Env-Model Slide show: https://www.slideshare.net/slideshow/environment-modelling-250401026/250401026#20

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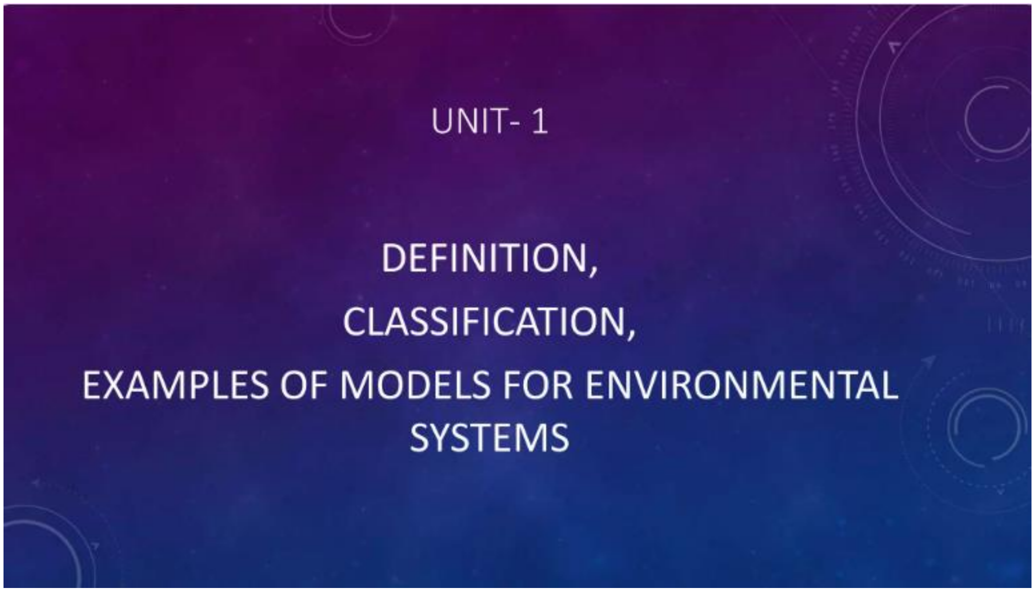

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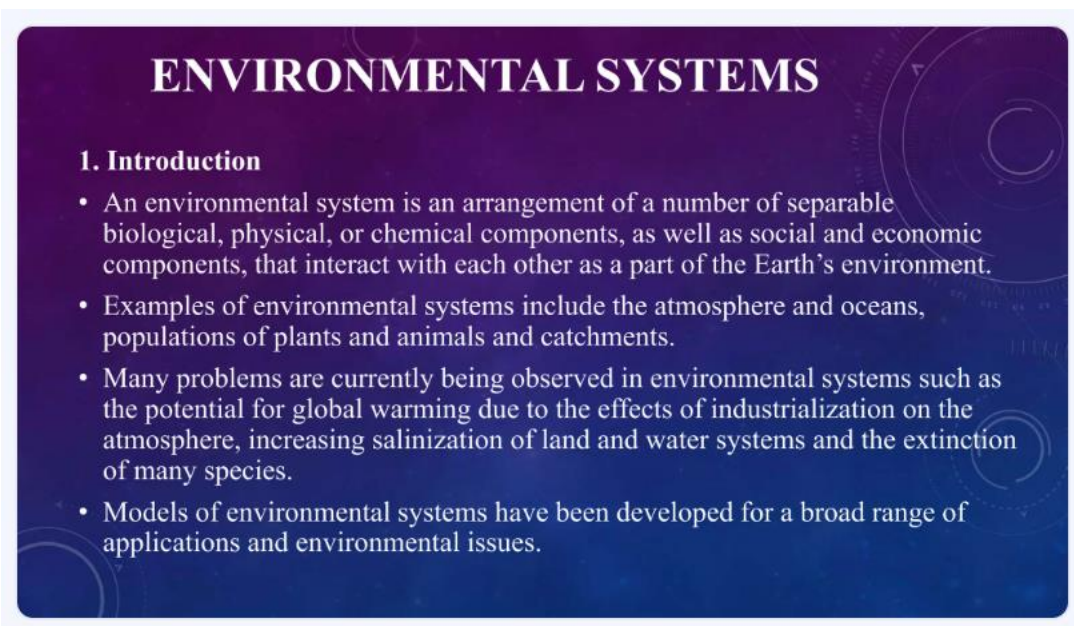

3


ENVIRONMENTAL SYSTEMS
Environmental systems are generally characterized by four main features.
(I) environmental systems generally depend on complex nonlinear interactions of different system components.
(Ii) the main forcing variables or states of environmental systems, such as those related to climate, topography, soil types or population density are commonly extremely heterogeneous, varying over fairly small temporal and spatial scales
(iii) the characteristic temporal and spatial scales of environmental system components are often incompatible, meaning that it presents challenges for combining models of different system components.
(Iv) many environmental systems are inaccessible, or their processes are unobservable, for example groundwater behavior cannot be observed directly; rather it must be inferred using sparse measurements.

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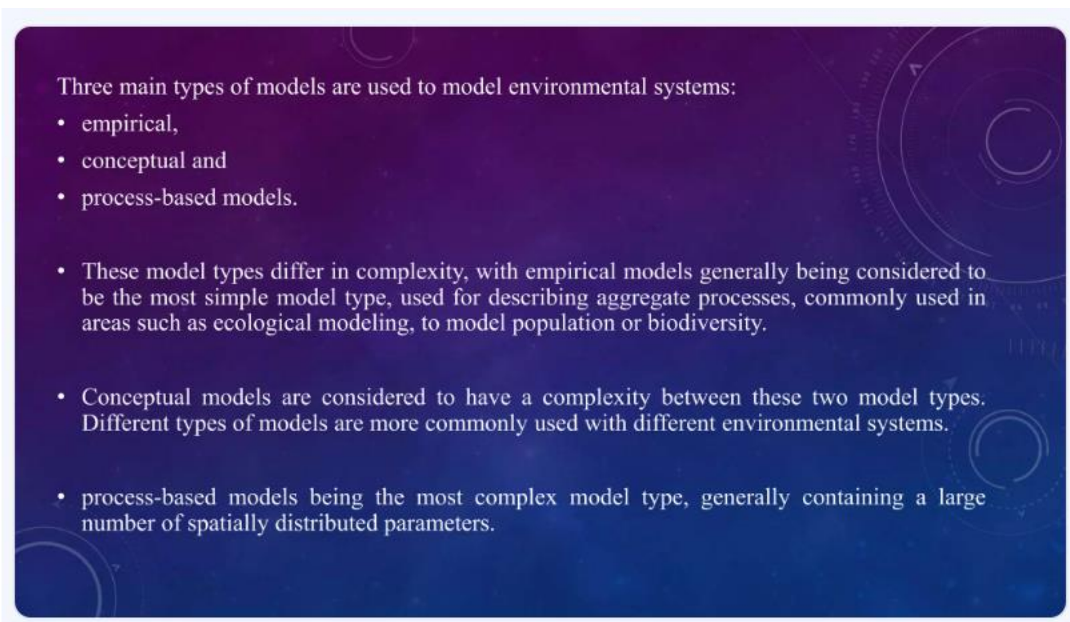
Three main types of models are used to model environmental systems:
• empirical,
• conceptual and
• process-based models.
• These model types differ in complexity, with empirical models generally being considered to be the most simple model type, used for describing aggregate processes, commonly used in areas such as ecological modeling, to model population or biodiversity.
• Conceptual models are considered to have a complexity between these two model types. Different types of models are more commonly used with different environmental systems.
• process-based models being the most complex model type, generally containing a large number of spatially distributed parameters.

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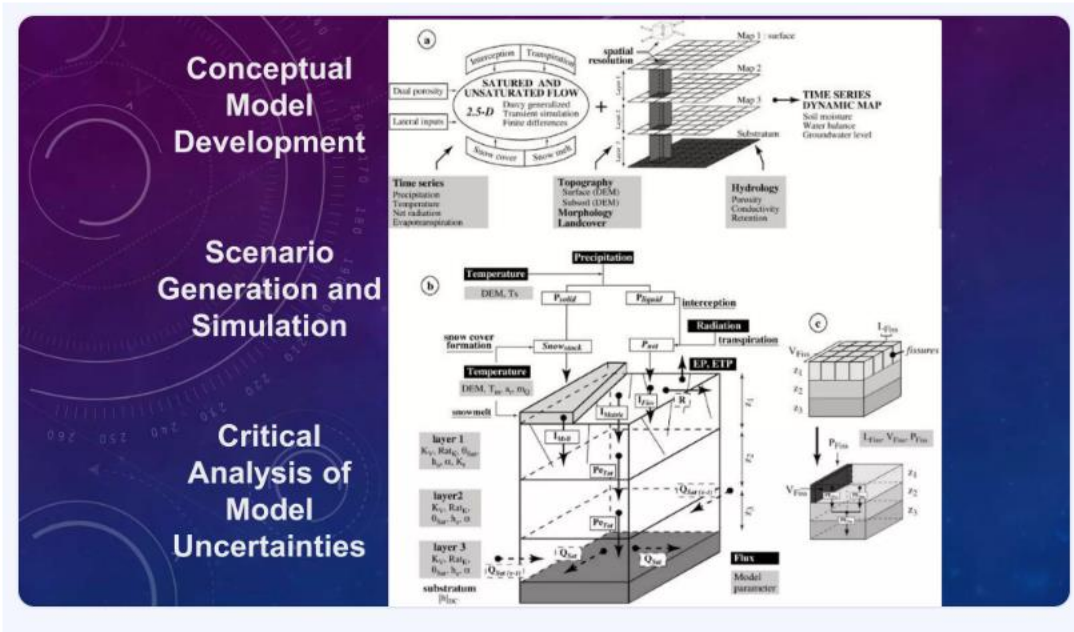

6

Common Features of Environmental Systems

While the term "environmental system" covers a myriad of possible systems and processes, including land, ocean and atmospheric based systems, there are a number of features which are common to almost all environmental systems, regardless of whether they are physical, biological, or chemical in nature.

1. Complex Nonlinear Interactions

Environmental systems generally consist of complex nonlinear interactions between different system features. Environmental systems are driven by the interaction of physical, chemical, biological, social, and economic processes.

2. Heterogeneity of System Features

Important characteristics of environmental systems vary both spatially and temporally over a variety of scales. Characteristic scales of component processes of environmental systems may be extremely small, as is the case for some ecological systems where spatial scales may be less than one millimeter and temporal scales may be over seconds to hours, to very large systems, such as those found for some ocean or groundwater processes where spatial scales may be in the order of hundreds or thousands of kilometers and temporal scales may range over decades or centuries, or longer. In many cases these heterogeneous features are difficult or even impossible to characterize with the limited observational data that are available.

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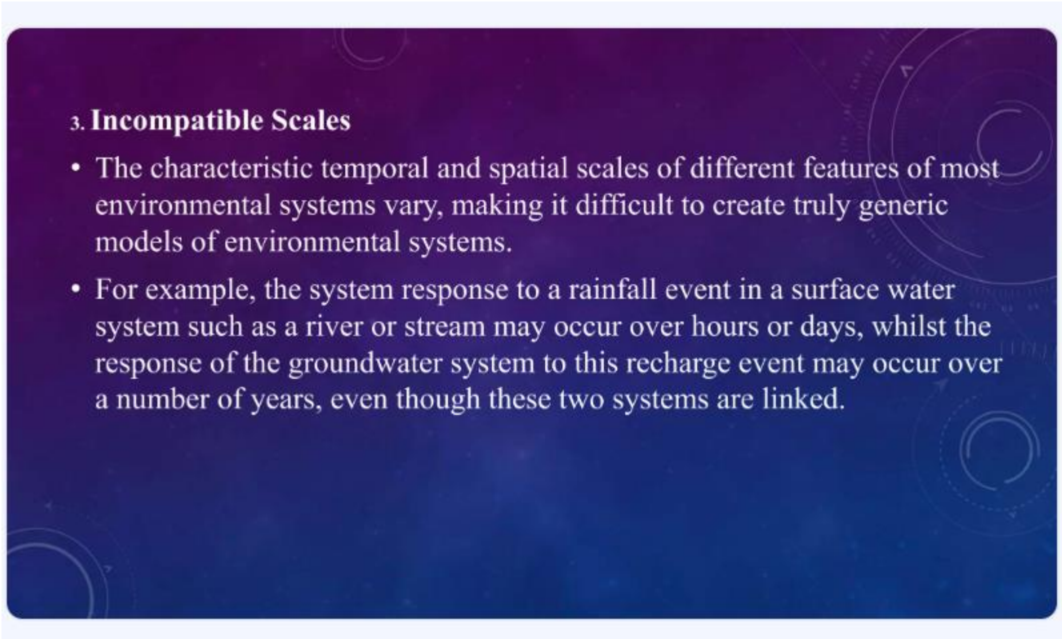
3. Incompatible Scales
• The characteristic temporal and spatial scales of different features of most environmental systems vary, making it difficult to create truly generic models of environmental systems.
• For example, the system response to a rainfall event in a surface water system such as a river or stream may occur over hours or days, whilst the response of the groundwater system to this recharge event may occur over a number of years, even though these two systems are linked.

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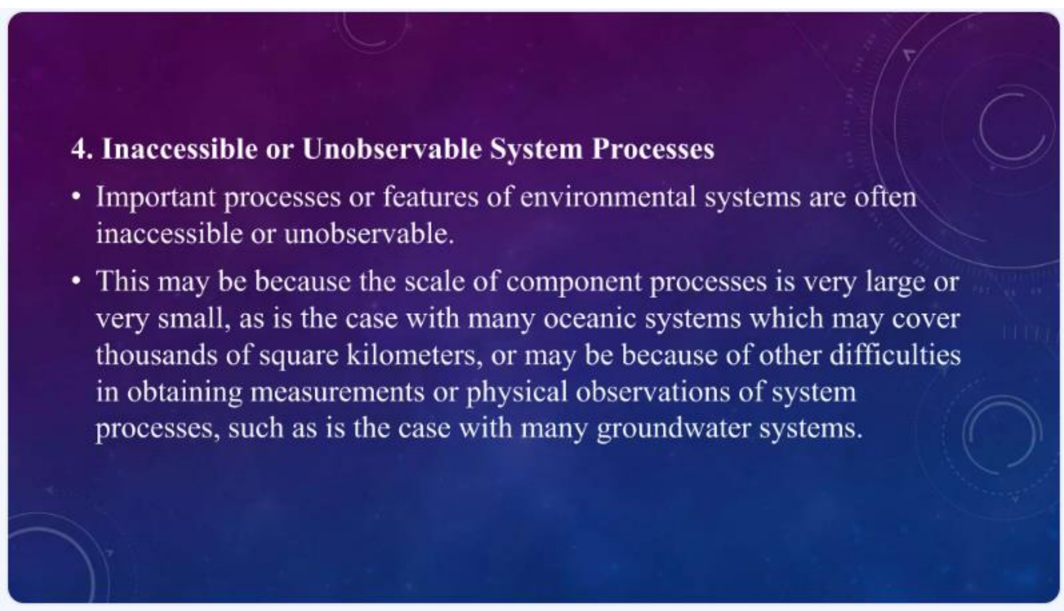
4. Inaccessible or Unobservable System Processes
• Important processes or features of environmental systems are often inaccessible or unobservable.
• This may be because the scale of component processes is very large or very small, as is the case with many oceanic systems which may cover thousands of square kilometers, or may be because of other difficulties in obtaining measurements or physical observations of system processes, such as is the case with many groundwater systems.

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9

TYPES OF ENVIRONMENTAL SYSTEMS

Given these common features, individual systems vary in terms of key processes, characteristic scales, different systems and modeling problems that arise may differ between types of environmental systems

Environmental systems can be split broadly into at least three main categories of Systems

1. hydrological,
2. ecological and
3. climatic.

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HYDROLOGICAL SYSTEM

- Hydrological systems consist of a number of individual systems including: surface water systems; subsurface systems; and coastal systems. These systems are not entirely independent of one another.
- Drainage from the surface water system contributes to recharge of the groundwater system. Discharge from the groundwater system contributes to lakes and rivers.
- Water and pollutants from the rivers and from runoff in coastal areas flow into the sea and contribute to coastal systems.

11

SURFACE WATER SYSTEMS

- Streamflow yields in a catchment system depend on a number of key climatic and landscape features.
- The amount of runoff that can be generated in a catchment depend on climatic features such as rainfall distribution and seasonal patterns, and evaporation.
- Streamflow and related contaminant, and pollutant loads, also depend on landscape factors such as topography, land use, soil type and land management.
- Different types of vegetation provide different densities of groundcover, affecting the amount of water that evaporates off the ground surface, the amount that forms recharge to the groundwater system, and the amount that runs off into the stream.

12

Subsurface Water Systems

- Subsurface water systems, or groundwater systems, are an important part of the hydrological cycle.
- Water and pollutants flow between the groundwater and surface water systems. In particular salt stores may reach the surface and affect agriculture and other ecology when the height of the water table changes. This can affect the quality of land and water for agriculture, as well as having impacts on urban infrastructure.
- Changes in groundwater quality and quantity can affect the surface water system, impacting on plants, animals and humans who use this water. The amount and quality of water in the groundwater system is dependent on factors that affect recharge and discharge.
- Rainfall and runoff will limit the amount of water that is available for recharge to the groundwater system.
- Land use and management as well as soils and topography will affect the amount and quality of rainfall that drains to the groundwater system. For instance, more water will drain through sandy soils than those that are clay based.

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Coastal Systems

- The coastal system may be seen as the area in which the terrestrial environment and the marine environment interact. These systems are very complex, varying in size over time, with tidal levels.
- A coastal system may consist of several kilometers of land inwards from the beach, out to a width of sea just beyond the breaking waves.
- The coastal system is affected by climatic influences such as storms as well as by human influence, in terms of human constructions.
- Tidal influences also effect the beach environment and the amount of erosion that has taken place. The width of beach, and the amount of sand erosion that has taken place, will depend not only on recent storms but also on human built structures that impede or expedite erosion.

14

Ecological Systems

- The term "ecological systems" is used here to refer to two major types of systems: agricultural systems and wildlife systems. These systems are not completely independent of one another, as changes in one system will often affect the other.
- For example, the introduction of crops will change the available food supply for various native populations, which may increase or decrease population numbers depending on the ability of different species to adapt their diet and habitat.
- Increased clearing of land for agricultural use will also impact on native populations.

15

AGRICULTURAL SYSTEMS

Agricultural systems consist of human developed systems of crop production and animal grazing.

The impact of these systems on the environment depends largely on the type of crop that is grown or animal that is grazed, as well as on the practices which are used to manage this production.

For example, the introduction of hard hoofed animals into australian environments is believed to have increased soil erosion, and the replacement of native vegetation with shallow rooted crops and pastures has increased groundwater levels, causing problems with dry land salinity.

Changes in the management or distribution of pastoral systems can also have effects at a range of scales. The capacity of a landscape to carry livestock depends on factors like soils, topography, rainfall patterns and solar radiation.

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CLIMATIC SYSTEMS

The response of the earth's climate to incoming solar radiation is determined by complex interactions between the atmosphere, cryosphere, biosphere, and solid earth. The dynamics of climate depend on the characteristic time scales of each component of the coupled system and the nonlinear interactions between them. The climatic system can be divided into a number of component subsytems: oceans, atmosphere, and the land surface.

1. OCEANS

Ocean systems are an important storage of heat and moisture for climatic systems. Processes of evaporation and precipitation as well as wind generation are important in the transfer of moisture between the oceans and the atmosphere. Climate variability on time scales of decades to centuries is strongly controlled by oceans.

Important processes in the ocean system include convection, dispersion, and turbulent mixing processes in the surface layer.

Changes in the ocean system, in terms of sea temperature or currents, can affect regional climate as well as ice cap formation at the poles.

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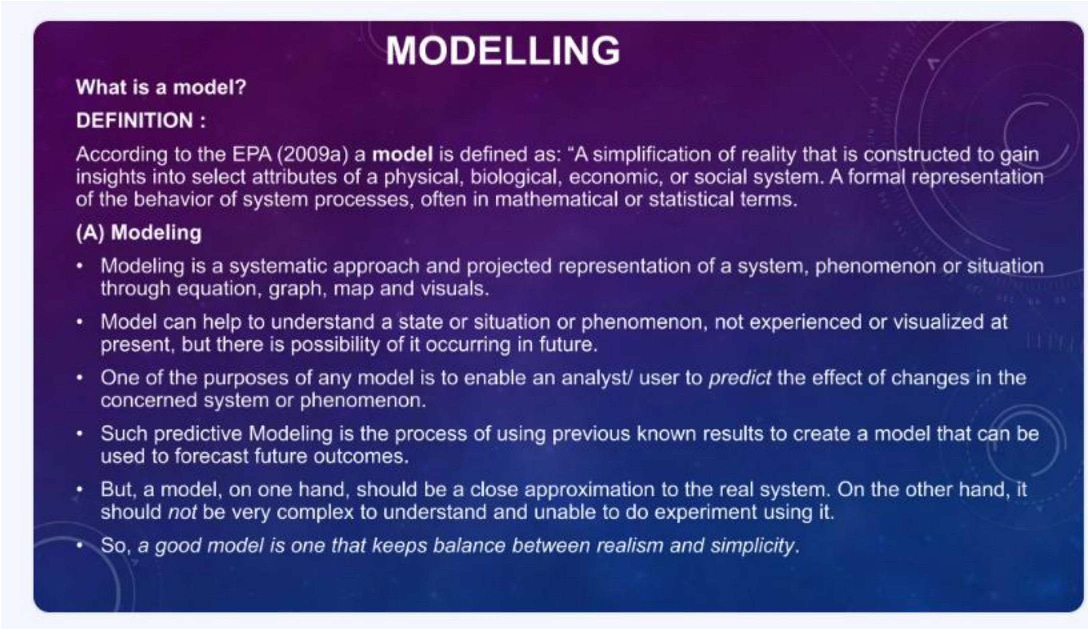
MODELLING
What is a model?
DEFINITION :
According to the EPA (2009a) a **model** is defined as: "A simplification of reality that is constructed to gain insights into select attributes of a physical, biological, economic, or social system. A formal representation of the behavior of system processes, often in mathematical or statistical terms.
(A) Modeling
• Modeling is a systematic approach and projected representation of a system, phenomenon or situation through equation, graph, map and visuals.
• Model can help to understand a state or situation or phenomenon, not experienced or visualized at present, but there is possibility of it occurring in future.
• One of the purposes of any model is to enable an analyst/ user to *predict* the effect of changes in the concerned system or phenomenon.
• Such predictive Modeling is the process of using previous known results to create a model that can be used to forecast future outcomes.
• But, a model, on one hand, should be a close approximation to the real system. On the other hand, it should *not* be very complex to understand and unable to do experiment using it.
• So, *a good model is one that keeps balance between realism and simplicity*.

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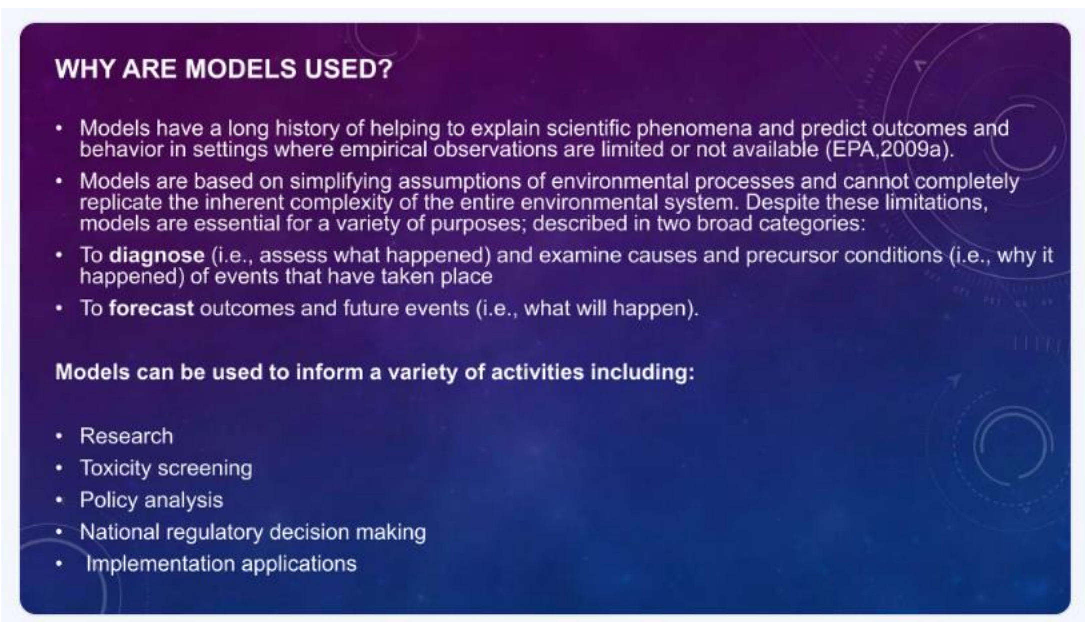
WHY ARE MODELS USED?
• Models have a long history of helping to explain scientific phenomena and predict outcomes and behavior in settings where empirical observations are limited or not available (EPA,2009a).
• Models are based on simplifying assumptions of environmental processes and cannot completely replicate the inherent complexity of the entire environmental system. Despite these limitations, models are essential for a variety of purposes; described in two broad categories:
• To **diagnose** (i.e., assess what happened) and examine causes and precursor conditions (i.e., why it happened) of events that have taken place
• To **forecast** outcomes and future events (i.e., what will happen).
Models can be used to inform a variety of activities including:
• Research
• Toxicity screening
• Policy analysis
• National regulatory decision making
• Implementation applications

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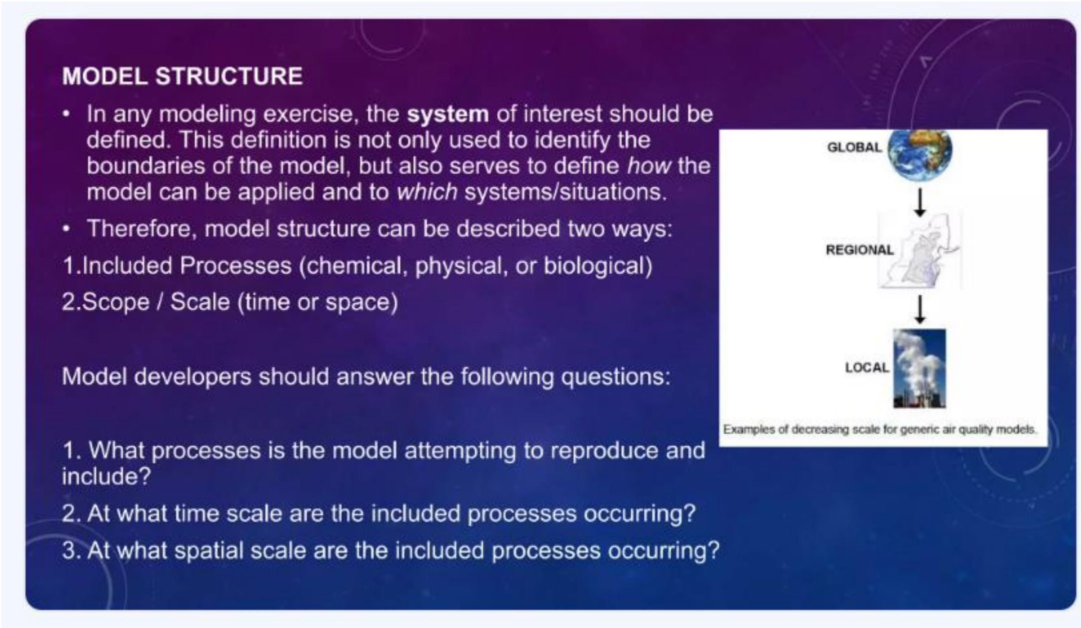
MODEL STRUCTURE
• In any modeling exercise, the **system** of interest should be defined. This definition is not only used to identify the boundaries of the model, but also serves to define *how* the model can be applied and to *which* systems/situations.
• Therefore, model structure can be described two ways:
1.Included Processes (chemical, physical, or biological)
2.Scope / Scale (time or space)
Model developers should answer the following questions:
1. What processes is the model attempting to reproduce and include?
2. At what time scale are the included processes occurring?
3. At what spatial scale are the included processes occurring?
GLOBAL
REGIONAL
LOCAL
Examples of decreasing scale for generic air quality models.

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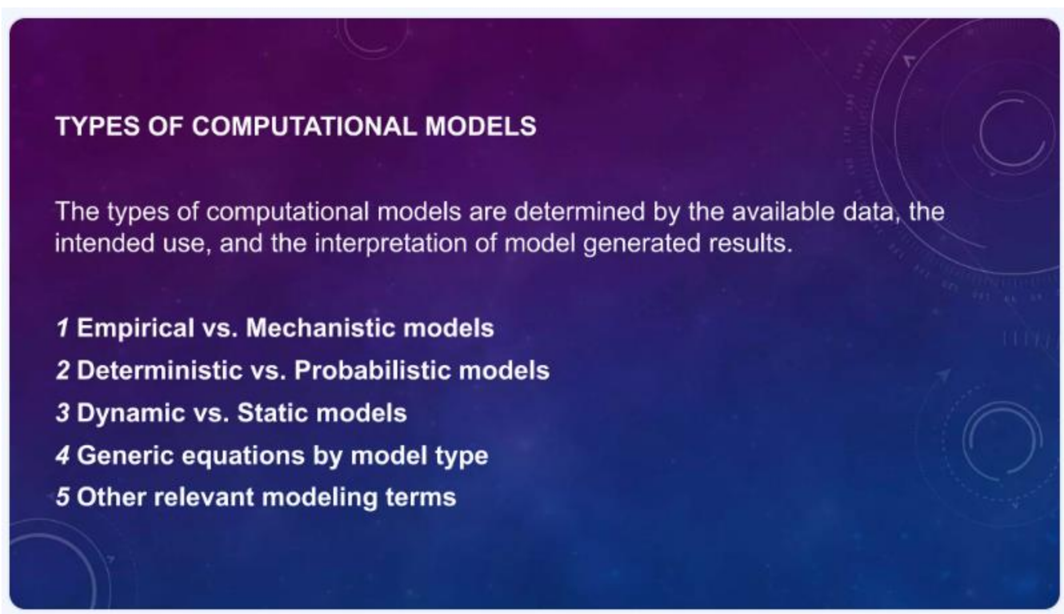
TYPES OF COMPUTATIONAL MODELS
The types of computational models are determined by the available data, the intended use, and the interpretation of model generated results.
1 Empirical vs. Mechanistic models
2 Deterministic vs. Probabilistic models
3 Dynamic vs. Static models
4 Generic equations by model type
5 Other relevant modeling terms

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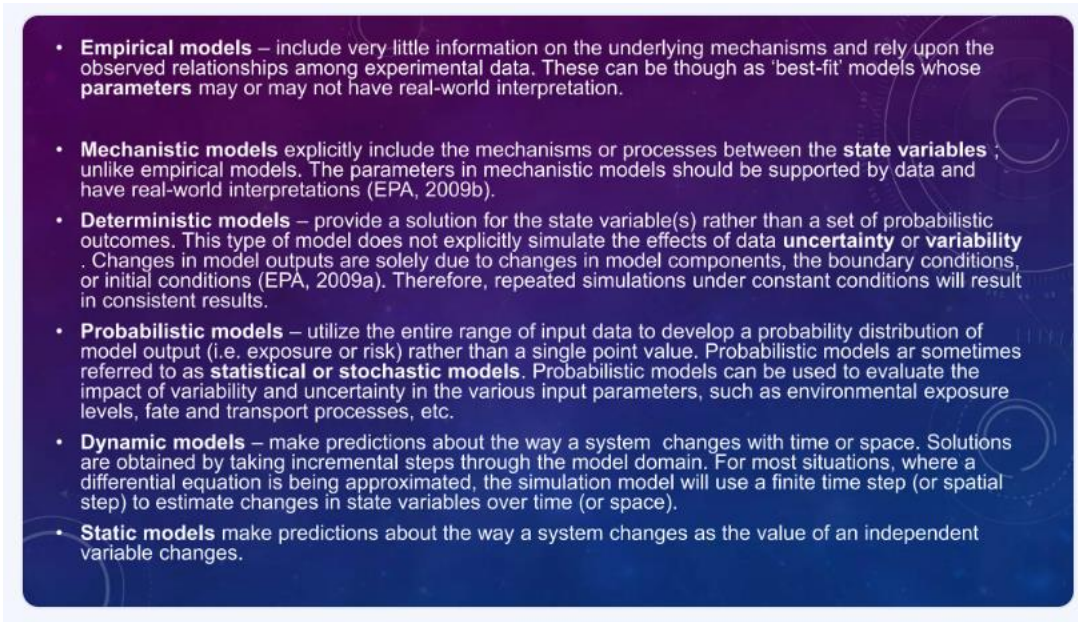
• Empirical models – include very little information on the underlying mechanisms and rely upon the observed relationships among experimental data. These can be though as 'best-fit' models whose parameters may or may not have real-world interpretation.
• Mechanistic models explicitly include the mechanisms or processes between the state variables ; unlike empirical models. The parameters in mechanistic models should be supported by data and have real-world interpretations (EPA, 2009b).
• Deterministic models – provide a solution for the state variable(s) rather than a set of probabilistic outcomes. This type of model does not explicitly simulate the effects of data uncertainty or variability . Changes in model outputs are solely due to changes in model components, the boundary conditions, or initial conditions (EPA, 2009a). Therefore, repeated simulations under constant conditions will result in consistent results.
• Probabilistic models – utilize the entire range of input data to develop a probability distribution of model output (i.e. exposure or risk) rather than a single point value. Probabilistic models ar sometimes referred to as statistical or stochastic models. Probabilistic models can be used to evaluate the impact of variability and uncertainty in the various input parameters, such as environmental exposure levels, fate and transport processes, etc.
• Dynamic models – make predictions about the way a system changes with time or space. Solutions are obtained by taking incremental steps through the model domain. For most situations, where a differential equation is being approximated, the simulation model will use a finite time step (or spatial step) to estimate changes in state variables over time (or space).
• Static models make predictions about the way a system changes as the value of an independent variable changes.

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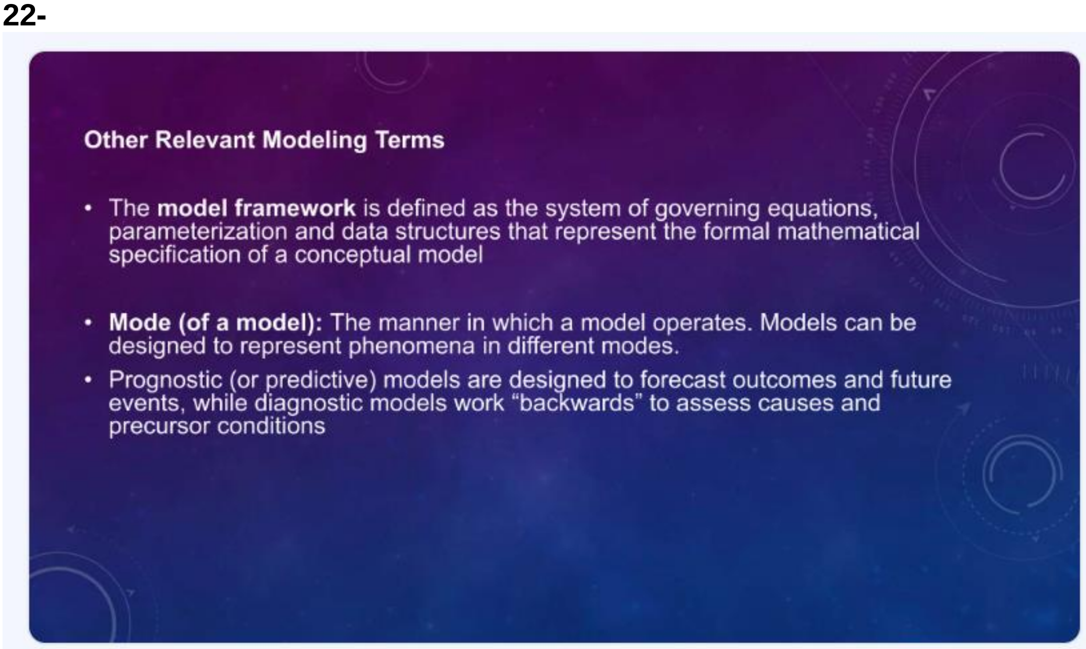
Other Relevant Modeling Terms
• The model framework is defined as the system of governing equations, parameterization and data structures that represent the formal mathematical specification of a conceptual model
• Mode (of a model): The manner in which a model operates. Models can be designed to represent phenomena in different modes.
• Prognostic (or predictive) models are designed to forecast outcomes and future events, while diagnostic models work "backwards" to assess causes and precursor conditions

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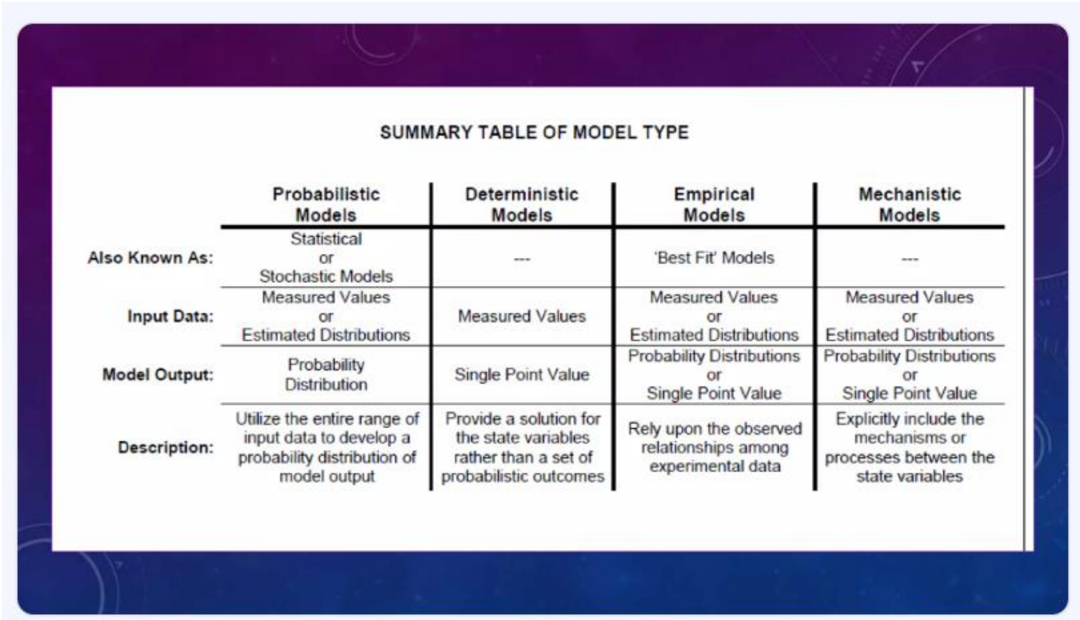

SUMMARY TABLE OF MODEL TYPE

	Probabilistic Models	Deterministic Models	Empirical Models	Mechanistic Models
Also Known As:	Statistical or Stochastic Models	---	'Best Fit' Models	---
Input Data:	Measured Values or Estimated Distributions	Measured Values	Measured Values or Estimated Distributions	Measured Values or Estimated Distributions
Model Output:	Probability Distribution	Single Point Value	Probability Distributions or Single Point Value	Probability Distributions or Single Point Value
Description:	Utilize the entire range of input data to develop a probability distribution of model output	Provide a solution for the state variables rather than a set of probabilistic outcomes	Rely upon the observed relationships among experimental data	Explicitly include the mechanisms or processes between the state variables

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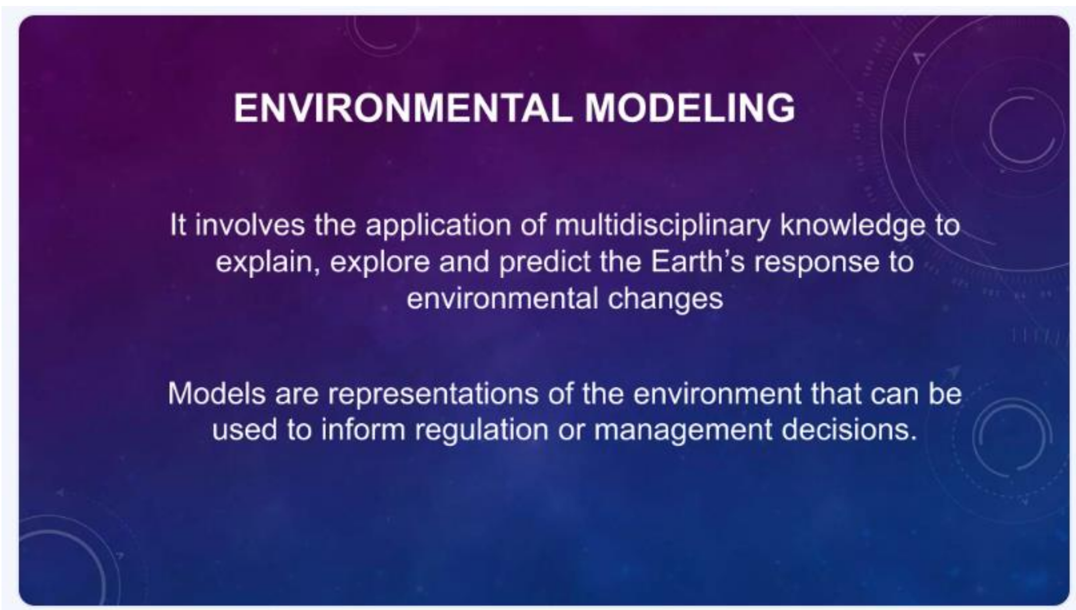

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WHY MODELLING IS ESSENTIAL ?

- Management of natural resource depends scientifically on reliable projections of future conditions (Modeling) to design, plan and implement desired actions towards sustainable living.
- Virtually, Modeling helps to visualize the future scenario from the historical information/events/data that aid to design and plan the activities for sustainable future.
- In addition, it also assists to forecast/ predict consequences of our quality of life in case we continue to exploit the natural resources irrationally to meet our demands. This also enables us to evolve sustainable way(s) for resource planning, allocation and management leading towards sustainable lifestyles for all.

26-

Physical model

it is a smaller or larger physical copy of an object. The object being modelled may be small (e.G., An atom) or large (e.G., Solar system).In other words, the physical models are smaller and simpler representations of the thing being studied (viz., A globe or a map). The structure of the model and the object it represents need be similar in the sense that one resembles the other. But in such cases, the scale is the most important characteristic to be followed accurately.

Fig.-4.2 Differences Between Model & Prototype

Schematic Model

Schematic models are more abstract than physical models. While they do have some visual correspondence with reality, they look much less like the physical reality they represent. Graphs and charts are schematic models that provide pictorial representations of mathematical relationships. Pie charts, bar charts, and histograms are all models of some real situations, but they really bear no physical resemblance to anything. Diagrams, drawings, and blueprints also are versions of schematic model.

Fig. 4.3 Schematic model of a typical eukaryotic interphase nucleus

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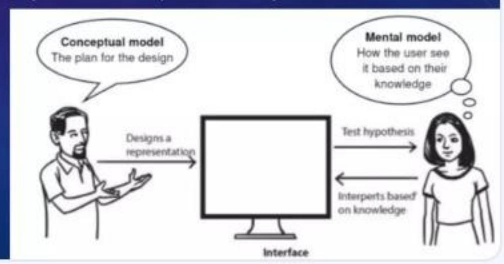
Conceptual models

Conceptual models tie together many ideas to explain a phenomenon or event.

It is representations of a system, made of the composition of concepts which are used to help people know and understand a subject that the model represents.

A conceptual model's primary objective is to convey the fundamental principles and basic functionality of the system which it represents.

A conceptual model, when implemented properly, should satisfy its fundamental objectives. The conceptual model plays an important role in the overall system development life cycle.



28-

Mathematical Model

- Mathematical models are perhaps the most abstract of the four classifications.
- These models *do not* look like their real-life counterparts at all.
- Mathematical models are built using numbers and symbols that can be transformed into functions, equations, and formulas.
- Mathematical Modeling is the process of using various mathematical structures - graphs, equations, diagrams, scatter plots, tree diagrams, etc., to represent real situations.

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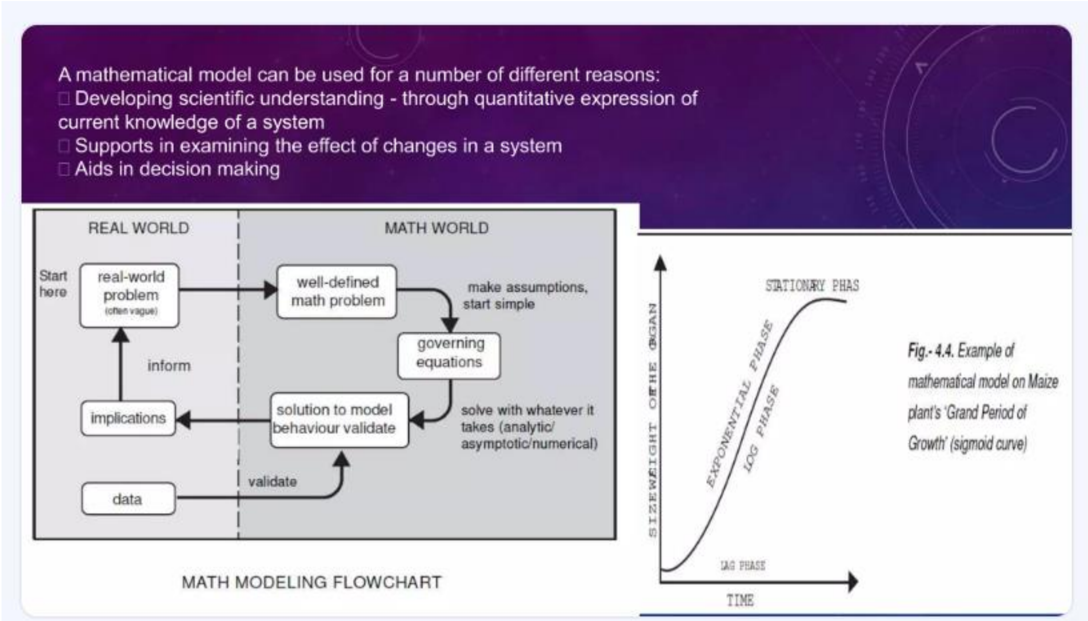
A mathematical model can be used for a number of different reasons:
Developing scientific understanding - through quantitative expression of current knowledge of a system
Supports in examining the effect of changes in a system
Aids in decision making
REAL WORLD
MATH WORLD
Start here
real-world problem
(often vague)
well-defined math problem
make assumptions, start simple
governing equations
inform
implications
solution to model behaviour validate
solve with whatever it takes (analytic/ asymptotic/numerical)
validate
data
MATH MODELING FLOWCHART
STATIONARY PHAS
EXPONENTIAL PHASE
LOG PHASE
LAG PHASE
TIME
Fig.- 4.4. Example of mathematical model on Maize plant's 'Grand Period of Growth' (sigmoid curve)

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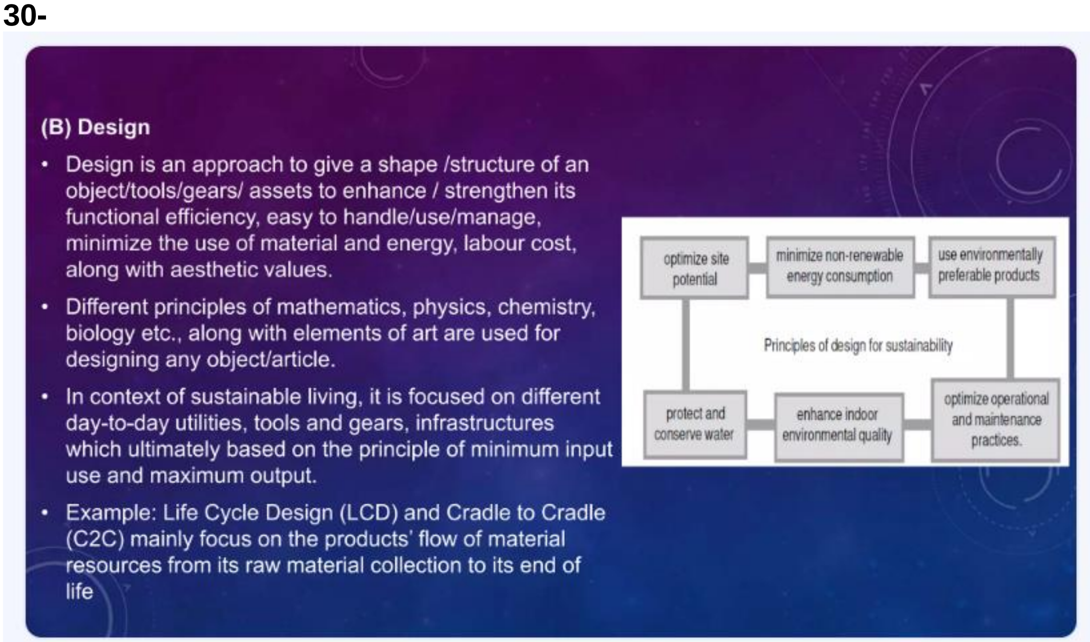
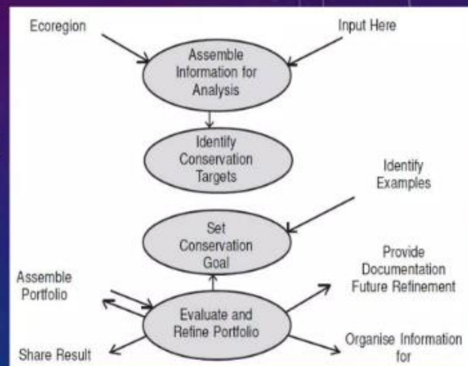

(B) Design
Design is an approach to give a shape /structure of an object/tools/gears/ assets to enhance / strengthen its functional efficiency, easy to handle/use/manage, minimize the use of material and energy, labour cost, along with aesthetic values.
Different principles of mathematics, physics, chemistry, biology etc., along with elements of art are used for designing any object/article.
In context of sustainable living, it is focused on different day-to-day utilities, tools and gears, infrastructures which ultimately based on the principle of minimum input use and maximum output.
Example: Life Cycle Design (LCD) and Cradle to Cradle (C2C) mainly focus on the products' flow of material resources from its raw material collection to its end of life
optimize site potential
minimize non-renewable energy consumption
use environmentally preferable products
Principles of design for sustainability
protect and conserve water
enhance indoor environmental quality
optimize operational and maintenance practices.

31-

(C) Planning

- Planning is a systematically organised actions for effective implementation strategy towards achieving a particular goal.
- It is a system that ensures developmental plan for people's interest, taking into consideration economic,
- environmental and social benefits (and also drawbacks). Such planning is undertaken using scientific approach with analysis of collected data, developing necessary models and then developing designs.



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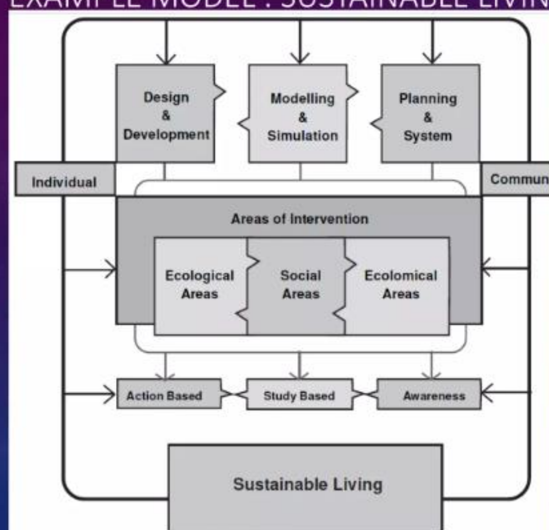
EXAMPLE MODEL : SUSTAINABLE LIVING



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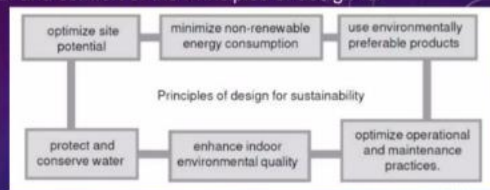
Sustainable **design** seeks to

- reduce negative impacts on the environment, the health and comfort of the Principles of design for sustainability include the ability to
- (a) optimize site potential,
- b) minimize non-renewable energy consumption,
- (c) use environmentally preferable products,
- (d) protect and conserve water,
- (e) enhance indoor environmental quality and
- (f) optimize operational and maintenance practices



In fact, environmental and natural resource **planning** use balanced decision-making that takes into consideration the natural environment.

- The process combines protection of environmental resources with community goals.
- Natural resource planning and management deal with managing the way in which people and natural landscapes interact in rational ways.
- It brings together land use planning, water management, biodiversity conservation, and the future sustainability of industries/ activities like agriculture, mining, tourism, fisheries, forestry and many more.

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Project – 1: Land use change and its impact on natural and cultural landscape

Background

Land use change is a process by which human activities transform the natural landscape, referring to how land has been used, usually the purpose. Land use changes are often nonlinear and sometimes may be causing multi-dimensional impacts to the environment. Therefore, land use changes need assessment, and it is also possible to model future conditions as per assumptions, to ensure sustainable conditions.

Objectives

1. To assess the land use changes over a time period
2. To conduct field level survey to verify and document land use changes.
3. To quantify changes in land use.

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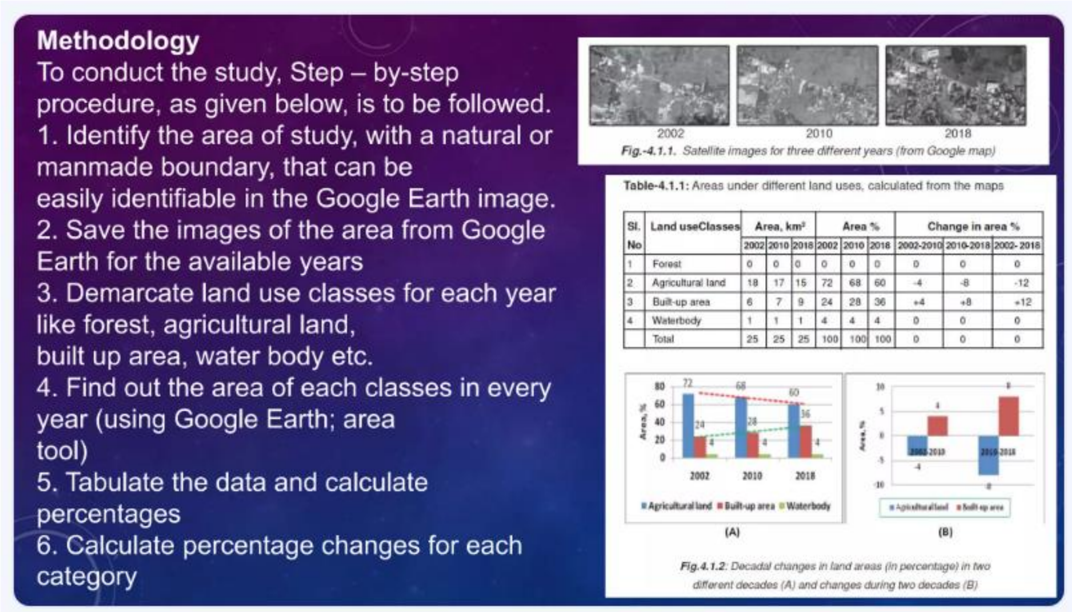

Sl. No	Land useClasses	Area, km²			Area %			Change in area %		
		2002	2010	2018	2002	2010	2018	2002-2010	2010-2018	2002- 2018
1	Forest	0	0	0	0	0	0	0	0	0
2	Agricultural land	18	17	15	72	68	60	-4	-8	-12
3	Built-up area	6	7	9	24	28	36	+4	+8	+12
4	Waterbody	1	1	1	4	4	4	0	0	0
	Total	25	25	25	100	100	100	0	0	0

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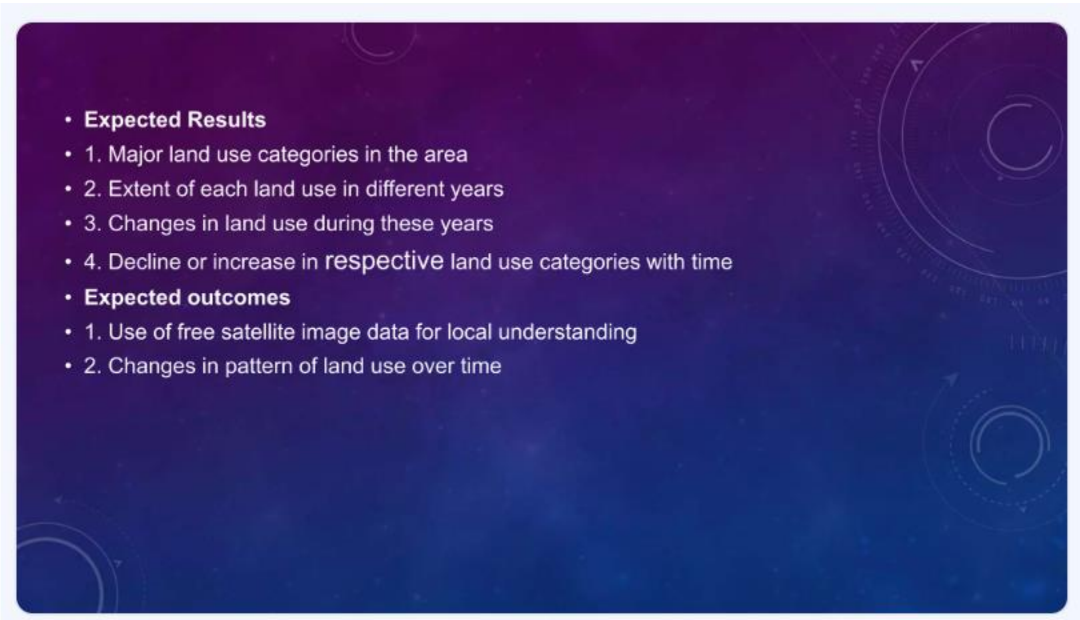

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THE MODEL LIFE-CYCLE

The model life-cycle is ongoing

Identification

- Determine correct decision-related questions and establish modeling objectives
- Define the purpose of the modeling activity
- Specify the model application context

Development

- Develop the conceptual model that reflects the underlying science of included processes
- Derive the mathematical representation of that science and then encode into a computer program

Evaluation

- Peer Review
- Conduct formal testing to ensure model expressions have been encoded correctly
- Test model outputs by comparisons with empirical(and independent) data

Application

- Run the model and analyze outputs to inform a decision

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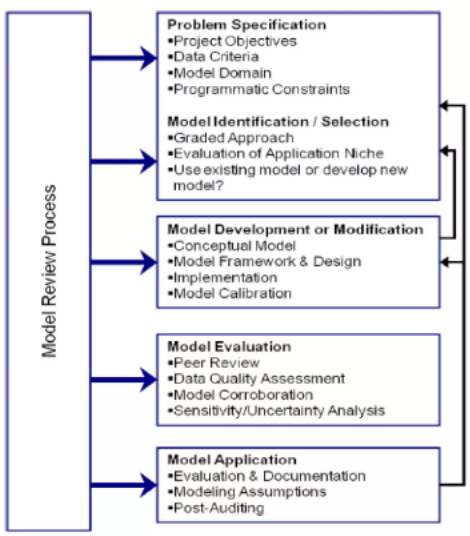

The Primary Stages of the Model Life-cycle: Identification/Selection, Development, Evaluation, and Application. Modified from EPA (2009a).

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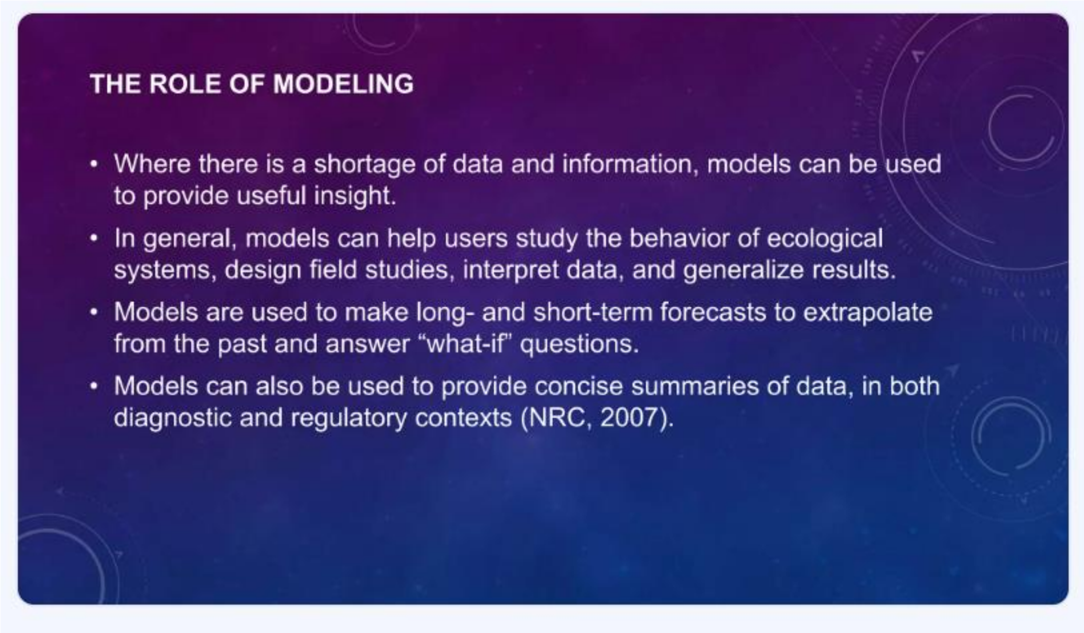
THE ROLE OF MODELING
• Where there is a shortage of data and information, models can be used to provide useful insight.
• In general, models can help users study the behavior of ecological systems, design field studies, interpret data, and generalize results.
• Models are used to make long- and short-term forecasts to extrapolate from the past and answer "what-if" questions.
• Models can also be used to provide concise summaries of data, in both diagnostic and regulatory contexts (NRC, 2007).

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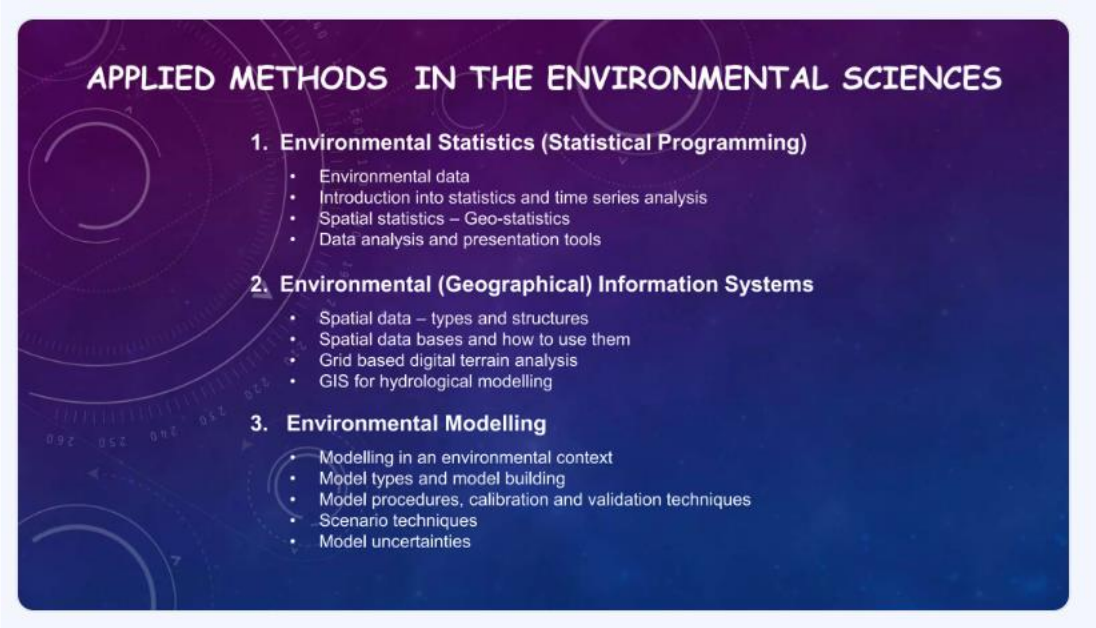
APPLIED METHODS IN THE ENVIRONMENTAL SCIENCES
1. Environmental Statistics (Statistical Programming)
• Environmental data
• Introduction into statistics and time series analysis
• Spatial statistics – Geo-statistics
• Data analysis and presentation tools
2. Environmental (Geographical) Information Systems
• Spatial data – types and structures
• Spatial data bases and how to use them
• Grid based digital terrain analysis
• GIS for hydrological modelling
3. Environmental Modelling
• Modelling in an environmental context
• Model types and model building
• Model procedures, calibration and validation techniques
• Scenario techniques
• Model uncertainties

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ENVIRONMENTAL MODELS

- Environmental models are categorized into groups representing a continuum of processes which translate the interactions between human activities and natural processes into human health and environmental impacts.
- •**Human Activity Models**
- •**Natural Systems Process**
- •**Emissions Models**
- •**Fate and Transport Models**
- •**Exposure Models**
- •**Human Health Effects Models**
- •**Ecological Effects Models**
- •**Economic Impact Models**
- •**Noneconomic Impact Models**

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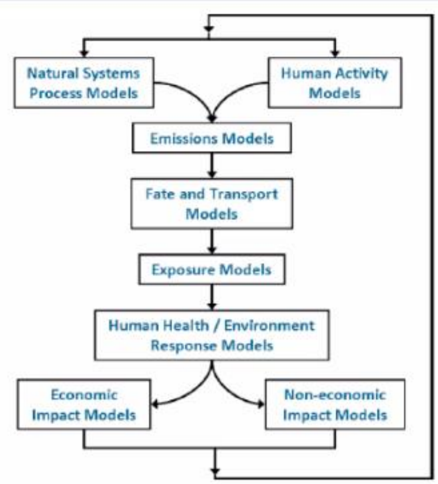

Classes of Environmental Models: These classes represent a research continuum from human activities and natural system processes to environmental and economic impacts. Modified from NRC (2007).

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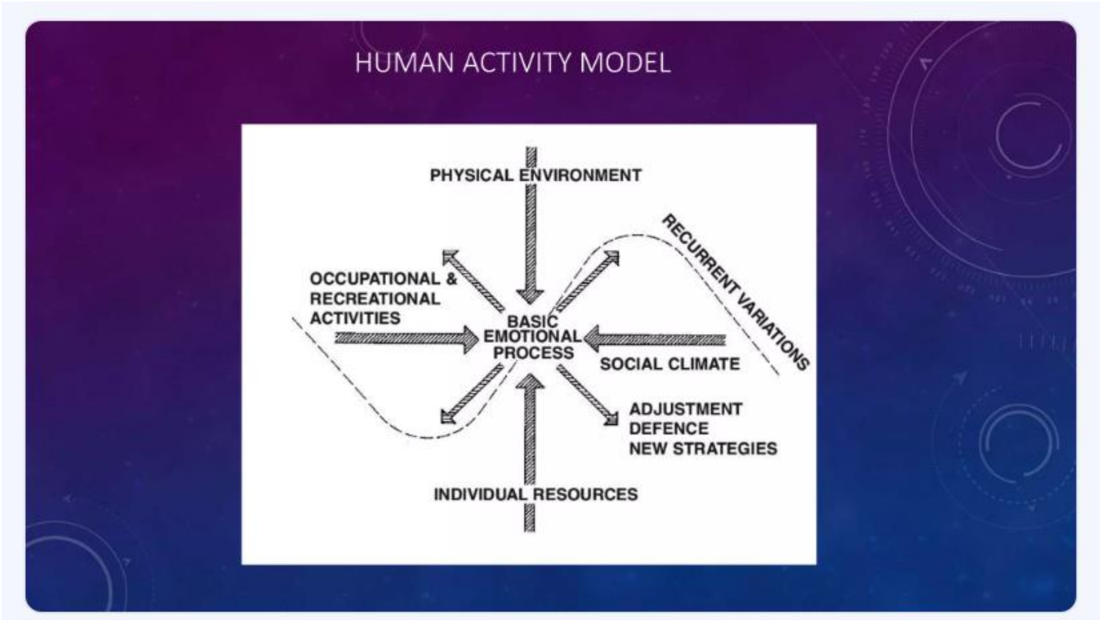
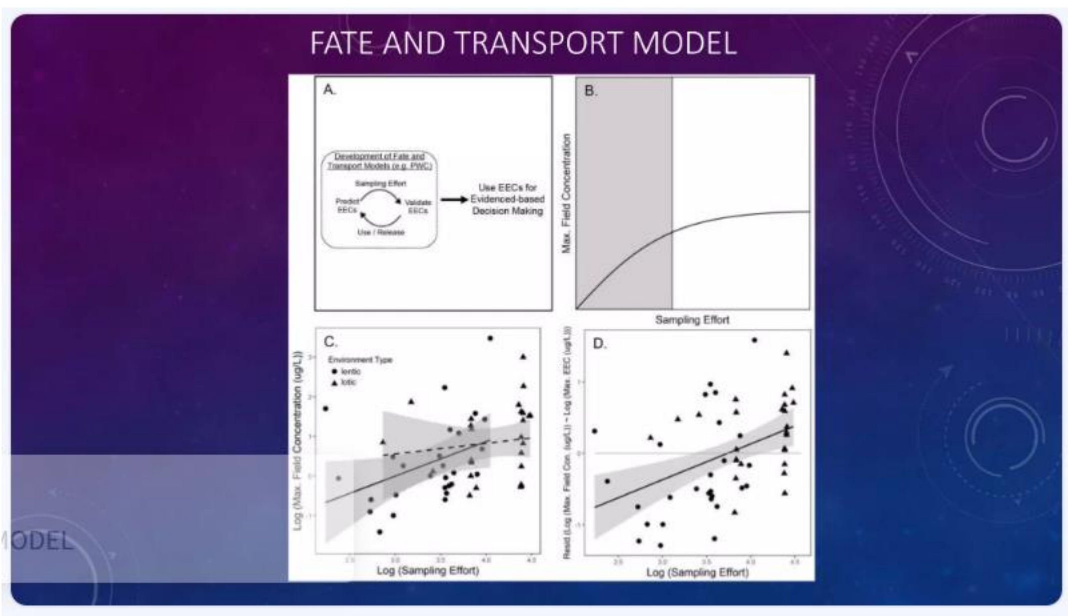

HUMAN ACTIVITY MODEL
PHYSICAL ENVIRONMENT
OCCUPATIONAL &
RECREATIONAL
ACTIVITIES
BASIC
EMOTIONAL
PROCESS
SOCIAL CLIMATE
RECURRENT VARIATIONS
ADJUSTMENT
DEFENCE
NEW STRATEGIES
INDIVIDUAL RESOURCES

44-


FATE AND TRANSPORT MODEL
A.
Use EECs for
Evidenced-based
Decision Making
B.
Max. Field Concentration
Sampling Effort
C.
Environment Type
lentic
lotic
Log (Max. Field Concentration (ug/L))
Log (Sampling Effort)
D.
Log (Sampling Effort)

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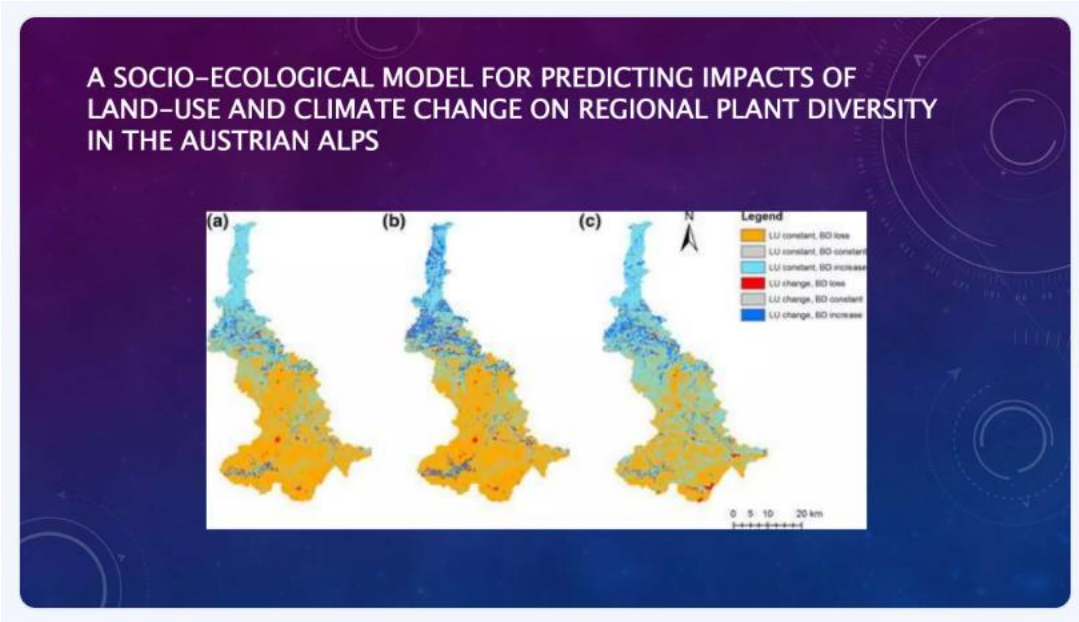
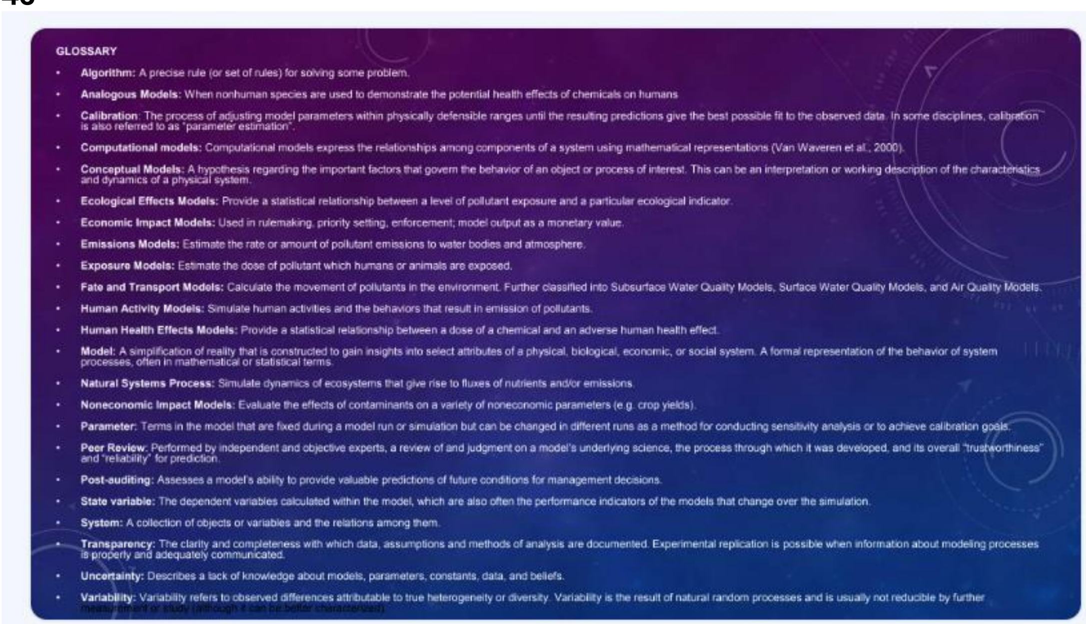

A SOCIO-ECOLOGICAL MODEL FOR PREDICTING IMPACTS OF LAND-USE AND CLIMATE CHANGE ON REGIONAL PLANT DIVERSITY IN THE AUSTRIAN ALPS
(a)
(b)
(c)
N
Legend
LU constant, BD loss
LU constant, BD constant
LU constant, BD increase
LU change, BD loss
LU change, BD constant
LU change, BD increase
0 5 10 20 km

46-


GLOSSARY
• Algorithm: A precise rule (or set of rules) for solving some problem.
• Analogous Models: When nonhuman species are used to demonstrate the potential health effects of chemicals on humans
• Calibration: The process of adjusting model parameters within physically defensible ranges until the resulting predictions give the best possible fit to the observed data. In some disciplines, calibration is also referred to as "parameter estimation".
• Computational models: Computational models express the relationships among components of a system using mathematical representations (Van Waveren et al., 2000).
• Conceptual Models: A hypothesis regarding the important factors that govern the behavior of an object or process of interest. This can be an interpretation or working description of the characteristics and dynamics of a physical system.
• Ecological Effects Models: Provide a statistical relationship between a level of pollutant exposure and a particular ecological indicator.
• Economic Impact Models: Used in rulemaking, priority setting, enforcement; model output as a monetary value.
• Emissions Models: Estimate the rate or amount of pollutant emissions to water bodies and atmosphere.
• Exposure Models: Estimate the dose of pollutant which humans or animals are exposed.
• Fate and Transport Models: Calculate the movement of pollutants in the environment. Further classified into Subsurface Water Quality Models, Surface Water Quality Models, and Air Quality Models.
• Human Activity Models: Simulate human activities and the behaviors that result in emission of pollutants.
• Human Health Effects Models: Provide a statistical relationship between a dose of a chemical and an adverse human health effect.
• Model: A simplification of reality that is constructed to gain insights into select attributes of a physical, biological, economic, or social system. A formal representation of the behavior of system processes, often in mathematical or statistical terms.
• Natural Systems Process: Simulate dynamics of ecosystems that give rise to fluxes of nutrients and/or emissions.
• Noneconomic Impact Models: Evaluate the effects of contaminants on a variety of noneconomic parameters (e.g. crop yields).
• Parameter: Terms in the model that are fixed during a model run or simulation but can be changed in different runs as a method for conducting sensitivity analysis or to achieve calibration goals.
• Peer Review: Performed by independent and objective experts, a review of and judgment on a model's underlying science, the process through which it was developed, and its overall "trustworthiness" and "reliability" for prediction.
• Post-auditing: Assesses a model's ability to provide valuable predictions of future conditions for management decisions.
• State variable: The dependent variables calculated within the model, which are also often the performance indicators of the models that change over the simulation.
• System: A collection of objects or variables and the relations among them.
• Transparency: The clarity and completeness with which data, assumptions and methods of analysis are documented. Experimental replication is possible when information about modeling processes is properly and adequately communicated.
• Uncertainty: Describes a lack of knowledge about models, parameters, constants, data, and beliefs.
• Variability: Variability refers to observed differences attributable to true heterogeneity or diversity. Variability is the result of natural random processes and is usually not reducible by further measurement or study (although it can be better characterized).