Modelling and Decision Support for Integrated Climate Change Impact and Vulnerability Assessment

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The talk by parts

1. Scenarios for the Region and challenges
2. Adaptation, risk and vulnerability frameworks
   - essence of the frameworks for the Mekong
3. The role of modelling versus tools
   - different types of integrated modelling: strengths and weaknesses
4. The role of decision support systems
5. Some examples
6. Lessons and key messages
Current Climate ‘Change’

- Observed past & present trends in SE Asia
  - 0.1 to 0.3°C increase per decade (1951-2000)
  - Decline in number of rainy days (1961-1998)
  - Increase in hot days & warm nights (1961-1998)
  - Decrease in cold days & nights (1961-1998)
  - Increased occurrence of extreme rains (e.g. floods in Vietnam & Cambodia in 2000)
  - Droughts associated with ENSO years

- Glaciers in Tibetan Plateau (Mekong source) melting faster in recent years

(Cruz et al., 2007)
Projected Climate Change

• By end of 21st Century:
  • Max monthly flow (compared with 1961-1990 levels)
    ➢ Increase 35-41% in Basin
    ➢ Increase 16-19% in Delta
  • Min monthly flow
    ➢ Decline by 17-24% in Basin
    ➢ Decline by 26-29% in Delta
  • Increased flooding risks during wet season
  • Increased water shortage in dry season
  • 40 cm sea level rise (conservative scenario)

(Cruz et al., 2007)
Examples of possible impacts of projected CC

Possible changes:

- Flooding
- Sea level rise
- Marine saline intrusion
- Glacial melt
- Heat stress
- Decreased flows in dry season
- Warmer sea surface temperature
- Increased frequency & intensity of tropical storms
- Changes to flow regime

(Cruz et al. 2007)
Examples of possible impacts of projected CC

• Impact on community
  - Flood residence of millions of people on coastal & riparian fringe
  - Damage to aquaculture industry & infrastructure
  - Loss of farm land
  - Climate-related diseases
  - Loss of income for those dependent on fisheries etc
  - Changes to crop yields
  - Drinking water supply

• Impact on natural resources
  - Water quality
  - Reduce recruitment of some species
  - Mangrove loss
  - Breeding & migration cycles/triggers of fish
  - Readjustments of floodplain veg
  - Weed species

(Penny 2006; Cruz et al. 2007)
Largest freshwater lake in SE Asia
Almost half Cambodia’s population benefits directly/indirectly from Lake’s resources
World’s largest freshwater fishery
Rich biodiversity
- Ecological hot spot – UNESCO biosphere
- Floodplain – feeding, breeding, recruitment site
Fish migrations from lake → restock Mekong
> 80% sediment received from Mekong stored in Lake & its floodplain
Flow reversal
- Dry months – water flows out of Lake back into Mekong
- Natural reservoir for Lower Mekong Basin
- Flood protection
- Assures dry season flow to Delta
- Controls salinity intrusion

(Kummu et al., 2006)
Tonlé Sap – current threats

- Overexploitation of fisheries & wildlife resources
- Deforestation
- Agricultural expansion
- Industrial & urban pollution
- Upstream dams
- Habitat fragmentation
- Introduction of non-native species
- Mining

(ADB, 2004)
Vietnamese Mekong Delta

• **Values**
  - 3.9 mill ha of Delta in Vietnam (of 6 mill ha total)
  - 14 mill people living in VMD
  - In 2000 – rice production 78 % land use

• **Threats**
  - 60 % soils – acid sulphate & saline soils
  - Upstream abstractions
  - 1.7 mill ha by salt water intrusion
  - ~ 1 mill ha affected by tidal flooding
  - Sept – Oct prone to large flooding
    - ~30% VMD flooded at depths of 0.5-4.0m
    - Inundation can last 2-6 months
  - Droughts
  - Deforestation - <10 % forest cover
  - Agricultural expansion

(Wassmann et al. 2004; Penny 2006)
Ongoing changes/threats in the Mekong

- **Increasing economic development**
  - increased demand for water & energy
  - hydropower, irrigated agriculture, industry, inter-catchment diversions
- **Overexploitation & degradation of land & water resources**
  - Overfishing
  - Deforestation
  - Pollution
  - Poor farming practices
- **Floods, droughts**
- **Population growth**

(MRC 2005; ADB 2004)
CC Challenges in the Mekong

- Ongoing changes:
  - Socio-economic change
  - Environmental change
  - Land use change
  - Technological advancement
- Interactive effects of CC & other anthropogenic stressors
- Dependency of millions of people on natural resources
- Poverty – major barrier to developing capacity to cope & adapt
- Insufficient knowledge on:
  - Impacts of CC
  - Responses of natural systems
- Limited biophysical & socio-economic data
- Large natural climate variability

(Cruz et al. 2007)
Part 2: A short list of frameworks

- IPCC Technical Guidelines
- ICLIPS (Potsdam)
- UKCIP (UK Climate Impacts Programme)
- UNDP-GEF Adaptation Policy Framework
- Risk assessment/management frameworks
  - generic – e.g. AS/NZS 4360 Risk Management,
  - for climate change – e.g. Jones 2001
7-step Framework for Assessment

1. Define Problem
2. Select Method
3. Test Method/Sensitivity
4. Select Scenarios
5. Assess Biophysical Impacts
   Assess Socio-Economic Impacts
6. Assess Autonomous Adjustments
7. Evaluate Adaptation Strategies

Evaluation of Adaptation Strategy

1. Define Objectives
2. Specify Important Climatic Impacts
3. Identify Adaptation Options
4. Examine Constraints
5. Quantify Measures/Formulate Alternative Strategies
6. Weight Objectives/Evaluate Trade-offs
7. Recommend Adaptation Measures

(Carter et al. 1994)
ICLIPS Integrated Assessment Framework

- Impact Module
  - CIRFs
  - Regional and sectoral impacts
- Technology Module
  - Scenarios
  - Mitigation cost functions
- Integrated Climate-Economy Model
  - Integrated Climate Model
  - Global and regional climate change
    - Global and regional emission corridors
    - Cost-effective emission reduction paths
- Exogenous Scenarios
  - Population, total factor productivity, non-CO2 GHG emissions, etc.
- Aggregated Economic Model
  - Baseline development and emissions
- User/Decision maker input: Acceptable mitigation costs, quotas, instruments
- Dynamic Applied Regional Trade Model
  - Medium-term baseline development
  - Medium-term optimization
  - Regional and sectoral mitigation costs
- Agriculture and Land-use Model
  - Land-use emissions
- Forward mode
- Inverse mode
- Supplementary analysis

Complements the Aggregated Economic Model for detailed analysis of interesting paths

(Toth et al. 2003)
UKCIP Decision-Making Framework

1. Identify problem and objectives
2. Establish decision-making criteria, receptors, exposure units and risk assessment endpoints
3. Assess risk
4. Identify options
5. Appraise options
6. Make decision
7. Implement decision
8. Monitor

(Willows & Connell, 2003)
Risk assessment/management framework

(Risk assessment/management framework (Jones, 2001))
Climate Change Impact Assessment and Adaptation: some key components for the Mekong

- No single approach to assessing, planning & implementation
  - eg top-down and bottom-up risk and vulnerability identification
- An iterative, adaptive framework & ‘models’ to identify and integrate knowledge types, recognising, reducing and communicating uncertainty
  - integrate qualitative and quantitative information
- Build on current plans and strategies re sustainable development
  - utilise low regret options, non-climatic risk factors, current climate risks
- Active engagement & sustaining partnerships; implementation incentives; investment in projects and people
- Cost-effective, equitable, politically realistic options
Climate Change in the Mekong

- Climate Adaptation Strategy: Building on existing processes in the Basin

- IWRM: Basin Development Plan
  - Development scenarios
  - An IWRM-based Basin Strategy
  - A project portfolio of structural (investment) projects and supporting non-structural projects

www.mrcmekong.org
Programmes supporting IWRM across the Lower Mekong Basin.
But what are the Adaptation options?

- Engineering options
- Traditional local strategies
- Social responses
  - resettlement
- Land use planning
  - zoning, development controls
- Economic instruments
  - subsidies, tax incentives
- Natural systems management
  - rehabilitation, enhancement
- Sector-specific adaptation practices eg in agriculture

(Carew-Reid, 2009)
What else does a robust climate change assessment entail?

- ‘State of the art’ models
  - Climate, hydrology, ecology, agriculture, human health, demography, social, economic.... and **INTEGRATION** of models
  - address uncertainties in: climate predictions; knowledge of and variability in system responses; and the coupling of different models
Part 3: Integrated Modelling (simplified)

Assumptions/Alternatives
- Climate
- Shocks
- Demography
- Policy drivers
- Adaptation options
- External drivers

Environmental System

‘Sustainability’ indicators
- Economic
- Social
- Environmental

Assess tradeoffs to balance and compare alternatives
Integrated Modelling Approaches

The main types of integrated models with different strengths and weaknesses in particular situations:

- Systems dynamics
- Bayesian networks
- Coupling complex models
- Agent-based models
- Hybrid expert systems
Bayesian Networks

- A fundamental adaptive modelling tool for decision-making and management where key considerations are:
  - wide-scale issue and knowledge integration
  - knowledge is of varying quality and type
  - system knowledge and data can be updated

- Uses conditional probabilities as a common basis to link cause and effect – ie to determine likelihood of different outcomes

- Conditional probabilities derived from:
  - many (1000’s) of runs of component models
  - expert elicitation
  - stakeholder surveys
  - observed data – categoric and numeric

- Excellent availability of technical/analytic tools
Bayesian Decision Networks: linking nodes or variables

- Management decisions
- Environmental social or economic indicator(s)
- Cost/benefit to society &/or environment

Decision Variable

State Variable

Utility Variable

*probability* 0.1 0.2 0.7

*increase* *no change* *decrease*
<table>
<thead>
<tr>
<th>Step</th>
<th>Tasks involved</th>
<th>Tools</th>
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<tbody>
<tr>
<td>1. Identify objectives</td>
<td>• Identify issues, concerns</td>
<td>• Participatory methods</td>
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<tr>
<td></td>
<td>• Build consensus on the problem(s) to be addressed</td>
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<td>2. Problem framing</td>
<td>• Understanding the problem(s)</td>
<td>• Exploratory analysis</td>
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<td></td>
<td>• Define boundaries/scope</td>
<td>• Visualisation tools (e.g. conceptual models, mind maps)</td>
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<td>3. Identify performance measures</td>
<td>• Identify criteria to be used to compare and evaluate alternatives</td>
<td>• Participatory methods</td>
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<tr>
<td></td>
<td>• Gather value judgments</td>
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<td>4. Identify alternatives</td>
<td>• Identify potential management options based on objectives</td>
<td>• Participatory methods</td>
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<tr>
<td></td>
<td></td>
<td>• Scenario tools</td>
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<tr>
<td>5. Evaluate alternatives</td>
<td>• Evaluate each alternative based on how it is predicted to affect the</td>
<td>• Predictive/Simulation models (e.g.</td>
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<tr>
<td></td>
<td>performance measures</td>
<td>disciplinary tools)</td>
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<tr>
<td></td>
<td>• Explore tradeoffs</td>
<td>• Integrated models (e.g. Bayesian networks, coupled component models, system dynamics, hybrid expert systems)</td>
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<td></td>
<td>• Narrow options</td>
<td>• Expert elicitation</td>
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<td></td>
<td></td>
<td>• Optimisation tools (e.g. heuristic search methods, optimisation models, pareto-optimal tradeoff curves)</td>
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<td></td>
<td></td>
<td>• Decision trees</td>
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<tr>
<td>6. Rank/select final alternative</td>
<td>• Compare and rank different outcomes</td>
<td>• Multi-criteria analysis</td>
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<tr>
<td></td>
<td>• Select satisficing option</td>
<td>• Cost-benefit analysis</td>
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<tr>
<td></td>
<td></td>
<td>• Bayesian decision models</td>
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<td></td>
<td></td>
<td>• Participatory methods</td>
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</tbody>
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Part 4: DSS

- **Modern Decision Support Systems**
  - Adaptive; suitable for investigating structured & semi-structured problems
  - Interactive and easy to understand
  - Quantitative & qualitative (hybrid), credible, good evidence-base for decision makers
  - Facilitate integration
  - Transparent and well-documented

- **DSSs can be used for engagement in**
  - Aligning tools with stakeholder & user needs
  - Investigating scenarios, priorities and strategies that are robust to uncertainties
  - Sharing likely outcomes of climate change scenarios
  - Identifying research needs to better understand climate change and its outcomes
Packaging it all up into a DSS

- Decision Support Systems for Climate Change
  - More than just a set of models

DECISION SUPPORT SYSTEM
User privileges (expert vs. default)

Models
Hydrological-Hydraulic models coupled to Ecological response models

Information Sheets
Background information, scientific studies, system observations, model documentation

Maps
System information

IBIS: Environmental flow DSS for NSW Wetlands
Building on the existing DSS?

**Figure 2-1. MRC Decision Support Framework**
Part 5: Two examples of integrated modelling & DSS relevant to the Mekong

1. **EXCLAIM:** EXploring CLimAte Impacts on Management
   - Configuration of Bayesian Network models with hydrological time series inputs

2. **IBIS:** Wetland Decision Support Systems
   - Configuration of Bayesian Network, empirical and rule-based models integrated with hydrology and hydraulic models
Exploring climate impacts on management
Impacts of Climate Change on…

- **Water flows**
  - Irrigation and environmental needs
  - ‘High’ security requirements
- **Water quality**
  - Salinity
  - Nutrients
- **River and wetland ‘health’**
  - Ecological indicators
    - Algae, Vegetation, Birds, Fish
Spatial sub-network components

Empirical relationship derived from literature or data

Historical data or multiple model outputs

Qualitative relationship from literature or expert knowledge

Based on or related to CAP targets

Scenarios

Burrendong Dam starting volume

Weekly climate period

Global projection sensitivity

Projected Burrendong Dam volume

Historic Burrendong Dam volume

Change in marsh inflow

Water allocation sub-network

Water available for general security allocation

High security allocation

Inflow allocation

Efficiency allocation

Change in marsh inflow

Thermal stratification

Water temperature

Total P

Location flooded

Flood duration

Flow requirement

Oyster annual flow

Spring flood or flood recession

Susceptibility to algal blooms

Total N

Turbidity

Susceptibility to algal blooms

Water quality sub-network

River water quality

Health of Macquarie Marsh

Thermal stratification

Water temperature

Total P

Flow sub-network

Monthly river flow

Daily river flow

Flow and biota sub-networks

Flow warning time frame

Pre-dam/Post-dam conditions

Season

Climate sub-network

Rainfall (% change)

Evaporation (% change)

Temperature (°C change)

Rainfall (mm)

Evaporation (mm)

Monthly river flow

Carinda daily salt load

Carinda annual salt load

Thermal stratification

Wet/dry climatic period

Change in storage
Climate change into system views

Macquarie Valley (% change)

Evaporation Macquarie Valley (% change)

SCENARIO

Node: Climate Projection time frame

This represents a user-defined scenario and allows comparisons between current climate, short and longer term projections.

Possible scenarios:

1. Current (1990 climate)
2. 2015
3. 2070

SCENARIO RATIONALE

Description: This node gives scenario choices of current climate and projected climate in 2015 and 2070. Scenarios chosen to give climate change projections for 2015 (length of the GAF process (Central West Catchment Management Authority 2005)), 2070 (long term projections) and a baseline for comparisons (current climate, taken as 1990 climate).

Current climate is the 1990 baseline climate used in OzClim version 2.0.1 (Page and Jones 2001) for the defined study area, as long term monthly averages from 1961. Climate projections for the study area are monthly OzClim projections at 2015 and 2070. Climate scenarios chosen are consistent with the most recent climate projections for the central west (Manney et al. 2004; Jones and Page 2001; Jones et al. 2002). Three of the SRES marker scenarios as described by the International Panel on Climate Change (IPCC 2000) are used to inform the prototype DSS. The SRES marker scenarios are based on global carbon emissions resulting from plausible global economic, social and environmental conditions projected into the future, and each scenario results in global projections of temperature change. The three marker scenarios chosen for the DSS include the lowest, mid-range, and highest global projections of temperature change for 2015 and 2070 to give the broadest range of plausible climate change scenarios and are representative of their selected scenario families (Table 1). These are marker scenarios A1B, B1 and A1T for 2015 and A1B, B1 and A1T for 2070. Each of these global temperature changes are regionalised to the Central West by forcing through the full range of available global and regional climate models via the Australian Climate Scenario Generator, OzClim v.2.0.1 (Page and Jones 2001).

Table 1: SRES marker scenarios chosen for modelling

<table>
<thead>
<tr>
<th>SRES marker scenario</th>
<th>Temperature increase (°C) 2015</th>
<th>Temperature increase (°C) 2070</th>
<th>Scenario Storyline</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1B</td>
<td>0.30 to 0.50</td>
<td>1.66 to 2.67</td>
<td>The A1 scenario family describes a future with very rapid economic growth, combined with the rapid development and introduction of new and efficient technologies. Population peaks in mid-century and declines after. The three A1 scenarios are separated based on their predominant use of energy sources. A1F = fossil intensive energy sources. A1T = non-fossil energy sources. A1B = balance across different energy sources.</td>
</tr>
<tr>
<td>A1T</td>
<td>0.42 to 0.66</td>
<td>Not modeled</td>
<td></td>
</tr>
<tr>
<td>A1F</td>
<td>Not modeled</td>
<td>2.30 to 3.77</td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>0.33 to 0.55</td>
<td>1.17 to 2.08</td>
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</table>
IBIS Component Models

- User-friendly interface overlies the models and provides access to supporting information, model documentation and model results

- Designed to support environmental flow decision-making (short and long term)
Integrated Model Structure

- Continuous daily hydrology model
- Characteristics of ‘event’ passed through discrete probabilistic response models
- *For each event:* the likely success of an outcome
Part 6: Our Lessons

- **Project process:**
  - Builds relationships between institutions, researchers and stakeholders
  - Builds capacity, understanding, promotes systems thinking, leads to innovative ideas for change

- **Participation needs to be flexible and a feature of the entire project cycle**
  - Time, resources and effort are required to engage stakeholders
  - Goals of this need to be clearly defined

- ‘Products’ (DSS plus…) need to be adaptive, iterative and promote discovery of new knowledge
Key messages for Assessment

- Manage and communicate uncertainty - complexity, knowledge & data gaps; incorporate qualitative knowledge
- Utilise current programs and methods effectively
- Consider climatic and non-climatic risks jointly
- Prioritise options under resource constraints, balancing tradeoffs
- Look for robust solutions in the face of uncertainties
- Document, monitor and review: adaptive to incorporate new information
- Engage for transparency, accountability, legitimacy and adoption

Implies an adaptive but systematic process: explicit frameworks, eclectic modelling & decision support in a learning setting
References

Climate Change problem involves:

- Geophysical, biological, socioeconomic systems
- Multiple decision makers (inc. other sectors)
- Countless stakeholders
- Web of constraints – barriers to adaptation
- Numerous competing objectives
- Uncertainties about future changes to climate variables & system responses
- Identifying priorities inc vulnerable ‘communities’ and assets
- Passive/existing and transformational changes - policy, institutional and practice
Five preconditions to successful planned adaptation to CC

1. Availability of effective intervention measures
2. Availability of resources to implement these measures
3. Awareness of the problem
4. Information about these measures
5. Incentives for actually implementing these measures

(Fussel and Klein, 2004)
Integrated Assessment Models

Representation of a generalised IAM for climate change (IPCC 1996)