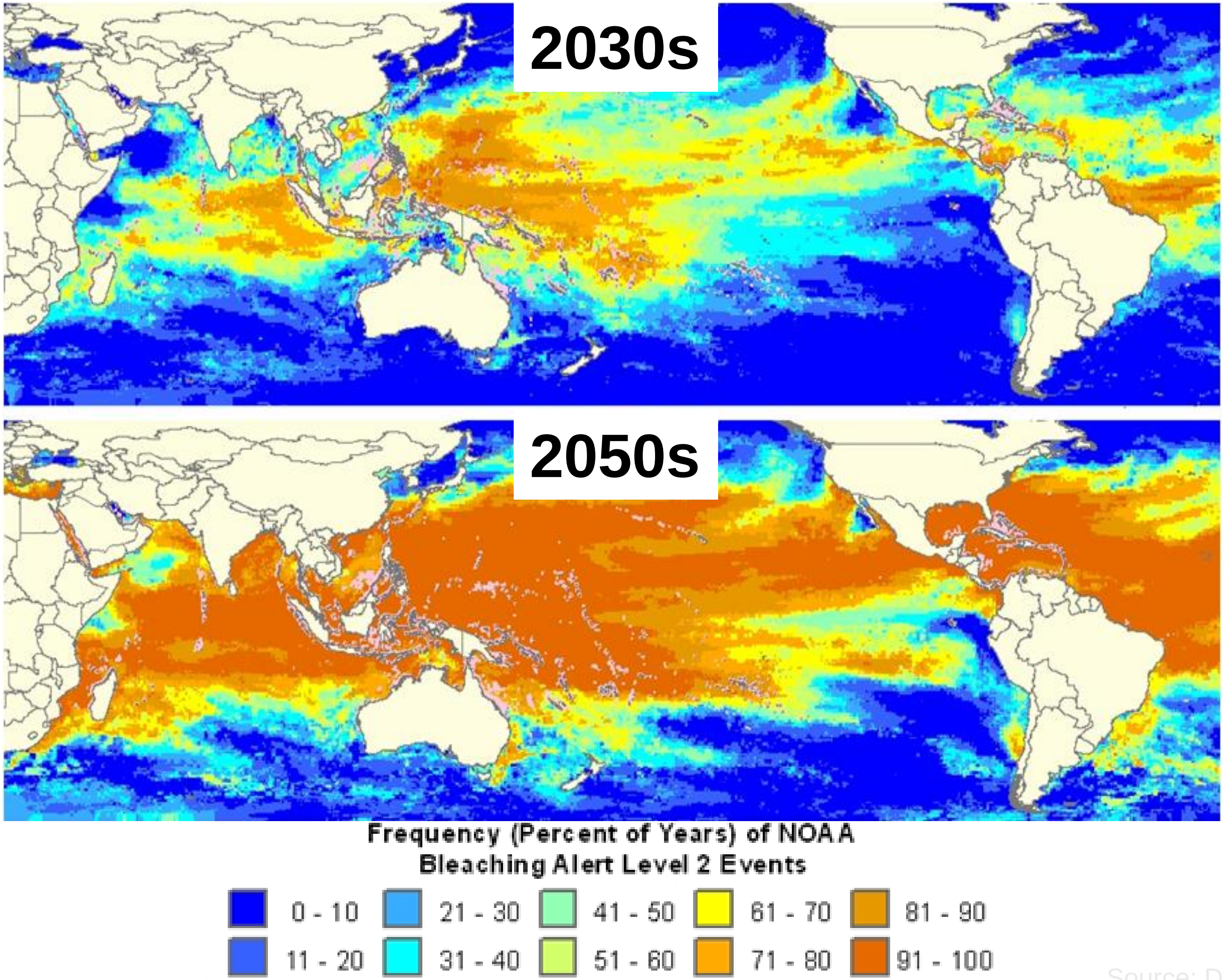
Climate change is affecting marine and coastal ecosystems through various ways:

Biophysical impacts:

- Sea level rise - impacts the condition and distribution of coastal habitats
- Inhibition of primary production processes
- Changes in the distribution of pathogenic microorganisms
- Enhanced competition for limited resources, and amplification of existing stressors, such as habitat fragmentation and pollution.

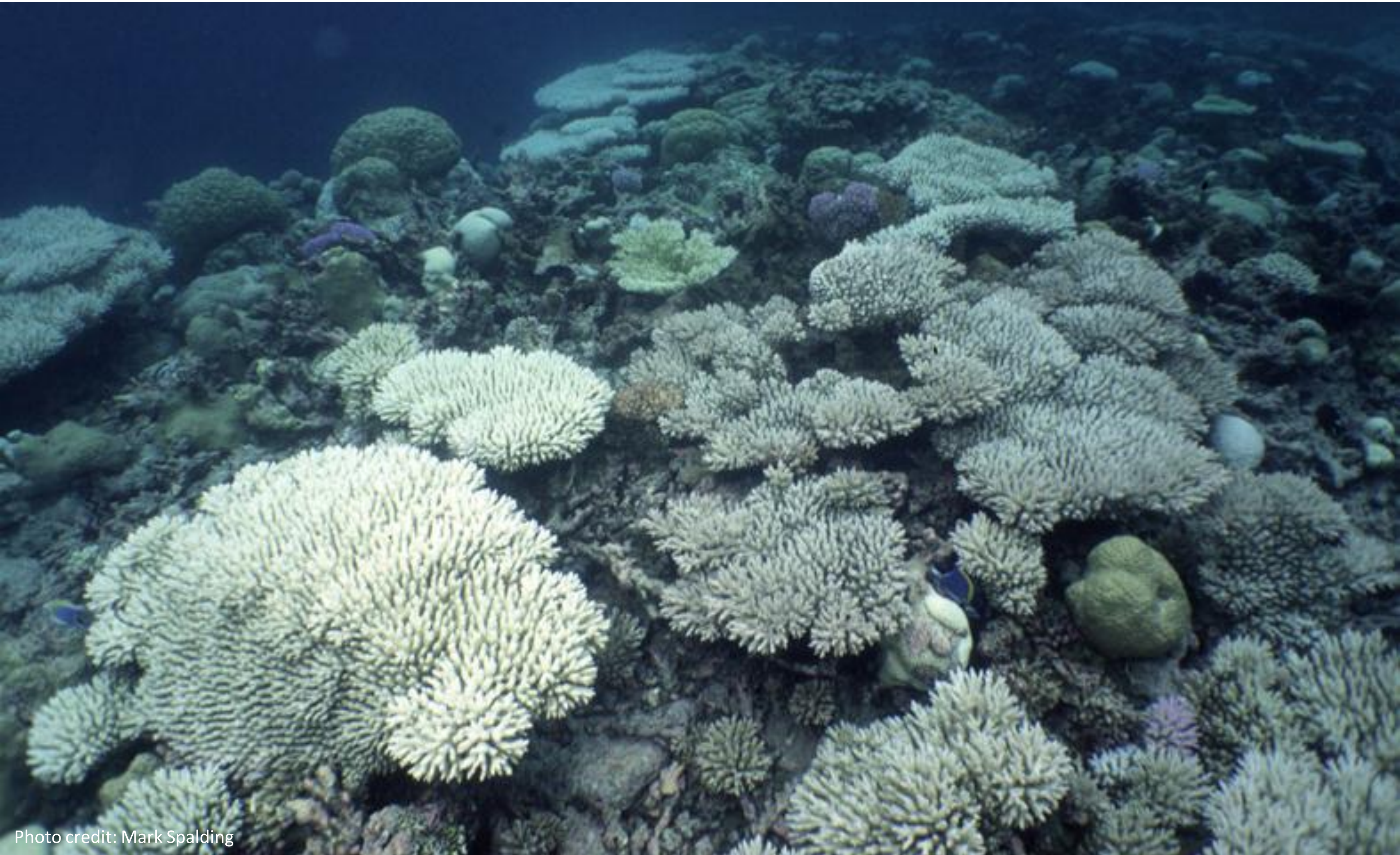
Source: IPCC,2007; Griffis *et al., 2008)*

Projections of thermal stress (2030 and 2050)



Source: Donner, 2009.

Threat: Warming Seas

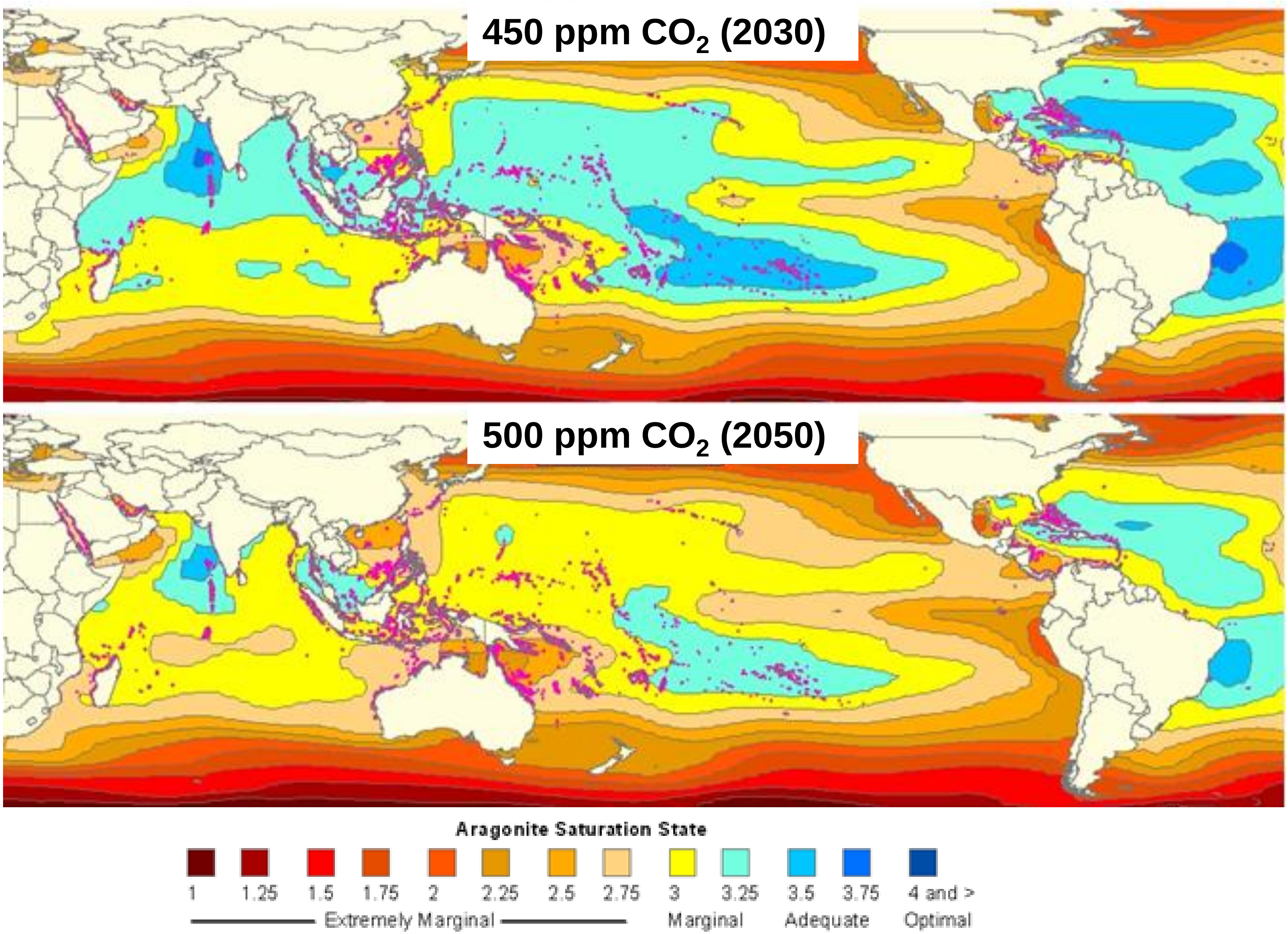


- Gradual increases in sea surface temperatures = frequent bleaching events (1993, 1998, 2005)

- Ocean physical changes (e.g. changes in water temperature, stratification, and currents)
  - - affects species survival and distributions, ocean productivity, and the timing of biological events.

Bleached brain coral.
Source: NOAA

Projections of ocean acidification (2030 and 2050)



- Ocean acidification - impacts the growth and viability of sensitive marine organisms such as corals, bivalves, crustaceans, and plankton.

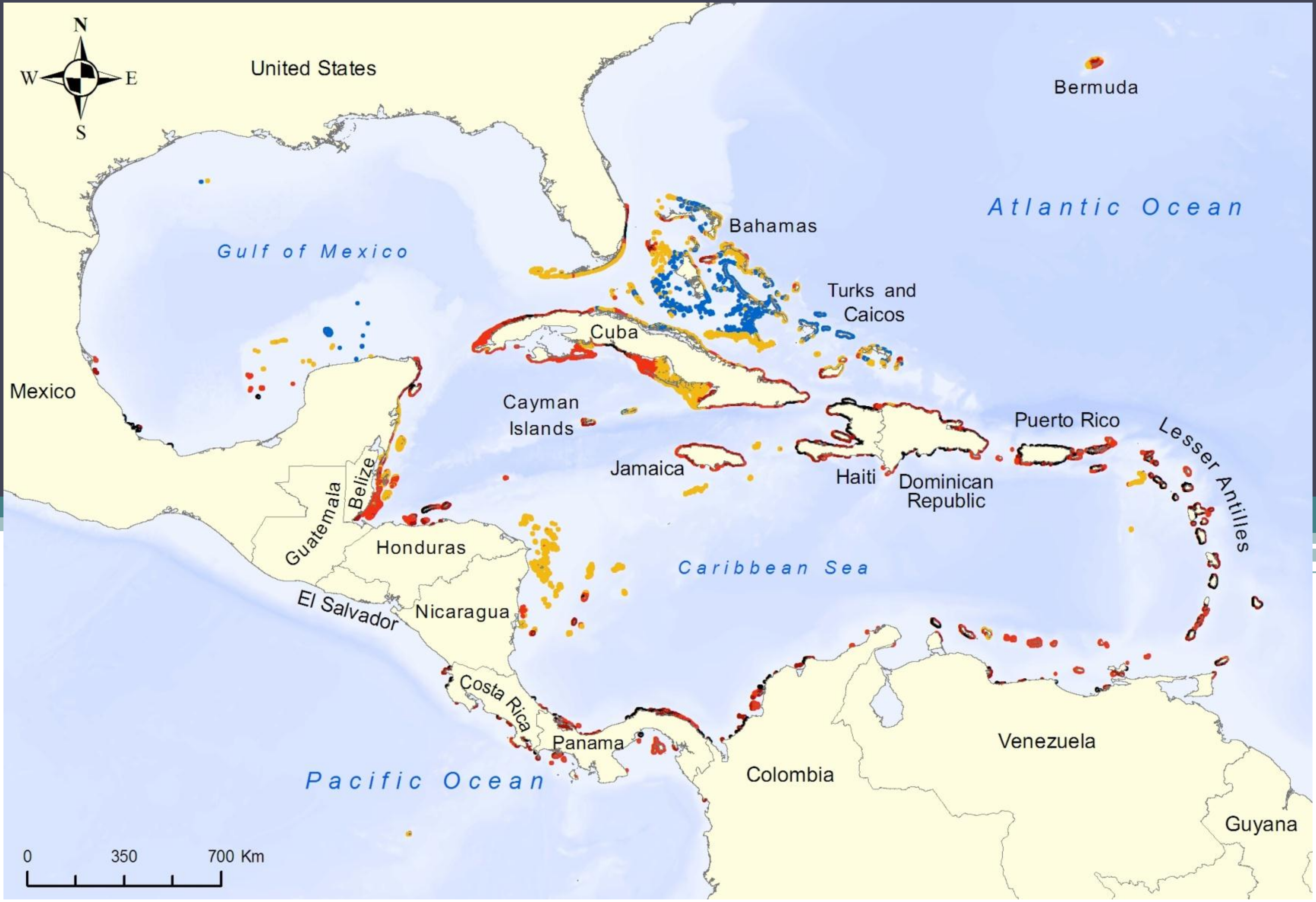
Bleached brain coral.
Source: NOAA

- Altered freshwater supply and quality - impacts coastal habitats, spawning migrations, and survival of anadromous species.

Integrated threat from local activities: today

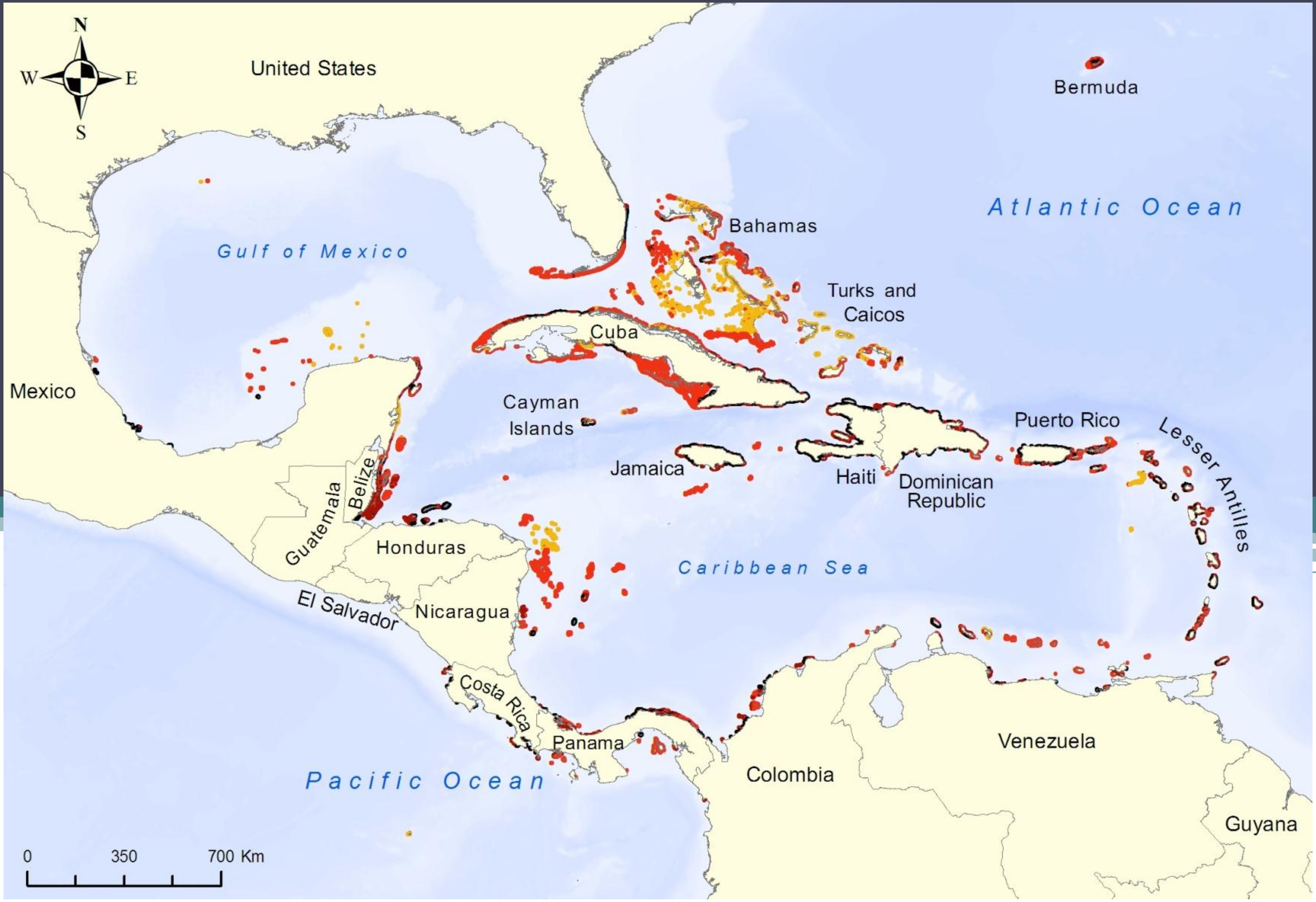
Low Medium High Very High

Integrated local and global threat: 2030



Low Medium High Very High Critical

Integrated local and global threat: 2050

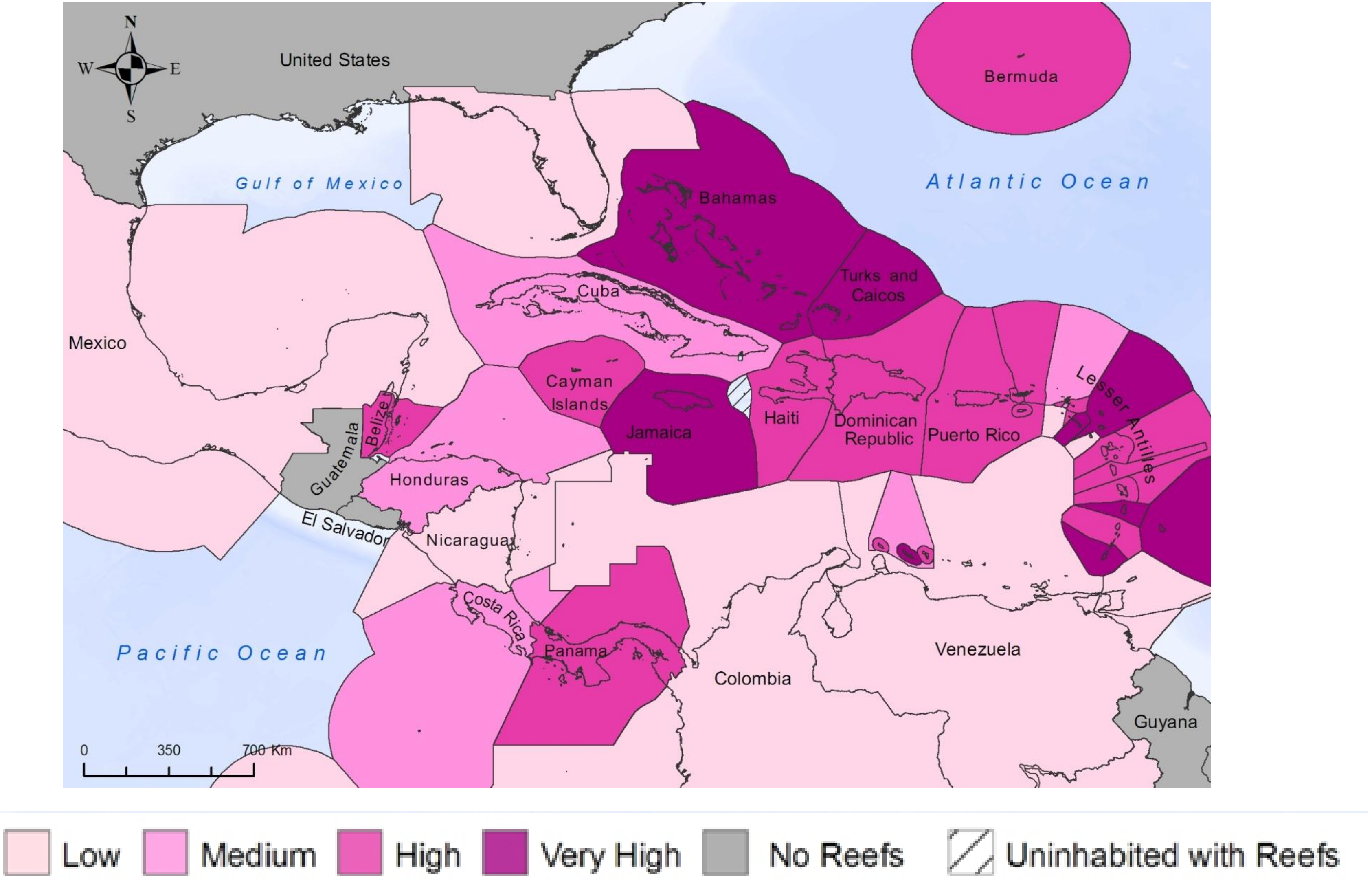


Low Medium High Very High Critical

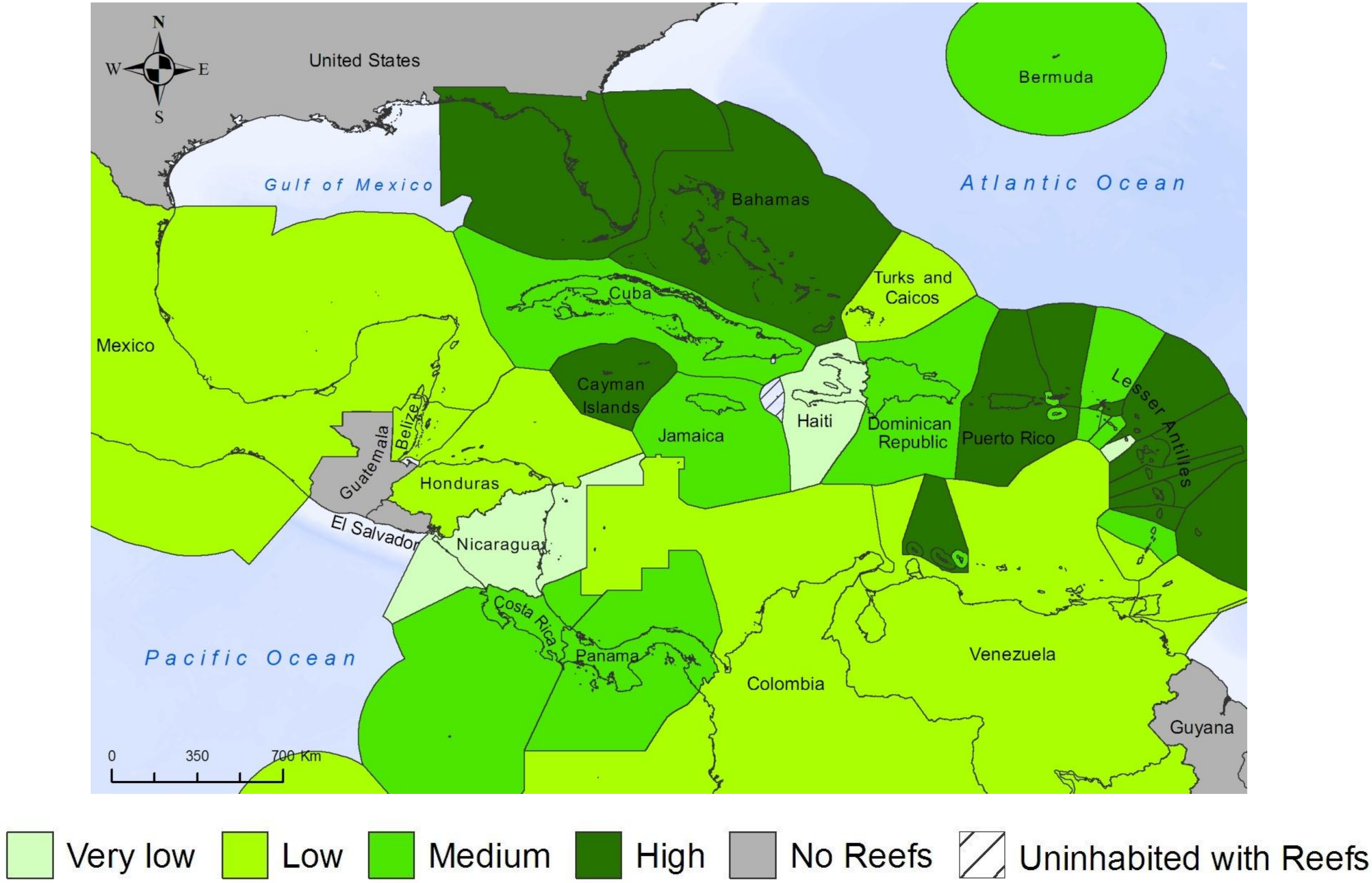
Socioeconomic impacts:

- Increased loss of property and coastal habitats
- Increased flood risk and potential loss of life
- Damage to coastal protection works and other infrastructure
- Increased disease risk
- Loss of renewable and subsistence resources
- Loss of tourism, recreation, and transportation functions
- Impacts on agriculture and aquaculture through decline in soil and water quality.

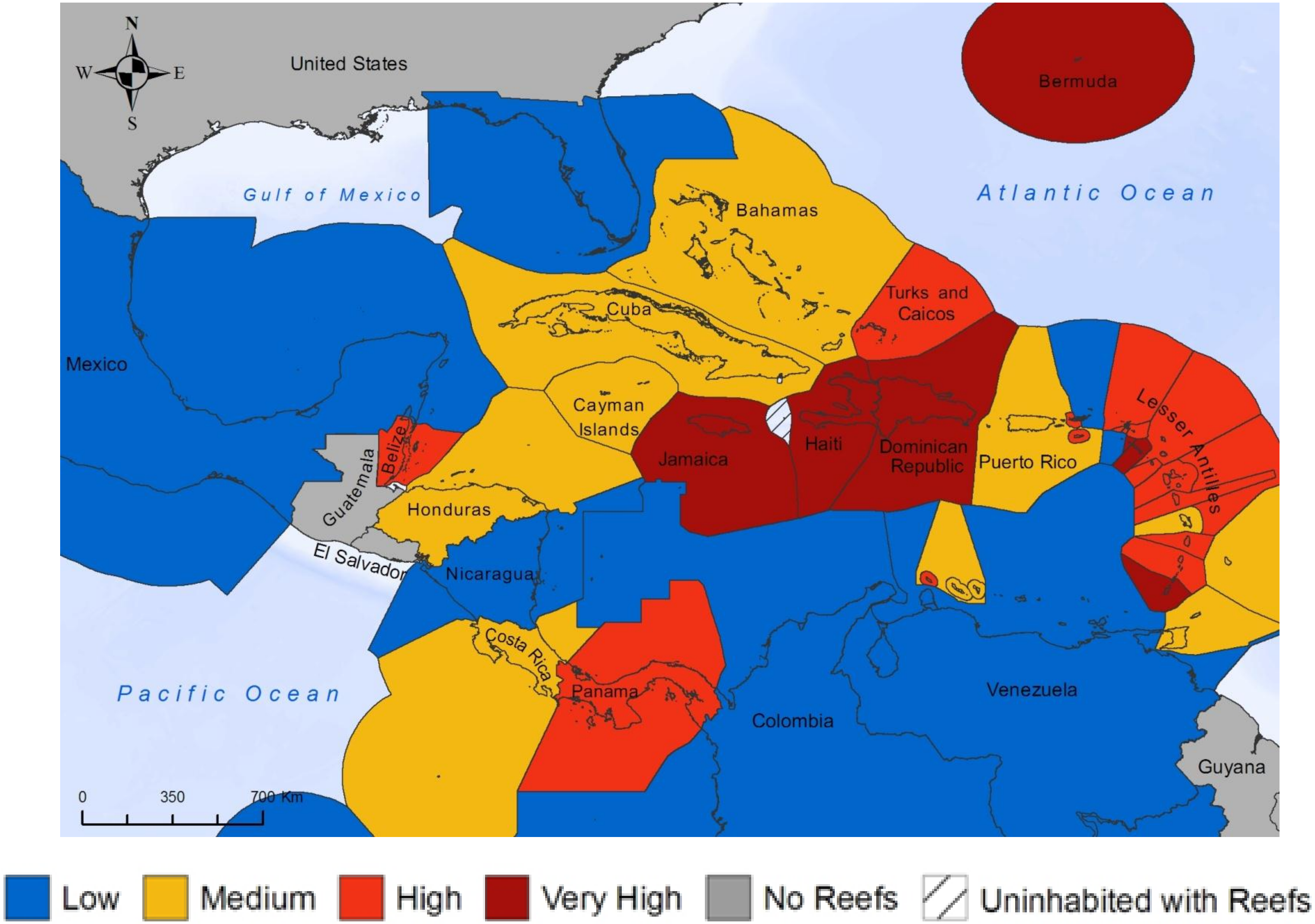
Social and economic dependence on coral reefs



Capacity to adapt to degradation and loss of reefs



Social and economic vulnerability to reef degradation



Hydrological Modeling and Climate Change in the Caribbean Islands

Caribbean Coastal Scenario Project
with
Florida International University

Caribbean Coastal Scenarios
Core Science Objectives

- **Determine spatial and temporal variability in climate across the region.**

- **Determine geographic & demographic characteristics of catchments**
  - **topography, land cover, geology, soil, land management techniques, population, roads and infrastructure, urban systems, etc.**

- Consider present & future trends in the nature & distribution of <u>dynamic</u> characteristics
  - e.g. land cover, management techniques, population, infrastructure, urban systems.

Caribbean Coastal Scenarios
Core Science Objectives (cont.)

- **Simulate seasonal and inter-annual fluxes of fresh water, sediments, and dissolved loads to coastal zones as a function of climate and catchment characteristics.**

Caribbean Coastal Scenarios Management/Policy Objectives

- ❑ Examine specific scenarios of future change in driving variables.
- ❑ Evaluate the risk to coastal ecosystems and vulnerability of humans to projected changes.
- ❑ Quantify impacts along coastlines using ecological economic indicators.
- ❑ Explore sustainable and desirable scenarios for the future.

Caribbean Coastal Regions

- Puerto Rico
  - Manate and Plata Basins
- Dominican Republic
  - Haina and Yuna watersheds
- Jamaica
  - Great River and Rio Cobre

Islands of interest

- **Watershed models are increasingly used to implement alternative management strategies in the areas of**
  - water resources allocation
  - flood control
  - *impact of land use change*
  - *impact of climate change*
  - environmental pollution control

SWAT (Soil water Assessment Tool)

- SWAT is a river basin scale developed to predict the impact of land management practices on water, sediment and agricultural chemical yields

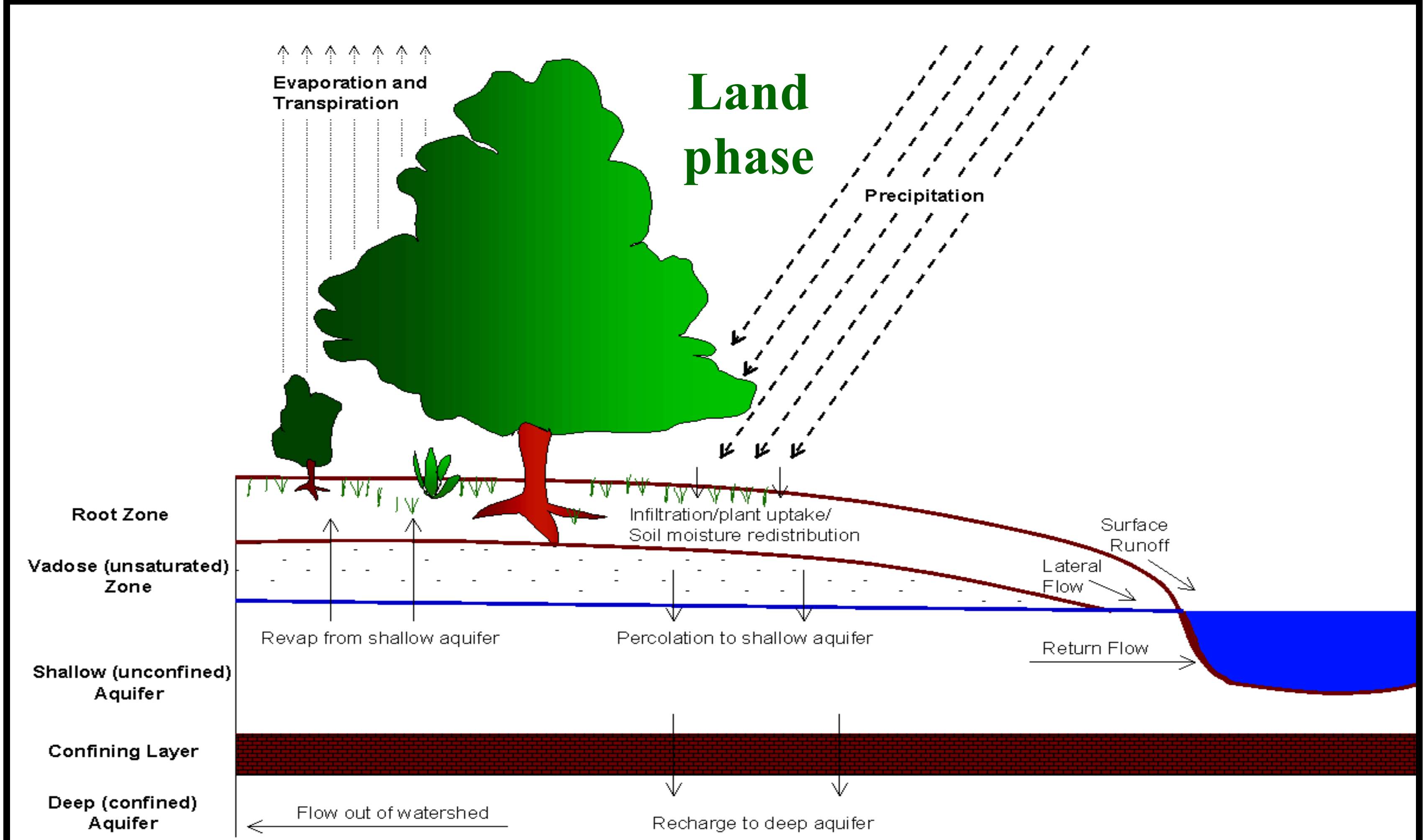
- It is a public domain model actively supported by the USDA Agricultural Research Service at the Grassland, Soil and Water Research Laboratory in Temple, Texas, USA.

- SWAT uses hydrologic response units (HRUs) to describe spatial heterogeneity in terms of land cover, soil type and slope within a watershed.

SWAT cont.

- The model is physically based
  - i.e., it requires specific information
- It is computationally efficient
  - Simulation of very large basins
- SWAT enables to study long-term impacts

Phases of hydrologic cycle simulated by SWAT



Courtesy: SWAT Manual

1. Physical setting of the watershed -- its topography, soils, land cover (comprises vegetation, land use, management practices etc)
2. Input climatic variables, such as precipitation, solar radiation, temperatures, wind speeds, relative humidity, etc.
3. Model simulates the watershed hydrological processes -- how much of the precipitation is intercepted, how much infiltrates, how much runs off, how much transpires, and so forth.
4. Model can also calculate some water-quality variables, i.e., how sediment and nutrients (and some pesticides) move through the system and are modified.
5. Model outputs the volume and rate of outflow of water at the bottom of the watershed, along with the loading of selected water-quality variables
6. HYDROLOGY IS THE MAIN DRIVER HERE!! The model figures out how water moves through the system first, and then calculates how sediment and nutrients are carried along by that water.

Model Input

- GIS input files needed for the SWAT model include
  - the digital elevation model (DEM),
  - land cover, and
  - soil layers
- The DEM can be utilized by ArcSWAT to delineate basin and subbasin boundaries, calculate subbasin average slopes and delineate the stream network.
- The **land use, soil and Slope** layers are used to creat and define Hydrological response units (HRU’s).

Soil physical properties required by the SWAT

- Number of layers in the soil
- Soil hydrologic group (A, B, C, D)
- Maximum rooting depth of soil profile
- Fraction of porosity from which anions are excluded
- Texture of soil layer [optional]
- Depth from soil surface to bottom of layer
- Moist bulk density
- Available water capacity of the soil layer
- Saturated hydraulic conductivity
- Organic carbon content
- Clay content
- Silt content
- Sand content

Metrological Data

- The weather variables for driving the hydrological balance are
  - precipitation,
  - air temperature,
  - solar radiation,
  - wind speed and
  - relative humidity.
- SWAT requires daily meteorological data that can either be read from a measured data set or be generated by a weather generator model.

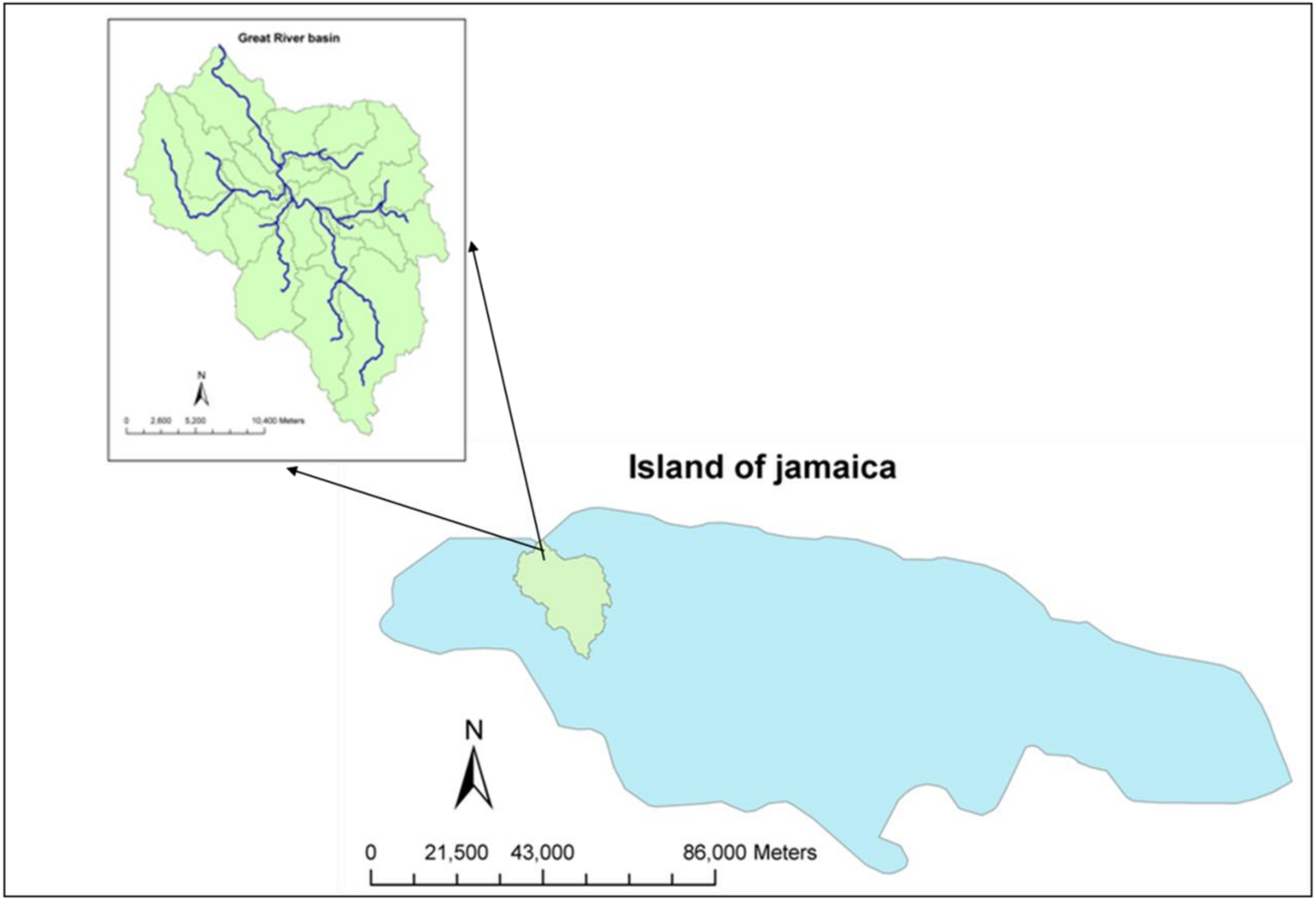
Model Calibration and Evaluation

- **The ability of a watershed model is evaluated through sensitivity analysis, model calibration, and model validation.**

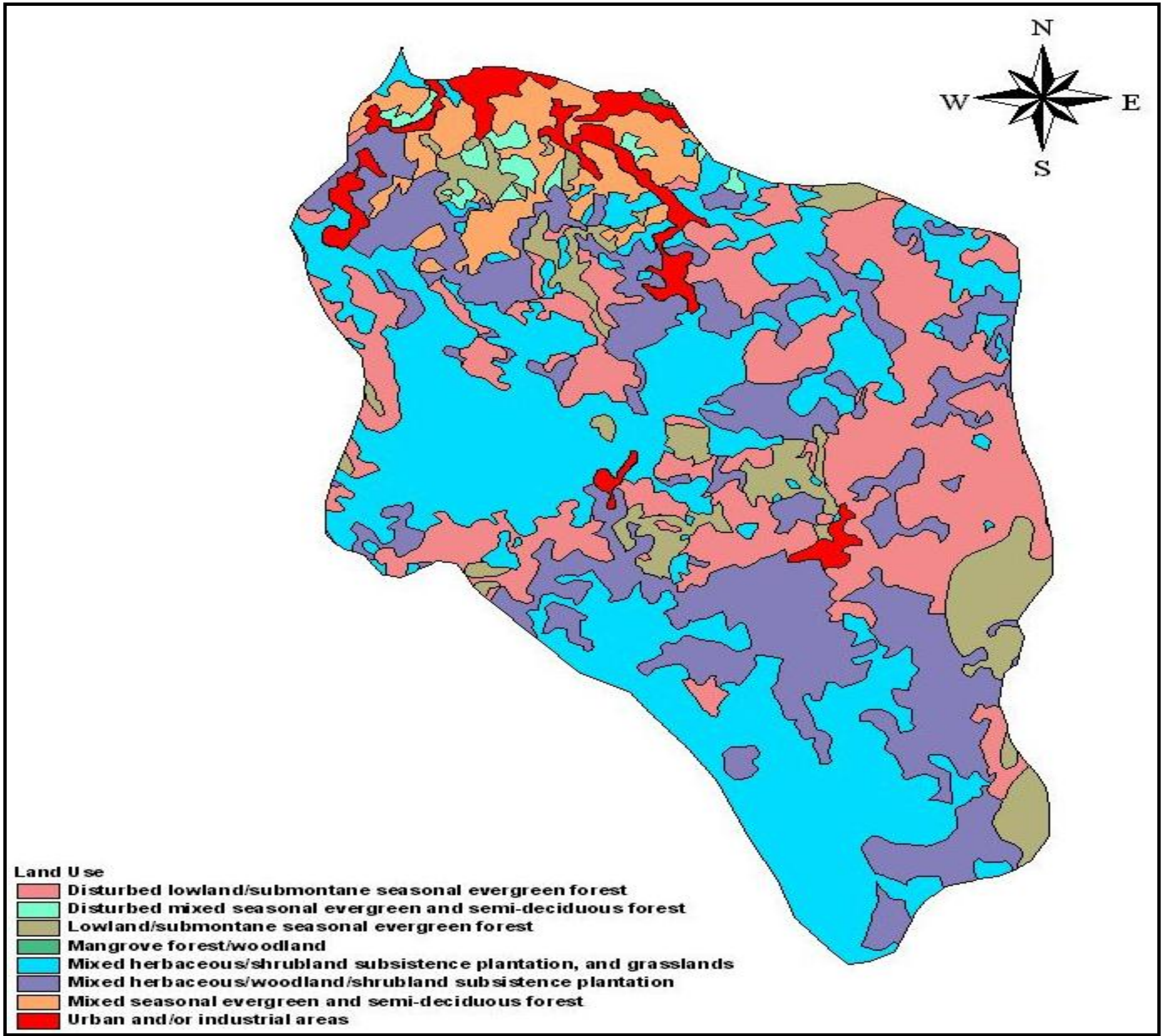
- **For model evaluation we used the goodness of measures such as NSE, R^2,**

MODELING RESULTS

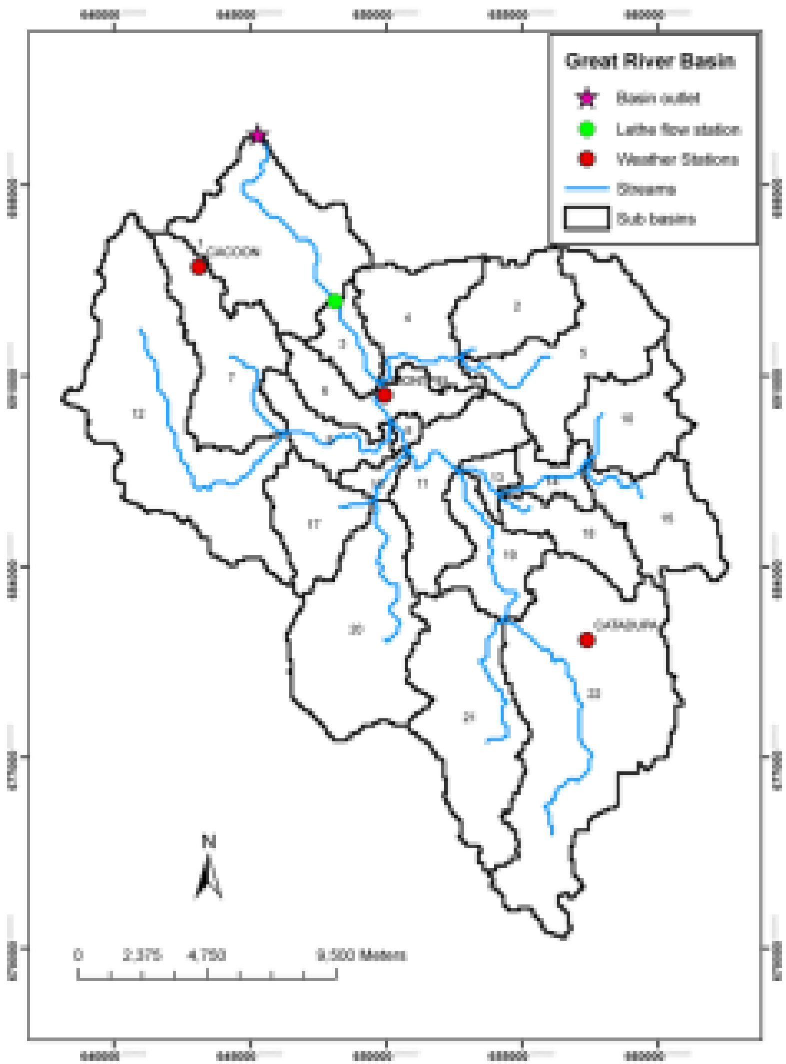
Great River Basin, Jamaica



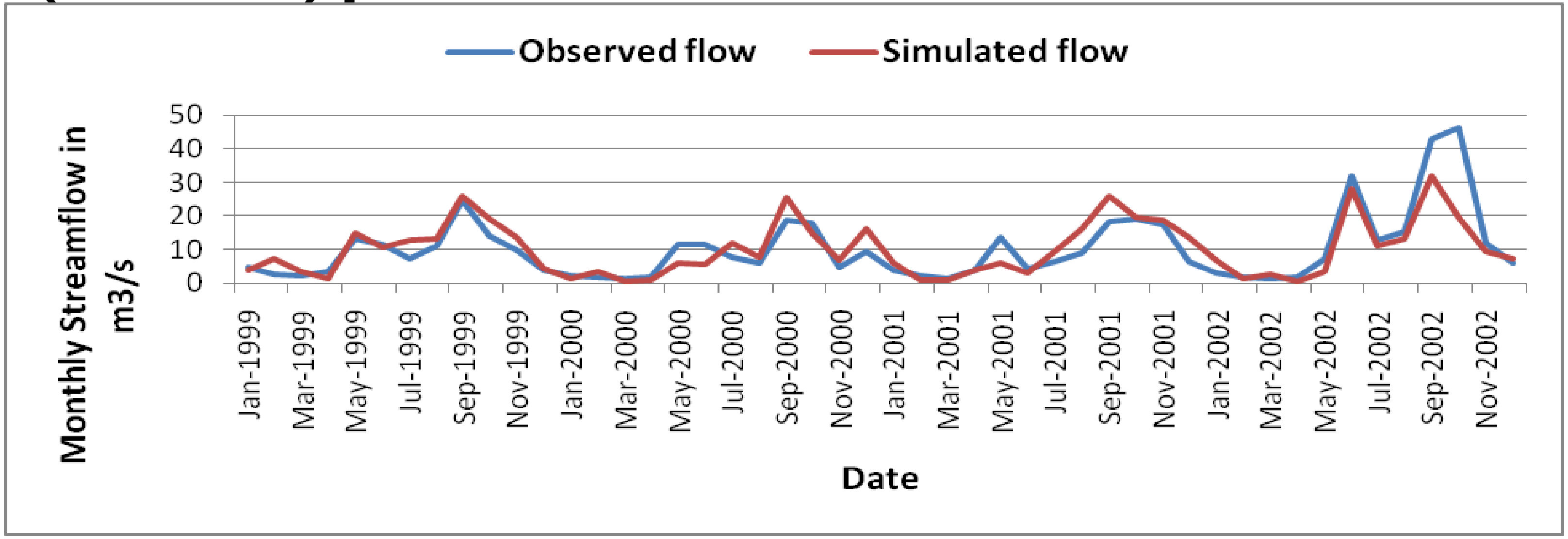
Land use - Great River Basin, Jamaica

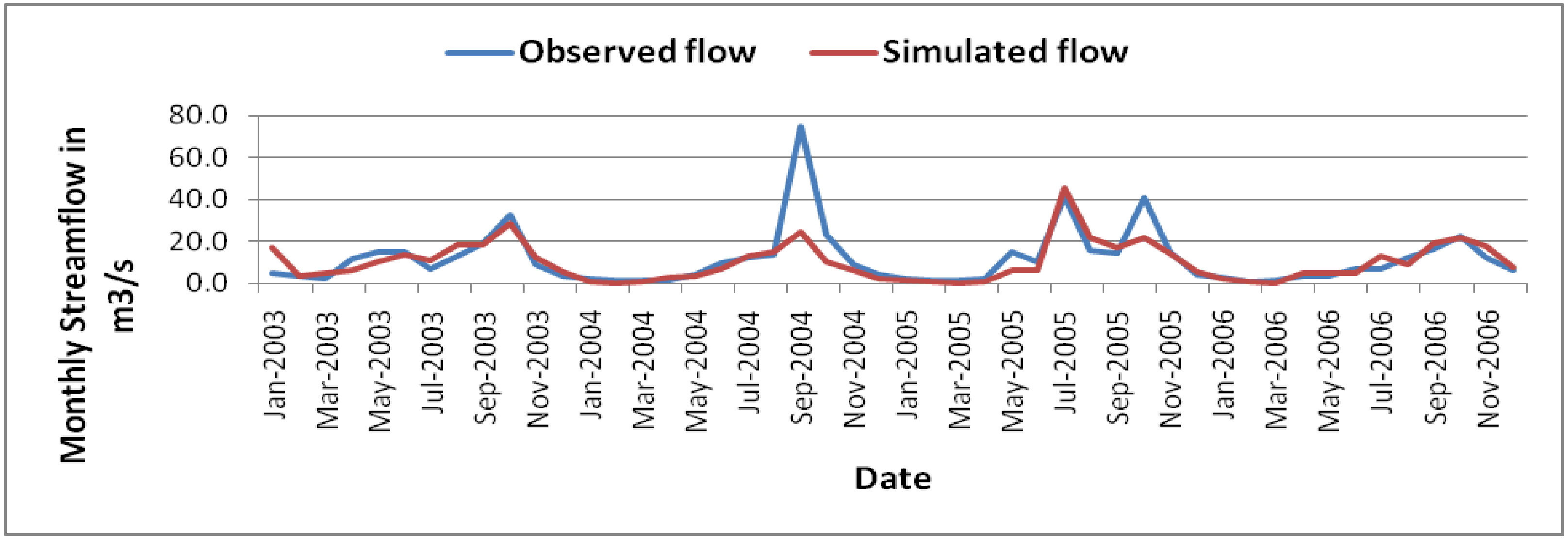


Great River basin - Great River monitoring station (Lethe), weather stations, stream network and sub-basins

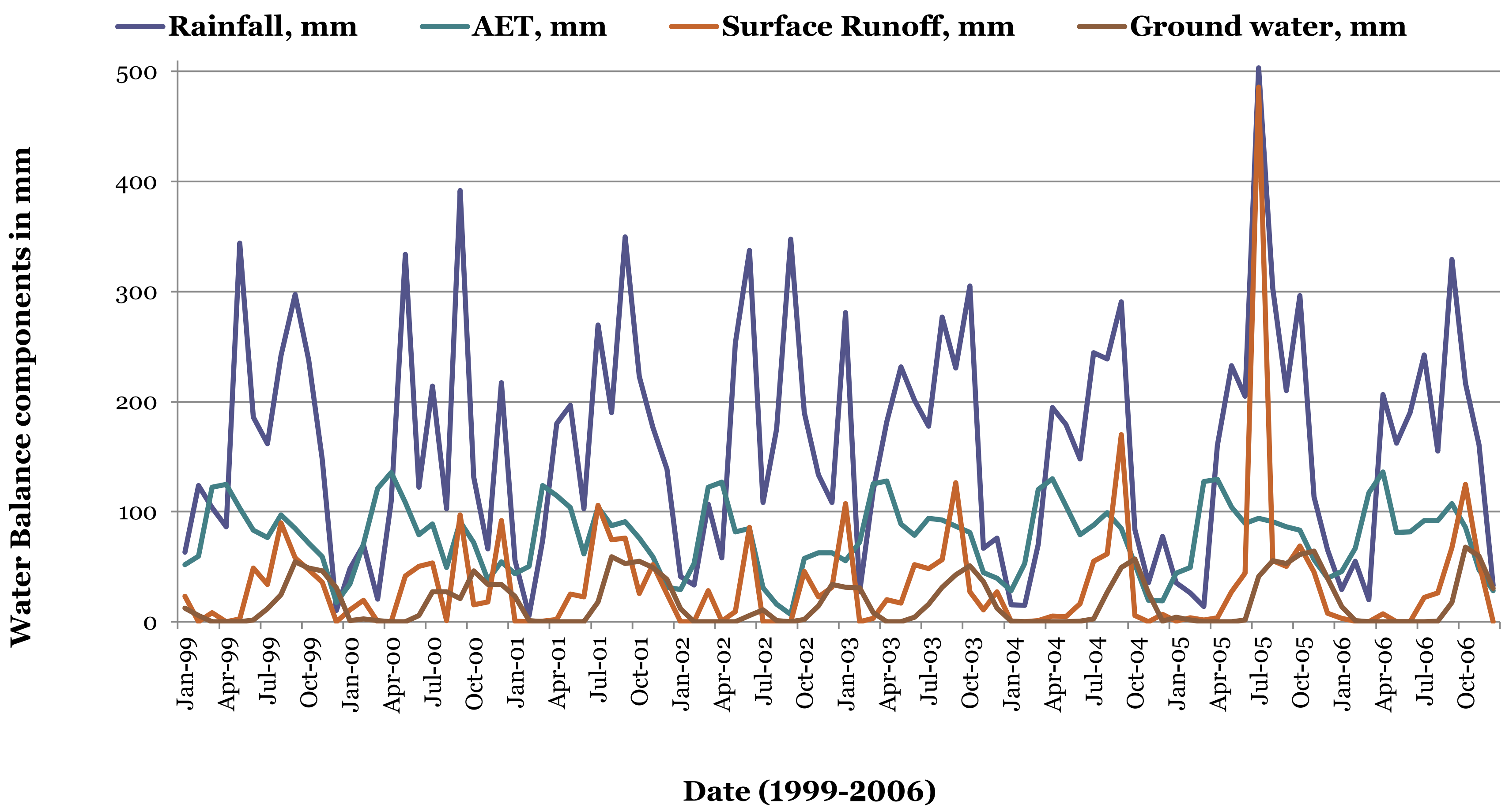


Time series of observed and simulated monthly flow for calibration (top) and validation (bottom) period at Lethe station of Great River

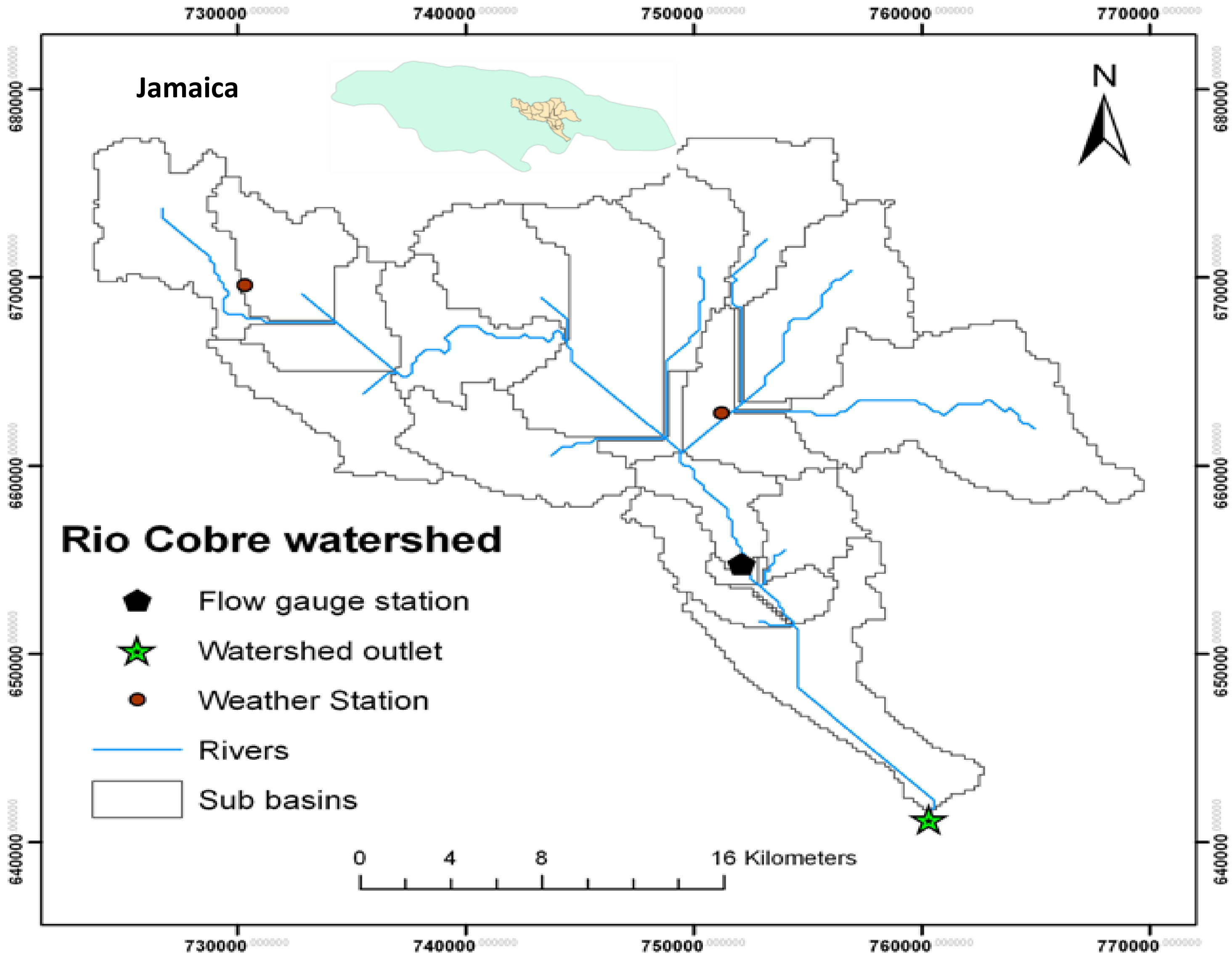




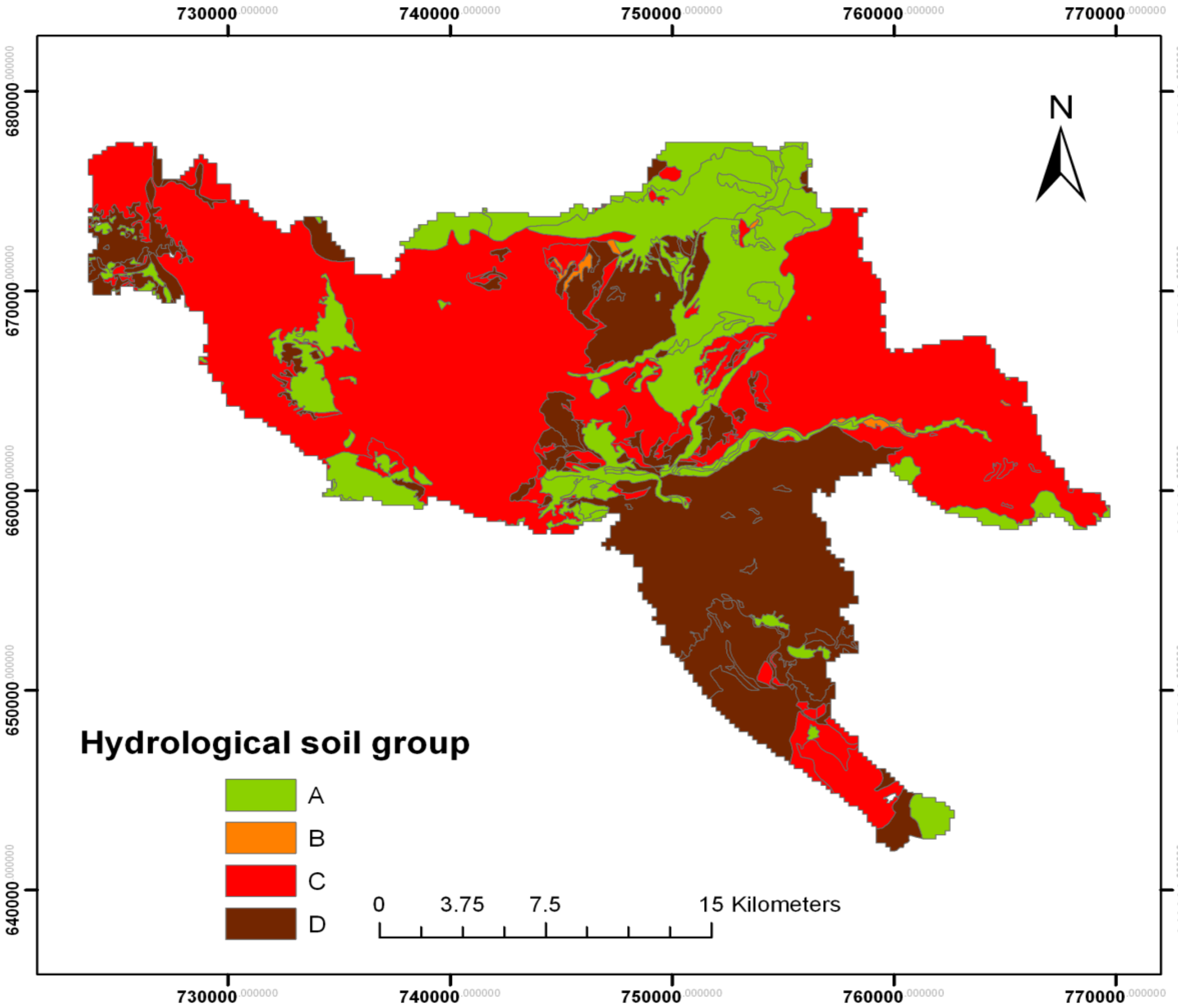
Monthly major water balance components for the great river basin for the period of 1999 to 2006.



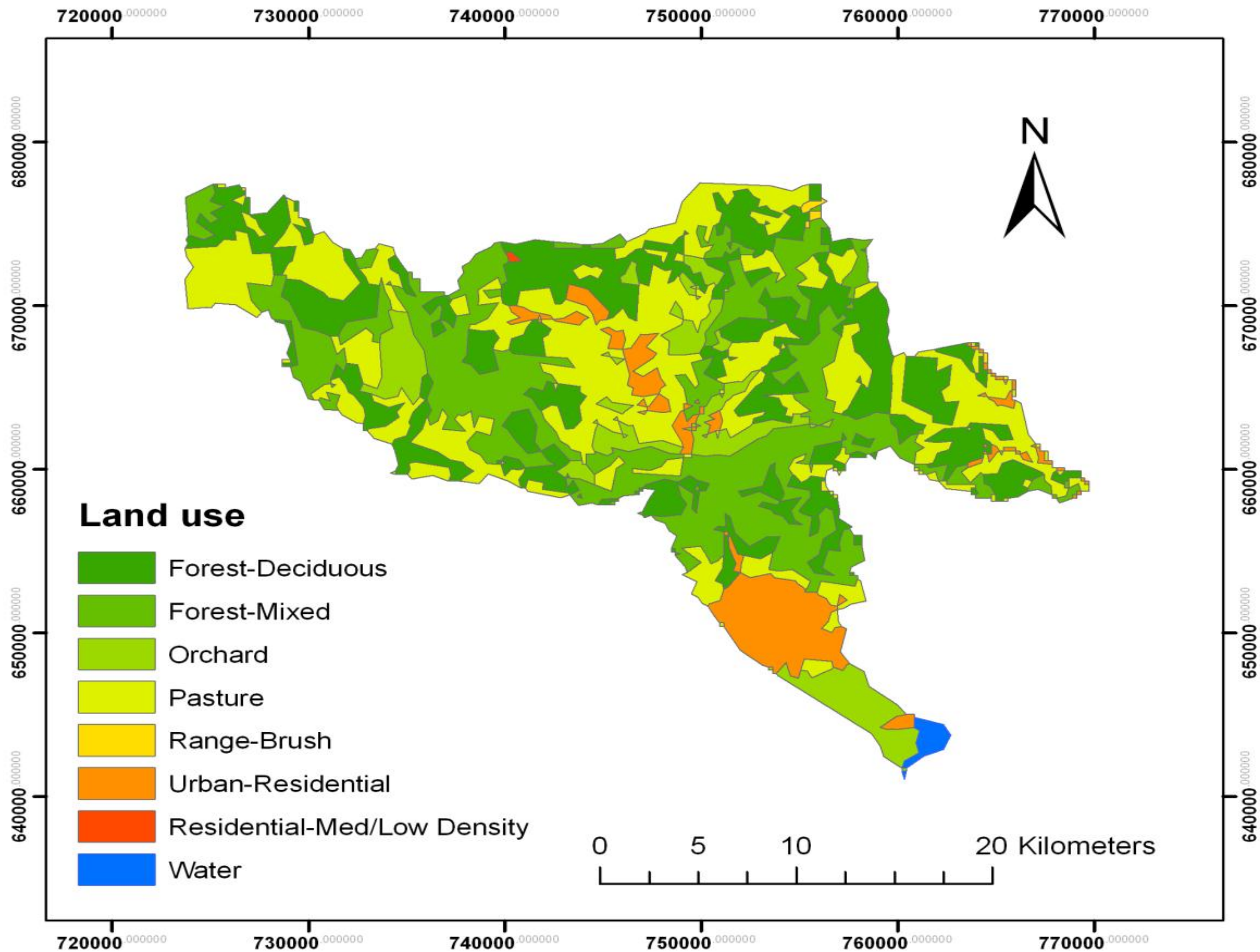
Rio Cobre Watershed, Jamaica

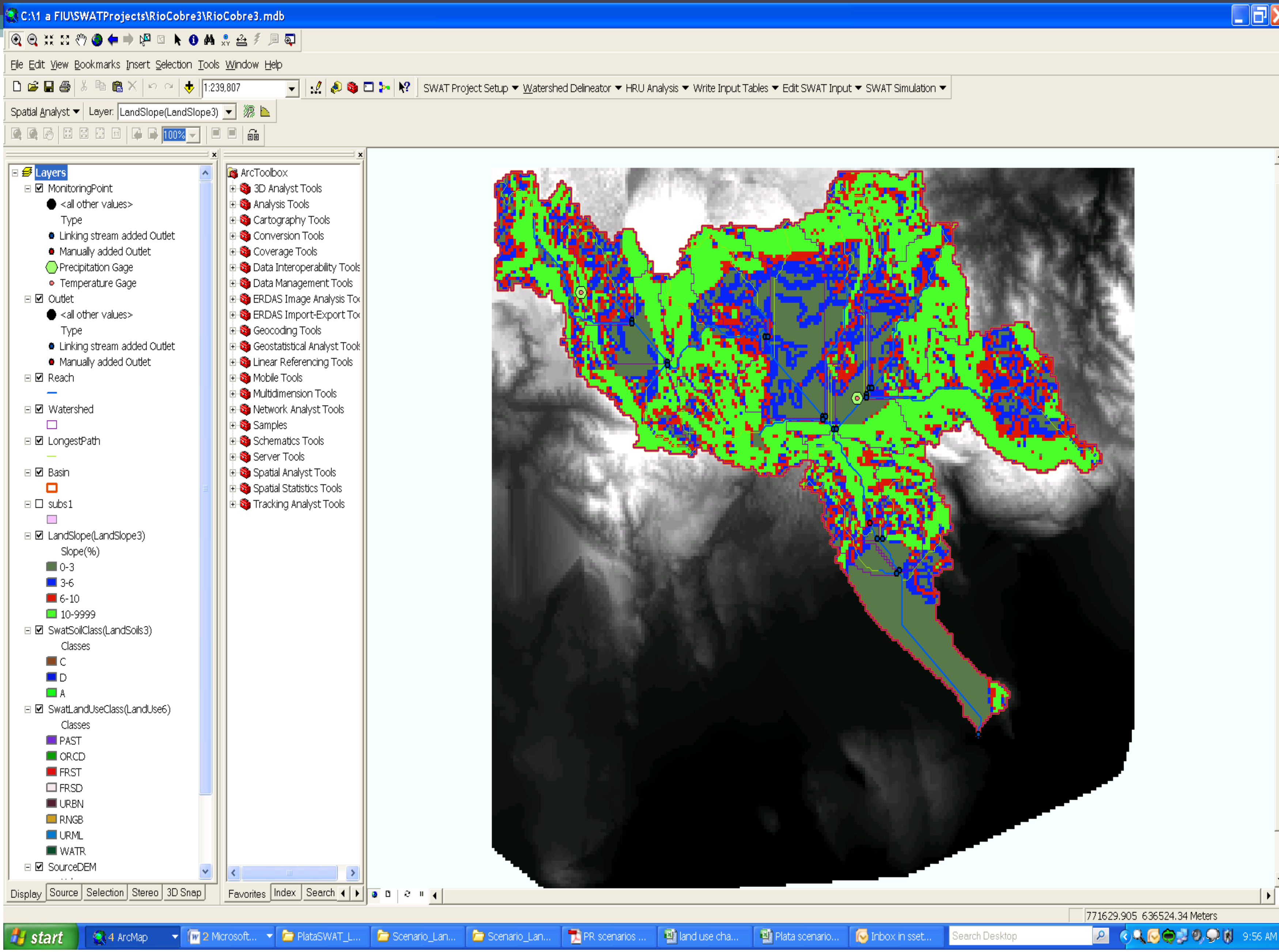


Soil Map - Rio Cobre Watershed, Jamaica



Land use map- Rio Cobre Watershed, Jamaica





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SWAT Project Setup
Watershed Delineator
HRU Analysis
Write Input Tables
Edit SWAT Input
SWAT Simulation
Spatial Analyst
Layer: LandSlope(LandSlope3)
100%
Layers
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Linking stream added Outlet
Manually added Outlet
Precipitation Gage
Temperature Gage
Outlet
<all other values>
Type
Linking stream added Outlet
Manually added Outlet
Reach
Watershed
LongestPath
Basin
subs1
LandSlope(LandSlope3)
Slope(%)
0-3
3-6
6-10
10-9999
SwatSoilClass(LandSoils3)
Classes
C
D
A
SwatLandUseClass(LandUse6)
Classes
PAST
ORCD
FRST
FRSD
URBN
RNGB
URML
WATR
SourceDEM
Display
Source
Selection
Stereo
3D Snap
ArcToolbox
3D Analyst Tools
Analysis Tools
Cartography Tools
Conversion Tools
Coverage Tools
Data Interoperability Tools
Data Management Tools
ERDAS Image Analysis Too
ERDAS Import-Export Too
Geocoding Tools
Geostatistical Analyst Tools
Linear Referencing Tools
Mobile Tools
Multidimension Tools
Network Analyst Tools
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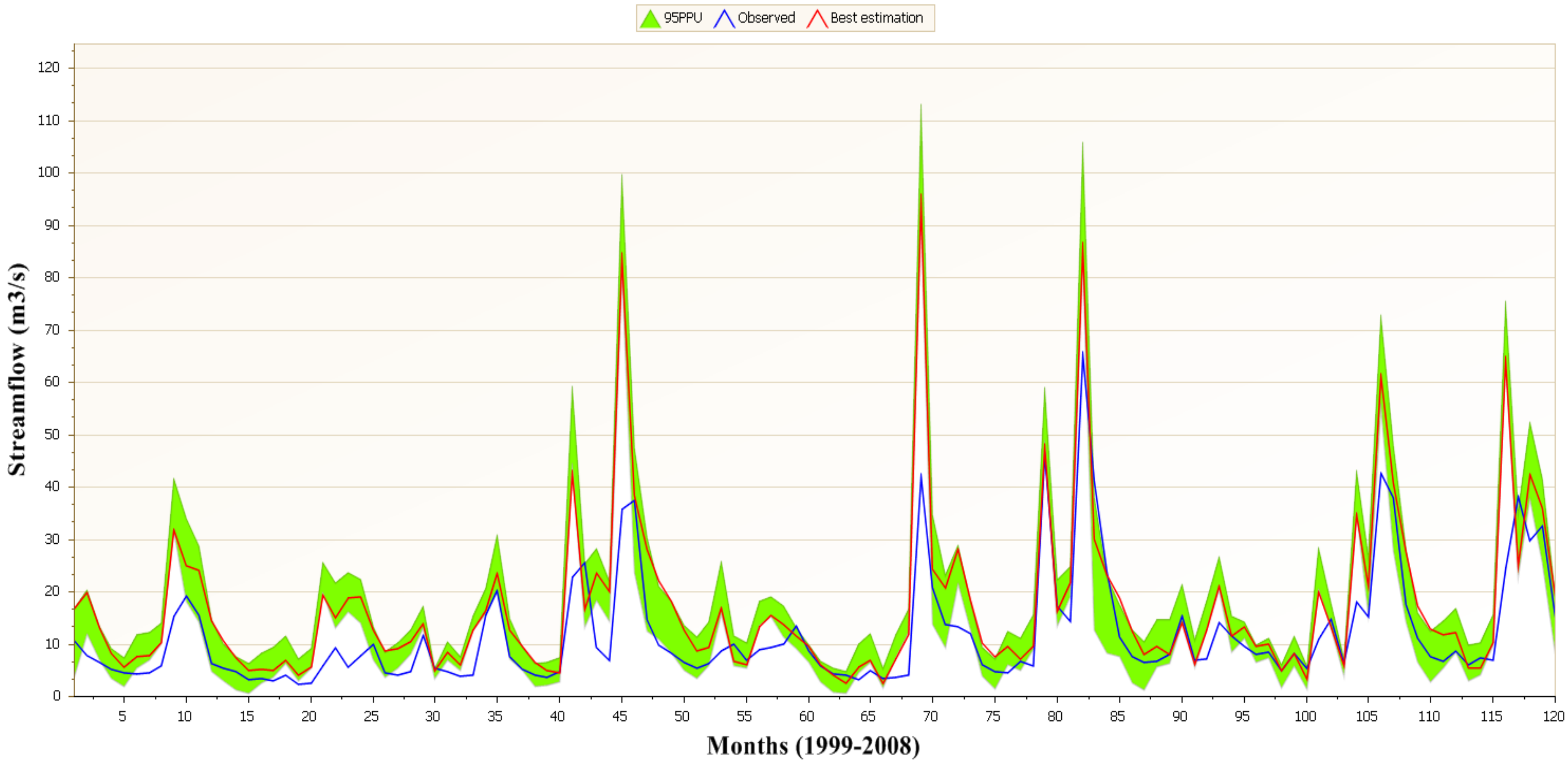
The time-series comparison between measured and simulated monthly flow at Rio Cobre Watershed



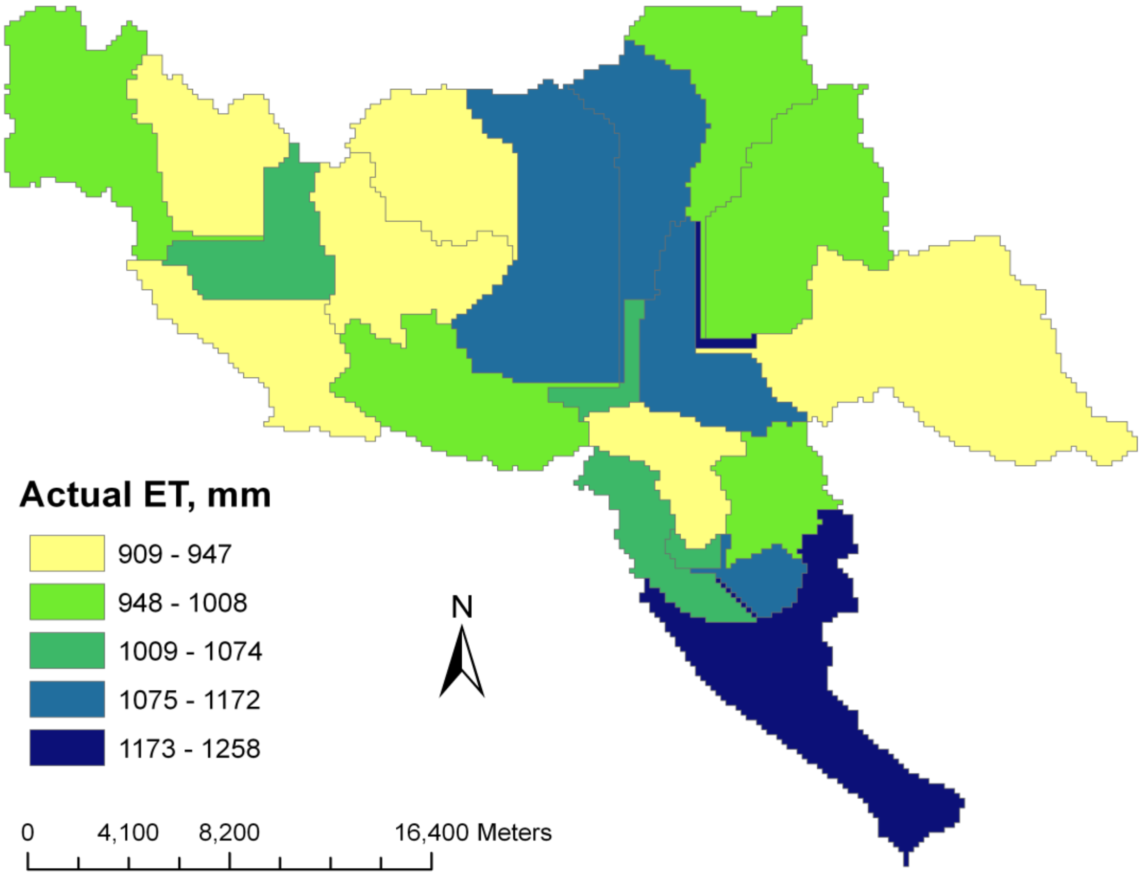
Annual average water balance of the Rio Cobre watershed (1997-2008).

Water balance Component	Annual Average (mm)
Precipitation	1953.0
Surface runoff	102.8
Lateral soil flow	427.7
Groundwater flow (shallow aquifer)	368.8
Revap (shallow aquifer => soil/plants)	9.0
Deep aquifer recharge	19.9
Total aquifer recharge	397.6
Total water yield	899.0
Percolation out of soil	393.5
Actual evapotranspiration	1028.3
Potential evapotranspiration	1579.8

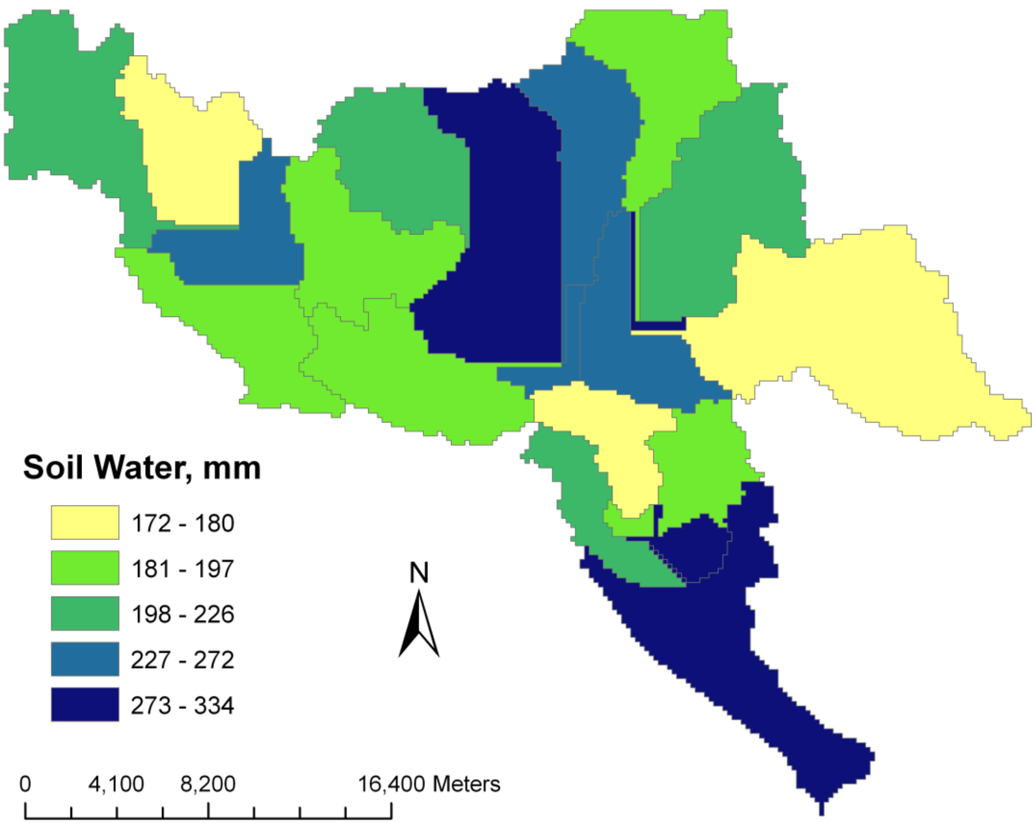
Monthly mean and seasonal water balance components for the Rio Cobre watershed

Seasons/months	Rainfall, mm	Surface runoff, mm	Lateral flow, mm	Water Yield, mm	AET, mm	PET, mm
Average (1997-2008)	154.44	21.68	38.10	79.73	71.50	180.42
Dry (Jan-Mar)	57.72	4.20	11.67	28.24	68.12	180.33
Wet (Aug-Oct)	267.09	52.20	72.15	151.99	77.49	179.79

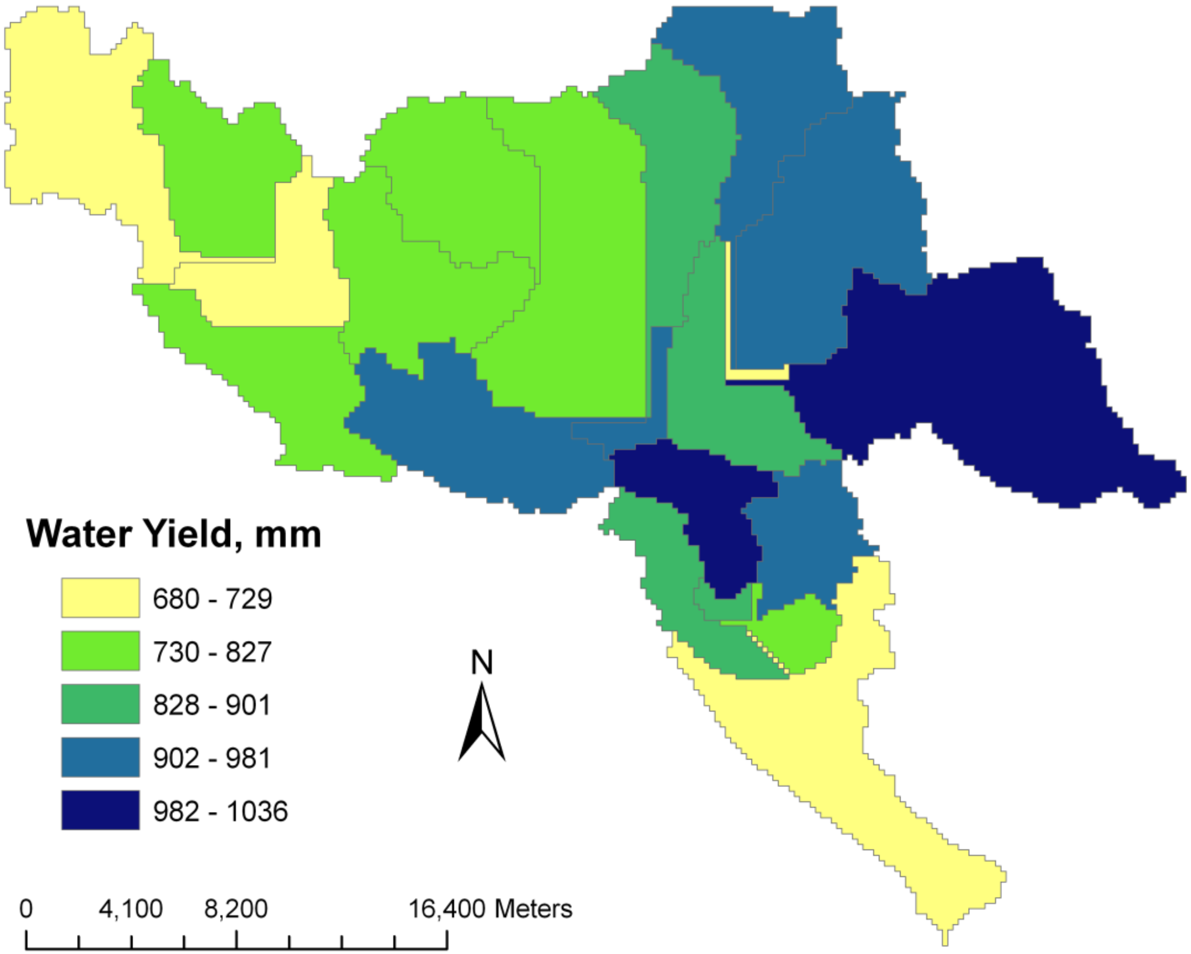
Spatial distribution of actual evapotranspiration in the Rio Cobre Watershed, Jamaica.



Spatial distribution of soil moisture storage in the Rio Cobre Watershed, Jamaica



Spatial distribution of water yield in the Rio Cobre Watershed, Jamaica.



Climate Change

30 August 2010, Gran Melia, Puerto Rico, photo by Shimelis S

Climate Change Impact on Water Resources.

- GCM's are numerical coupled models that represent various earth systems including the atmosphere, oceans, land surface and sea-ice and offer considerable potential for the study of climate change and variability.

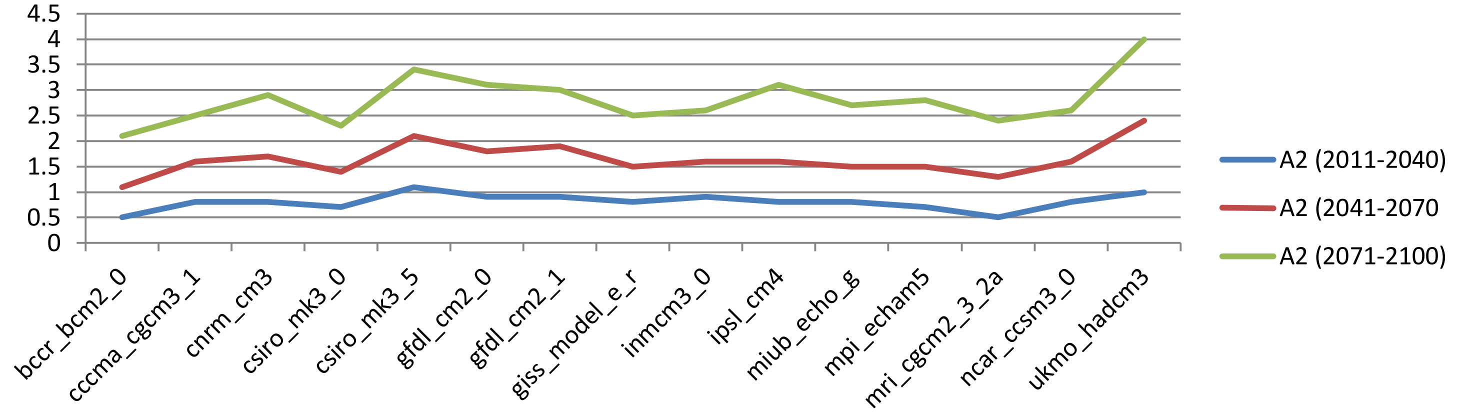
Climate change scenarios

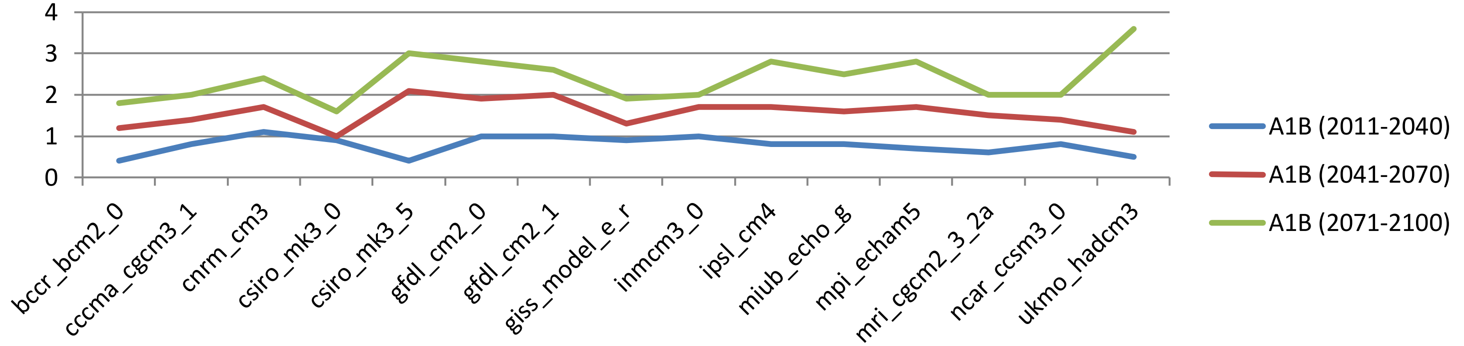
- Scenarios are images of the future, or alternative futures. They are neither predictions nor forecasts.

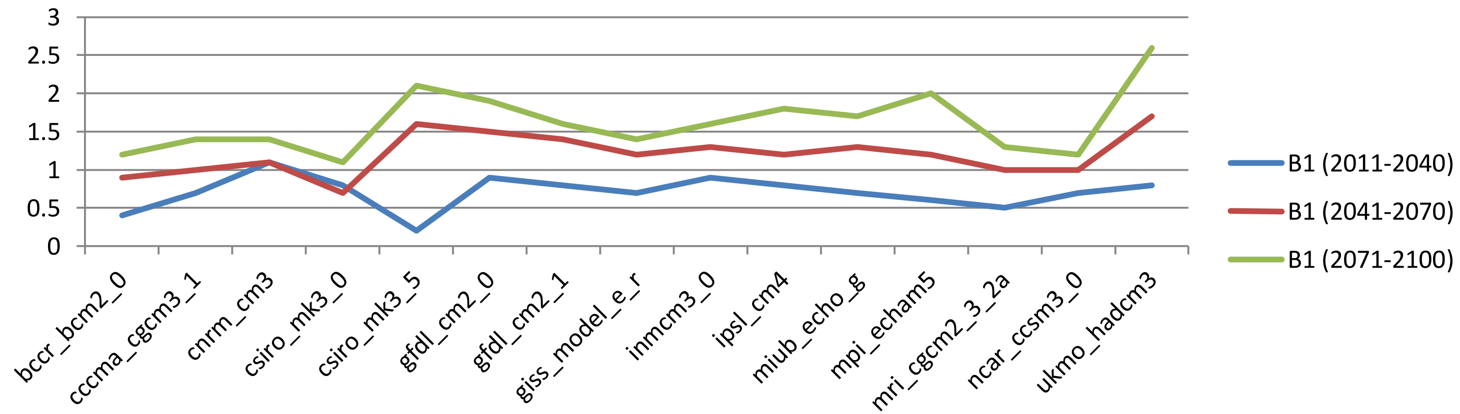
- The Special Report on Emissions Scenarios (**SRES**) are grouped into four scenario families (A1, A2, B1 and B2) that explore alternative development pathways, covering a wide range of demographic, economic and technological driving forces and resulting GHG emissions.

Center	Model	Atmospheric resolution (approx)
NASA Goddard Institute for Space Studies (NASA/GISS), USA,	AOM 4x3	4° x 3°
Goddard Institute for Space Studies (GISS), NASA, USA	GISS_ModelE-H	4 ° x 5°
Canadian Centre for Climate Modelling and Analysis (CCCma)	Coupled Global Climate Model (CGCM3)	
Hadley Centre for Climate Prediction and Research, Met Office United Kingdom	Hadley Centre Global Environmental Model, version 1 (HadGEM1)	1.25° x 1.875°
Bjerknes Centre for Climate Research Norway (BCCR)	Bergen Climate Model (BCM2.0)	2.8°×2.8°
Canadian Center for Climate Modelling and Analysis Canada (CCCMA)	Coupled Global Climate Model (CGCM3)	3.75°× 3.7°
Centre National de Recherches Meteorologiques France(CNRM)	CNRM-CM3	2.8°× 2.8°
Australia's Commonwealth Scientific and Industrial Research Organisation Australia (CSIRO)	CSIRO Mark 3.0	1.9°× 1.9°
Australia's Commonwealth Scientific and Industrial Research Organisation Australia (CSIRO)	CSIRO Mark 3.5	1.9°× 1.9°
Max-Planck-Institut for Meteorology Germany (MPI-M)	ECHAM5/MPI-OM	1.9°× 1.9°
Meteorological Institute of the University of Bonn (Germany), (MIUB)	ECHO-G	3.75°× 3.7°
Geophysical Fluid Dynamics Laboratory USA (GFDL)	CM2.0 - AOGCM	2.5°× 2.0°
Geophysical Fluid Dynamics Laboratory USA (GFDL)	CM2.1 - AOGCM	2.5°× 2.0°
Institute for Numerical Mathematics Russia (INM)	INMCM3.0	5.0°× 4.0°
Institut Pierre Simon Laplace France (IPSL)	IPSL-CM4	3.75°× 2.5°
Meteorological Research Institute Japan (MRI)	MRI-CGCM2.3.2	2.8°× 2.8°
National Centre for Atmospheric Research USA (NCAR)	Parallel Climate Model (PCM)	2.8°× 2.8°
National Centre for Atmospheric Research USA(NCAR)	Community Climate System Model, version 3.0 (CCSM3)	1.4°× 1.4°
Hadley Centre for Climate Prediction and Research, Met Office, United Kingdom - UK Met. Office UK (UKMO)	HadCM3	3.75°× 2.5°

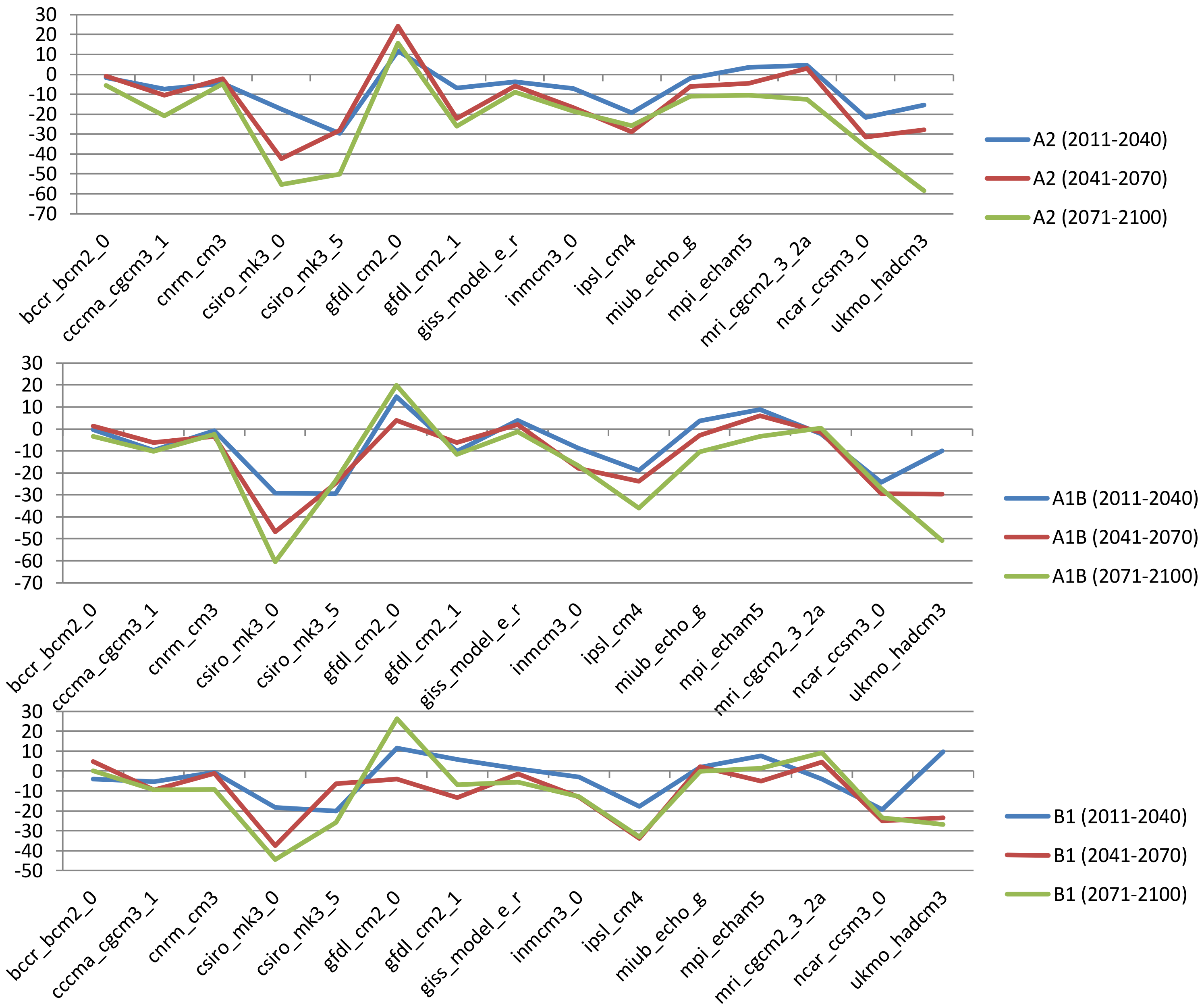
Trends in Climate Change - Temperature



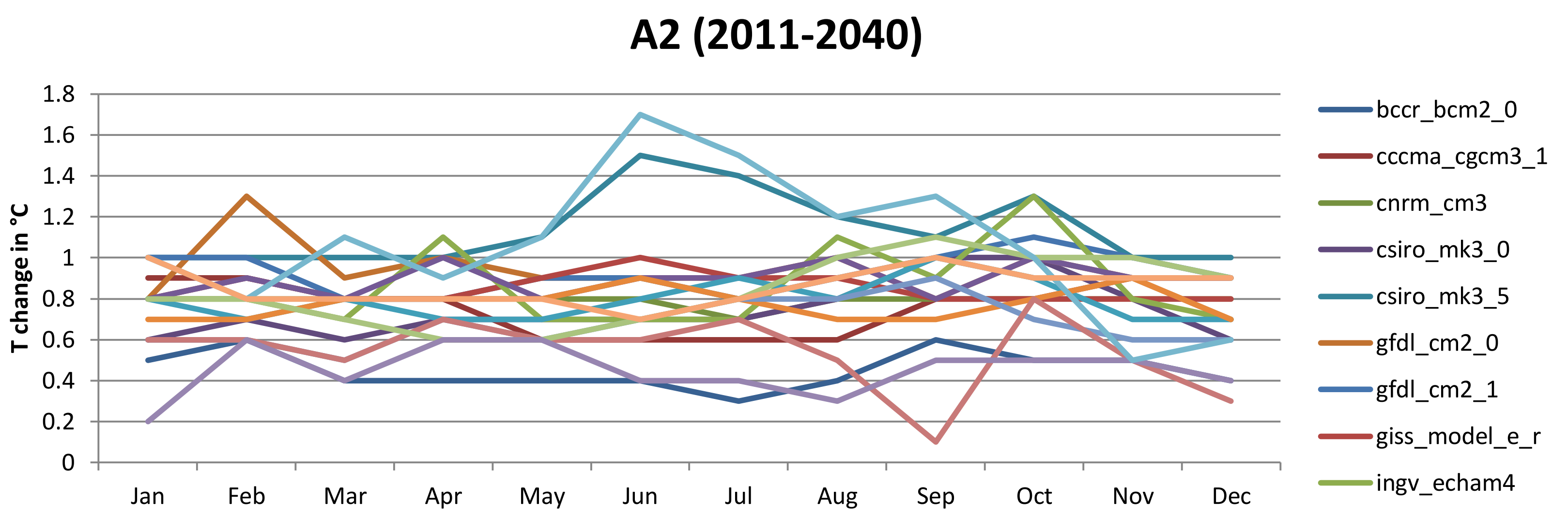


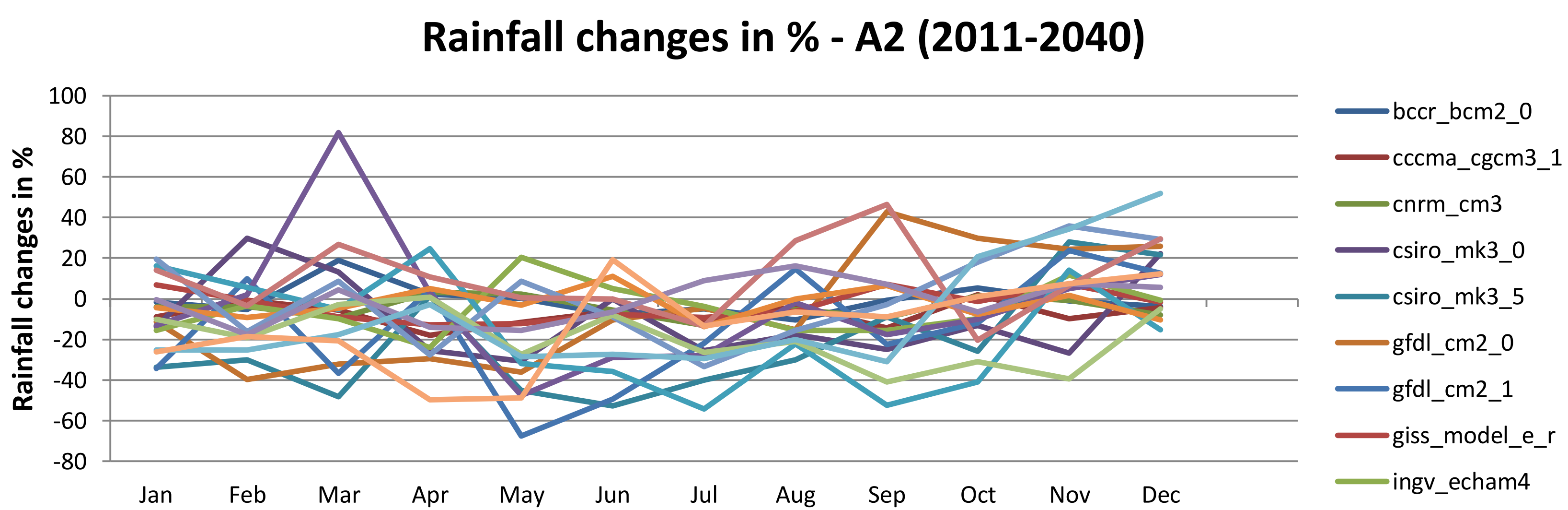


Trends in Climate Change - Rainfall

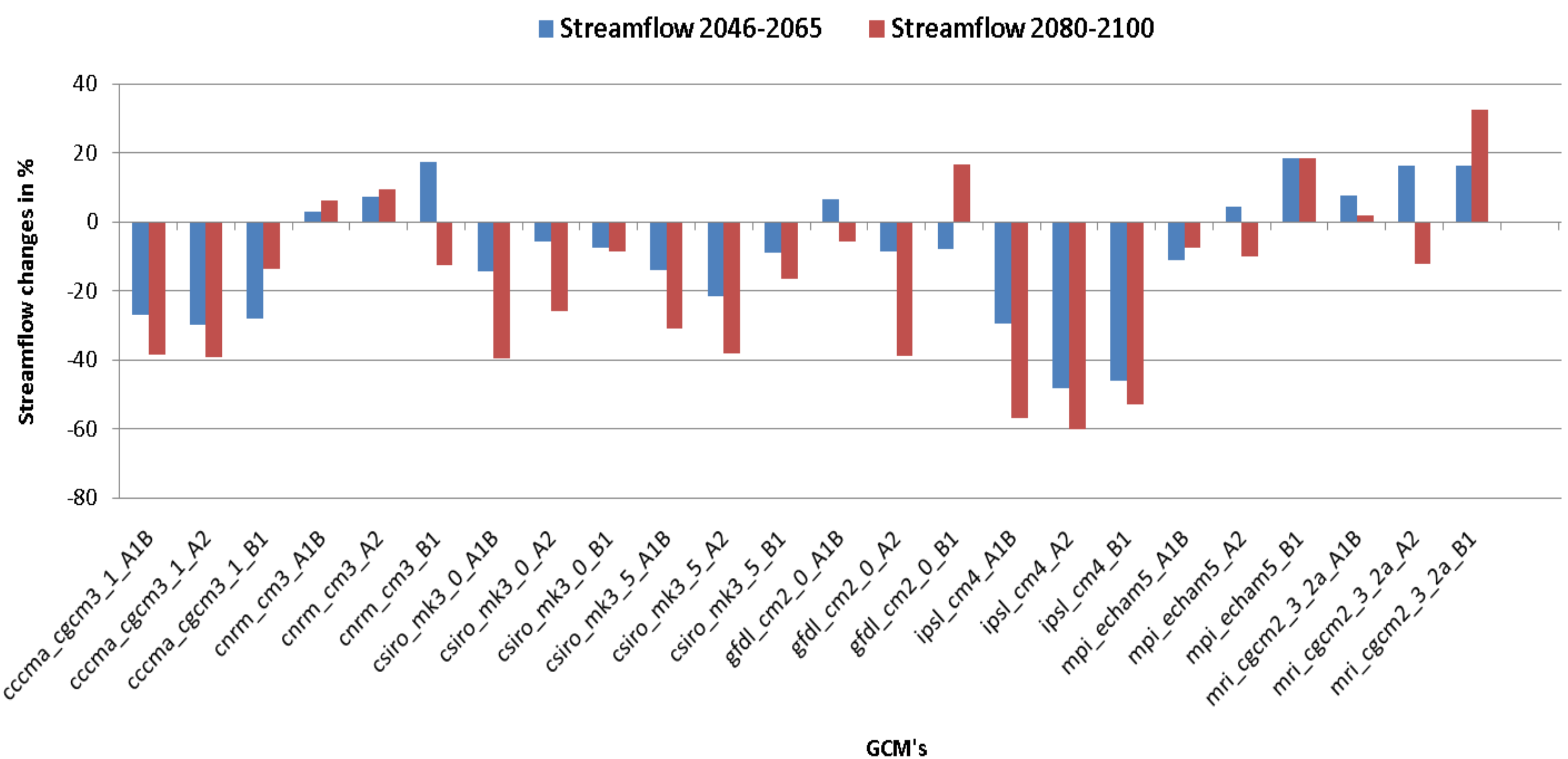


Uncertainties in GCM model outputs

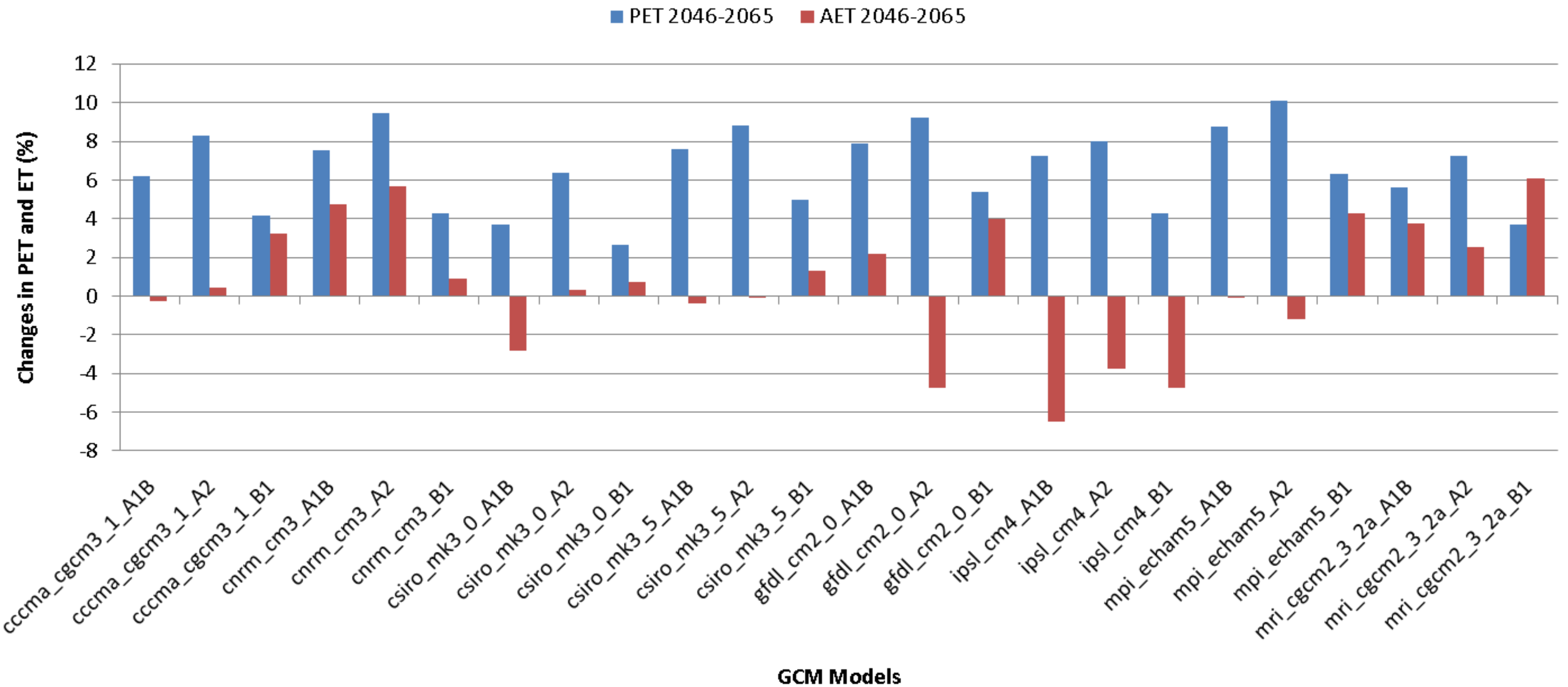




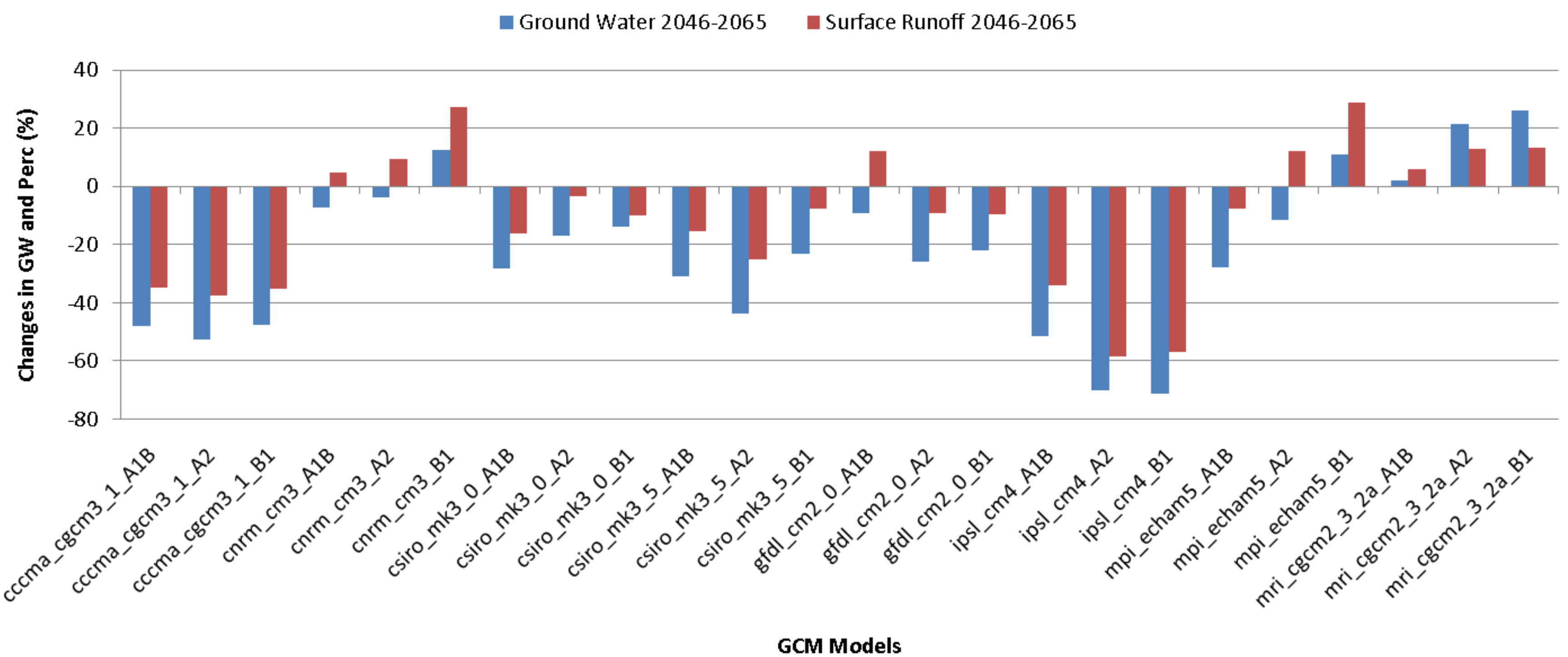
Changes in stream flow due to changes in precipitation and air temperature for the period 2046-2065 and 2080-2100



Changes in potential and actual evapotranspiration (PET and AET) for the 2046-2065



Changes in surface and ground water for 2046-2065 and 2080-2100 periods



Climate Change

- Scenarios for 3 timelines including the Jamaica Vision 2030
  - Near-Term: 2015 Temperature/drought/storm
  - Medium-Term: 2030 Temperature/drought/storm
  - Long-Term: 2050 Temperature/drought/storm
- Based on projections from 4 GCMS

GCM	Resolution	Developer
ECHAM 5/MPI-OM	1.875° x 1.875°	Max Planck Institute for Meteorology (Germany)
HadCM3	2.5° x 3.75°	Hadley Centre (UK)
MRI-CGCM2	2.8° x 2.8°	Meteorological Research Institute (Japan)
PRECIS	50 km	Hadley Centre (UK)

Scenario Background

- ~1800 mm of rain each year; with significant year to year variability (Chen and Taylor, 2008).
- Global temperatures have increased by about 0.74˚C (0.56˚C to 0.92˚C) since the 19th century (IPCC, 2007).
- Warming trend from 1950-2001 with min. temp increasing at a higher rate than max. temp (Alexander et al., 2006).
- Monthly precipitation change over the Caribbean from 21 models (MMD) using A1B from 1980's to 2080's projects decreases in annual precipitation, with few suggesting increases (Chen and Taylor, 2008).

Scenario Background

- How might climate variability and change exacerbate or ameliorate water availability and impact on watershed sustainability?

- Heavy rains often contaminate watersheds by transporting human and animal waste products and other water pollutants to surface and groundwater resources.

- Evidence of water contamination following heavy rains is well documented.

Climate Scenario Basis

Averages of A2 & B2 from Special Report on Emission Scenarios

- A2 storyline and scenario family: a very heterogeneous region with continuously increasing regional population and regionally oriented economic growth that is more fragmented and slower than in other storylines. (highest extreme)

- B2 storyline and scenario family: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development. (but not B1)

Ecosystem-based Adaptations (EbA)

- An approach to address declines in ecosystem health and enable sustainable adaptation to climate change.

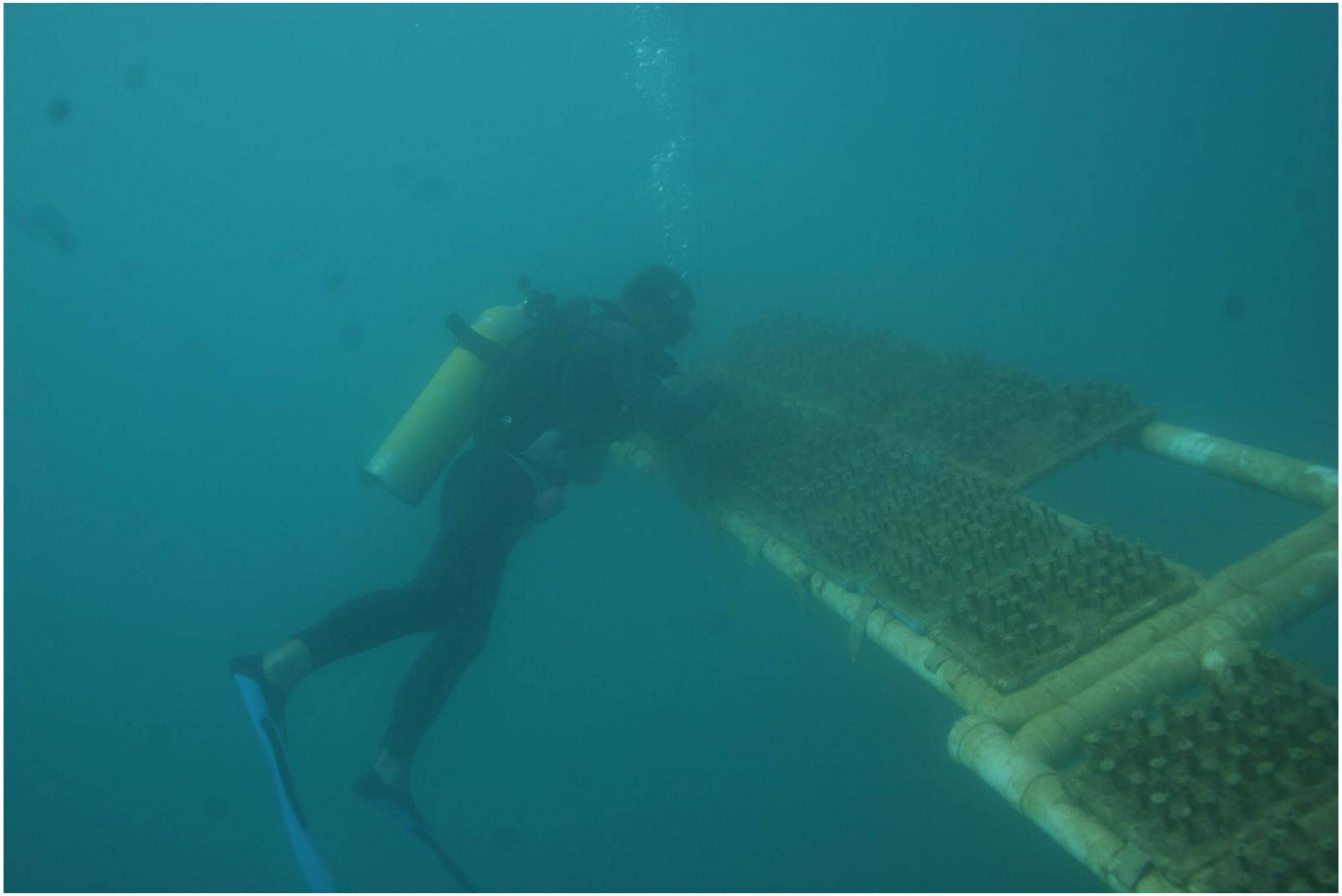
(Source: Hale et al. 2010).

EbA aims to:

1. Preserve and restore natural ecosystems that can provide cost-effective protection against some of the threats that result from climate change.
    - For example, coastal ecosystems like wetlands, mangroves, coral reefs, oyster reefs, and barrier beaches all provide natural shoreline protection from storms and flooding in addition to their many other services (CBD 2009).

Coral Reef rehabilitation (Artificial Reef) to include coral gardening/restoration techniques

Israeli style nubbins



- Nursery raised seedlings being prepared for transplanting →

← Transplanting of seedlings

Red Mangrove Planting Simulation Using PVC Encasements

Site of mangrove restoration

Encasements set for the initial planting

Encasements should be filled with sediment from the site sufficient to set the seedlings at an elevation consistent with the mean-high-water mark.

Seedling is transplanted into the sediment within the encasement.

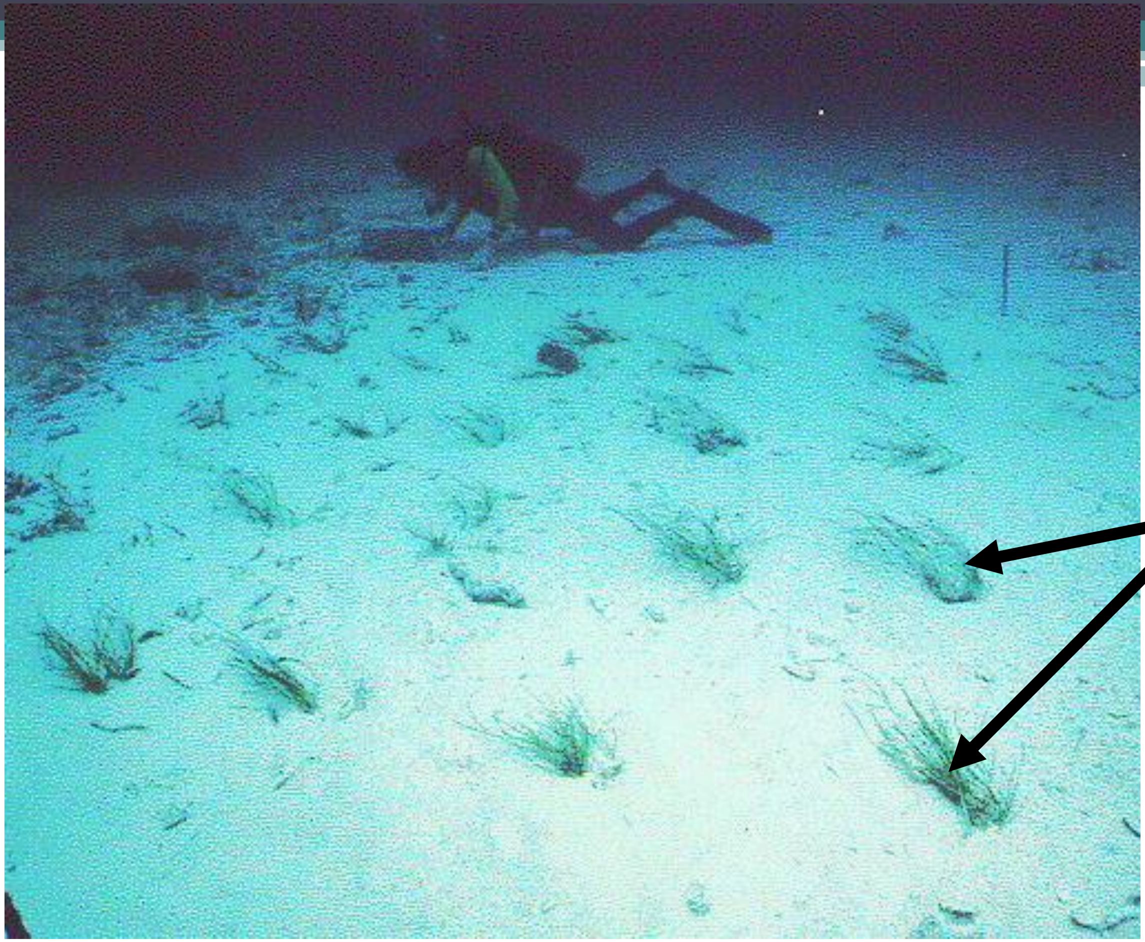
Early development during the first 2 years of growth.

Within 8 – 10 years the aerial roots & foilage are well established.

Re-vegetating bare dune areas with native dune species.

- Selection of plant species is of paramount importance when restoring vegetation in bare areas of existing dunes.

- The combination of sand fencing and re-vegetation offers the greatest possibility for restoration success.

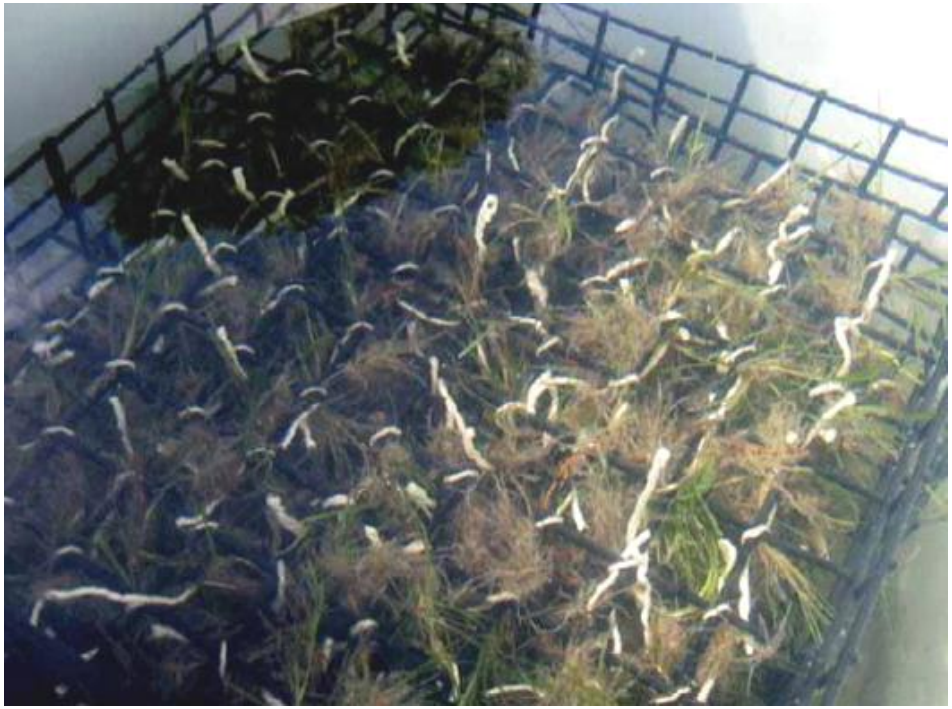


Seagrass transplanted using the staple method

- The stapled plants are inserted into the sediment so that the roots and rhizomes are buried nearly parallel to the sediment surface.

THE FRAME METHOD

- 2 shoots of seagrass are attached with biodegradable ties to rubber-coated wire frames.
- Pairs of plants are tied to each frame 5 cm apart.



Seagrass transplants attached to the frame.

2. Conserve biodiversity and make ecosystems more resistant and resilient in the face of climate change so that they can continue to provide the full suite of natural services.

- Particularly important for sustaining natural resources (e.g., fish stocks, fuel, clean water) on which vulnerable communities depend for their subsistence and livelihoods.

Guiding principles for developing effective ecosystem-based adaptation strategies include:

- ***Use nature's infrastructure first***
  *Natural ecosystems provide valuable protection a*nd other services for free, and we should take advantage of them. Maintaining and restoring "nature's infrastructure" should be a priority for reducing vulnerability to climate change impacts.

  As the effects of climate change become more severe, there will be, however, situations where engineering and hard structures may be necessary, such structures need be built in sync with nature and its changing patterns.

- ***Healthy ecosystems will be more resilient to climate changes.***

- **Effective integrated coastal management programs**

Billana Cicin Sain 2009 Oceans and Climate Change.

Guiding principles cont'd

- ***Involve diverse stakeholders in strategy development.***

Example: In Belize, through a participatory research effort and consultations involving government, fishers and NGOs, fisheries legislation has been used to support management of the commercially valuable Nassau Grouper, which is vulnerable to both overfishing and climate change.

- ***A regional approach is needed.***

  Efforts need to be made to design adaptation measures that are not limited by these boundaries. Adaptation measures for a resource shared by multiple states can succeed only through integration of a regional or transboundary dimension.

- ***Adaptive management is imperative.***

  Ecosystem-based adaptation strategies should include monitoring so that management actions can be quickly adjusted in response to changing conditions. Management objectives may need to be revised and geographic priorities may need to be reconsidered to protect natural climate change "refugia", or to triage places suffering severe climate change impacts.

Multiple Benefits of EbA

Ecosystem-based adaptation strategies provide a cost effective way to reduce vulnerability to climate change and have multiple benefits to people and local communities.

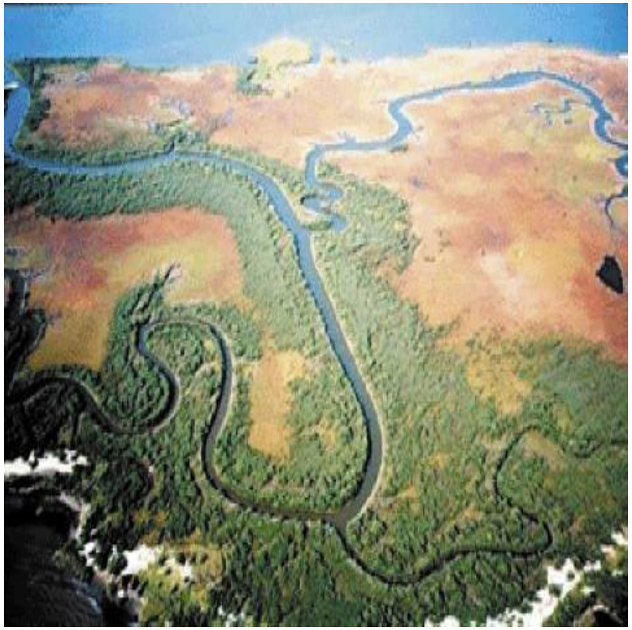
Some of these benefits in the marine and coastal environment are:

1. ***Shoreline protection.***
    - Coastal wetlands, in particular mangroves provide a coastal protection function. About 1,160 ha of the Nariva Wetlands in Trinidad and Tobago was targeted for restoration. The restoration of the wetlands will result in additional environmental benefits, including reduction of GHG emissions and the conservation of endemic species in the area.

Benefits cont'd

2. ***Sustenance of local livelihoods.***
3. ***Re-enforce mitigation efforts***

   Coastal wetlands, including marshes and mangroves, sequester substantial amounts of carbon (Pritchard, 2009), so also play a crucial and incremental role in reducing the pace and scale of climate change itself.




Thank You
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