PRESENTATION: GROUP-3

EMERGING OPPORTUNITIES FOR LANDSCAPE ECOLOGICAL MODELLING

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Introduction

WHY USE LANDSCAPE ECOLOGICAL MODELLING?

- To illuminate the relationships between the structure (or pattern) and ecological processes occurring on the land surface is one of the goal.

- The dynamic complexities between patterns and processes which presents difficulties for many aspects of landscape science can be overcome by the modelling.

- Simulation modelling, valuable in landscape ecology.

Empirical Studies	Simulation Methods
Prohibitively challenging and expensive to mount field experiments at appropriately large spatial and temporal scales, or to establish experimental controls and replications	Promote the key ecological processes of movement and dispersal of particular species. Few shows increase in targeted patterns like population size and species diversity
Data collection on processes is time-consuming. When mobile organisms are studied its difficult if species need to be tracked, captured, or monitored. Studied population may be undetectable, and bias in sampling methods.	It allows "virtual" experiments to be run repeatedly, generating many data and exploring effects.
Can't extend inference and further studies targeted at processes or factors that appear especially important.	Assumptions are required for define a bounded and tractable system which potentially contributes to the misinterpretation and error.
Produce highly case specific and non-generalisable results	Understanding the integrated dynamics of land systems and their responses to global change.

BACKGROUND TO LANDSCAPE, ECOLOGICAL, AND LANDSCAPE ECOLOGICAL MODELLING

It’s necessary to provide future perspectives for landscape ecological modelling.

- Work focused at the intersection between landscape modelling and ecological modelling:

Modelling methods
(landscape modelling, ecological modelling, and landscape ecological modelling)

Pattern-based approaches

- Identification of existing patterns in the landscape or ecological system.
- Replicating or extrapolating it.

Process-based approaches

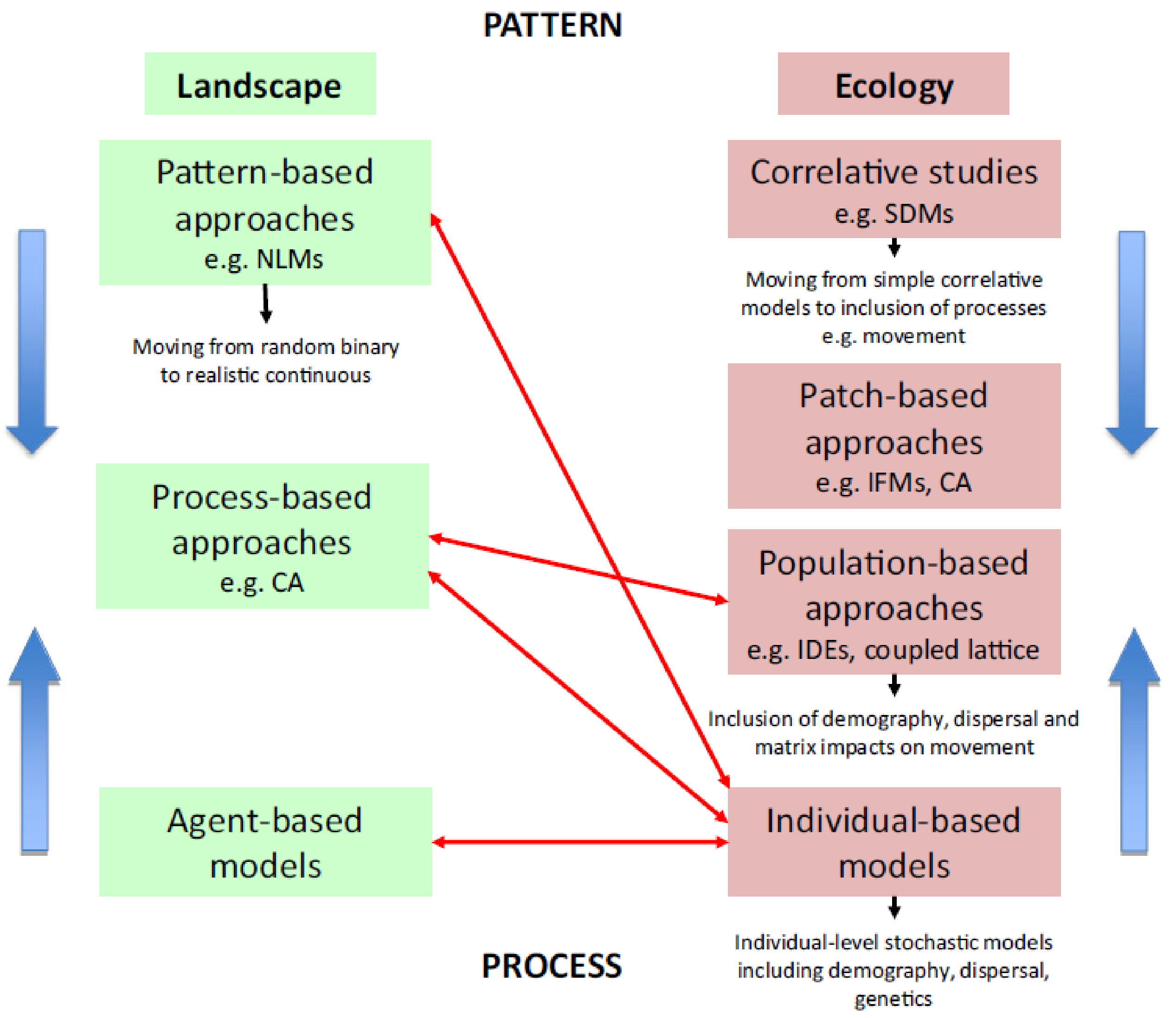
- Representation of the underlying processes that formed observed landscape.

- Work focused on progress in one field that has not yet been applied in the other (substantial amount):

Type	Example(s)
Landscape	
Neutral landscape models	QRULE [29]
Process-based anthropogenic disturbance models	G-Raffe [30]
Biogeochemical models	RHESSys [31]
Process-based land-use models	CRAFTY [33] LUCITA [34] SWISSland [35]
Ecology	
Species distribution models	MaxEnt [38] DOMAIN [39] BIOCLIM [40] Other statistical approaches not originally created for SDMs: Random Forests [41] GAMs [42]
Forest landscape dynamics, succession and disturbance	iLand [45] LANDIS [46] SORTIE [47]
Dynamic global vegetation model (integrated biogeochemical and vegetation models)	CESM [49] ORCHIDEE [50] LPJ-GUESS [51]
Hybrid species distribution models	[53–55]
Meta-population (patch occupancy) or meta-community models	RAMAS Metapop [57] M-SET [58] [59, 60]
Cellular automata	[62]
Population abundance models	MIGRATE [64] Integrodifference equation models [65, 66]
Individual-based models	RangeShifter [67] HexSim [68]
ntegrated models	
Integrated human decision making and biophysical models	PALM [70] IMSHED [71]
Integrated socio-ecological models	[60, 72, 73]

- ➢ Chart showing different simulation methods (with examples) applied for either the Landscape or Ecology modelling.

PATTERN-BASED AND PROCESS-BASED MODELS OF LANDSCAPES AND LAND-USE DYNAMICS



- The suite of approaches available for landscape and ecological modelling.

NEUTRAL LANDSCAPE MODELS

(PATTERN-BASED)

1. Neutral landscape models (NLMs) are a set of approaches intended to create partially realistic landscape patterns, whilst remaining neutral with respect to the processes that formed them.

2. NLMs are the landscape modelling approach that has been used the most in an ecological context.

3. There is no basic data requirement for this model.

4. NLM can be used to generate artificial landscape patterns with predefined characteristics, To verify other models, i.e. to investigate effects of landscape structure on model results, To study effects of landscape structure on processes – social, ecological, biogeochemical, biophysical.

STATISTICAL LANDSCAPE MODELS

(PATTERN-BASED)

1. Statistical landscape models aim to generate anthropogenic landscape or land-use patterns without direct representation of the underlying processes.

2. This type of model mainly termed either top-down or pattern based.

3. We will use differential equation, regression theory, transition probability model etc. in the statistical landscape models.

4. This type of model has been developed to include demands for different land uses, allowing alternative future scenarios to be investigated.

CELLULAR AUTOMATA

(PATTERN-BASED)

1. Cellular automata (CA) models represent a middle ground between process- and pattern-based approaches.

2. CA have also been used to study land-use transitions and residential dynamics among other applications.

3. CAs consist of a grid of cells which each exist in one of a finite set of states, with the future state of each cell determined by its previous state and that of its neighbors.

4. CAs have generally been applied with either a land-scape or an ecological focus, however they have also been applied in landscape ecology studies, for example to evaluate conservation interventions in a human-dominated tropical landscape.

AGENT-BASED MODELS

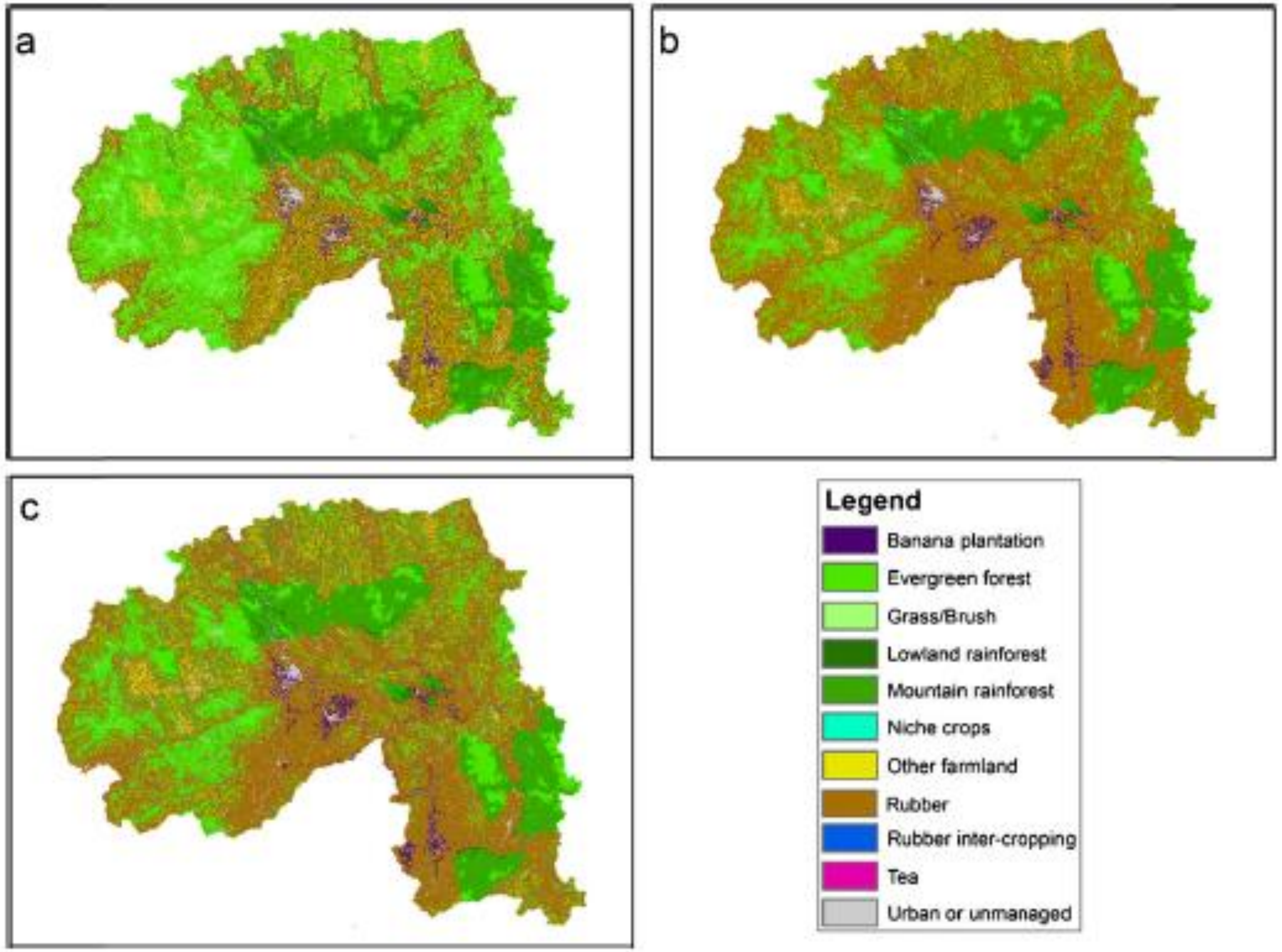
(PROCESSED-BASED)

1. ABM is also a process based model that are used to increase model accuracy but also to explore alternative accounts of human decision-making under socio-economic or environmental pressures.

2. Because of the complexity of the modelled system, land-use ABMs initially focused on carefully constrained systems and behaviors, covering small geographical extents, and specific land-uses.

3. It makes models ideal for testing the (potentially unexpected) outcomes of policy interventions.

4. Incorporating some of the complexity of these interactions into models can lead to the identification of unexpected non-linear behaviors and regime shifts.



- This example shows output from the agent-based model CRAFTY, of land-use scenarios in Xishuangbanna, China.

  a) Model of land-use in 2010.
  b) Projection for 2030 with increasing demand for rubber;
  c) Projection for 2030 with increasing demand for rubber, and institutional support for new niche crops and rubber inter-cropping.

Pattern-based and process-based models in spatial ecology

METAPOPULATION MODELS

(PROCESSED-BASED)

1. Developed in need for spatial context in ecological models.

2. Since they typically represent populations as either present or absent in each habitat patch, they're also referred to as patch occupancy models.

3. Widely used for population viability analysis. Example incidence function model (IFM).

4. IFM like models can be used to assess the potential of networks of habitat patches to support viable Metapopulations of given species.

5. Such models do not account for what is between the habitat patches, i.e. the matrix.

COUPLED MAP LATTICES

(PROCESSED-BASED)

1. Developed to incorporate population dynamical realism that cannot be captured in classical metapopulation

2. Coupled map lattice is a group of models that represent the environment as a grid of cells, where each grid supports a population.

3. In these models, local dynamics in each patch are simulated and the patches are linked by dispersal.

4. Dispersal can be incorporated in differing degrees of complexity/realism.

5. These models are used to address a broad range of ecological, and eco-evolutionary questions.

INTEGRODIFFERENCE EQUATIONS
(PROCESSED-BASED)

1. Integrodifference equations (IDEs) are often used to predict species spread over landscapes.

2. Similar to Coupled map lattice, however, they typically assume space to be continuous.

3. Because of that estimates of population spread in homogeneous landscapes are possible via analytical techniques.

4. That makes parameter sensitivity analysis straightforward.

5. Because of the challenges involved in developing these analytical techniques and a lack of computational resources, few mechanistic IDE models have used large complex mapped heterogeneous landscapes to model spreading species.

INDIVIDUAL-BASED MODELS

(PROCESSED-BASED)

1. Individual-based models(IBMs) are now widely used to study ecological processes, with their major strength being that they account for inter-individual, as well as spatio-temporal variation in individual behavior.

2. IBMs are particularly useful for constructing plausible hypotheses about how aggregate-level patterns emerge from individual behavior.

3. IBMs have seen substantial use in landscape ecology. They have been used to address questions at a range of spatial and temporal scales varying from models of home range dynamics and daily movements to multi-decadal models of species range shifting.

4. Most applications of IBMs for landscape connectivity have focused on the process of dispersal, while the ability of the focal organism to form home ranges is rarely explicitly modelled.

INTEGRATED MODELS

(PROCESSED-BASED)

1. There is increased understanding of the need to understand the interactions between human decision making, our environment and ecological processes.

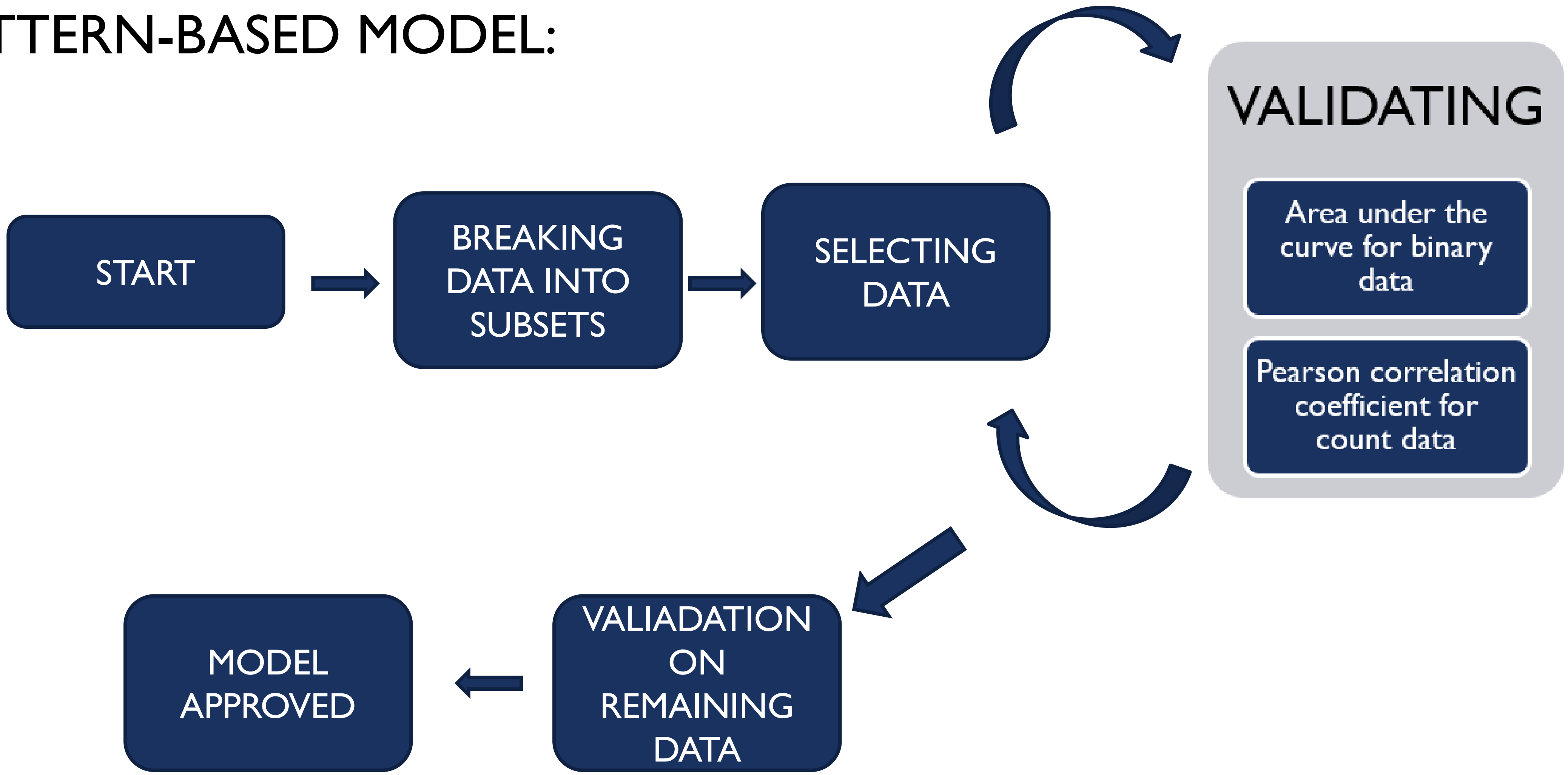
2. A number of modelling approaches now integrate human behavior with biogeochemical processes, e.g. linking human decision making to hydrological processes and soil nutrient flow.

3. There have also been studies on interactions between human decision making and ecology.

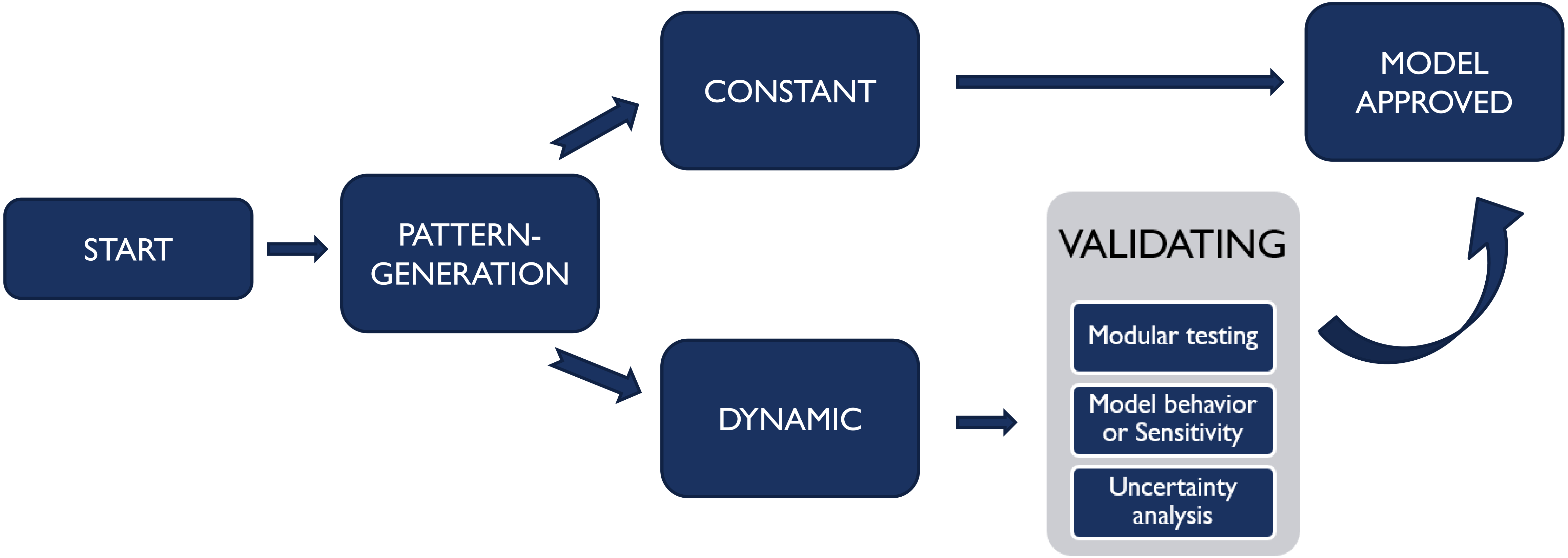
4. Interactions between farmer decision making and ecological processes have perhaps received the greatest focus, with farm-based ABMs integrated with CA and spatial stochastic simulation to model pest species, and with metacommunity models to study the impact of agri-environmental incentive schemes on biodiversity

Model verification and validation

PATTERN-BASED MODEL:



PROCESSED-BASED MODEL:



Nevertheless, models of complex natural and human systems can never be entirely accurate. Simplification inherent in the modelling process inevitably reduces accuracy, especially in its requirement for artificial systems boundaries.

Discussion

The development of models to represent systems from multiple fields of study can be a significant technical challenge, it can be achieved by integrating the model.

The model while integrating face many issues:

- ❑ Issues of scale and aggregation become particularly important when linking landscape, land-use, biogeochemical, ecological, and evolutionary processes. 268]. The level of aggregation of actors and processes can also be important for shaping interactions.

- ❑ The geometry of the landscape is another important, but rarely considered issue. Use of regular grids introduces bias when studying connectivity and animal movement Some studies have used hexagonal geometry because it gives equal weight to neighborhood interactions. However, irregular grids have been suggested as a solution for complete unbiases.

- ❑ Consideration for future landscape ecological modelling is the temporal dynamics of the study system.

Current models of human-environment systems commonly consider only a unidirectional interaction which is rare. However, Fully dynamically coupled models will provide the ideal environment to gain improved understanding and thus a capability to manage dynamic landscape ecological systems.

Current opportunity

- Eco-Evolutionary Simulations on NLMs

- Modelling Organism Spread Rates by Integrating Population Density Ecological Models and Pattern-Based Landscape Models

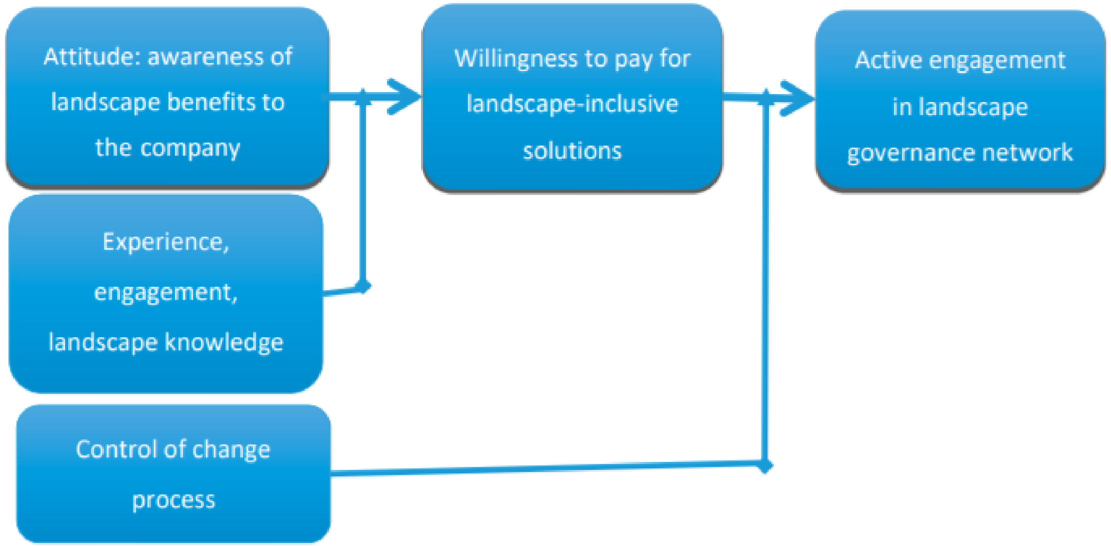
- The figure shows areas of water, hostile, and fertile land. The contours depict predicted annual maximal spread of the spruce trees from the initial location.

- Use of NLMs for Systematic Assessment of Modelling Decisions
- Study Population Viability under Future Scenarios Using IBMs with Output from Pattern-Based Landscape Models
- Dynamic Coupling of ABMs of Land-Use with IBMs for Ecological Systems

Companies like the Danone Ecosystem Fund and agricultural industry run project for that includes the use of the models which gives them the relationship between ecology, sustainability and design and help them grow.

This helps in creating landscape-inclusive solutions.

General Mills, Union Carbide Corporation (Dow chemical), Diageo invest in landscapes services for studying pollination, waste water purification, biodiversity, recreation, ecological connectivity, irrigation water.



- Three phases in the level of involvement of companies in creating landscape-inclusive solutions

There's a variety of industries, e.g., food industries interacting with agricultural landscapes, chemical and car industries, as well as energy-providing companies that uses the models for their sustainability and increasing productivity.


THANK
YOU!