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 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, dialogues, and negotiations.
Mozambique:
Impact of 2000 floods on the economy

<table>
<thead>
<tr>
<th>Actual</th>
<th>Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before the Floods</td>
<td>1998</td>
</tr>
<tr>
<td>Real GDP (annual growth rate)</td>
<td>12.0</td>
</tr>
<tr>
<td>Inflation (annual average, %)</td>
<td>0.6</td>
</tr>
</tbody>
</table>

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

Strengthen National Action Plans on Climate Adaptation and Mitigation Activities

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 landholders to plan for sustainable ecosystems that provide valuable services (carbon sequestration, eco-hydrology, agro biodiversity, native 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

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Adaptive Management

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

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

Major Tools

- Dynamic Information Framework
- Geographical Information Systems
- Good site specific, local, regional data
Production Landscapes
Watershed to Basin Scales

“DYNAMIC INFORMATION FRAMEWORK (DIF)”
.....noting especially issues of data gaps........

(Transboundary) Political Boundaries
Landuse/Landcover
Physical “Template”

Express Societal Impact on a “Biophysical” World

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

- [Zambezi River Case Study]
  - Assess Problem
  - Design
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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.
    - 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).
Create a Dynamic Hydrology Analysis Framework

DISTRIBUTION OF WATER ACROSS THE ZAMBEZI

(Variable Infiltration Capacity)

DHSVM (Distributed Hydrology Soil Vegetation Model) (150m)

Source: Richey et al. Univ. of Washington

Climate – Landsurface – Water Cycle (2)

Climate and landscape structure: Water and “stuff” movement

Adaptive Management

- [Zambezi River Case Study]
  - Assess Problem
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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

Empowering Local Communities - Water Quantity and Quality Issues

Field training local professionals during data collection missions - Rapid Biodiversity Assessments

Zambezi River Carbon & Sediments Laboratory

Field data checking and processing

http://www.riversystems.washington.edu/zambezi_dif/

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
ERA-VIC-modeled (0.5° 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)

Soil Moisture
Evapotranspiration
Precipitation
Runoff

PRELIMINARY VIC-MODELING (cal/val in progress)

2001 Flood
2001 Flood

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

http://www.riversystems.washington.edu/zambezi_dif/

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


Review Tools for Sustainable "Site-specific" Development

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

- [Zambezi River Case Study]
  - Assess Problem
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  - Adjust
    - Review and renew


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

"NSF + World Bank Netherlands Partnership Program"
<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>Annual yield, mm (m^3/s)</td>
</tr>
<tr>
<td>Veg 2000</td>
<td>I  215 (26.2)</td>
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<tr>
<td></td>
<td>Ni 249 (30.5)</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>Ni 223 (27.2)</td>
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<tr>
<td>Scenario 2</td>
<td>I  202 (24.7)</td>
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<td>Ni 261 (31.8)</td>
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<tr>
<td>Scenario 3</td>
<td>I  220 (25.6)</td>
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<td>Scenario 4</td>
<td>I  230 (26.0)</td>
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<td>Ni 251 (30.7)</td>
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