29/07/13

Lecture 1: Intro to unit.

Natural resource management is about the organization, use and conservation of natural resources

NRM challenges:

- Large scale systems (Murray darling)
- Long term impacts: pollution may not be immediately apparent (Carbon Dioxide)
- Complex and multicomponent ecological systems (flora, fauna, soils, inorganic elements)
- Uncertainty (in environmental conditions, knowledge uncertainty, future process and costs)
- Multidisciplinary issues (ecology, economics, agronomy, hydrology)

Decision support tools

- Models – abstract representation of the real world
- Models can help to tackle complex NRM problems
  - Bio-economic models

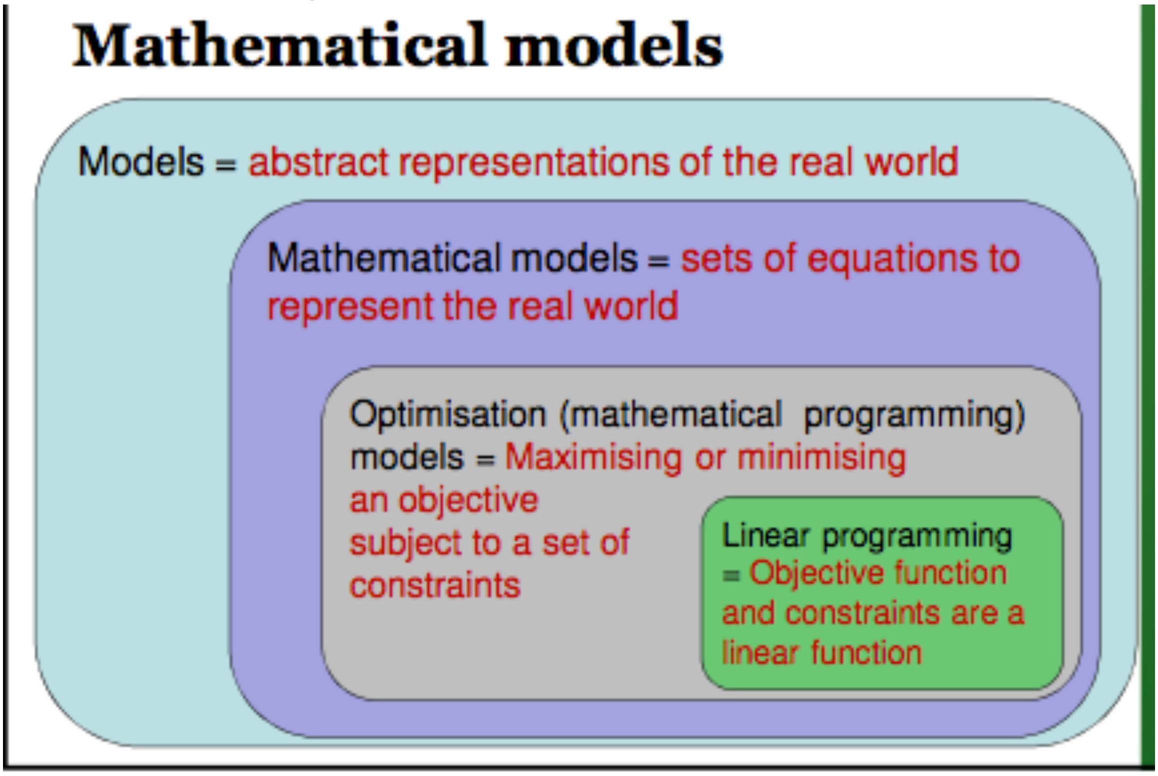
Model objectives

- Help better understand systems and processes
- Reconstruct past or predict future behavior
- Guide development and assessment of new policy decisions
- Help to run experiments that may not be possible to carry out in reality
- Find optimal controls paths.
- Simulation models predict the future and predict a scenario
- Optimization models have some objective to optimize the control path.

Types of models:

- Scale
- Pictorial
- Flow charts
- Physical
- Mathematical

- Sets of equations to represent relationships between variables in a system
- Use calculations/algorithms to solve complex problems

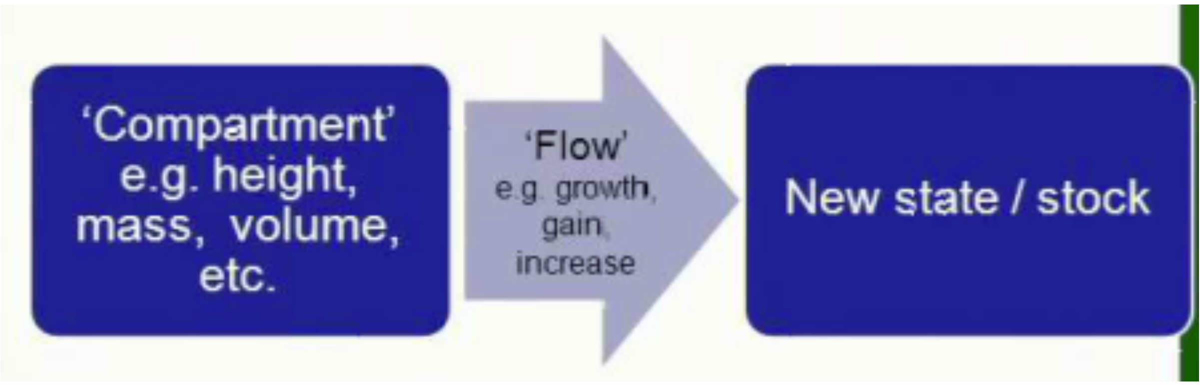


- Classes of mathematical models:
  - Empirical – describe behavior between variables based on observations of the real world. eg regression models
  - Process based – Deduct physical principals (rules) that match observed reality. More focus on explaining processes then calibrated to fit observations.
  - Randomness
    - Deterministic – set of inputs always lead to same output.
    - Stochastic (random) – A set of inputs can produce different outputs depending on random processes within the model. This model takes uncertainty in the system into account.
  - Scale
    - Spatial – lumped, semi-distributed, distributed
    - Time – static (one step in time), dynamic (have a time component).

Model structure:

- Environmental modeling originates from systems thinking and systems analysis

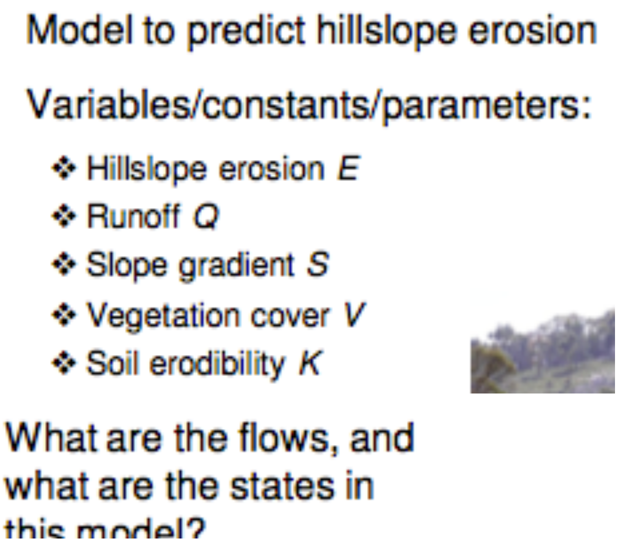
• A system is a set of inter-related components and relationships between them.



• ***QUIZ QUESTION***
Stock flow diagram is static or dynamic? – dynamic (because something changes). Where as a static model only looks at what we will predict will be there.

Model building blocks:
• Variables – change over time and space
• Constants – does not vary in your system
• Parameters – coefficient that doesn’t vary in your particular case but may vary between cases (in the same system)
• Equations/functions – rules that describe the relationship in the system
  – Causality relationships – one thing impacts on the other and not the other way round.
• Assumptions – explain how the model is abstracted from reality
• Boundary conditions – define scale and scope of the modeling system (spatial and temporal)

EXAMPLE: Erosion



- Parameters:
  - ❖ Runoff power *m*
  - ❖ Slope constant *n*
  - ❖ Vegetation protection *i*

- Equation:
  $E = k\, Q^m\, S^n\, e^{-iV}$

- Example scales:
  - ❖ Space e.g. 25 metre raster cells
  - ❖ Time e.g. one monthly time step for 50 years

- Boundary conditions (e.g.):
  - ❖ Soil type (erodibility)?
  - ❖ Vegetation (cover)?
  - ❖ Catchment?

model development:

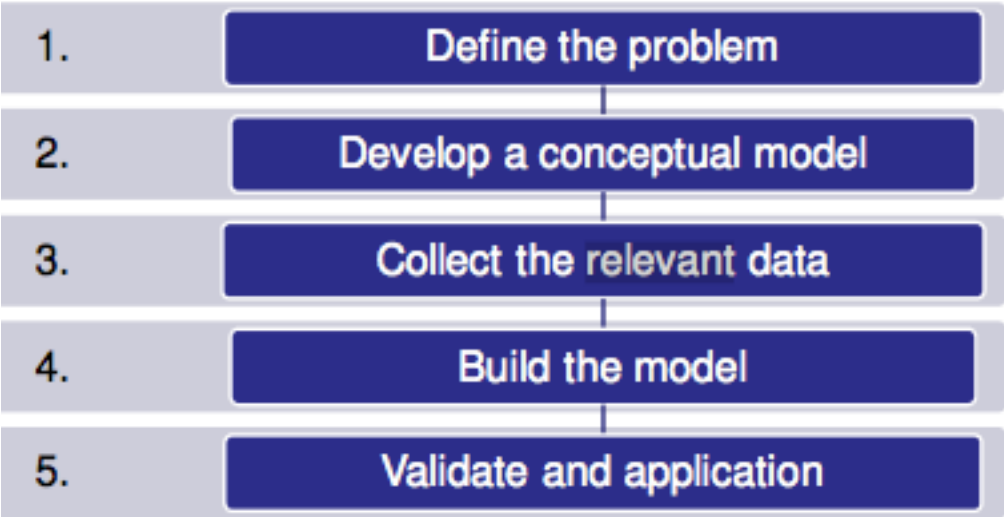
1.	Define the problem
2.	Develop a conceptual model
3.	Collect the relevant data
4.	Estimate / solve the model
5.	Validate and application

Revision:

- What are modeling objectives?
- Define:
    - ❖ Simulation versus optimisation
    - ❖ Process-based versus empirical
    - ❖ Static versus dynamic
    - ❖ Deterministic versus stochastic
    - ❖ Various spatial and temporal scales
- what are the modeling building blocks?

5/8/13

Lecture 2 – Steps in model development



STEP 1) Define the Problem:

- What is the reason for developing a model?
  - Are we interested in representing complex system interactions, or in predicting changes in outcomes?
  - Clear model objectives will help to decide:
    - What type of model is best
    - What level of model parsimony is required – simplest model while still being useful for achieving objective.
    - What type of data needs to be collected
- What is the issue that you will consider / the specific question to be addressed?
  - What is its scale and scope? (national or local catchment area?)
  - Who is involved in the issue (stakeholders)?
  - What are the drivers and outputs of the system?
  - What is it that you want to be able to predict?
  - Selecting system boundaries is important
    - cannot account for everything – have to make assumptions and boundaries for a model.

STEP 2) Conceptual model

- Capture the hypothesis – keep it in mind.

- Mapping system structure – the structure of the model – make it relevant to what you defined the problem as.
  - Model boundaries
  - Subsystems diagram
  - Stocks and flows maps

STEP 3) collecting data
- Relevant data
- May need to re-assess steps 1 and 2

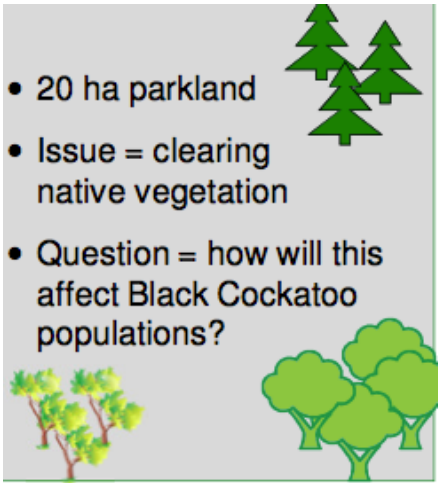
STEP 4) Building the model
- Specifying structure and decision rules (equations and equation boundaries)
- Estimating parameters and relationships
- Testing consistency
- May need to repeat steps 1-3

STEP 5)
Validation and application
- Policy scenarios
- Sensitivity analysis
- “What if...” analysis
- May need to revise earlier steps

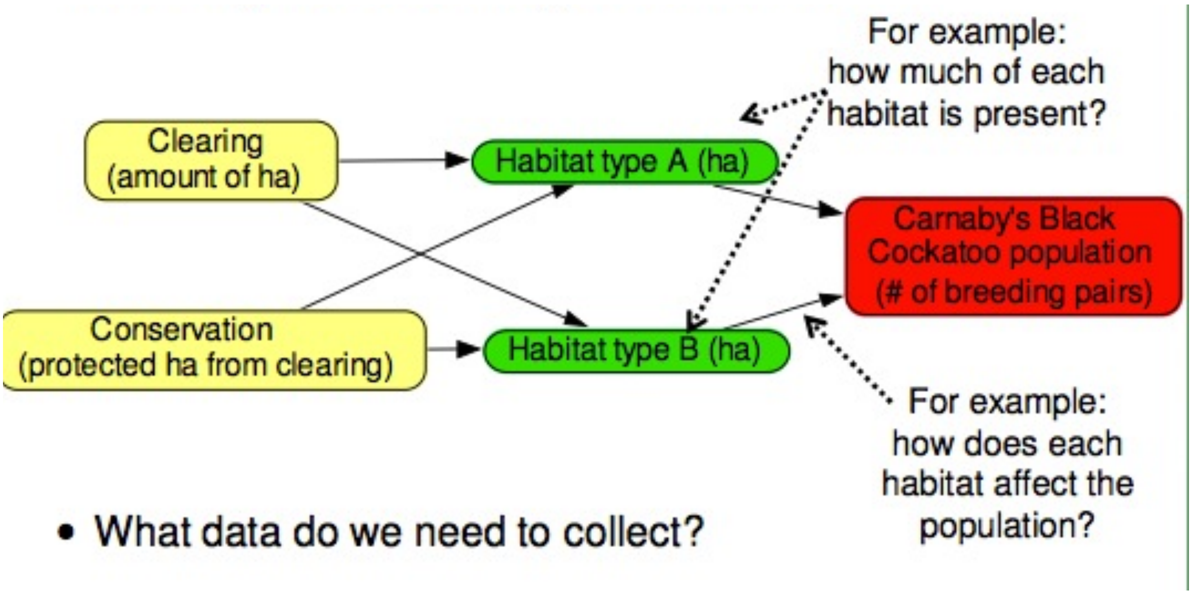
STEPS 1 & 2:
Conceptual modeling:
- Conceptual model = mental map of the system
- Decide about temporal and spatial scales
- Decide about structural resolutions and range
  - Empirical model – observe something in real world and model it.
  - Process-based model – understanding of processes and interactions between variables that are represented by equations the test against the real world. (more complex).
- Decide about system components
- Important to match structural complexity with:
  - Goals of the study – the objective.
  - Available data
  - Appropriate spatial and temporal resolution?

- Different people have different perceptions of reality – talk to experts to see if the model relates to them/if you've missed something.

Example conceptual model



- Objective = Assessing the impacts of clearing native remnant vegetation on threatened Black Cockatoo populations in Western Australia
- For example = Existing parkland of 20ha with some remaining areas of native vegetation.
- Issue to be considered = Proposal to clear additional areas
- Do we need a static or dynamic model?
  - Static – it's a one off thing, when the effect of a sand mine will have on the population.
- Simulation or optimization?
  - Could do both. Sim you have proposal then just simulate the area cleared. Optimization maximizes one or more objectives. Could be the we maximize mining potential as well as maximizing cockatoo population. The middle ground would define the amount of land that's cleared.
- What are the model boundaries – area only or areas of surrounding vegetation where populations migrate.
- What do we need to know?
  - What factors affect the presence/absence of Black Cockatoos?
  - Which of these factors is relevant to the issue that we are considering in this model?
  - What type of habitat is present?
  - How much habitat is present?
  - How will clearing affect this habitat?
  - What is the relation between habitat and Black Cockatoo populations?
  - Which Cockatoo are we interested in?
  - Which habitat does this species live in?



Data:
• Data sources
• Data integration
• Data marts
• Data governance
All these effect the information catalogue

What data do you need?
• First and foremost – define the model objectives
• The data supporting your model should match the model objectives.
  – Conceptualizing a system
  – Eliciting a review existing knowledge
  – Forecasting and prediction
  – Optimization
  – Simulation.
• Do you need cross sectional or time series data
• Typical data needs
  – Input-output coefficients (constants) (for example production coefficients regions or farm types)
  – Resource endowments (stocks)
  – Status-quo situation (quantity produced, soil thickness, environmental condition)
  – Input ant output flows (for example fertilizer application, soil deposition.

- Complete and consistent datasets are rare
- Can the data limitations and gaps be addressed – eg extrapolation, expert opinions, research.
- One may be tempted to include all available data, but it may not be needed to achieve your modeling objectives.
- Model and hence data parsimony is desirable
- Level of detail is subjective.

Data sources:
- Observational data (monitoring)
- Experimental data
- Literature reviews
- Expert opinion
- Commercial data sets exist but are expensive, so you need to know what you need and know wether you are buying the proper data.
- Monitoring / measurements in situ:
  - Real values
  - Labour- and cost-intensive
- Lab experiments:
  - E.g. when in situ experiments are impossible
- Values from previous studies:
  - Literature review or personal communications
  - Errors may arise when transferring values to your specific system

Characteristics of your data
- Spatial coverage (across study area?)
- Spatial scales and accuracy
- Temporal coverage (continuous?)
- Temporal scales and accuracy (time steps sufficient?)
- Data representativeness (cover all required variables?)
- Data consistency (across time and space?)

Spatial scales:
- Spatial shapes may differ across data:
  - Sub-catchments
  - Squares
  - Hexagons
  - Points

  - Stretches

Temporal scales:
- Different systems analysed at different time-steps
- Seasonal variation (e.g. rain)
- Ecological life cycles (e.g. fish migration)
- Stream-flow data (e.g. hourly or daily flow)
- Economic systems (e.g. annual income or business cycle)

Data management:
- Good management practices are crucial for repeatability and transparency in the modeling process (and hence decision making)
- Carefully document each step in the data preparation phase.
- Document for example
  - Data sources
  - Data coverage
  - Manipulation to your data
  - How you handled missing data
  - Names and interpretation of variables
  - Where you stored your data.
- Good data management is useful to remember what you did and where your data is.
- Good data management is proper documentation and metadata
- Data should be treated as an intrinsic part of the model not just input.
- Many separate models will include a spate data module.
- This simplifies tracking errors and calibration models.

Warnings for model building
- Remember that all models are partial – they will never represent the entire system.
- Models are built for a specific purpose – it may not serve other purposes
- Models are built for a certain scope – it may not have validity outside the time/scale region
- Always keep objectives in mind – what is it that your trying to achieve?