BREE ALL ABM: Update

Best Management Practice Adoption in the Missisquoi Bay Watershed

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All Hands Meeting

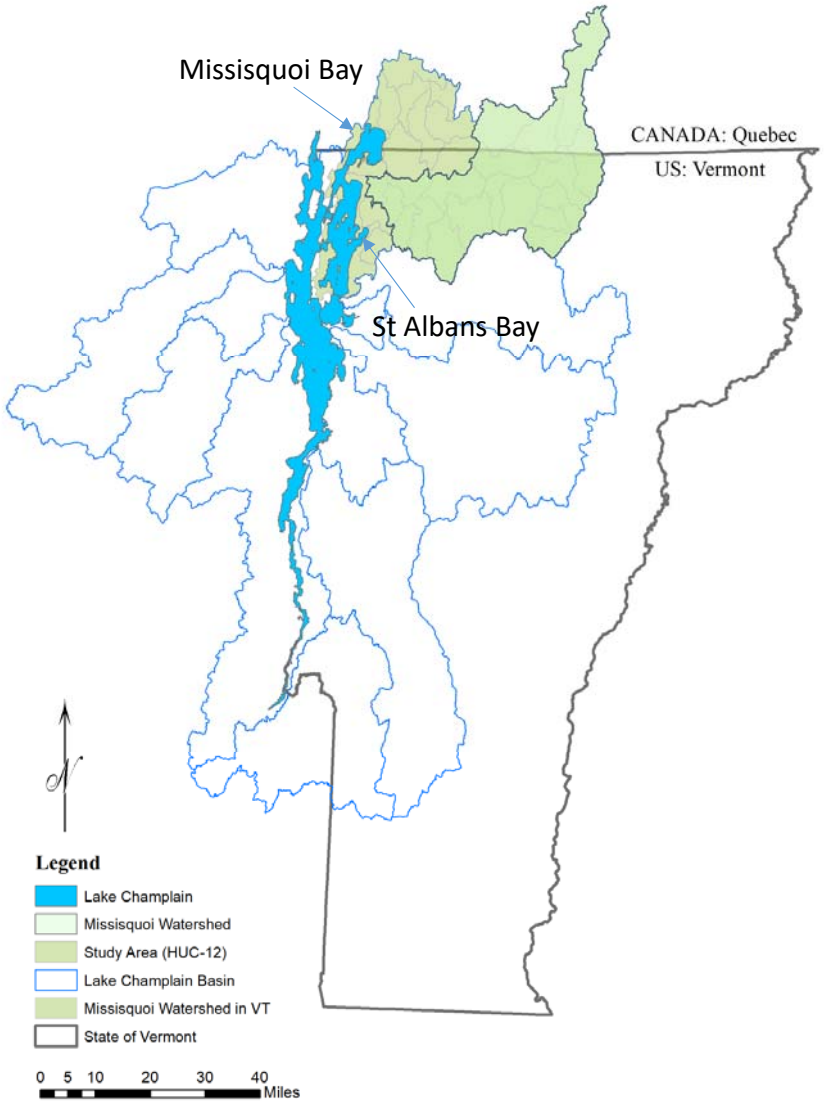
VT EPSCoR BREE Project

June 4, 2019

The Problem

Excessive nutrient pollution (phosphorus, P) entering Vermont's rivers and water bodies leading to *harmful algal blooms* (HABs).

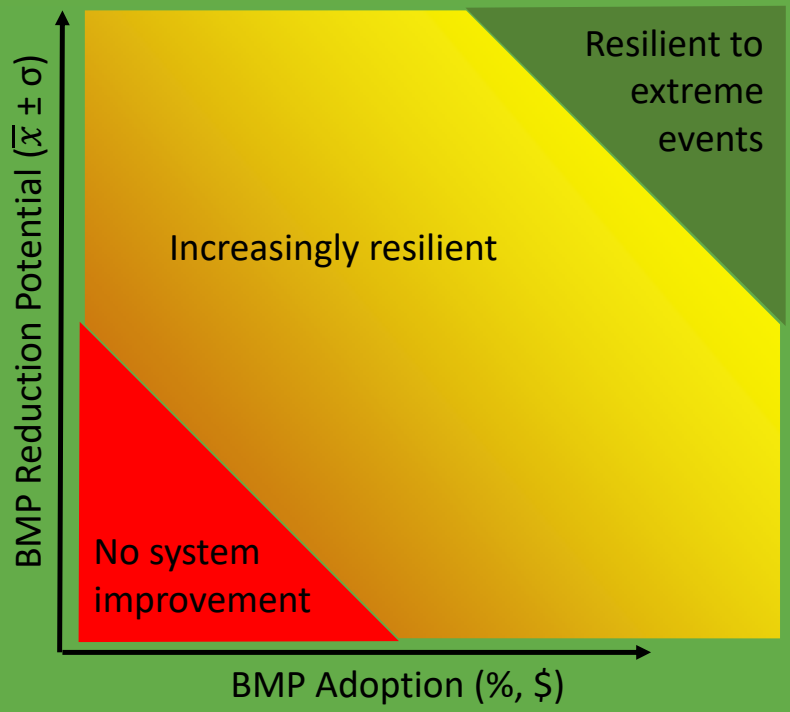
PC: Burlington Free Press



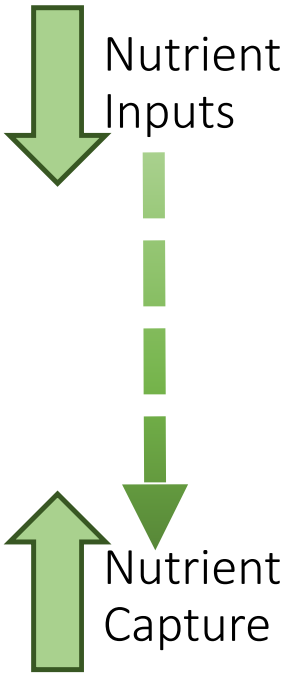
The Question:

What level of efficacy and adoption of (or investment in) ***nutrient best management practices*** (NBMPs) by **individuals** across the landscape will lead to improved resilience in water quality conditions in Lake Champlain's impacted bays under *extreme event and future climate scenarios*?

The Hypothesis:



To reduce excess nutrient input to lake, suite of ***Nutrient Best Management Practices*** (NBMPs) implemented across the watershed.



PC: VPR; St Albans Messenger;

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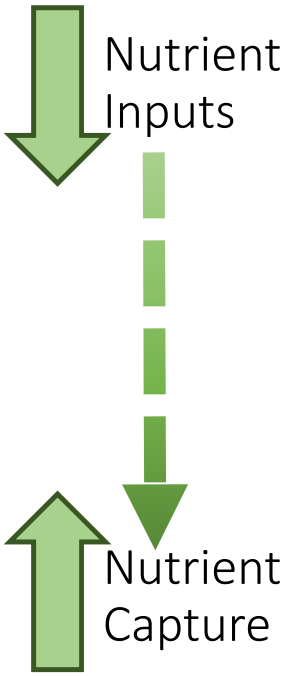
ALL ABM Landowner Populations

Farmers	Foresters	Households	Firms
"Best Management Practices (BMPs)"	"Acceptable Management Practices (AMPs)"	"Green Stormwater Infrastructure (GSI)"	"Green Stormwater Infrastructure (GSI)"



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Nutrient Inputs

Nutrient Capture

Fertilizer application based on soil testing

Reduced Tillage

Temporary Skidder Bridge

Low P Lawn Fertilizer

Picking up dog waste

Rain Barrels

Rain Gardens

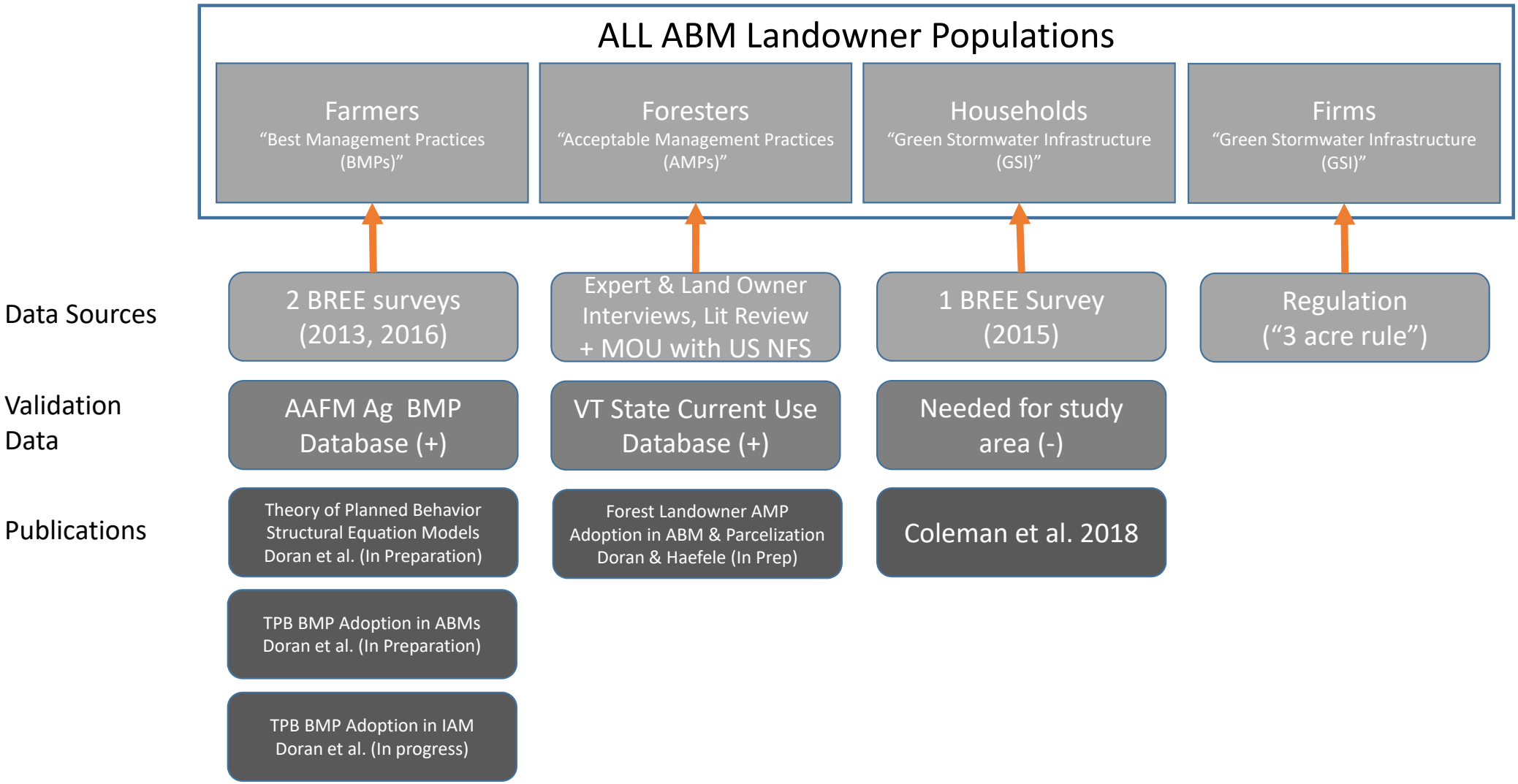
Low/No P Lawn Fertilizer

Pervious Pavement

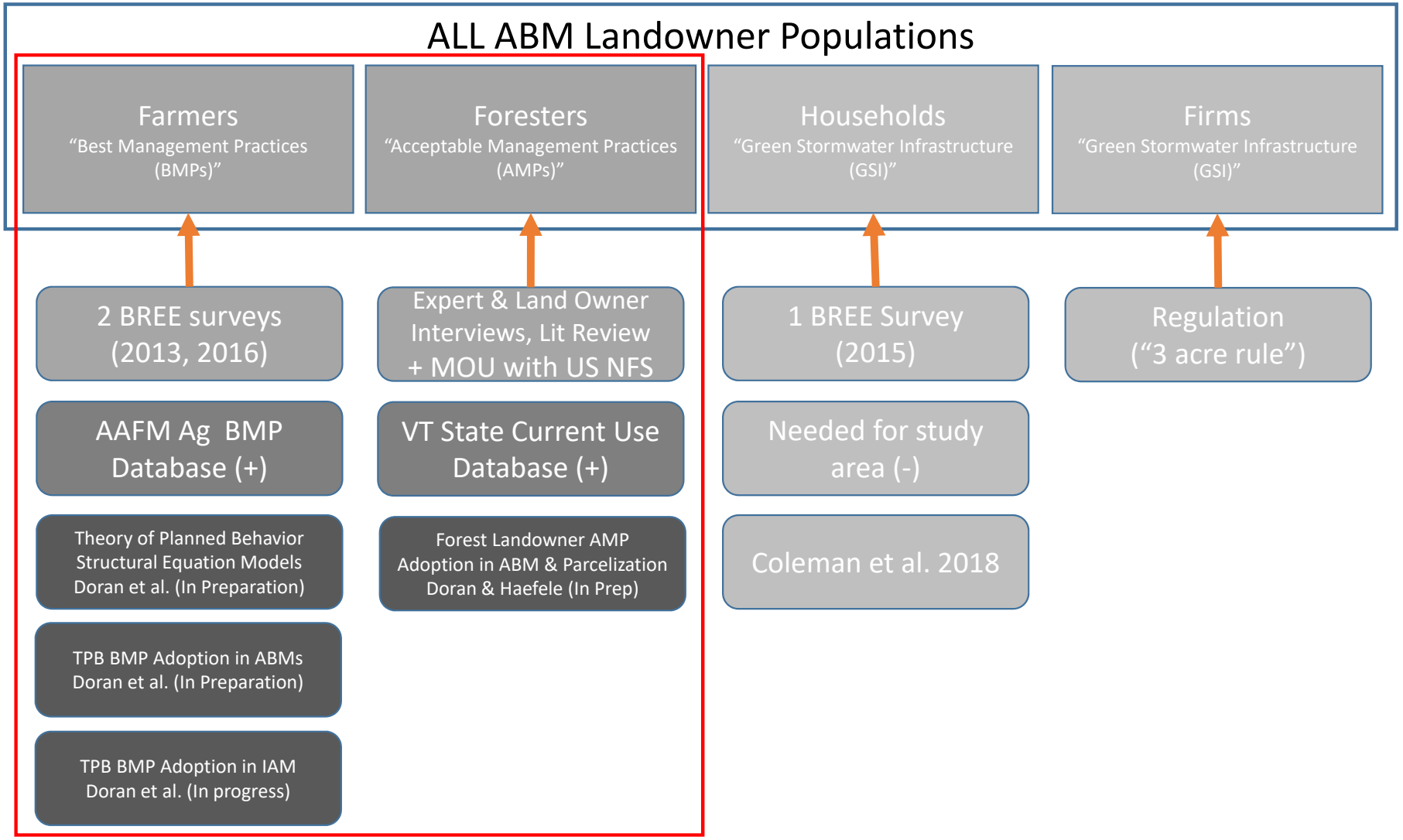
Constructed Wetlands

Retention Ponds

PC: VPR; St Albans Messenger;



Not shown: Municipal Agents in the GovNET model (19 BMP/GSI); Streams/Roads



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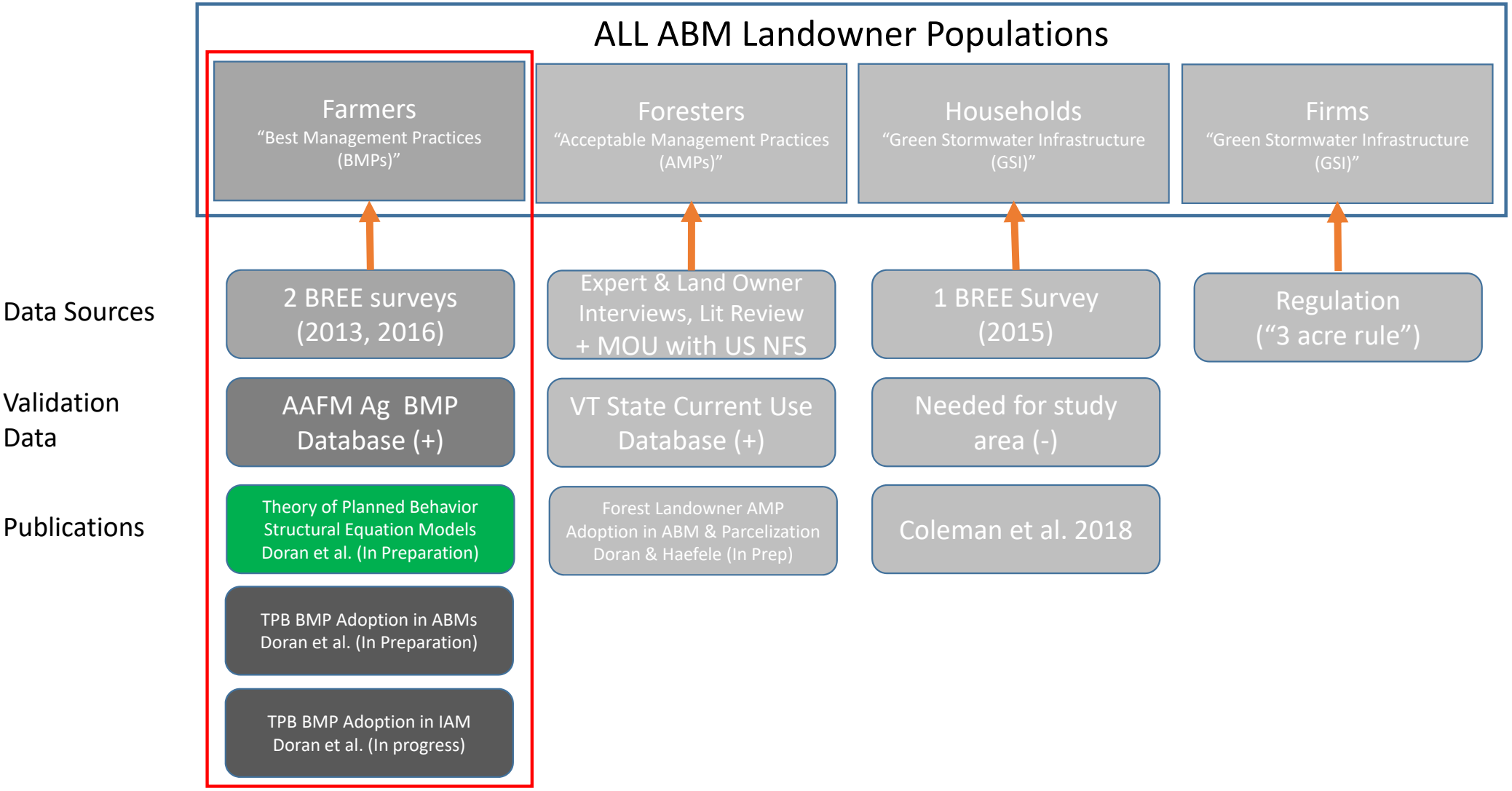

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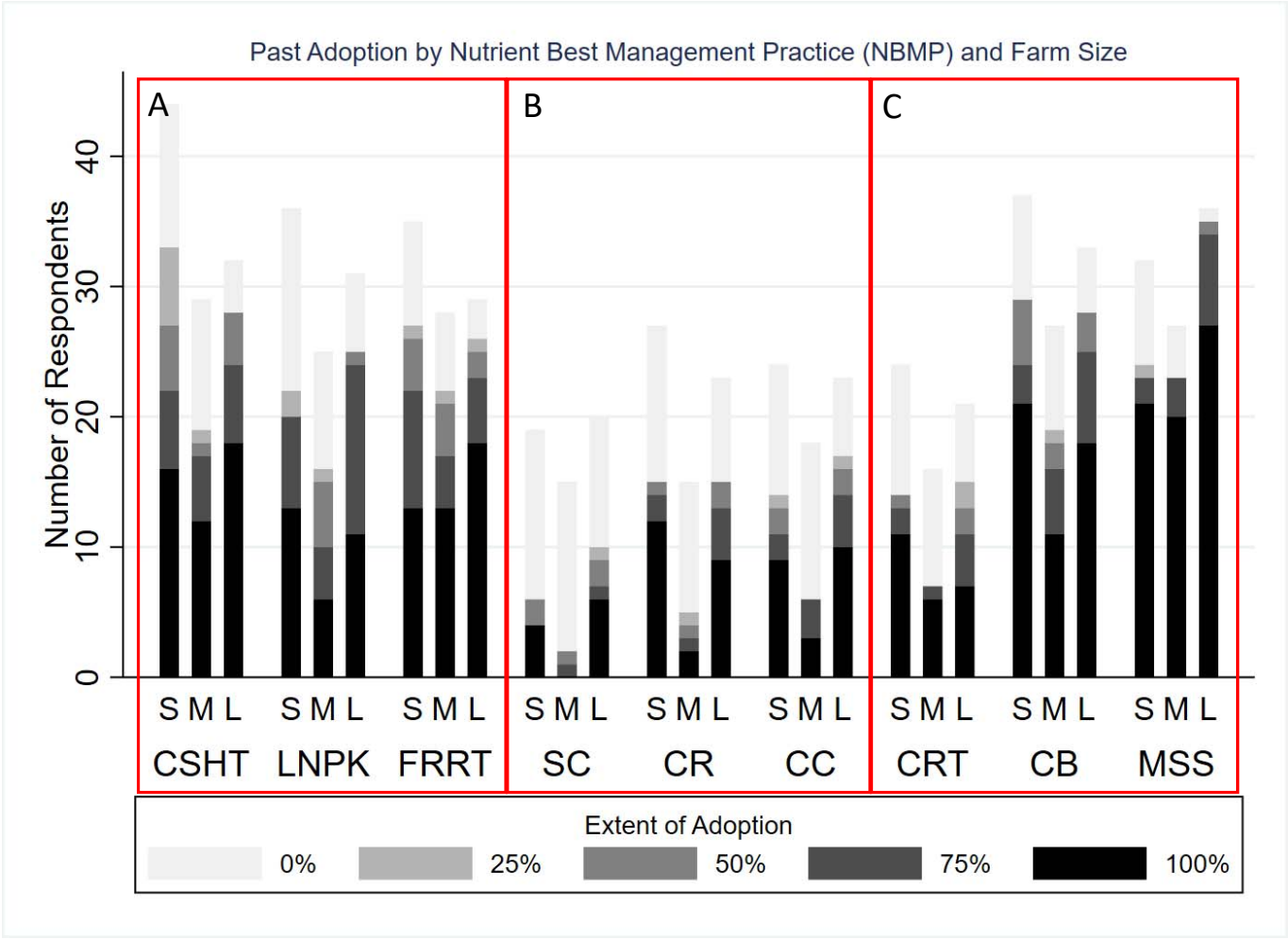
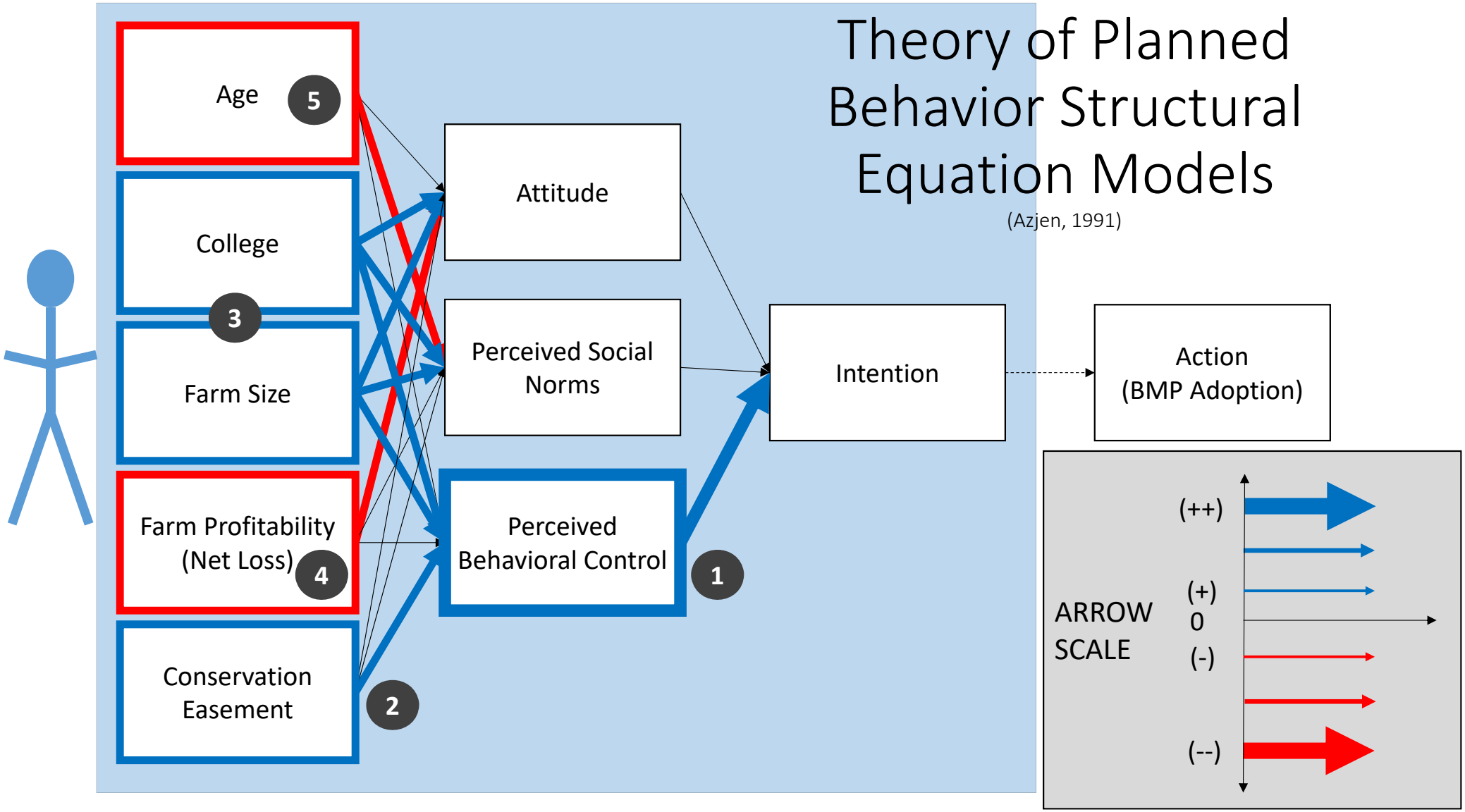
NBMP Groups

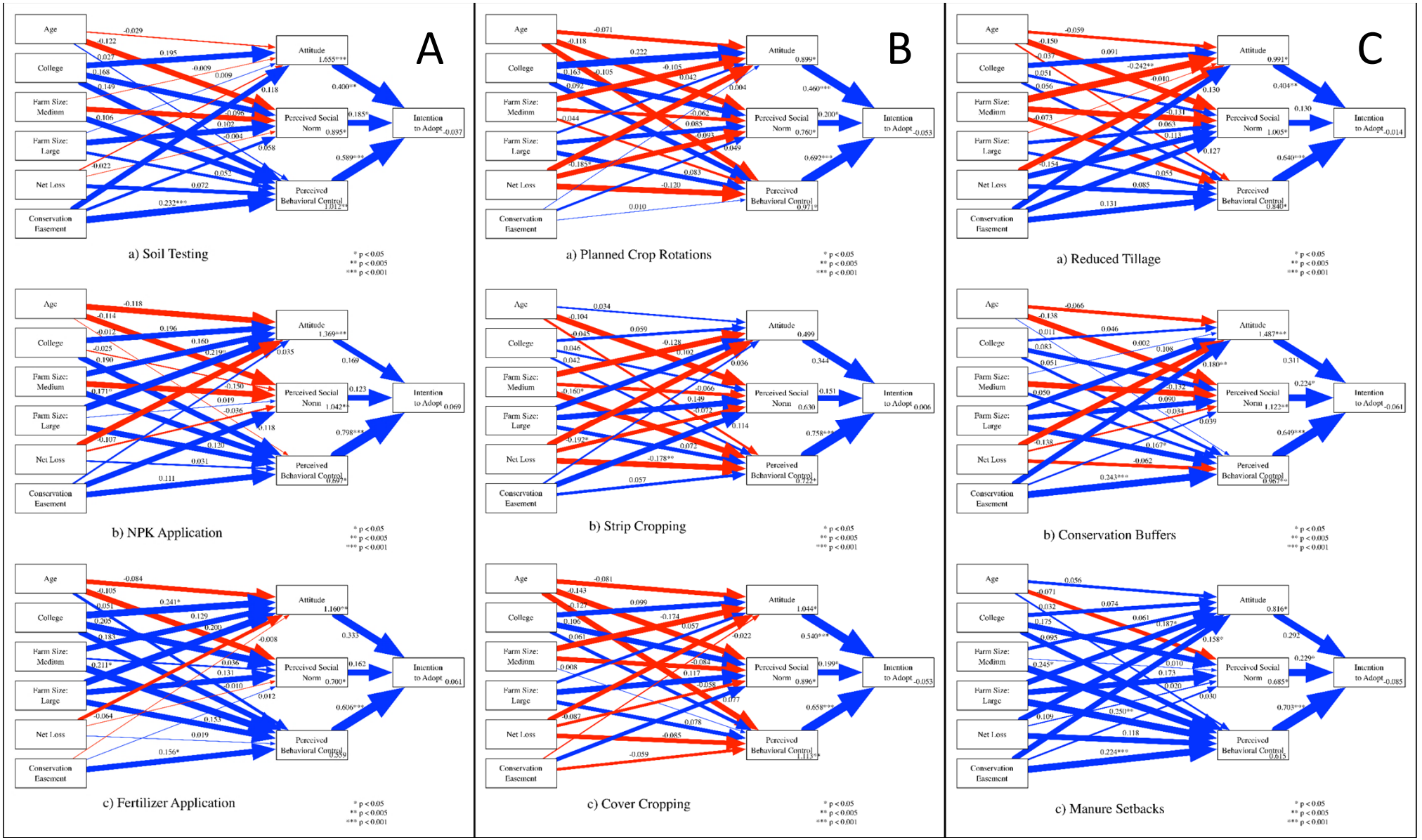
- Group A. Limiting Inputs
  - CSHT: Composite Soil Health Test
  - LNPK: Limited NPK Inputs
  - FRRT: Fertilizer Application at Right Rate and Time
- Group B. Cropping Practices
  - SC: Strip Cropping
  - CR: Crop Rotations
  - CC: Cover Crops
- Group C. Nutrient Capture
  - CRT: Conservation or Reduced Tillage
  - CB: Conservation Buffers
  - MSS: Manure Spreading Setbacks

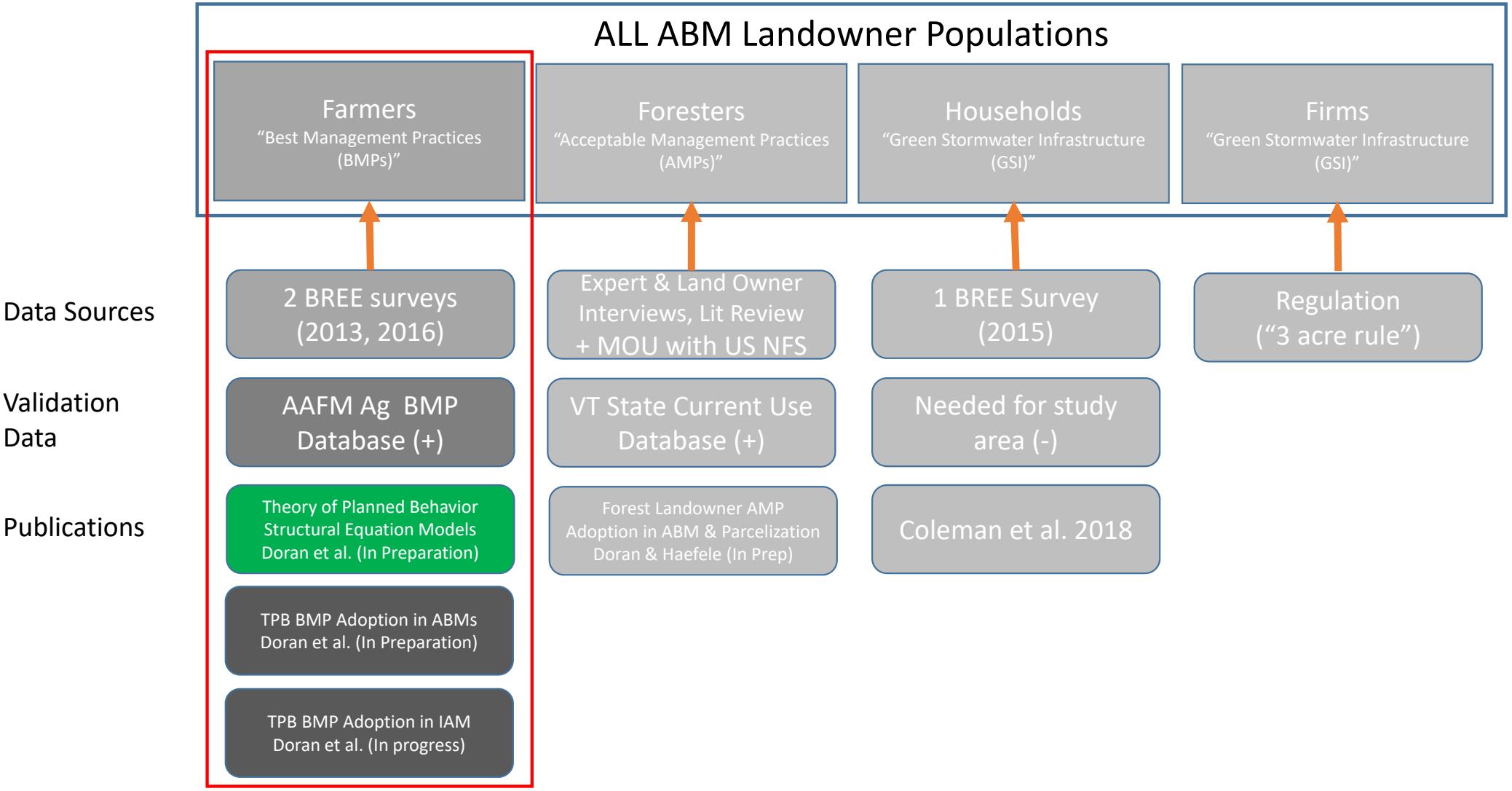


Theory of Planned Behavior Structural Equation Models

(Azjen, 1991)




A
Age
College
Farm Size: Medium
Farm Size: Large
Net Loss
Conservation Easement
Attitude 1.655***
Perceived Social Norm 0.895*
Perceived Behavioral Control 1.012**
Intention to Adopt -0.037
a) Soil Testing
* p < 0.05
** p < 0.005
*** p < 0.001
B
Attitude 0.899*
Perceived Social Norm 0.760*
Perceived Behavioral Control 0.971*
Intention to Adopt -0.053
a) Planned Crop Rotations
C
Attitude 0.991*
Perceived Social Norm 1.005*
Perceived Behavioral Control 0.940*
Intention to Adopt -0.014
a) Reduced Tillage
Attitude 1.369***
Perceived Social Norm 1.042*
Perceived Behavioral Control 0.997*
Intention to Adopt 0.069
b) NPK Application
Attitude 0.499
Perceived Social Norm 0.630
Perceived Behavioral Control 0.725*
Intention to Adopt 0.006
b) Strip Cropping
Attitude 1.487***
Perceived Social Norm 1.122**
Perceived Behavioral Control 0.967**
Intention to Adopt -0.061
b) Conservation Buffers
Attitude 1.160**
Perceived Social Norm 0.700*
Perceived Behavioral Control 0.539
Intention to Adopt 0.061
c) Fertilizer Application
Attitude 1.044*
Perceived Social Norm 0.896*
Perceived Behavioral Control 1.115**
Intention to Adopt -0.053
c) Cover Cropping
Attitude 0.816*
Perceived Social Norm 0.685*
Perceived Behavioral Control 0.615
Intention to Adopt -0.085
c) Manure Setbacks



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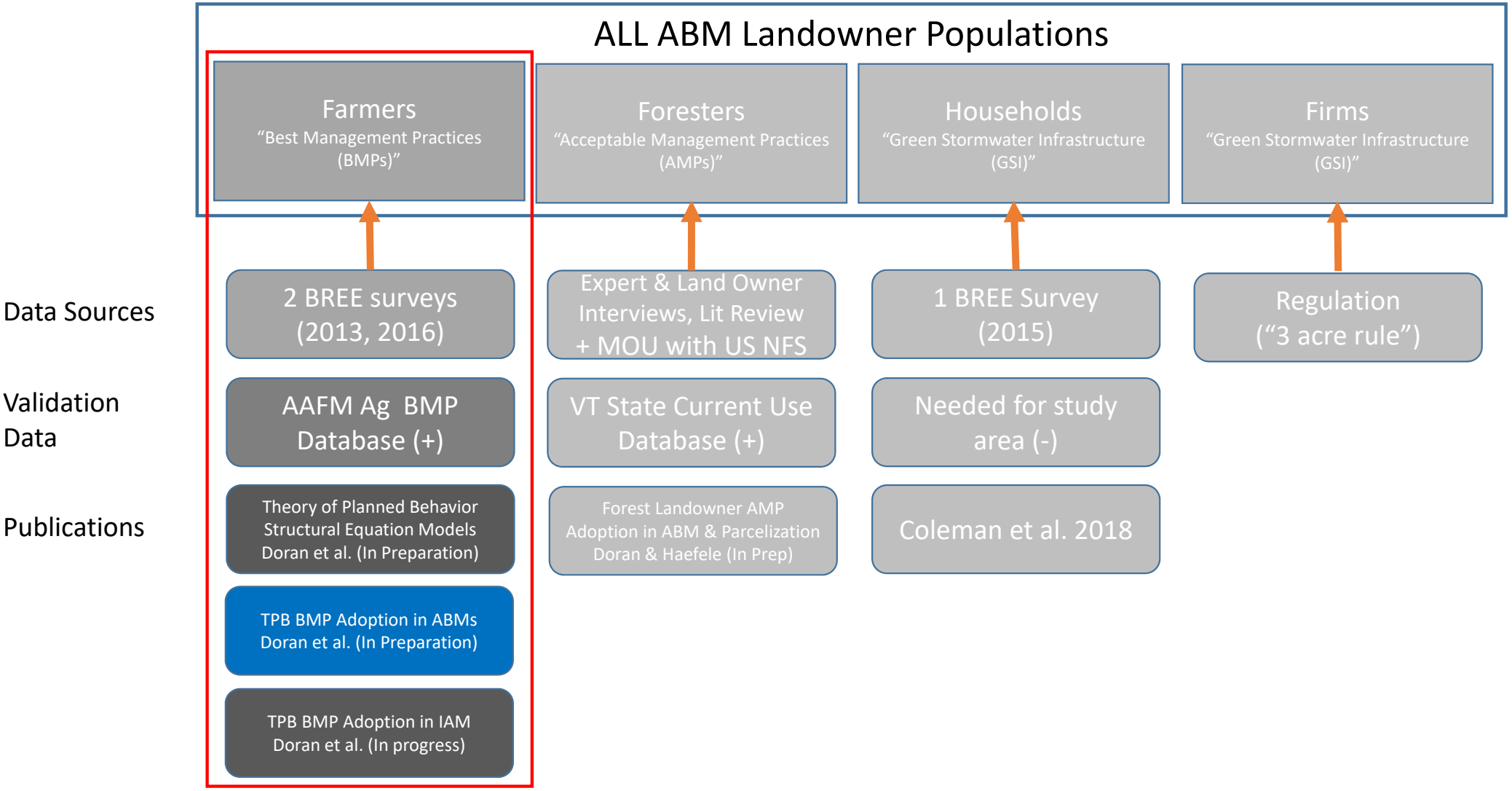

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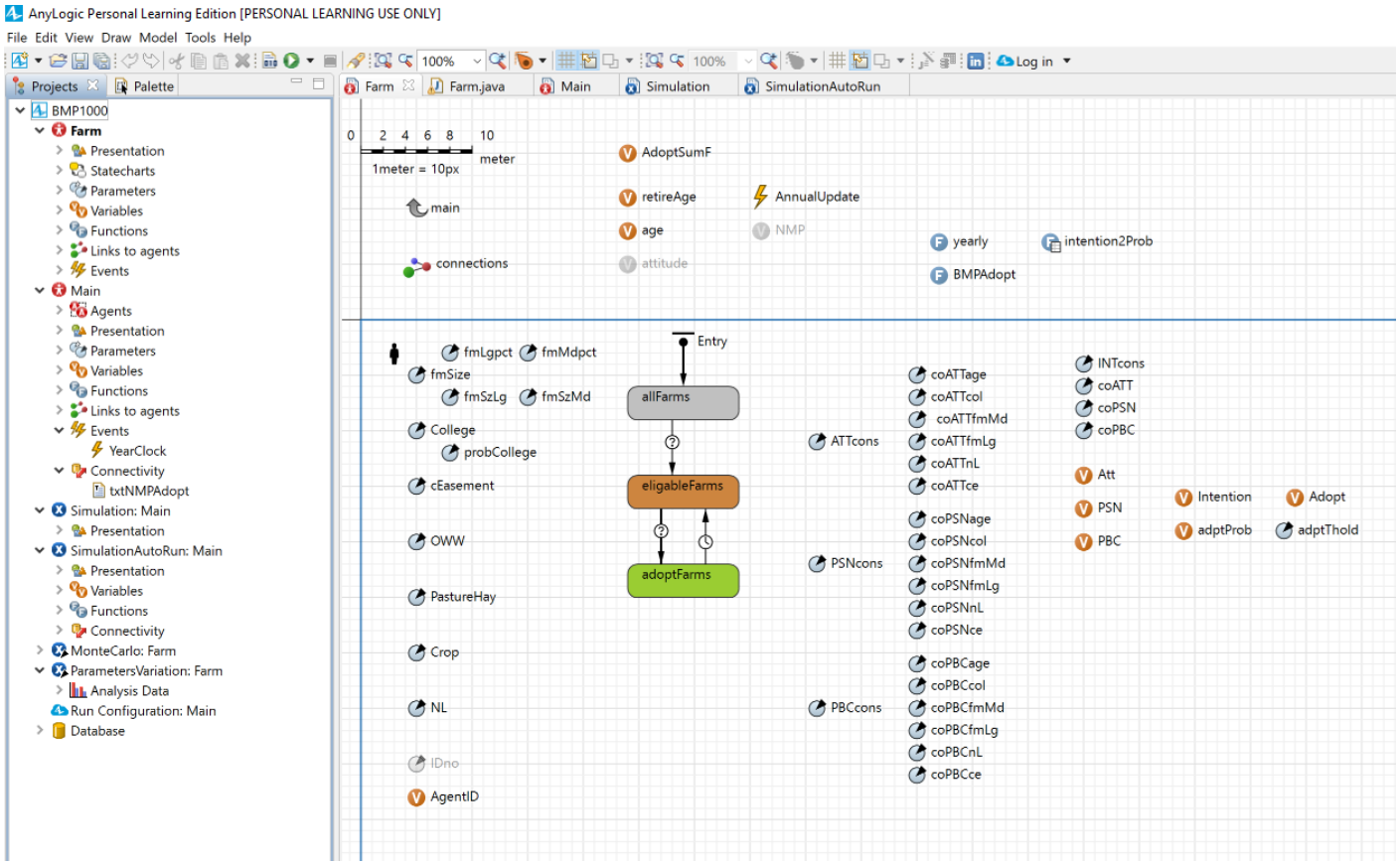
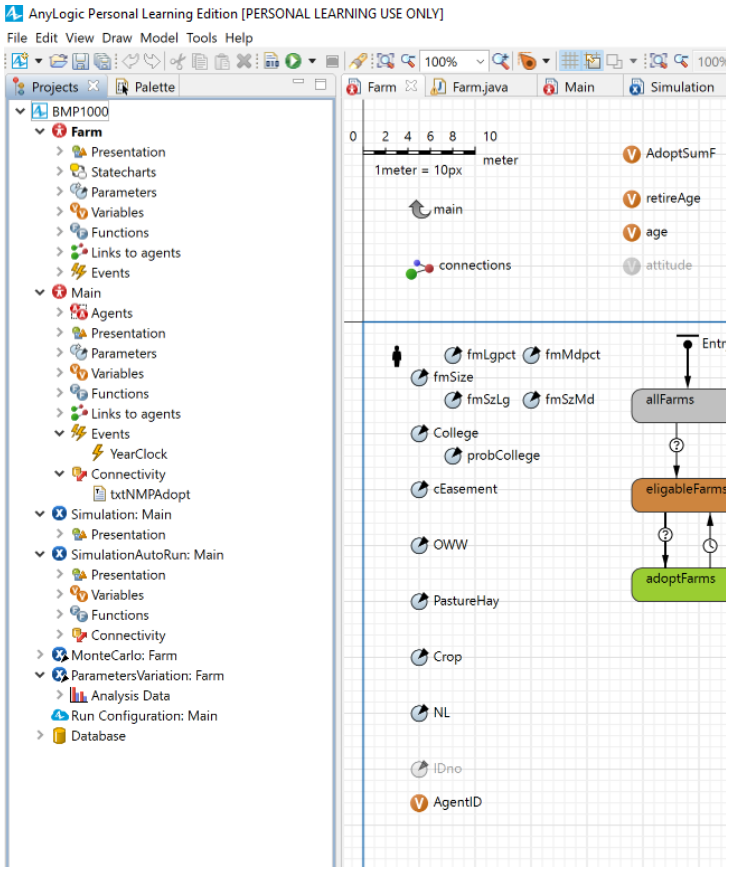
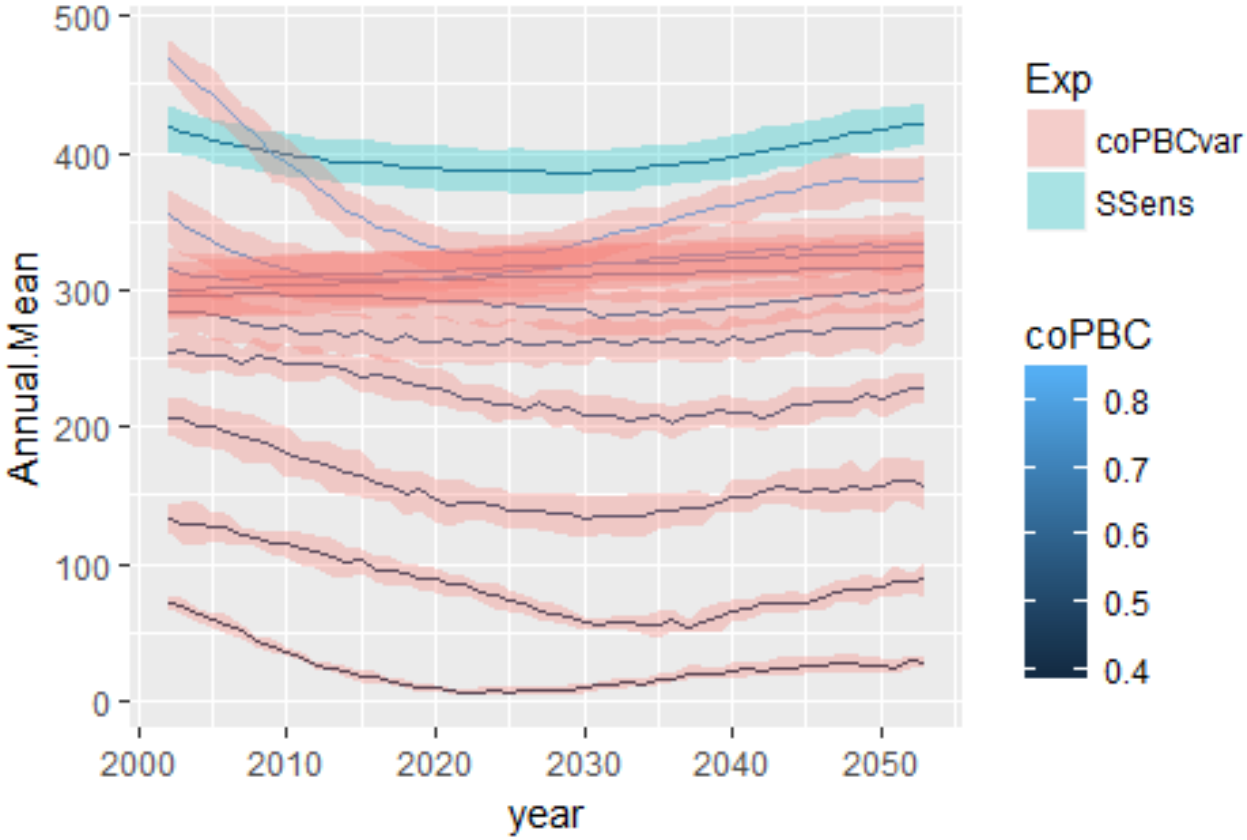
BMP 1000 Baseline TPB Model



- 1000 Farmer Agents
- 1/3 each Large/Med/Small farm size
- 30% Conservation easements
- 50% Water adjacent
- 90% Pasture or Hay
- 70% Crop
- 30% Net Loss (randomly assigned annually)
- New agent triangle Age dist. (20, 65, 40)
- Triangle Retirement age (60, 100, 80)
- 53.7% College
- 60% Adopt Threshold
- Eligibility criteria based on BMP

BMP 1000 Baseline TPB Model





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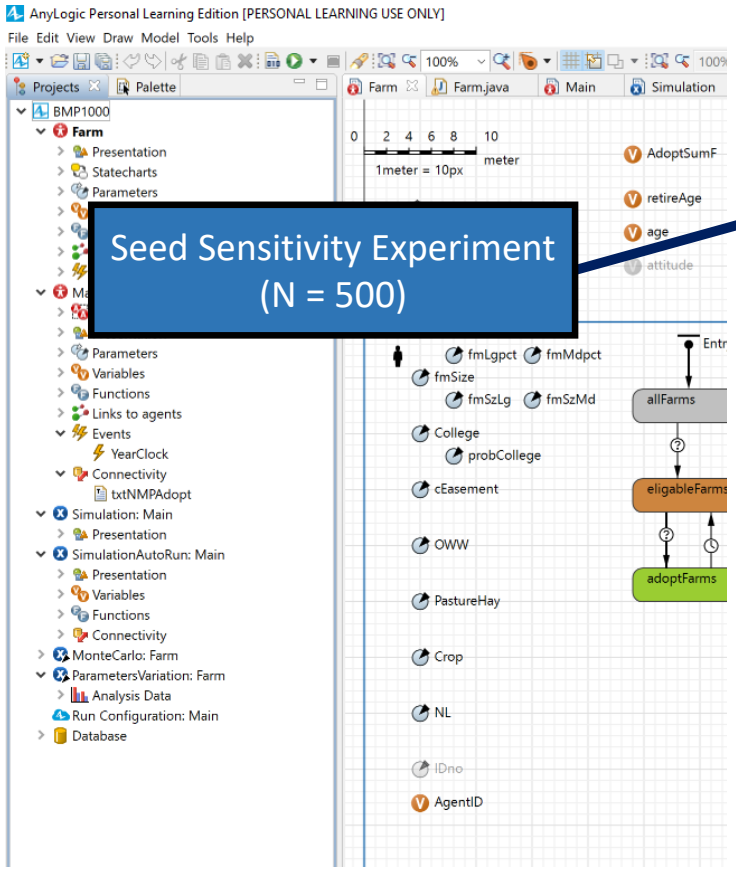
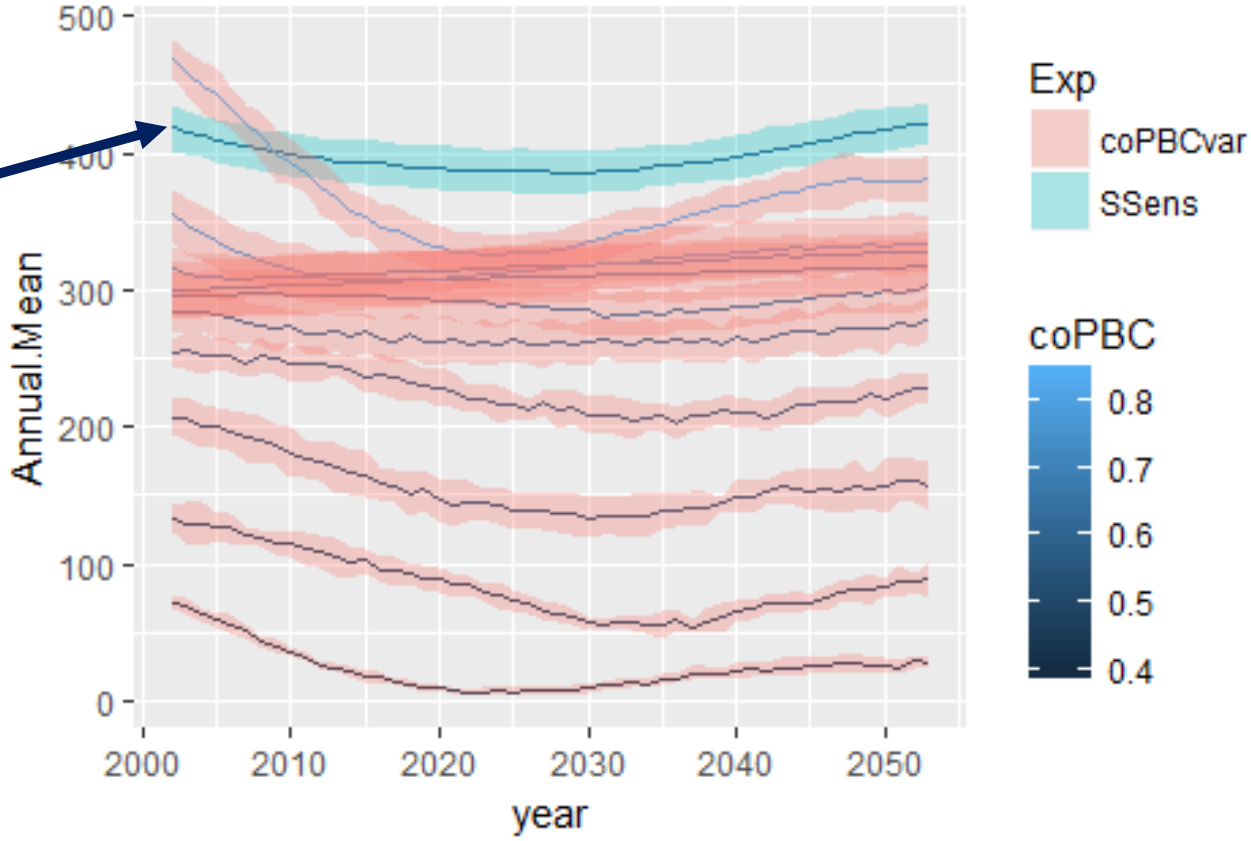


Seed Sensitivity Experiment
(N = 500)



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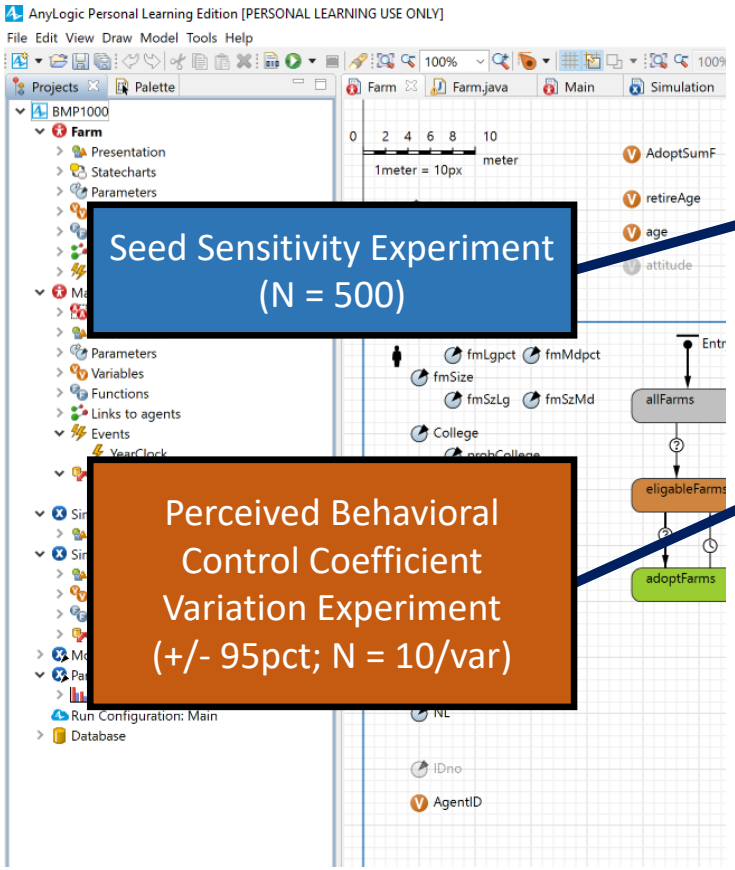
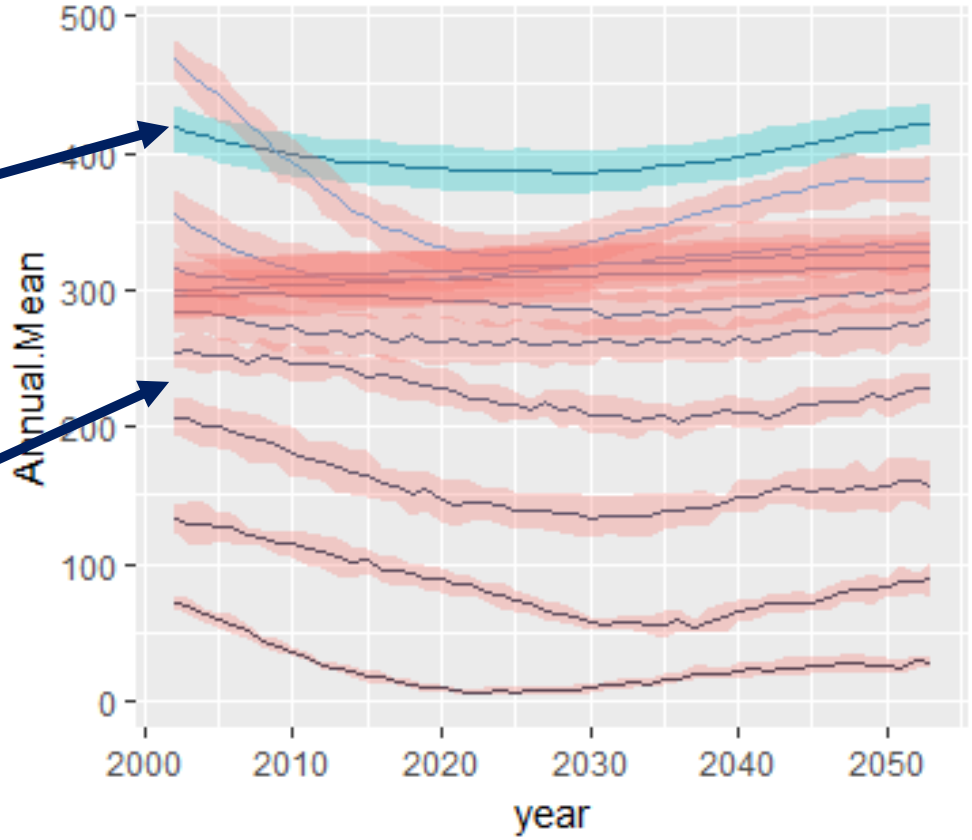
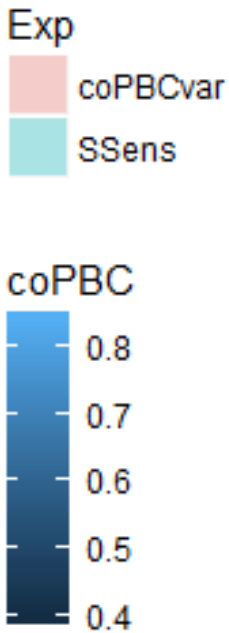
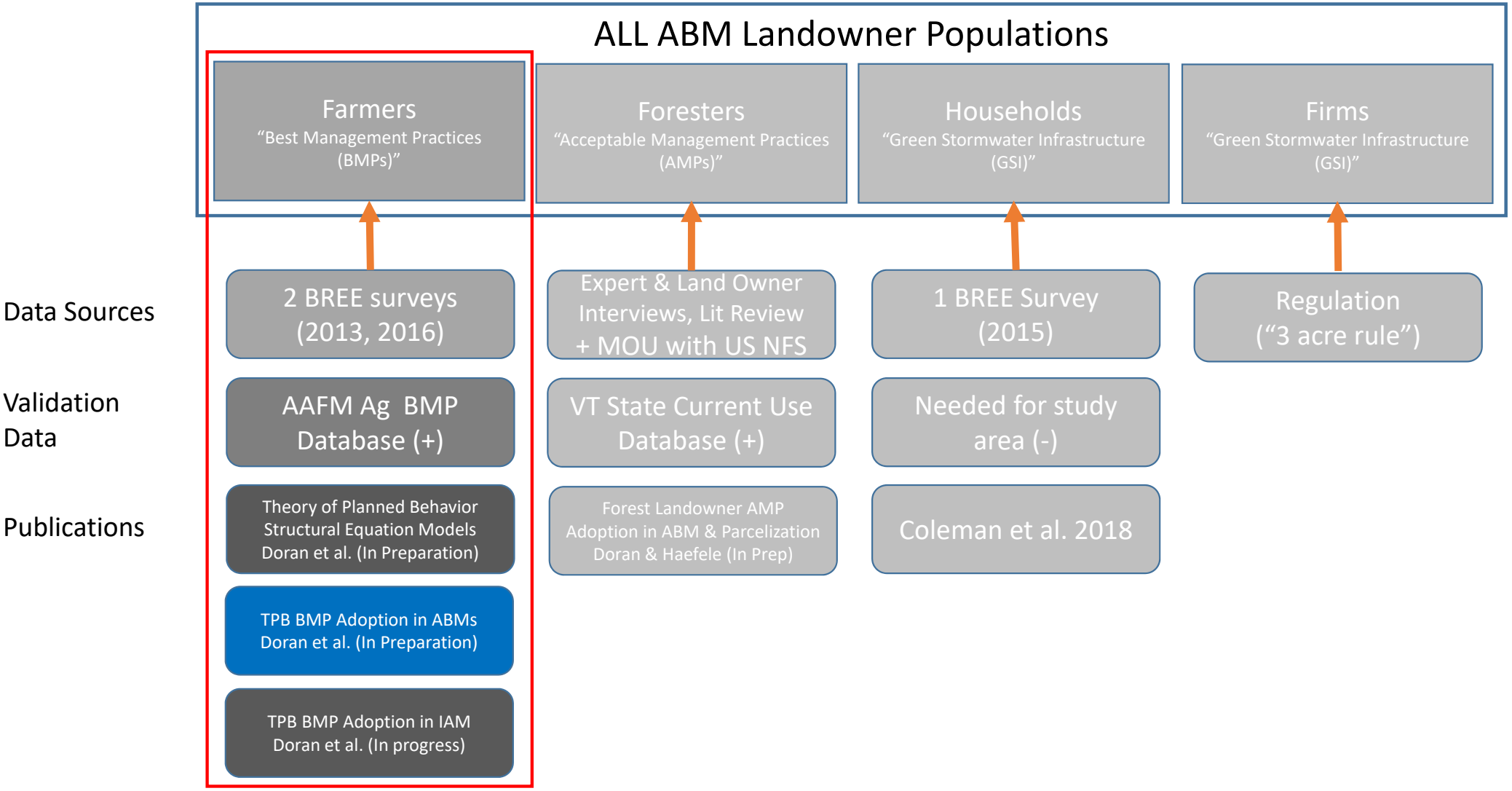


Seed Sensitivity Experiment
(N = 500)

Perceived Behavioral Control Coefficient Variation Experiment
(+/- 95pct; N = 10/var)







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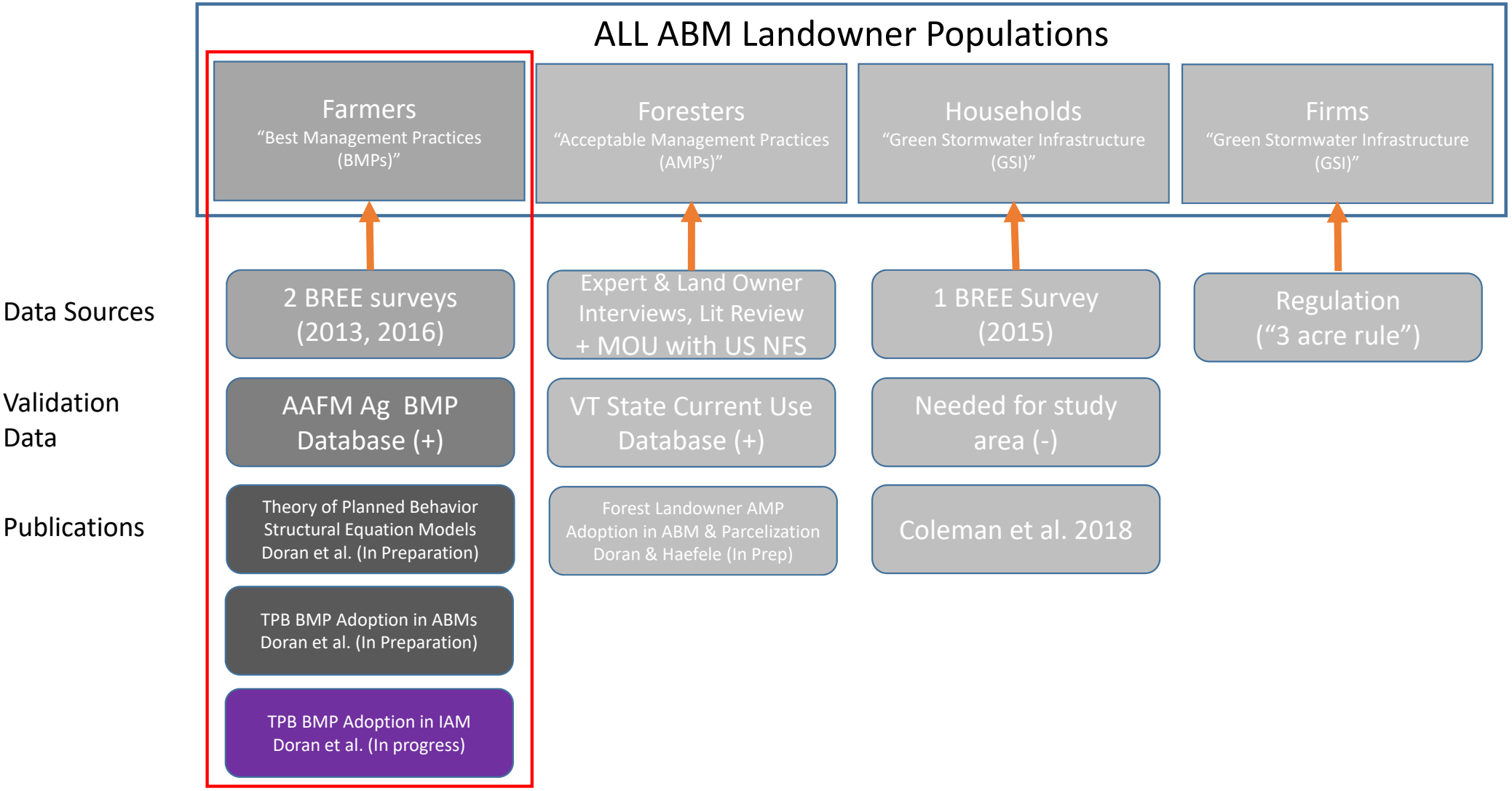

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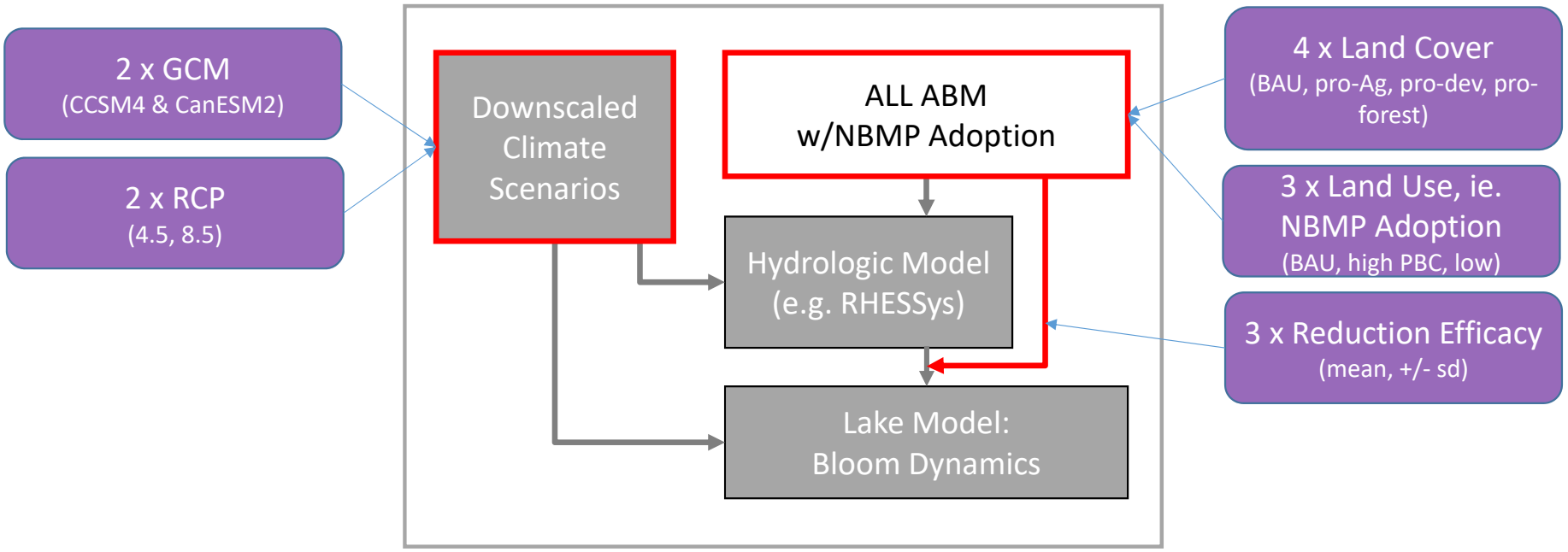
IAM Model Scenarios: Farm Nutrient Management

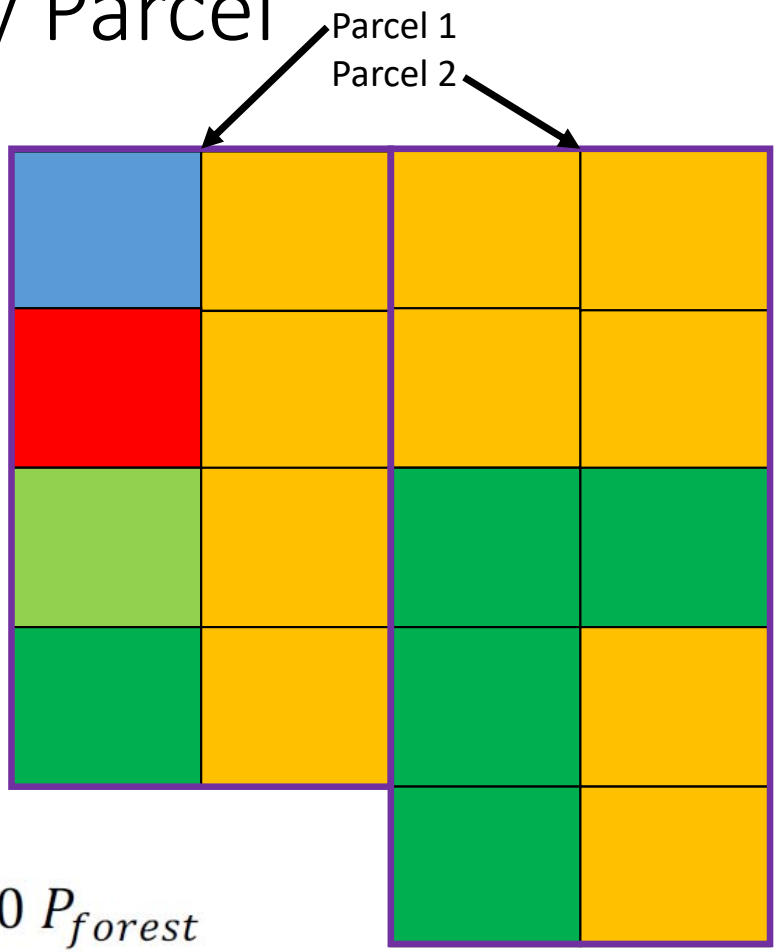


144 Scenarios + Event size reduction extension

Cell based BMP adoption By Parcel

Land Use proportions:

Ag	= 10 cells ->	P_{ag} = 0.59
Forest	= 6 cells ->	P_{forest} = 0.35
Urban	= 1 cells ->	P_{dev} = 0.06



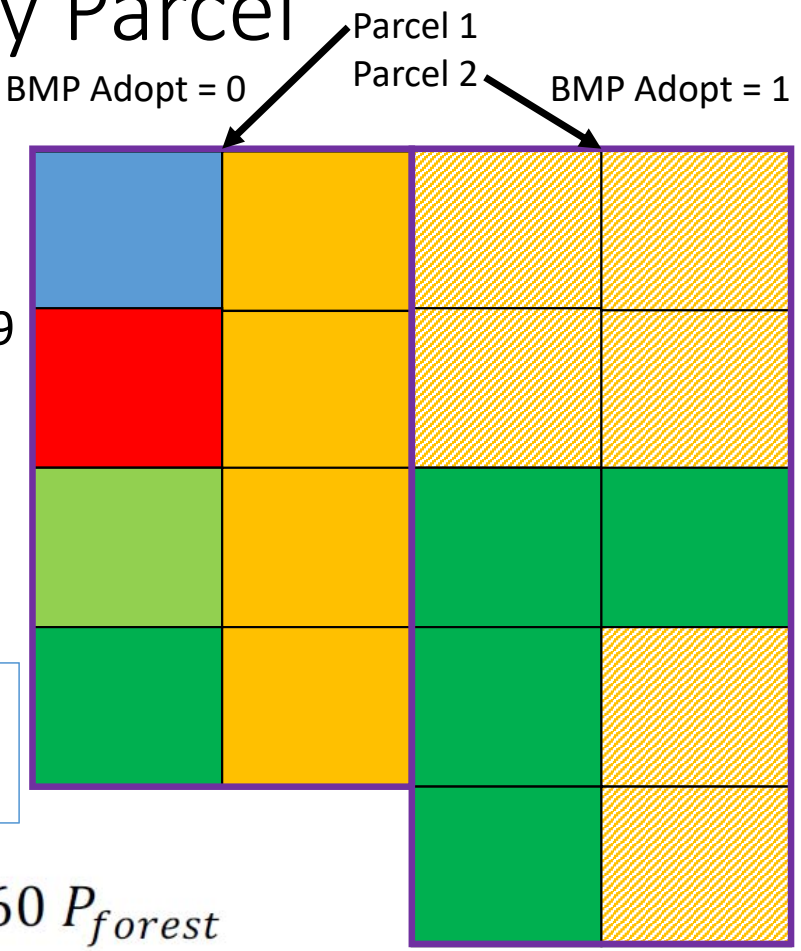
$$TP_{loading\_coef} = 9.978P_{dev} + 2.43\,P_{ag} + 0.160\,P_{forest}$$

Cell based BMP adoption By Parcel

Land Use proportions:

Ag	= 4 cells ->	$\overline{P}_{ag}$	= 0.24
Ag_{BMP}	= 6 cells ->	P_{agBMP}	= 0.35
Forest	= 6 cells ->	P_{forest}	= 0.35
Urban	= 1 cells ->	P_{dev}	= 0.06

0.59



$P_{ag} = (\overline{P}_{ag} + \eta P_{agBMP})$

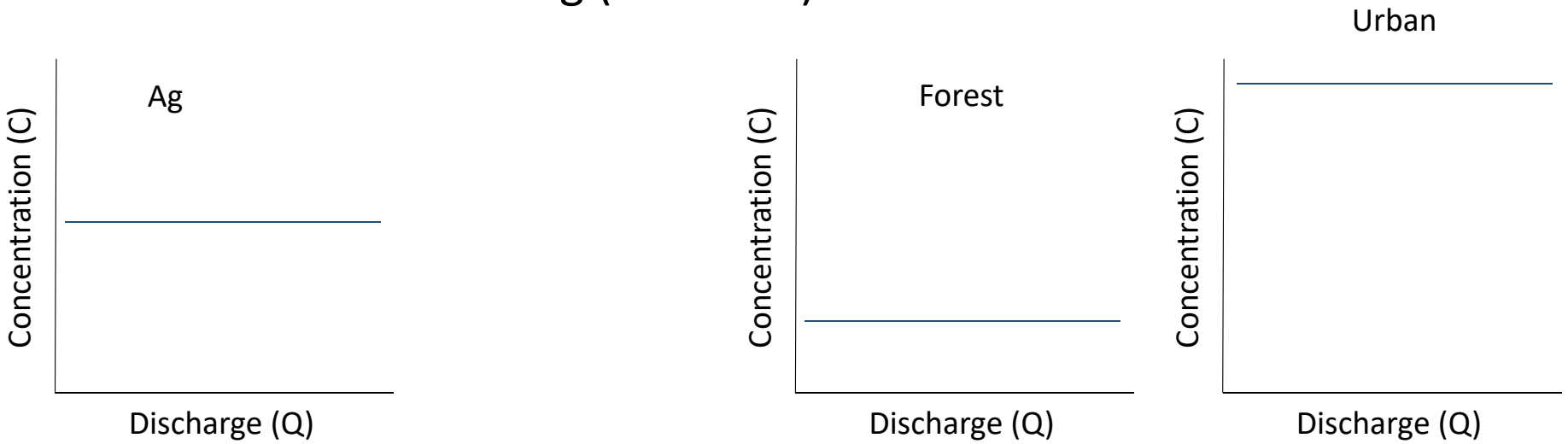
where η = efficiency

$$TP_{loading\_coef} = 9.978P_{dev} + 2.43\,P_{ag} + 0.160\,P_{forest}$$

Core Experiment (social/spatial)

Three Behavioral Decision Model Modifications: Perceived Behavioral Control, Net Loss and Conservation Easements

Fixed LULC-based loading (no BMPs)…



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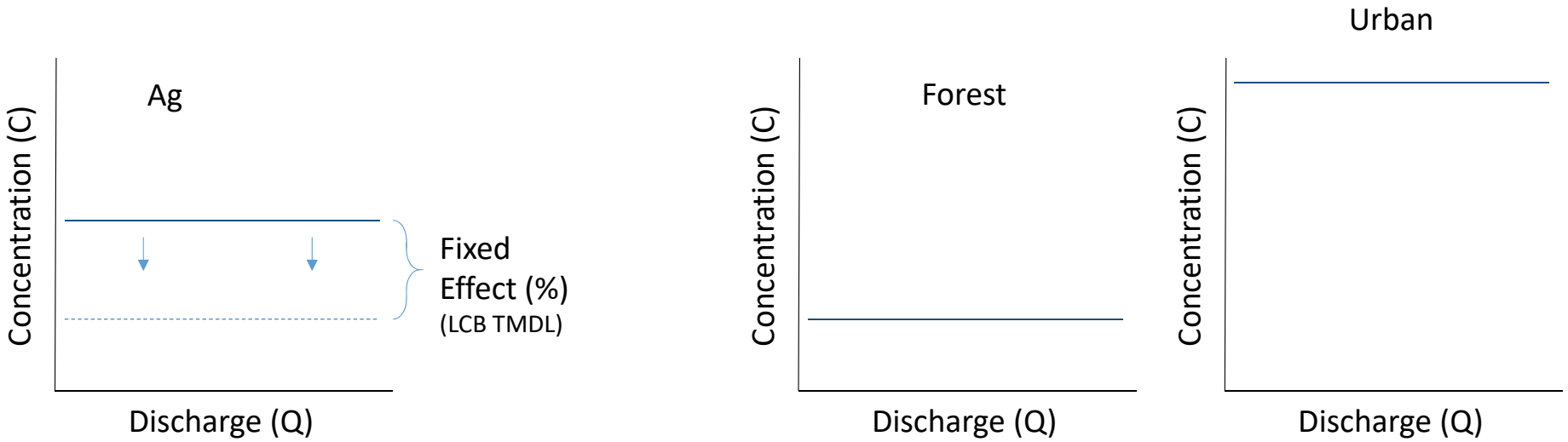
…fixed effect BMP reductions



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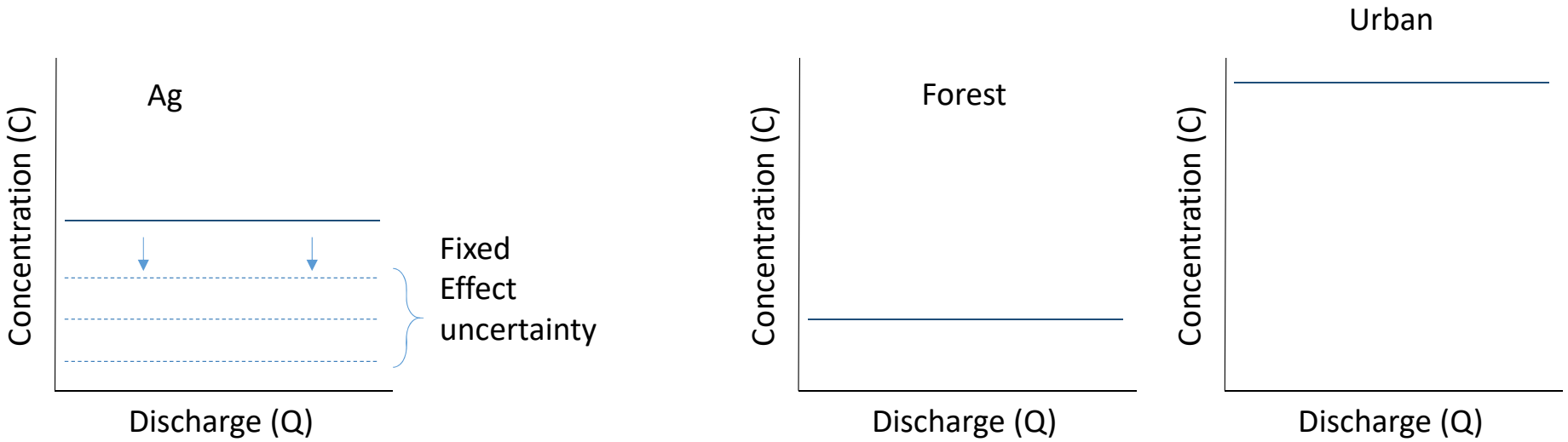
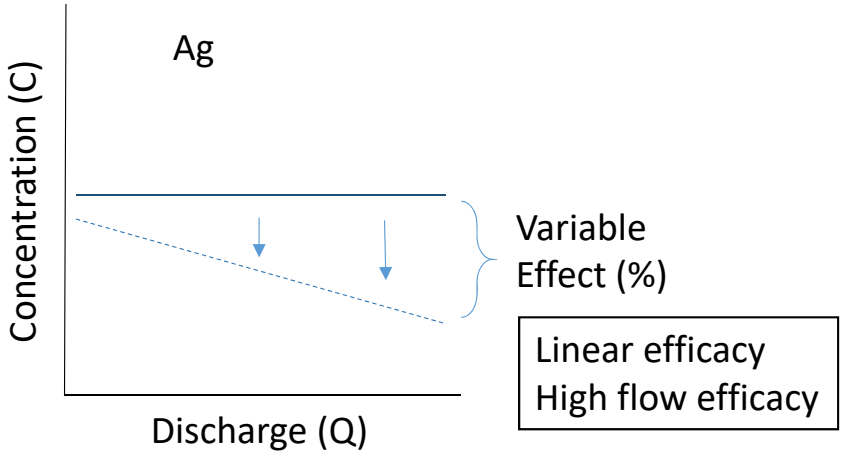
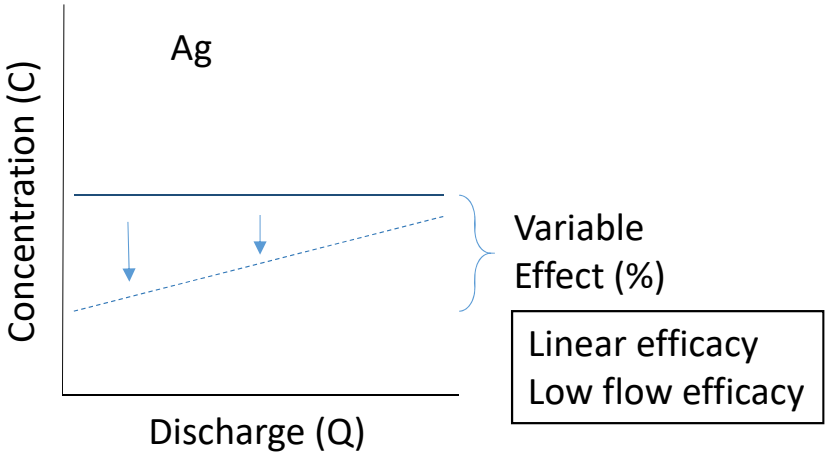


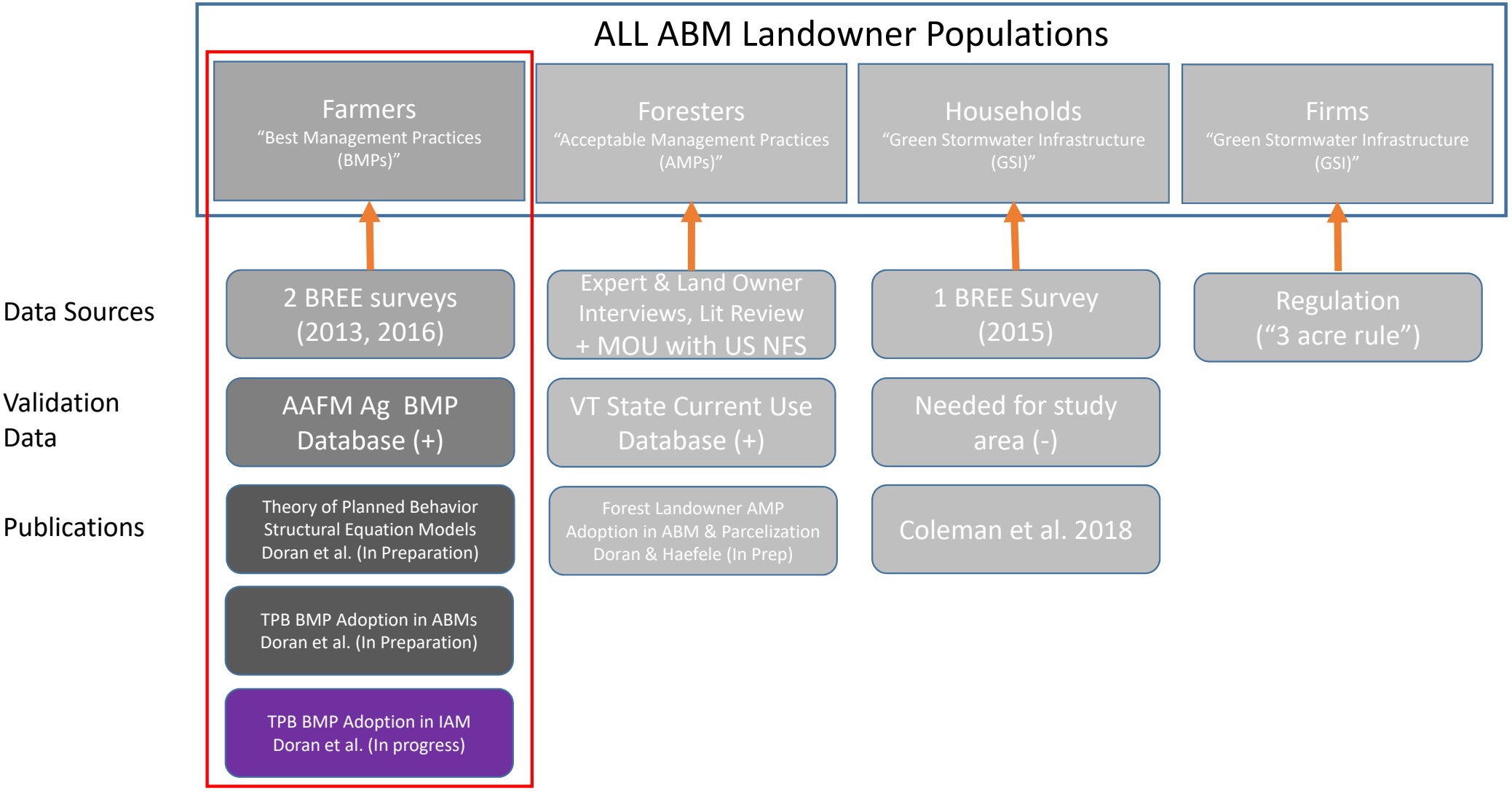
Event-based Extension (physical)

Standard decision model coefficients

Event-based BMP Reduction efficacy







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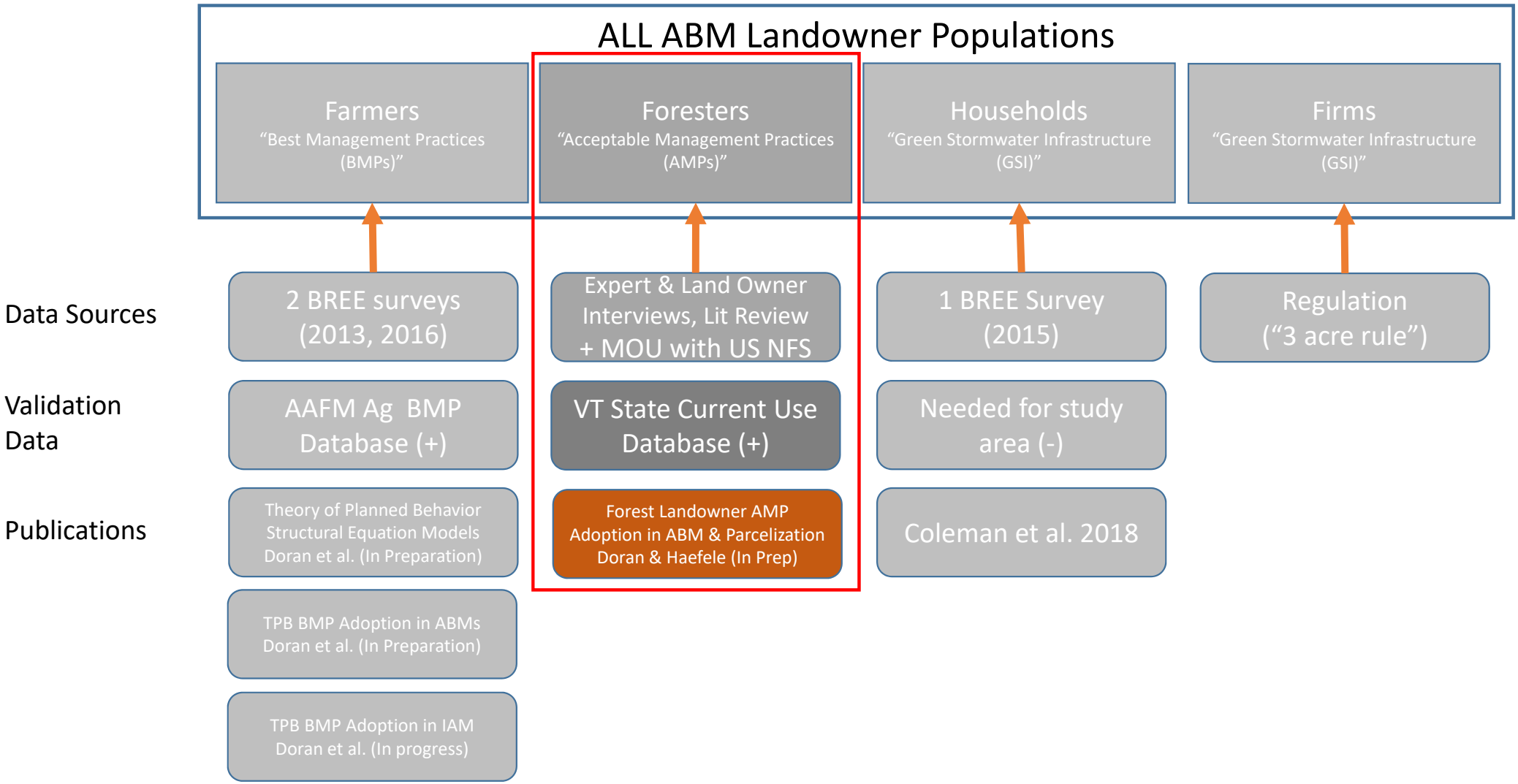

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Forest Land Use Activities, Parcelization and Water Quality: Model and Methods

Mikayla Haefele, VT EPSCoR BREE Intern 2018

Data Collection:

Quantitative

-A literature review of nutrient export and phosphorus cycling was conducted to obtain the following data: phosphorus loading coefficients in undisturbed watersheds and watersheds disturbed by timber harvesting (Table 1), private forest landowner demographics, and the efficacy of landowner/forester interactions.

Qualitative

-Qualitative interviews were conducted with forestry experts and private forest landowners to better understand forest management practices in the study area and investigate how people use their forested land.

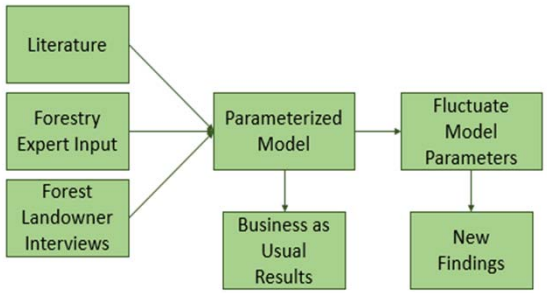


Figure 1. Flowchart of model development. Multiple data sources parameterized the model, and then the parameters were manipulated to produce results.

Table 1. Phosphorus export coefficients based on background phosphorus levels, harvest with and without acceptable management practices (AMPs), and a general export value that combines several forest activities.

Type	P export value (kg/ha yr)	References
Background Output	0.009; 0.015; 0.02	Bormann et al (1974); Hobbie and Likens (1973); Yanai (1997)
Harvest w/ AMPs Output	1.72	Edwards and Williard (2010)
Harvest w/o AMPs Output	12.61; 0.178; 0.03	Edwards and Williard (2010); Hobbie and Likens (1973); Yanai (1997)
Combined Output	0.1; 0.04; 0.04; 0.24	Budd and Meals (1994); Hegman et al (1999); Troy et al (2007); Haltemann (2015)

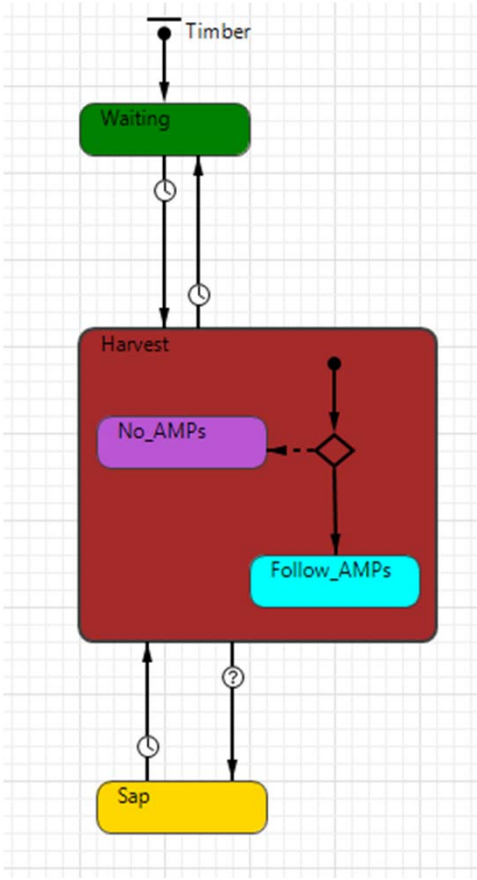


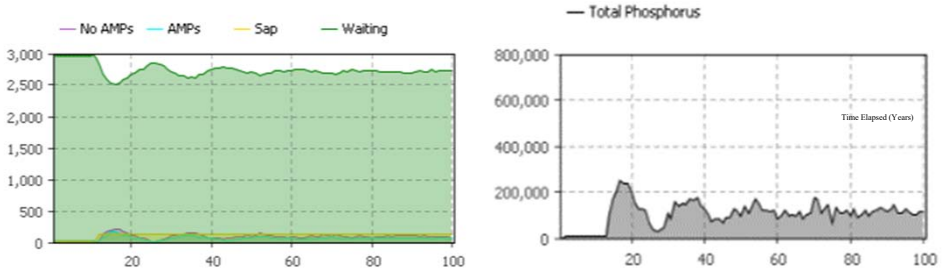
Figure 2. Forest landowner statechart in Forest ABM. The rate at which the landowners transition from state to state and whether or not they follow the Acceptable Management Practices is based on information collected from interviews with forest landowners and County Foresters.

Forest Land Use Activities, Parcelization and Water Quality: Preliminary Results

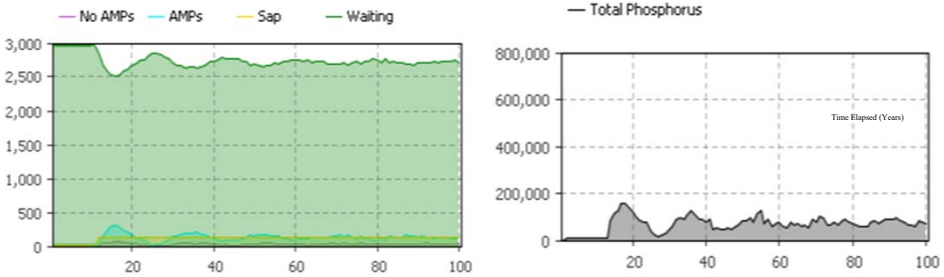
Mikayla Haefele, VT EPSCoR BREE Intern 2018

Model Results

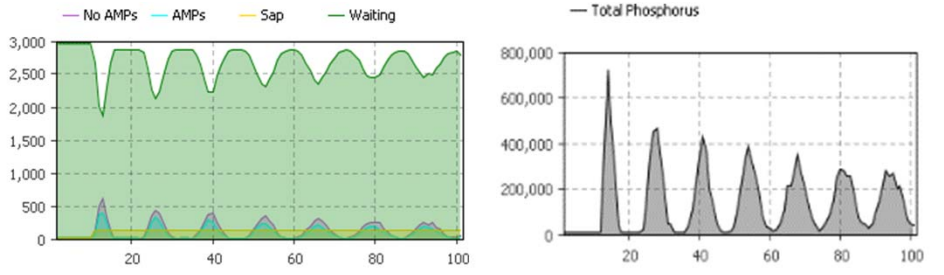
Scenario 1: Business as Usual



Scenario 2: Use Value Appraisal (UVA) 100% Enrollment



Scenario 3: Commercial Harvesting top Management Priority



Interview Results

Photo: A well-managed forest stand in Enosburg Falls, VT.

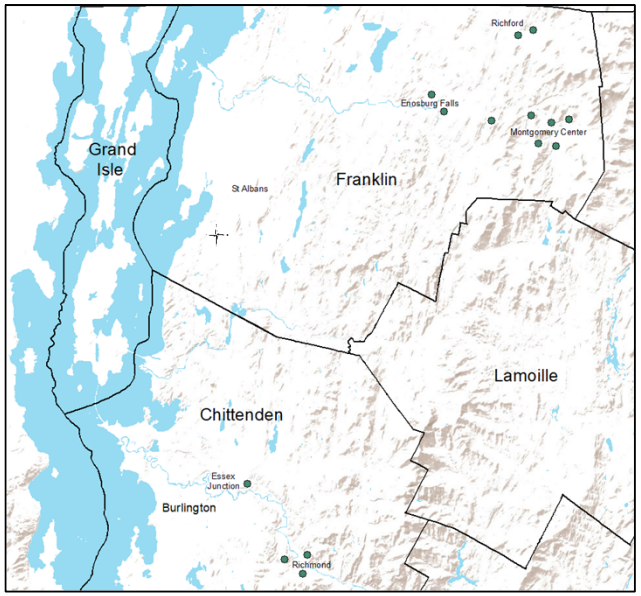


Figure 6. Map of approximate locations of interviewees' forested land in Franklin and Chittenden Counties, VT (N = 14)

Some Findings from the Interviews (N = 14):

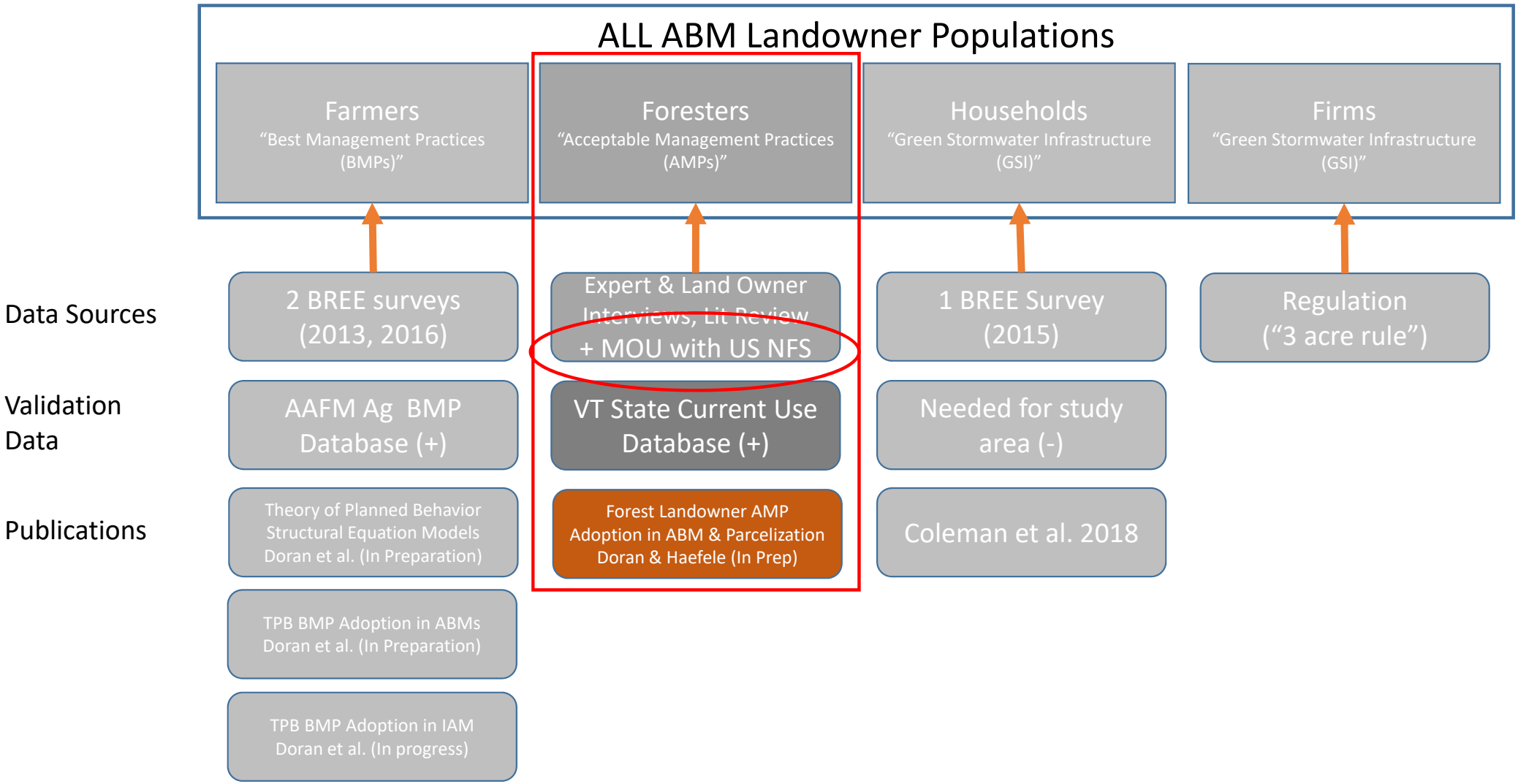
-All interviewees were older than 50, and most were in their 60s and 70s.

-Many are from out-of-state but bought property in Vermont upon reaching retirement age.

-The consulting forester and county forester relationships with landowners were cited as influential in decisions to engage in conservation practices and programs within the community.

-When asked about the threat of forest fragmentation and water quality problems from timber harvesting, one interviewee said, "This is a wonderful wildlife habitat where we live, and there's great connectivity for wildlife here and we want to be able to contribute to that and keep it unchanged as much as possible and not be developed."

-Concerning Vermont's forested land and timber harvesting, one interviewee said, "I think the single catch word to use here is sustainability," and spoke about the need to think long-term about forestry and water quality.



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ALL ABM Landow

Farmers
"Best Management Practices (BMPs)"

Foresters
"Acceptable Management Practices (AMPs)"

…ms
…er Infrastructure
…)"

Data Sources

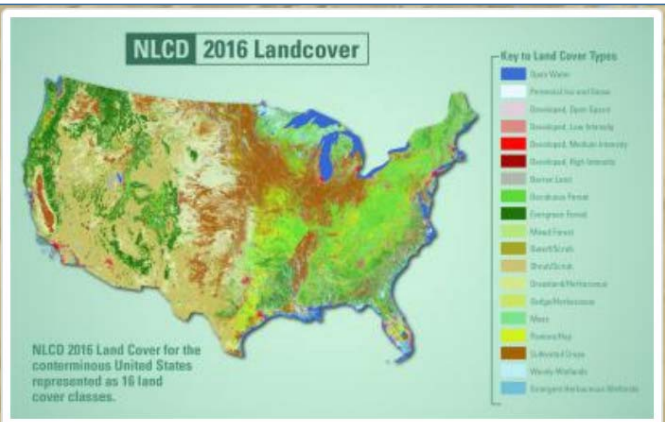
- 2 BREE surveys (2013, 2016)
- Expert & Land Owner Interviews, Lit Review + MOU with US NFS
- …ation …rule")

Validation Data

- AAFM Ag BMP Database (+)
- VT State Current Use Database (+)

Publications

- Theory of Planned Behavior Structural Equation Models Doran et al. (In Preparation)
- Forest Landowner AMP Adoption in ABM & Parcelization Doran & Haefele (In Prep)
- TPB BMP Adoption in ABMs Doran et al. (In Preparation)
- TPB BMP Adoption in IAM Doran et al. (In progress)



Now Available

Published May 10, 2019

The NLCD 2016 suite of Conterminous U.S. (CONUS) land cover and impervious products have now been released. This release includes seven epochs of land cover (2001, 2004, 2006, 2008, 2011, 2013, and 2016), a 2001 – 2016 land

ALL ABM Land Cover Transitions

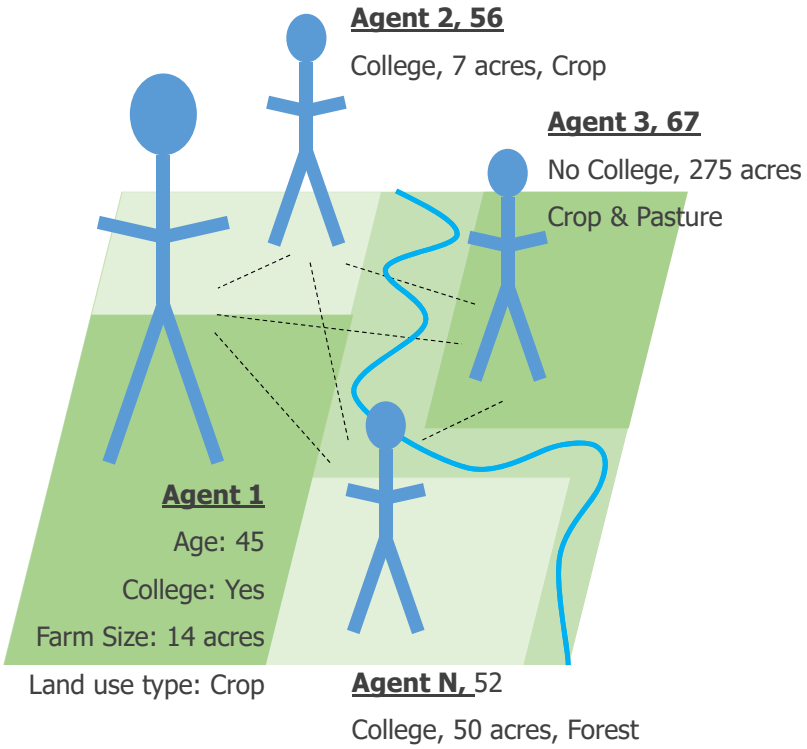
Data Source

- NLCD 2016 Data Product *(NEW)*
- Calibration and Validation of ALL ABM Land Cover Transitions Doran et al. (*Planned*)

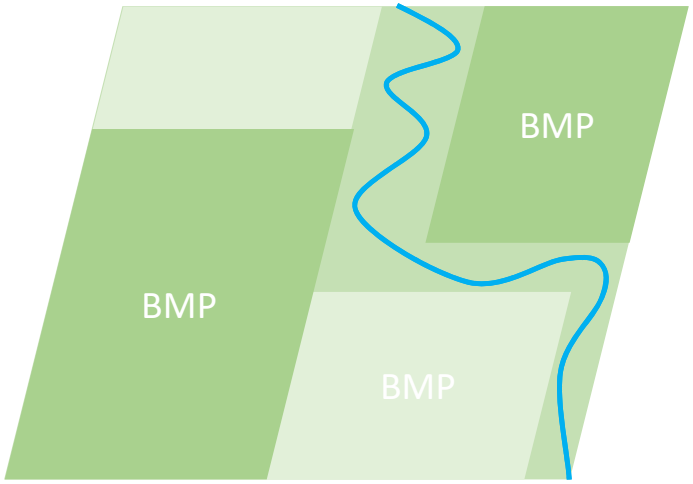
Questions

The University of Vermont

Land Use Agent Based Model

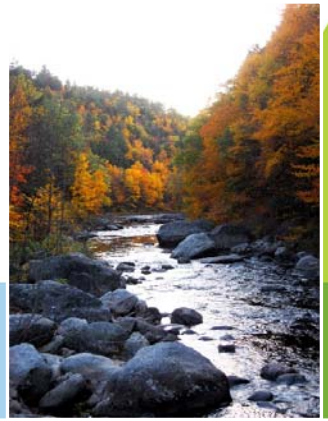


Land Use Agent Based Model

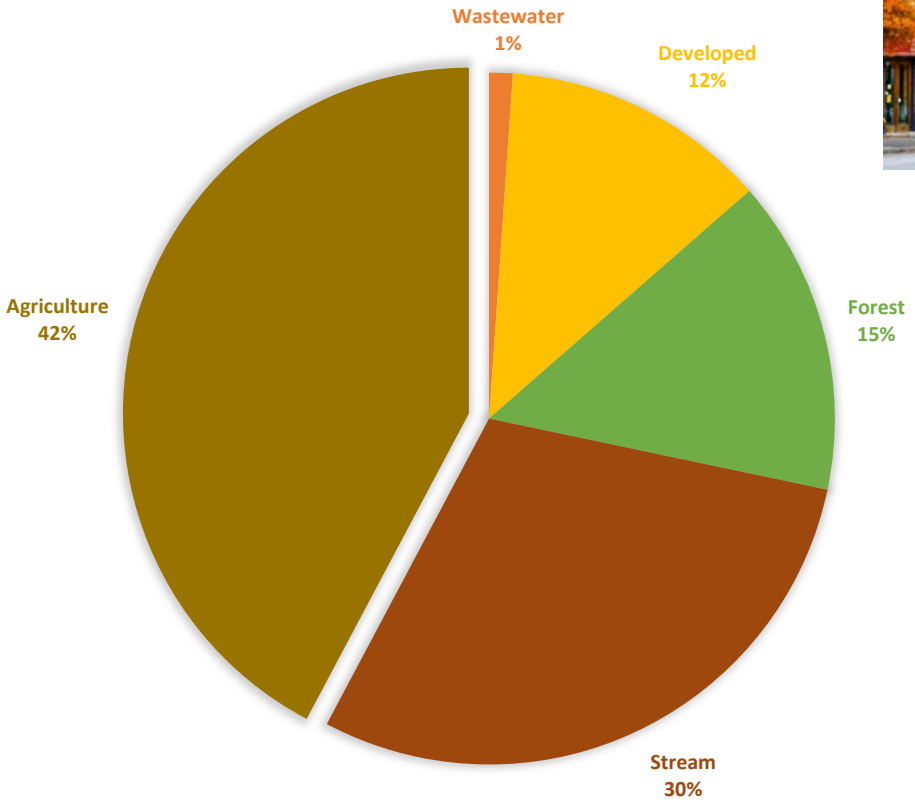


Who, and how likely are people – *farms* – to adopt specific best management practices?

Theory of Planned Behavior (TPB) to build a model of likely adoption for *each* BMP



MISSISQUOI BASE LOAD



Base loading based on SWAT model used in U.S. EPA TMDL
PC: VPR; St Albans Messenger; MacLennan Farm, VT Beachcomber
Wonderlustforone.com

Watershed Based Loading

- RHESSys calculates flow based on Missisquoi (purple)
- Proportional allocation for Rock (red) and Pike (green) Watersheds (+ St. Albans, not shown)
- LULC proportions and BMP adoption proportions will be calculated and applied to each watershed

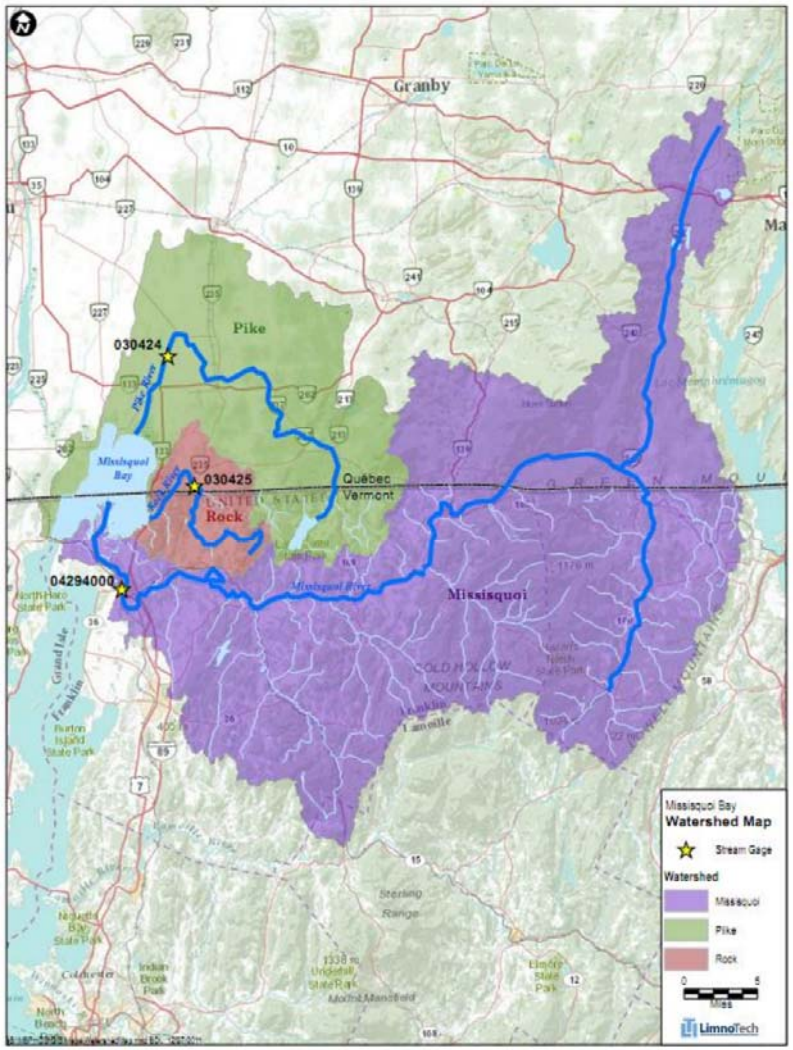


Figure 2-2. Map of Missisquoi Bay watersheds and stream gages.

(LimnoTech, 2012)