From Field to Basin-Scales
Tools to Manage Land and Water For Communities
Example from the River Zambezi

Erick Fernandes
Adviser, Agriculture and Rural Development,
The World Bank, Washington, DC.

Presentation Outline

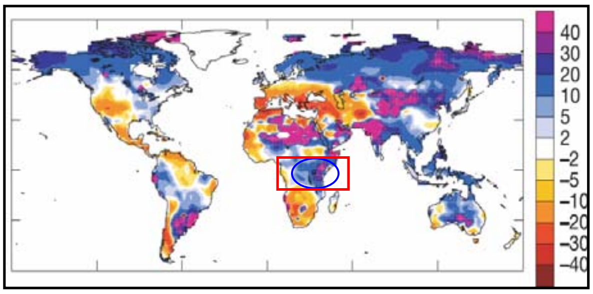
- The Challenges to Rural Communities
  - Land, Water, Climate Variability & Change
- Adaptive Management—Case Study
  - Assess Problem
  - Design
  - Implement
  - Monitor
  - Evaluate
  - Adjust
- Summary and Reflections

Zambezi delta, Mozambique

Climate Change

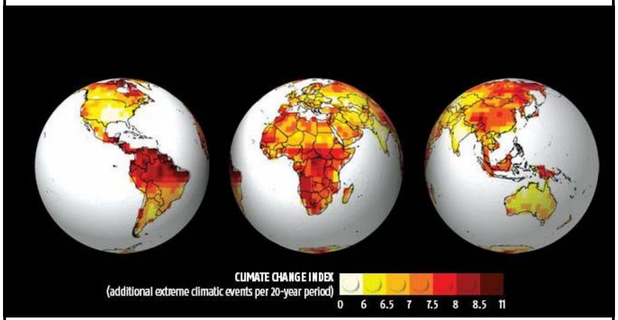
- Climate change presents an urgent challenge to the well-being of all countries...
- ….and particularly to the poorest countries and the poorest people (especially women and children) in vulnerable regions.
- Addressing climate change is central to the development and poverty reduction agenda.
- Tackling 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 <u>addition</u> to ODA]

Climate Change - % change in runoff by 2050

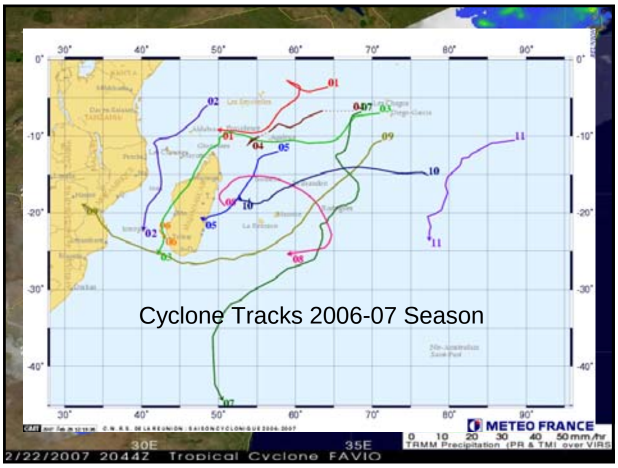


- ✓ Many of the major food-producing regions of the world are projected to become significantly drier
- ✓ Globally there will be more precipitation
- ✓ Higher temperatures will tend to reduce run off
- ✓ A few important areas drier (Mediterranean, southern South America, northern Brazil, west and south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

The Challenges Ahead



Projected Change in Frequency of Extreme Events in next 20 years



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:
  - Flooding, storms, etc. results in excess water, whereas drought results in water deficits.
  - Unpredictable food and forage crop, livestock, and tree yields
  - Displacement of communities, loss of livelihood and assets
- Management needs—Improved water and land management
  - Consider/value "buffer zones" that can buffer excess water and/or store water for times of drought—watershed/basin scale.
  - Other "value-added" tools and methodologies, at field scale.

Flooding in the Zambezi

- **Govt. of Mozambique:**
  The Govt. of Mozambique (GoM) requested WB assistance to help reduce poverty in the impoverished areas of the Zambezi River basin.
- **Goal:**
  Improve the livelihood of communities along the Zambezi river.
- **Assessment:**
  - High potential for agriculture, forestry, fisheries
  - Potential constrained by the unpredictable hydrological flow of the Zambezi
  - Zambezi has poor infrastructure, low institutional capacity, increasing climate-related risk.
- **Economic Potential**
  - Potentially high agriculture, mining, tourism and global environmental benefits (carbon, biodiversity) but lack of reliable data.
- **Development—a way forward.**
  Enhance local capacity to apply state of the art science and to learn by doing to strengthen GOM's capacity for national and transboundary assessments, dialogue, and negotiations.

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[illegible]
Inflation (ann. average, %)	0.6	2.0	6.6	5.0	9.5	5[illegible]
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

-23%
+44%

Source: Staff estimates, IMF and Government of Mozambique

Project Needs & Desired Outcomes

- ✓ Document and conserve traditional knowledge baselines and assets.
- ✓ Government national databases on Settlements, Land-Cover and Land-Use Change (LCLUC) dynamics, biodiversity, soils, agriculture potential, hydrology, climate. → Dynamic Information Framework [DIF]
- ✓ Tools to assess and manage risks
- ✓ Enhance agricultural and natural resource management capacity through training
- ✓ Develop national capacity to model the interactive impacts of climate change and prioritize adaptation & mitigation measures.



Zambezi Floods, Jan-Feb, 2007

Project Goals

1. Work with Govt. of Mozambique (GOM)
   - Assess and integrate climate change risk in current development plans/investments
   - Strengthen National Action Plans on Climate Adaptation and Mitigation Activities
2. Develop outreach projects with Stakeholders that will help them meet their needs
3. Empower small land holders to plan for sustained ecosystems that provide valuable services (carbon sequestration, eco-hydrology, agro-biodiversity, native biodiversity)
   - Reduce
     - Land degradation, Deforestation, Loss of riparian zones
     - Loss of above- and below- ground biodiversity

Using Adaptive Management

- Applying Science for Society
- Adaptive Management (Conservation)

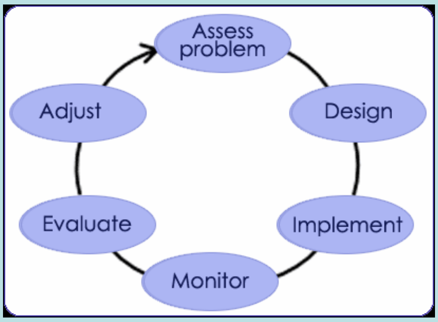
•Adaptive management incorporates research into [conservation] action.

•It requires an explicitly experimental — or "scientific" — approach to managing [conservation] projects.

•Specifically, it is the integration of design, management, and monitoring to systematically test assumptions in order to adapt and learn.

Source: http://fosonline.org/resources/Publications/AdapManHTML/Adman_1.html#intro

Adaptive Management



http://www.cmar.csiro.au/research/mse/images/adaptive_cycle.gif

Adaptive Management

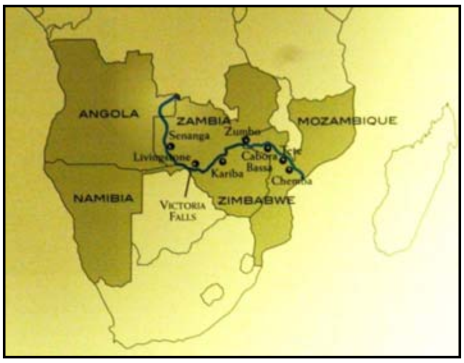
- [Zambezi River Case Study]
  - Assess Problem
  - Design
  - Implement
  - Monitor
  - Evaluate
  - Adjust

http://www.cmar.csiro.au/research/mse/images/adaptive_cycle.gif

Assess the Problem

- How does the Zambezi watershed/basin function?
- What information and models will help to inform GoM about transboundary water and other national environmental issues?
- How can the output from the data-collection and research efforts be transformed into applied information technologies (land, biodiversity, and water management tools) with local, national, regional, and global relevance?

Market-led Smallholder Development in the Zambezi Valley of Mozambique but with 'Upstream-Downstream' Focus



Project Hypothesis

“Evaluating the hydrologic, landuse, soil conditions, and weather patterns of the Zambezi River Basin will help to predict the characteristics of the basin, ultimately creating a risk reduction plan that communities, and developers can use to reduce risk, improve resource management and improve livelihoods.”

Biophysical Factors in Model (associated tools)

–Precipitation (GIS, stream monitoring, dam assessment)

–Soil moisture (soil testing, irrigation assessment)

–Stream flows (stream gauges)

Adaptive Management

- [Zambezi River Case Study]
  - Assess Problem
  - Design
    - Identify Tools
    - Identify Stakeholders
    - Allocate Roles
  - Implement
  - Monitor
  - Evaluate
  - Adjust

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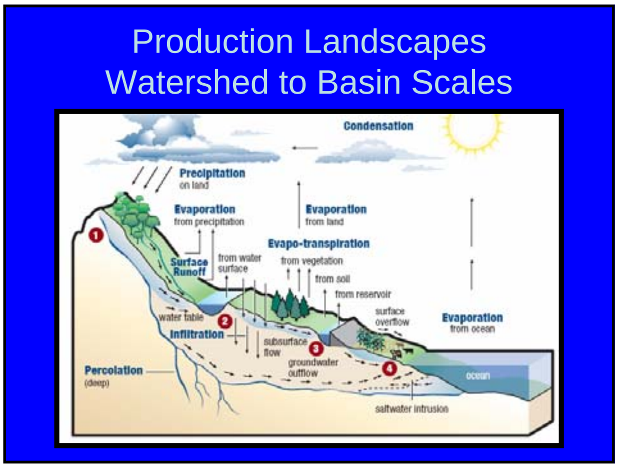
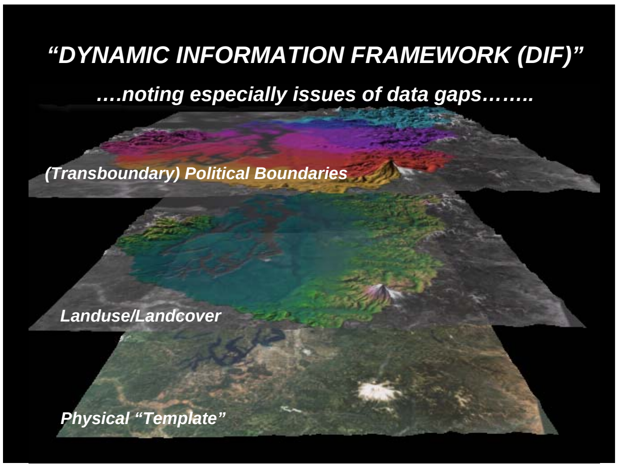
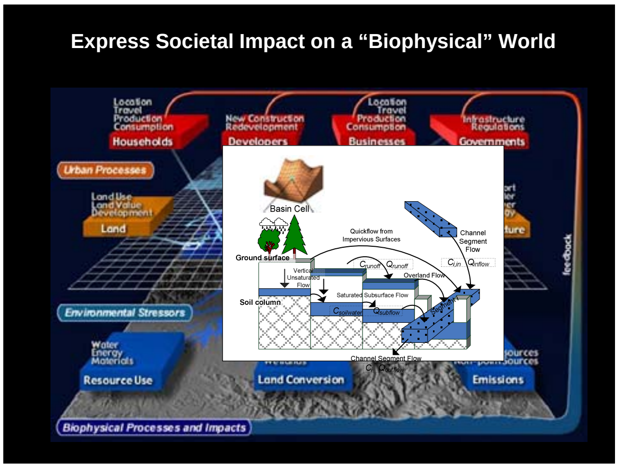
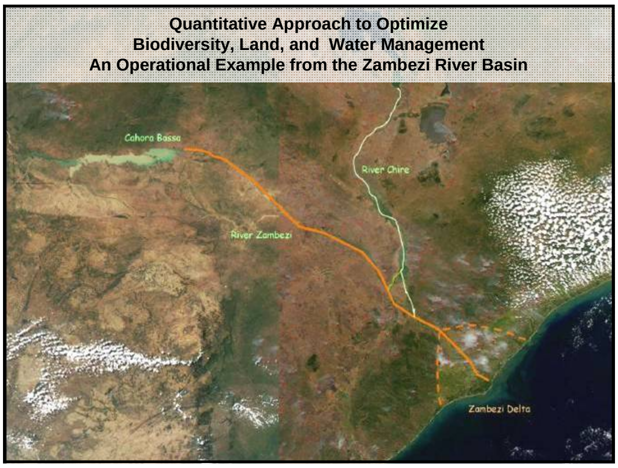
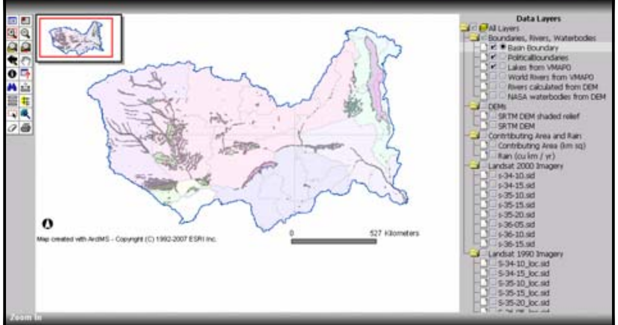

Production Landscapes
Watershed to Basin Scales
Condensation
Precipitation
on land
Evaporation
from precipitation
Evaporation
from land
Evapo-transpiration
Surface
Runoff
from water
surface
from vegetation
from soil
from reservoir
surface
overflow
Evaporation
from ocean
water table
Infiltration
subsurface
flow
groundwater
outflow
Percolation
(deep)
ocean
saltwater intrusion


“DYNAMIC INFORMATION FRAMEWORK (DIF)”
….noting especially issues of data gaps……..
(Transboundary) Political Boundaries
Landuse/Landcover
Physical “Template”


Express Societal Impact on a “Biophysical” World
Location
Travel
Production
Consumption
Households
New Construction
Redevelopment
Developers
Location
Travel
Production
Consumption
Businesses
Infrastructure
Regulations
Governments
Urban Processes
Land Use
Land Value
Development
Land
Basin Cell
Ground surface
Soil column
Channel
Segment
Flow
Overland Flow
Saturated Subsurface Flow
Channel Segment Flow
feedback
Environmental Stressors
Water
Energy
Materials
Resource Use
Land Conversion
Emissions
Biophysical Processes and Impacts


Quantitative Approach to Optimize
Biodiversity, Land, and Water Management
An Operational Example from the Zambezi River Basin
Cahora Bassa
River Shire
River Zambezi
Zambezi Delta

Geographic Information Systems: Zambezi Dynamic Information Framework (ZDIF)



Basin Boundary, Political Boundaries, Lakes

Stakeholder Involvement

- World Bank Staff
- Government of Mozambique (GOM)
  - Ministry of Agriculture, Natural Resources, Environment
- National/Local Experts
- International Resource experts
- University (Eduardo Mondlane University in Maputo)
  - Faculty
  - Post-doc
  - Graduate students
- Land managers—Farmers, Fishery Managers
- Small Land Holders

Stakeholder Training

- Hands-on training:
  - For local Ministerial staff, and Faculty, Post-doc and Graduate students from Eduardo Mondlane University in Maputo.
- Field Collection:
  - Soil sampling
  - Water sampling
  - Geographic Position Systems (GPS) technologies
- Participatory Interviews:
  - Local small land holder communities

Adaptive Management

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Design Implementation

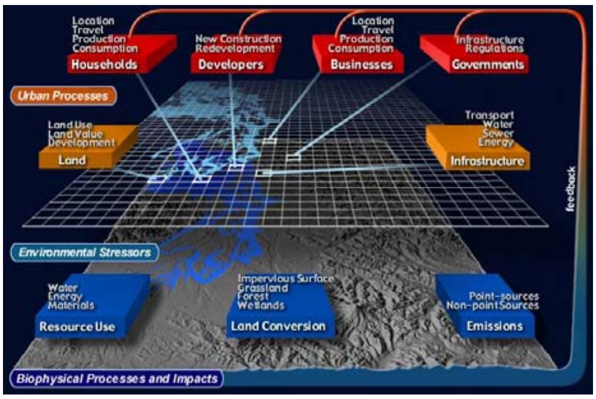
- Start Data Collection:
  - **1st Step** - develop **Digital Elevation Model (DEM)** of the basin using NASA's Shuttle Radar Topographic Mission (SRTM) dataset.
  - **2nd Step** - develop **Hydrology Model** of whole basin, a **Variable Infiltration Capacity (VIC)** model.
  - **3rd Step** - characterize **Land-use** and **Land-cover** dynamics (1995-2005)
    - 5 project districts of Mozambique's portion of the Zambezi basin.
  - **4th Step** – assess vegetation by **Georeferencing** plant diversity.
    - Rapid appraisal methods: low-cost, high-return, gradient directed transects (gradsects).

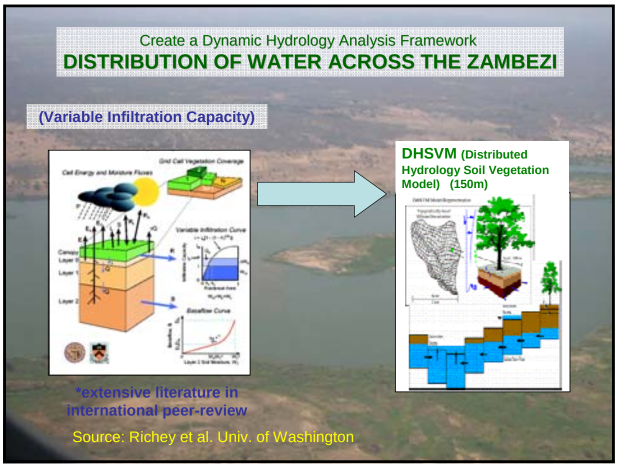
Dataset Access: Cost

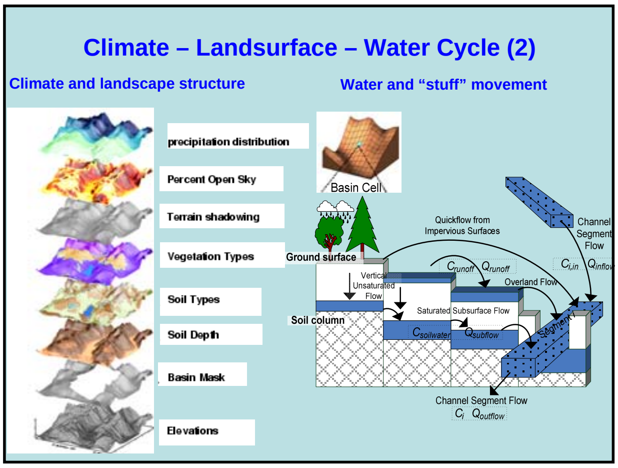
- Public domain datasets
  - Cost ~ $0 or relatively low cost BUT need to know where/how to access public domain data
    - LANDSAT images, Shuttle Radar Topographic Mission DEM tiles, soils data base (Source: Min. of Ag), Mozambique soils map (Source: Univ., Min of Ag., FAO).
- Climate data – A Major Constraint
  - Civil war in Mozambique destroyed meteorological and river gauging equipment
  - Created a 20 year weather data gap.
- Overcame Constraint
  - Data records from the World Meteorological Organization (WMO), and the daily re-analysis product (ERA40), from the European Center for Medium Range Weather Forecast (ECMWF).

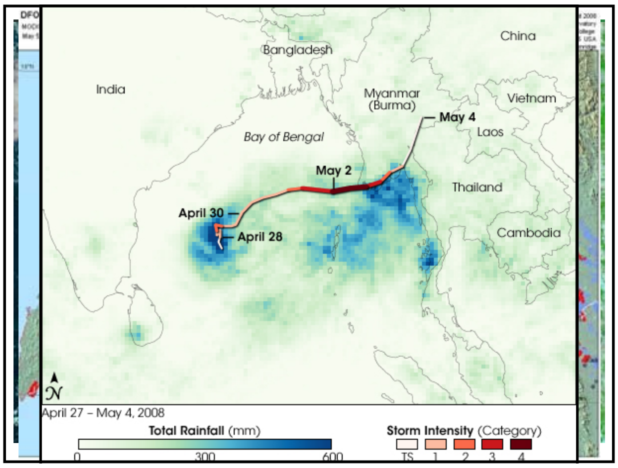
GIS Tools for Data Analysis

Scaling-up the hydro portion to the other basin countries is highly desirable given the dynamic land use changes (agricultural expansion, new forest plantations, natural forest logging).









Adaptive Management

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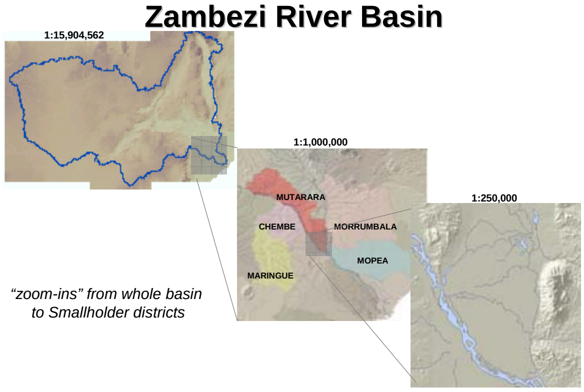
Empowering the 'Community'

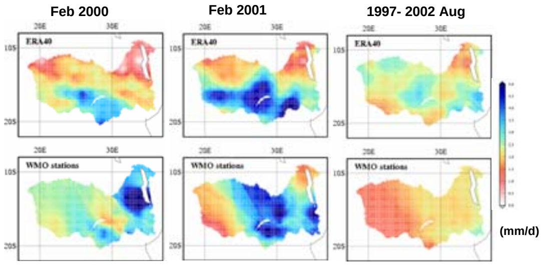
- Workshops, Seminars, Classes
- Field training: methods, data analyses
- Community surveys and data/knowledge sources
- Access to data bases, attribution, return to source
- Capital city, provinces, districts, community associations, fields

Digital Elevation Model (DEM) of Zambezi River Basin



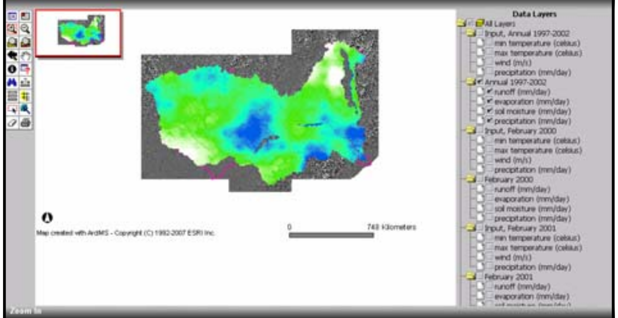
"zoom-ins" from whole basin to Smallholder districts

Raster Model of Zambezi Daily Average Precipitation



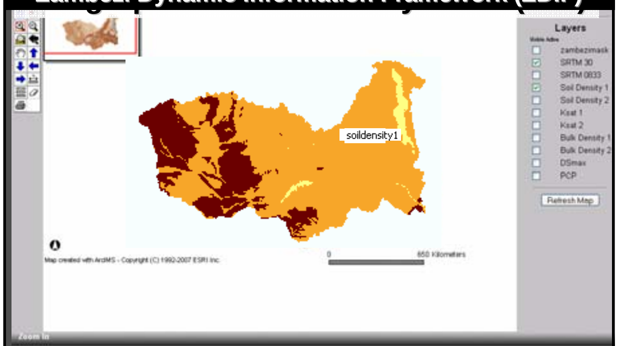
**ERA40: daily re-analysis product from the European Center for Medium Range Weather Forecast (ECMWF)*

Geographic Information Systems: Zambezi Dynamic Information Framework (ZDIF)



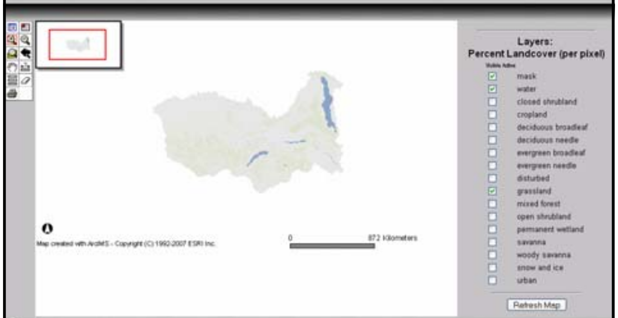
Runoff, Evaporation, Soil Moisture, Precipitation

Geographic Information Systems: Zambezi Dynamic Information Framework (ZDIF)



Soil Density

Geographic Information Systems: Zambezi Dynamic Information Framework (ZDIF)

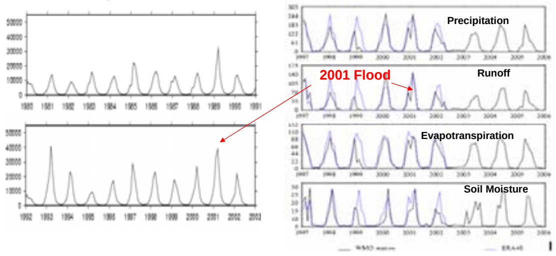


Water, Grassland

PRELIMINARY VIC-MODELING (cal/val in progress)

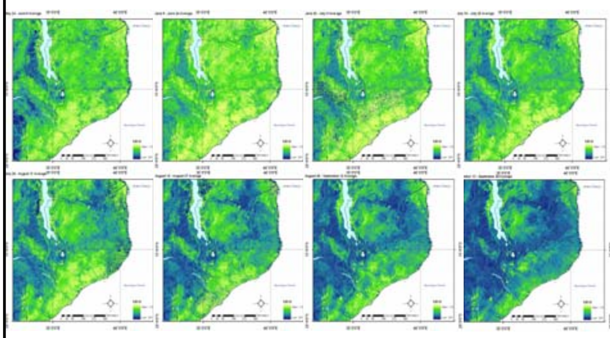
ERA- VIC-modeled (0.5º resolution) monthly mean discharge (m3/s) at Matundo-Cais, 1980-2003

Monthly average time series 1997-2006 of precipitation and simulated hydrologic variables (R, ET, SM; in mm)



SEASONAL PHENOLOGY (NDVI) Of THE ZAMBEZI REGION May-Sep 2000

Test-of-Concept /1st-Look MODIS 1-km 16-Day averages*



*Processing by Leon Delwiche/UW

Monitoring the Zambezi, Community RISK and Resource Management

NEXT STEPS IN THE ZAMBEZI?

Empowering local institutions and communities with geospatial and time referenced knowledge and data for:

- Improved natural resource management approaches,
- Adaptation to Climate Change,
- Managing Risk and Vulnerability
- Preparation for extreme events,
- Objective monitoring of progress based on quantitative indicators, and
- Better and more resilient livelihoods.
- One size does not fit all, so important to incorporate local and site specific information and knowledge

Adaptive Management

- [Zambezi River Case Study]
  - – Assess Problem
  - – Design
  - – Implement
  - – Monitor
  - – Evaluate
  - – Adjust
    - Review and renew

http://www.cmar.csiro.au/research/mse/images/adaptive_cycle.gif

Review Tools for Sustainable "Site-specific" Development

✓Field Scale
✓Watershed Scale
✓Water Quality
✓Crop Management
✓Conservation Activities
✓Forest Systems
✓Grasslands Management
✓Wetlands Preservation

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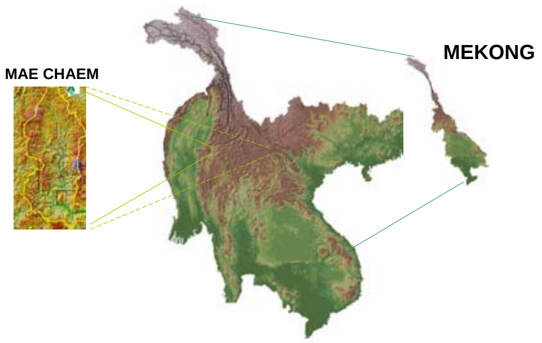
IS THIS APPROACH MORE WIDELY APPLICABLE?

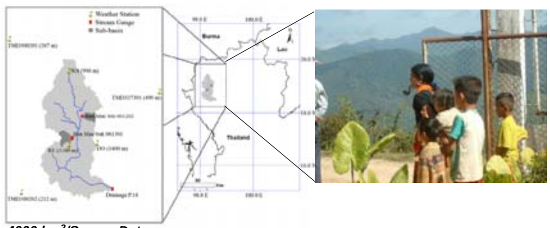
Yes! E.g. Amazon,China 3H, Lake Victoria, Mekong…

SCALING: From a Small Watershed to Far-Field Effects in “Basin Systems”



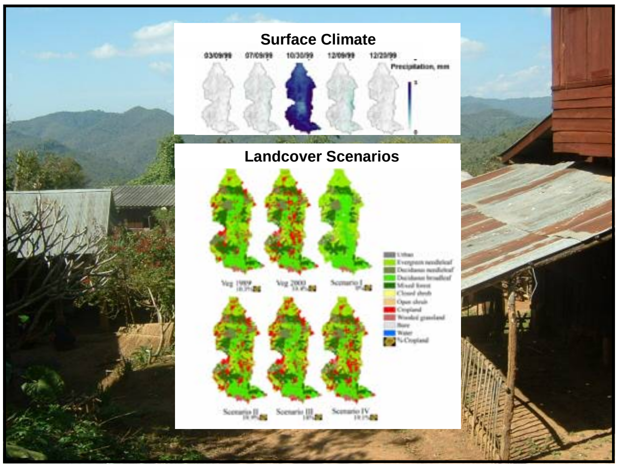
Effects of landuse change on the hydrologic regime of The Mae Chaem river basin, NW Thailand

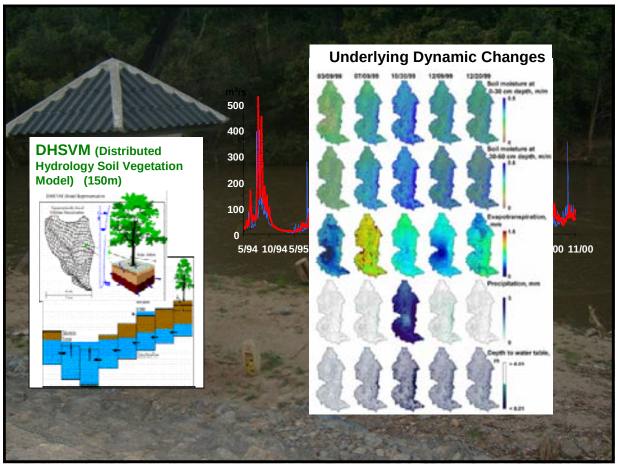
Thanapakpawin et al (2007) J. of Hydrology*



4000 km^2/Sparse Data

****NSF + World Bank Netherlands Partnership Program***





Landcover scenarios		Average hydrologic components (1995 – 2000)			
		Annual yield, mm (m^3/s)	High flow, m^3/s^a	Low flow, m^3/s	Annual evapotranspiration, mm
Veg 2000	I	215 (26.2)	54.7	7.6	762
	NI	249 (30.5)	58.6	12.0	727
Scenario I	NI	223 (27.2)	53.3	11.1	752
Scenario II	I	202 (24.7)	53.6	5.8	781
	NI	261 (31.8)	61.2	12.5	715
Scenario III	I	220 (25.6)	56.8	7.0	759
	NI	269 (32.8)	63.1	12.7	707
Scenario IV	I	193 (23.6)	51.6	5.6	786
	NI	251 (30.7)	59.1	12.2	724