Landcare Research
Manaaki Whenua

Approach to Assess the Impacts of Allocation Options

Suzie Greenhalgh
Landcare Research

New Zealand Forest And Agriculture Regional Model (NZ-FARM)

- A static catchment-level economic model of NZ land use
  - Objective is to maximize income from land-based activities
  - Sub-region/zone-level spatial scale
  - Key outputs include changes in income, land use, GHG emissions, and nutrient leaching
- Assess impact of changes in commodity prices, technology, resource constraints on agricultural output
- Evaluation of farm, resource or environmental policy on economic and environmental performance indicators
- Parameterised for Hurunui/Waiau & Manawatu catchments
- Being used in Hinds & Selwyn/Waihora catchments

NZ-FARM Objective

- Model Objective:
  - Landowners maximize net revenue from activities conducted on all major farm enterprises in catchment
- Subject to constraints:
  - Market Output Prices
  - Costs of Production
  - Physical Inputs Available
  - Land Available
  - Irrigation Water Available
  - Regulated Environmental Outputs and Taxes

- Model separates catchment into regions/zones and also major soil types
  - Important to characterise land productivity
  - Nutrient leaching can differ across soil types
  - Doesn’t incorporate groundwater lag times

NZ-FARM – Key Components

- Land-use/enterprises:
  - Pastoral: dairy, sheep, beef, deer
  - Arable: wheat, barley, maize
  - Horticultural: potatoes, grapes, berryfruit
  - Forestry: pine, eucalyptus, native
  - Other: scrub and DOC land
- Environmental outputs:
  - Nutrients: nitrogen and phosphorous
  - GHGs for farm and forest activities
  - Water use: irrigation area and type
  - Others being included
- Farm Management Options:
  - Keep status quo and pay regulatory tax
  - Change enterprise or land use
  - Adjust fertilizer and stocking rates
  - Add dairy feed pad or apply DCDs
  - Enter forest carbon sequestration programme

NZFARM Data Needs

Underpinning data

- Land area (ha) – Land use databases
- Soil type – Fundamental Soil Layers
- Enterprise type (ha) – Land use maps & Agribase
- Inputs – various sources
  - Water (mm/day)
  - Fertilizer (kg/ha/yr)
  - Stocking rates (units/ha)
  - Animals purchased (units/ha)
- Yields – various sources

NZFARM Data Needs

Economic Data

- Variable costs – various sources
- Fixed costs – various sources
- Output prices – MAF prices for all of NZ

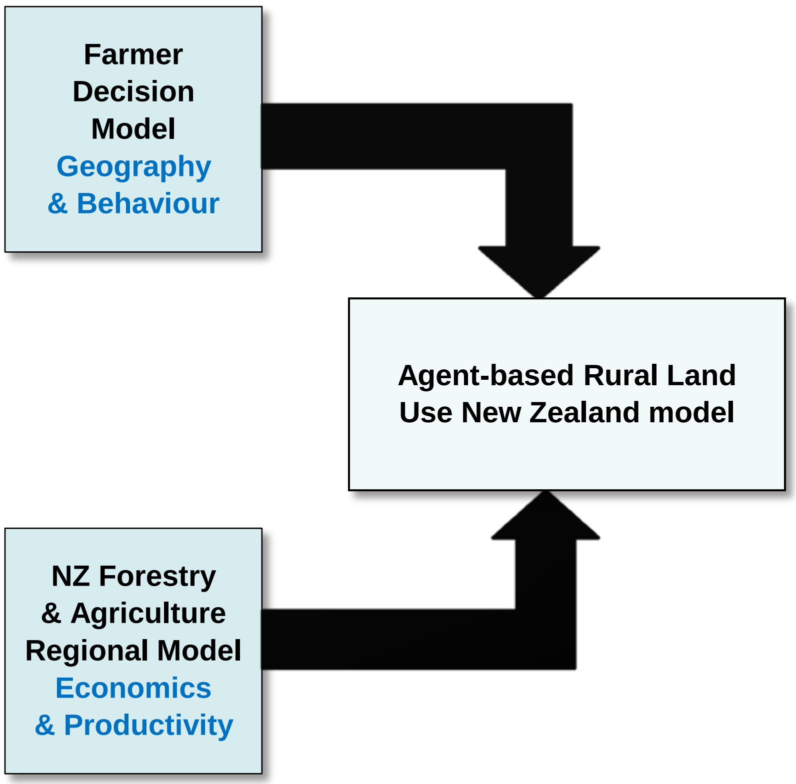
Environmental data

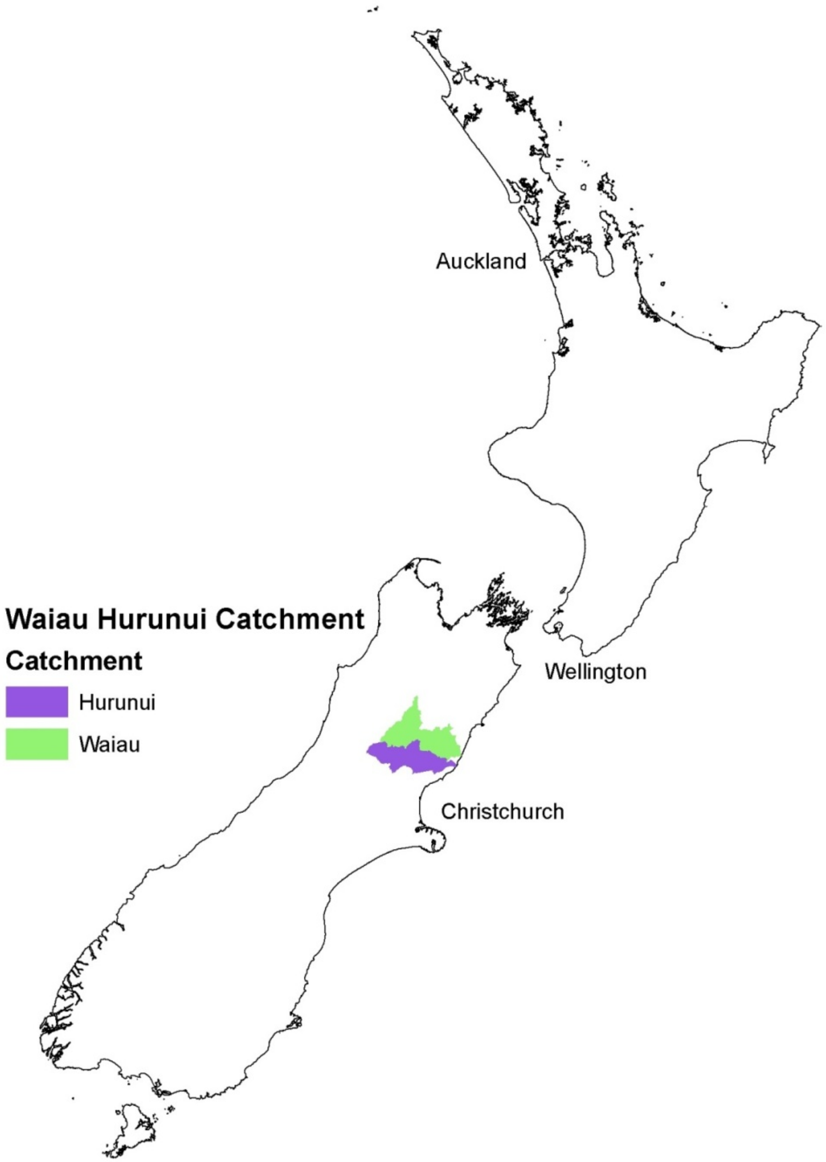
- Environmental outputs
  - N and P leaching rates – from OVERSEER &/or SPASMO
  - GHGs – Calculated from farm-level inputs
    & NZ GHG Inventory data & equations

Farmer Decision Model

- Agent-based approach
  - Behaviour, traits, communication, networks, mobility
- Farmer agents
  - Satisficing approach
  - Bounded rationality
- Heterogeneous farmer population
  - Various typologies
    - Sector, Attribute, Production, Life stage
  - Information networks (social and geographic)
    - Temporal changes to the networks

ARLUNZ

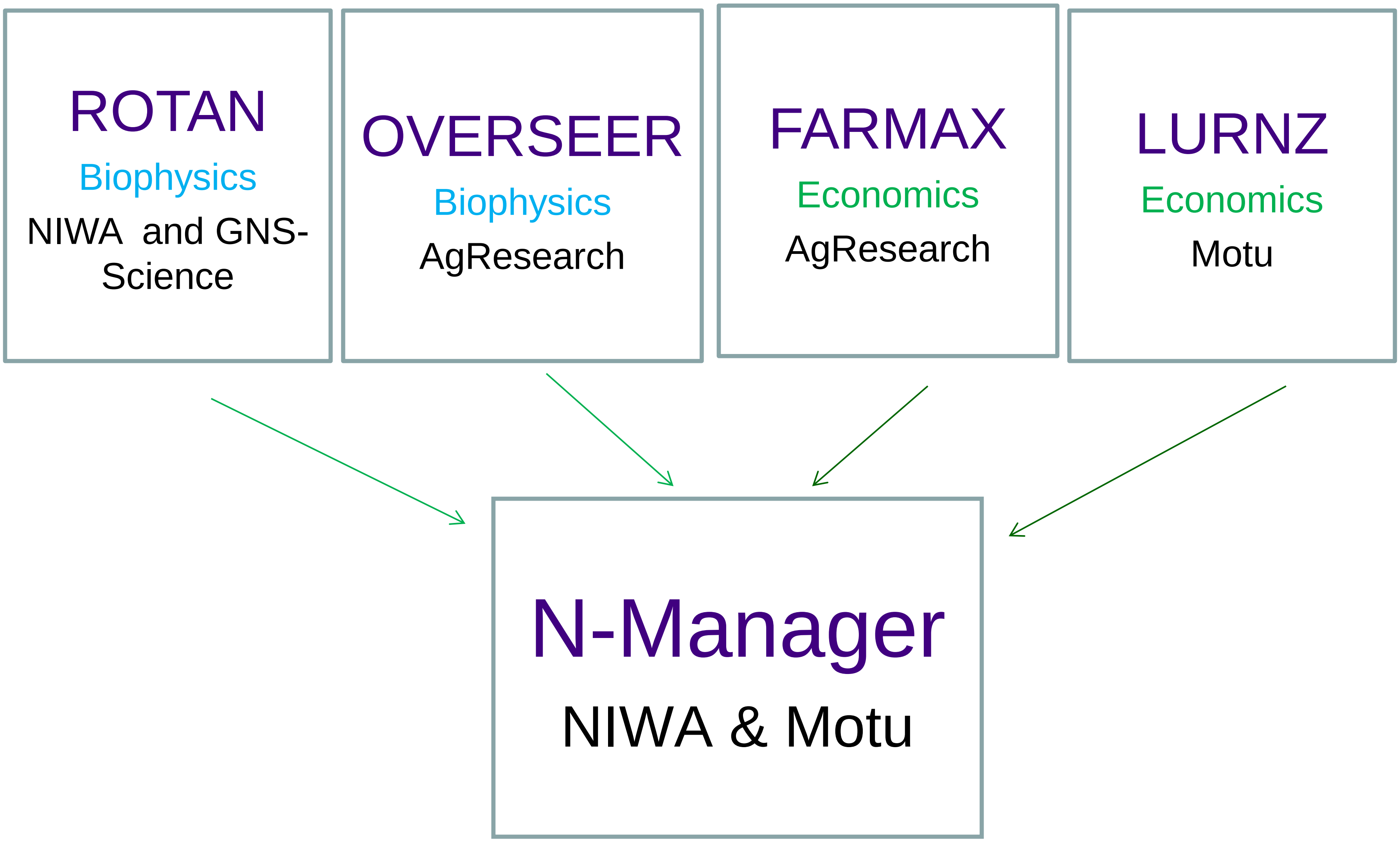

Farmer
Decision
Model
Geography
& Behaviour
Agent-based Rural Land
Use New Zealand model
NZ Forestry
& Agriculture
Regional Model
Economics
& Productivity


Auckland
Wellington
Christchurch
Waiau Hurunui Catchment
Catchment
Hurunui
Waiau

N-Manager

- Calibrated for the Rotorua catchment (using Rotan results)
- Integrated model that simulates different designs of N regulations
  - Incorporates complex hydrology that slows movement of N from farms to the lake\
  - Doesn't include explicit on-farm nutrient mitigation options
- Annual time step model

N-Manager Framework



N-Manager Inputs

- Regulatory design and environmental target
- Groundwater-surface water ratio
- Homogeneous groundwater zone
- Groundwater nutrient lags
- Land use map
- Mitigation cost functions for representative farms

N-Manager Outputs

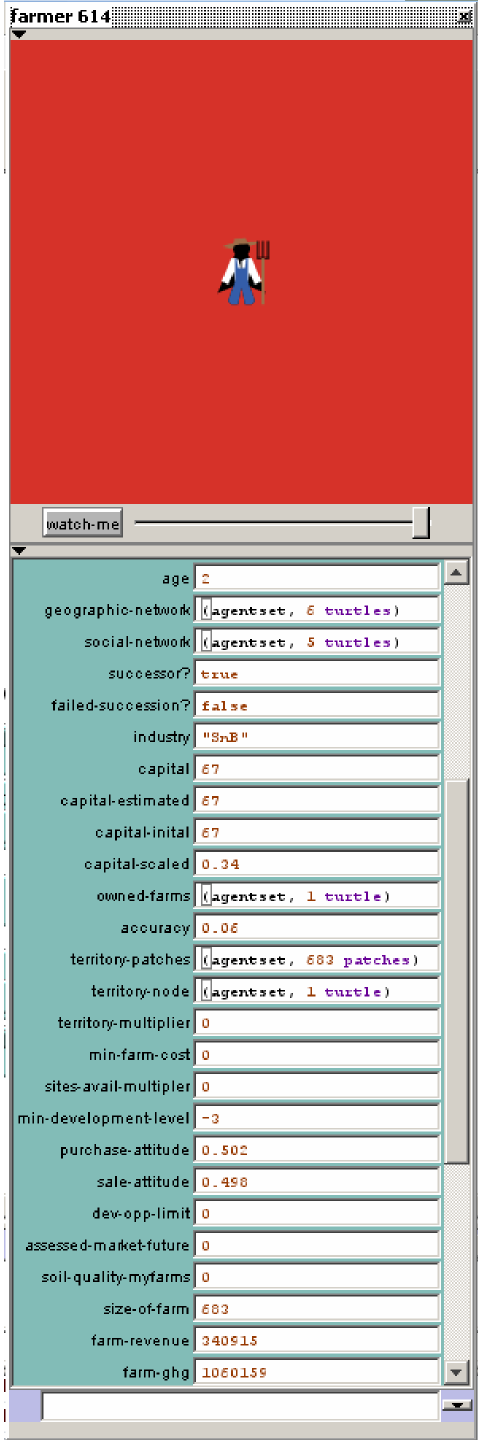
- N leaching & land use across sectors/zones
- N entering the lake
- Ave cost & marginal cost of mitigation
- Distribution of mitigation across farmers
- Required stringency of regulation

Other options

- Cost-benefit analysis, cost effectiveness
  - commonly used approach
  - challenge to consistently compare across options
- Bio-physical assessment only
  - No economic implications considered

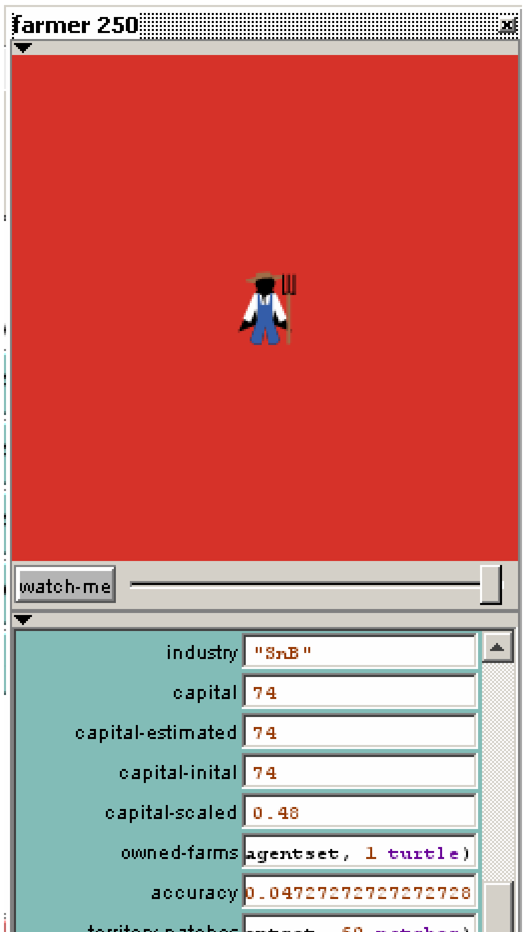
ARLUNZ Farmer agents

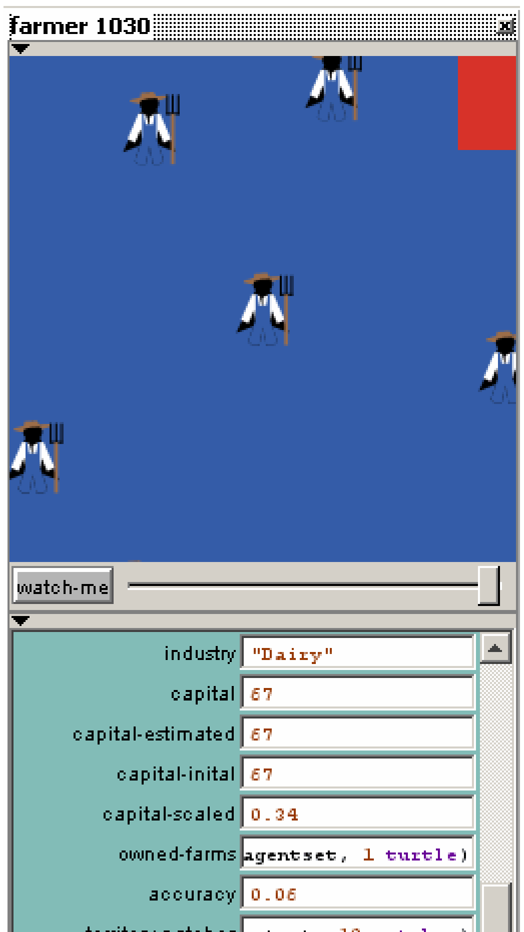
- Satisficing approach
- Economic input from GAMS
- Acceptance is tempered by
  - Type
  - Farm stage
  - Social and geographic networks

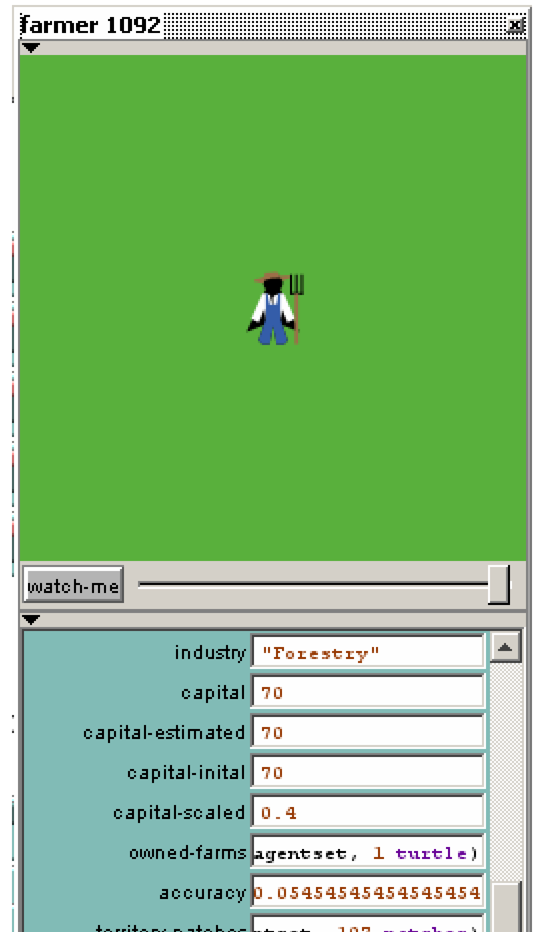


Typology

- Sector based (SnB, Dairy, Forestry)

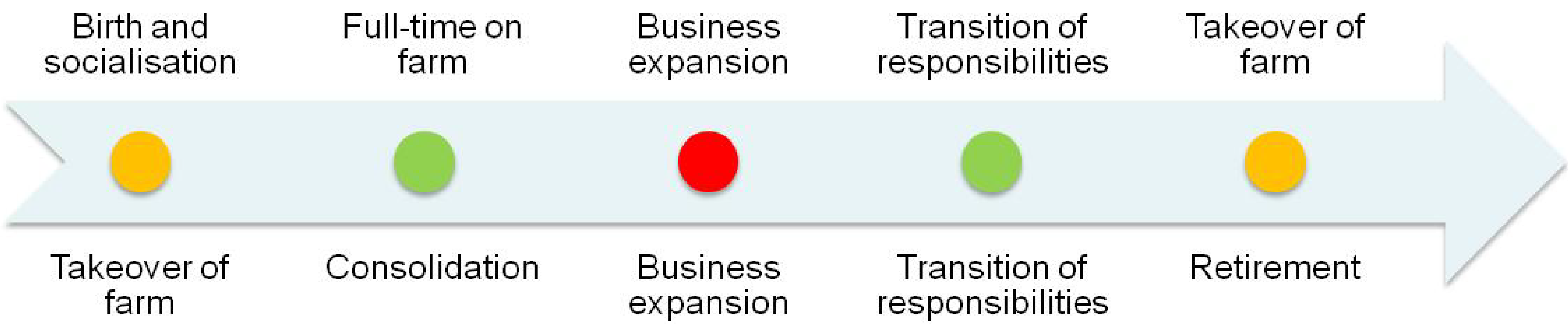






Farm Generational Model

Successor



Incumbent

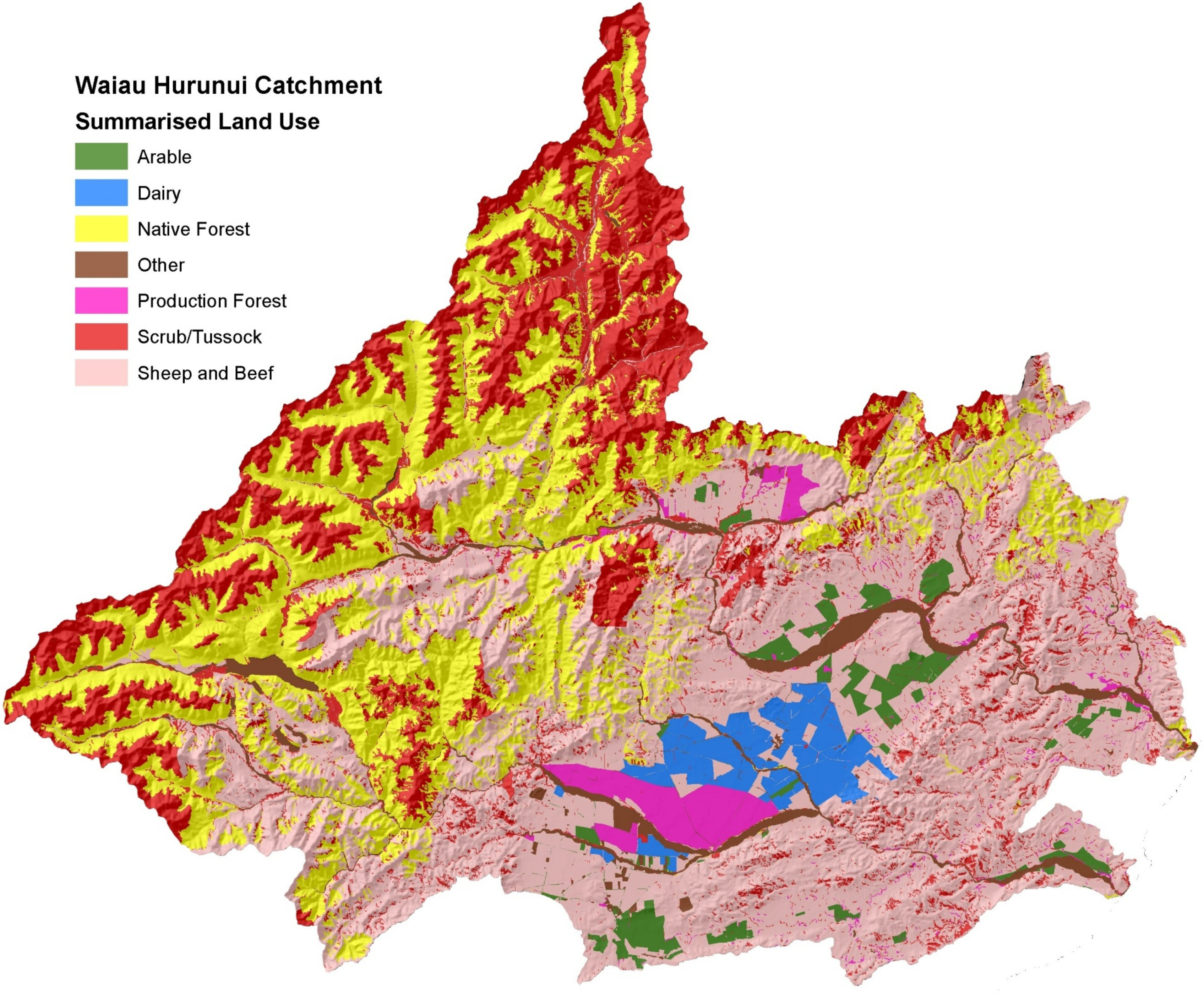
Burton, Forthcoming

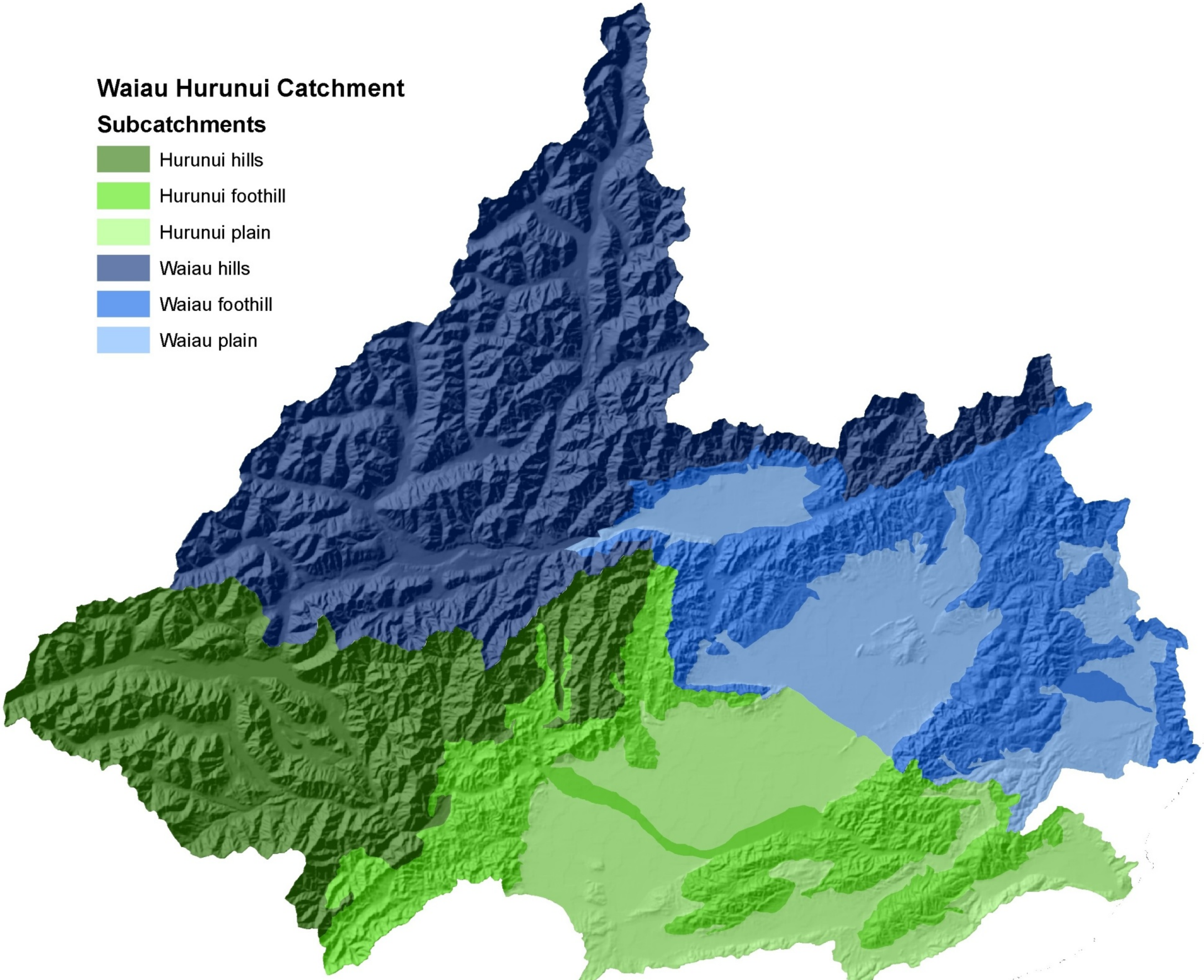
Life Stage	Incumbent	Successor	Type of Change
Farm life-stage 1	40-45 years	15-20 years	Succession
Farm life-stage 2	45-50 years	20-25 years	Consolidation
Farm life-stage 3	50-55 years	25-30 years	Expansion
Farm life-stage 4	55-60 years	30-35 years	Transition
Farm life-stage 5	60-65 years	35-40 years	Retirement

Networks

- Social interaction & life cycle
  - Succession, expansion, transition
- Social network
  - Sector based
  - Endorsements (Alam et al, 2010)
- Geographic network
  - Spatial based
  - Imitation (Schmit & Rounsevell, 2006)


Farms over 100ha


Waiau Hurunui Catchment
Summarised Land Use
Arable
Dairy
Native Forest
Other
Production Forest
Scrub/Tussock
Sheep and Beef


Waiau Hurunui Catchment
Subcatchments
Hurunui hills
Hurunui foothill
Hurunui plain
Waiau hills
Waiau foothill
Waiau plain

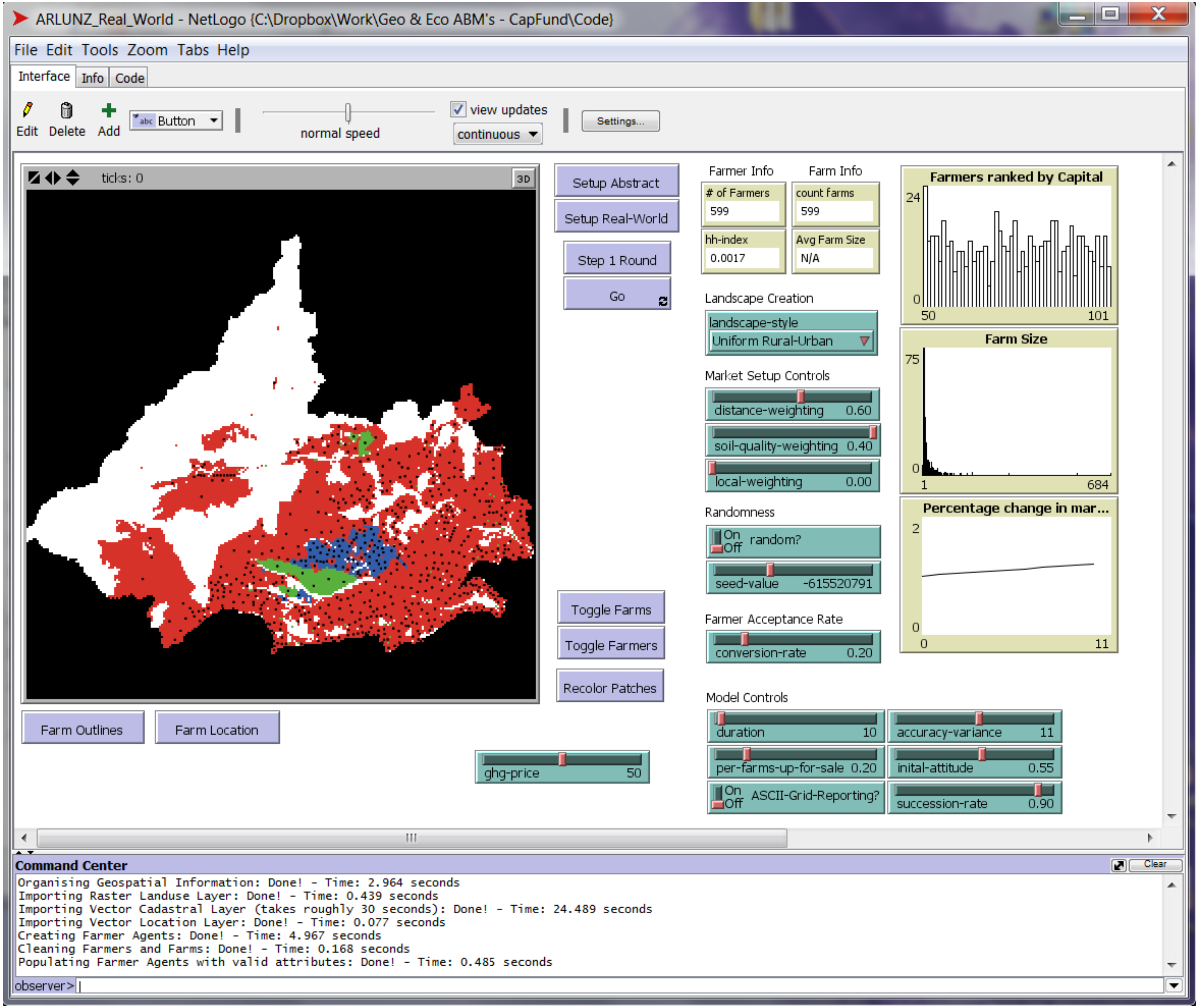
ARLUNZ Setup Stages

Import GIS Data
- Cadastral
- Land use
- Zonal

Create Farmer Agents
- Decision making
- Parcels > 100Ha
- Industry
- Networks
- GhG, Revenue, etc

Create Farms
- Static location
- Organisational units
- Soil quality
- Sub-catchment

Create Market
- Global market
- Land prices
- Commodity prices


ARLUNZ_Real_World - NetLogo {C:\Dropbox\Work\Geo & Eco ABM's - CapFund\Code}
File Edit Tools Zoom Tabs Help
Interface
Info
Code
Edit
Delete
Add
Button
normal speed
view updates
continuous
Settings...
ticks: 0
3D
Setup Abstract
Setup Real-World
Step 1 Round
Go
Toggle Farms
Toggle Farmers
Recolor Patches
Farm Outlines
Farm Location
ghg-price 50
Farmer Info
Farm Info
# of Farmers
599
count farms
599
hh-index
0.0017
Avg Farm Size
N/A
Landscape Creation
landscape-style
Uniform Rural-Urban
Market Setup Controls
distance-weighting 0.60
soil-quality-weighting 0.40
local-weighting 0.00
Randomness
On
Off
random?
seed-value -615520791
Farmer Acceptance Rate
conversion-rate 0.20
Model Controls
duration 10
accuracy-variance 11
per-farms-up-for-sale 0.20
inital-attitude 0.55
On
Off
ASCII-Grid-Reporting?
succession-rate 0.90
Farmers ranked by Capital
24
0
50
101
Farm Size
75
0
1
684
Percentage change in mar...
2
0
0
11
Command Center
Clear
Organising Geospatial Information: Done! - Time: 2.964 seconds
Importing Raster Landuse Layer: Done! - Time: 0.439 seconds
Importing Vector Cadastral Layer (takes roughly 30 seconds): Done! - Time: 24.489 seconds
Importing Vector Location Layer: Done! - Time: 0.077 seconds
Creating Farmer Agents: Done! - Time: 4.967 seconds
Cleaning Farmers and Farms: Done! - Time: 0.168 seconds
Populating Farmer Agents with valid attributes: Done! - Time: 0.485 seconds
observer>

ARLUNZ Run Stages

Market Adjustments

- Land
- Market
- Commodity

Evaluate Farmers & Age

- Increment age
- Find Succession (if in stage)
- Update farmer attributes
- Update farmer networks

Economic Input

- Export farmer agents to GAMS
- Run GAMS and evaluate best sector for each farmer
- Export back to NetLogo

Farmers decisions (LUCC)

- Social network
- Geographical network
- Farmer traits
- Economic information

Evaluate sale of farms

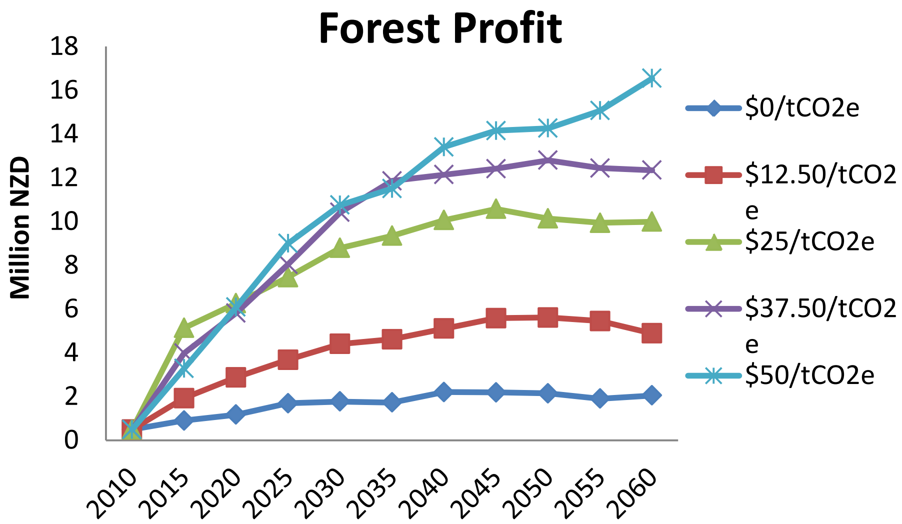
- Farms sold
  - No successor
  - Financial reasons
- Priority to similar sectors in geographic proximity

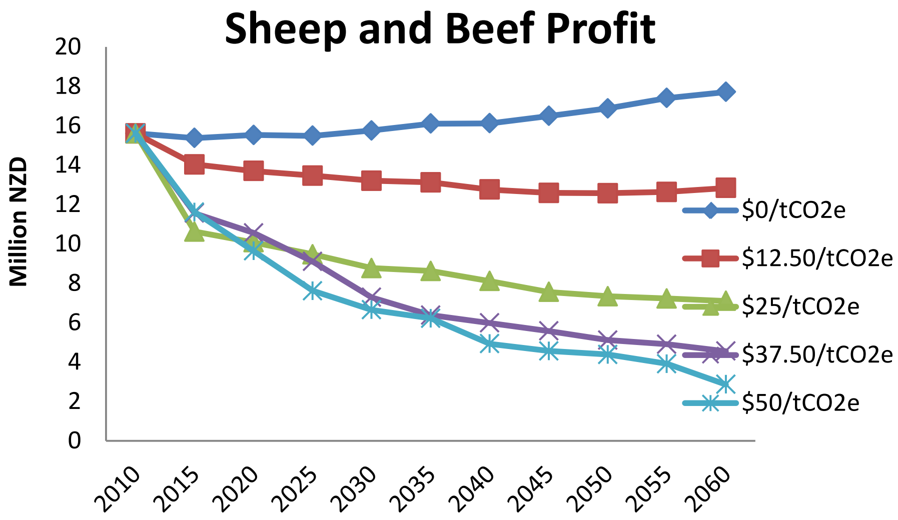
Experimental outputs

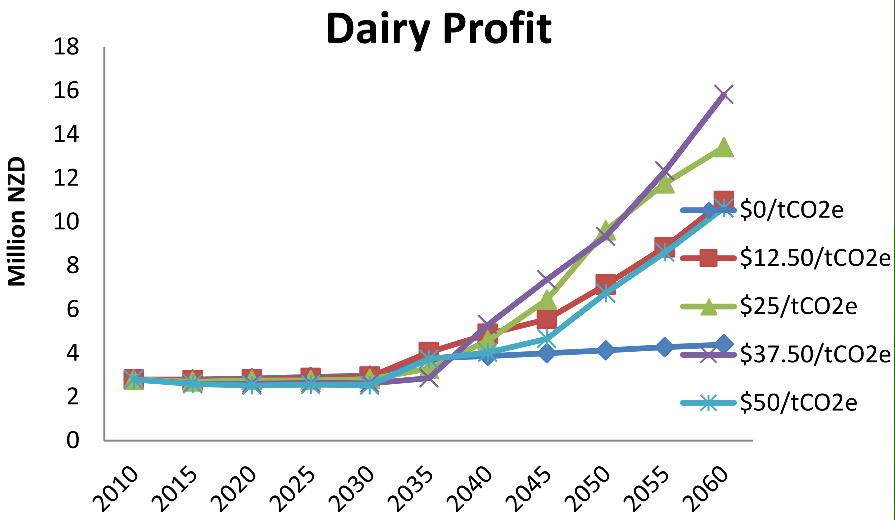
- GHG prices: \$0, 12.5, 25, 37.5 & 50/tCO_2e

GHG Price	Farm Profit (Million NZD)	GHG Emissions (Million tCO2e)	Net GHG Emissions (Million tCO2e)	N Leaching (tons)	P Loss (tons)
2015					
\$0/tCO_2e	19.1	1.0	0.8	2445	22.7
\$12.50/tCO_2e	-2%	-8%	-37%	-5%	-8%
\$25/tCO_2e	-3%	-29%	-146%	-14%	-28%
\$37.50/tCO_2e	-5%	-24%	-110%	-13%	-23%
\$50/tCO_2e	-8%	-23%	-91%	-15%	-23%
2035					
\$0/tCO_2e	21.6	1.1	0.8	2944	26.5
\$12.50/tCO_2e	1%	-16%	-111%	-6%	-15%
\$25/tCO_2e	-2%	-43%	-295%	-19%	-42%
\$37.50/tCO_2e	-2%	-57%	-392%	-26%	-56%
\$50/tCO_2e	-1%	-56%	-379%	-23%	-54%
2055					
\$0/tCO_2e	23.6	1.3	0.9	3474	31.1
\$12.50/tCO_2e	14%	-15%	-122%	6%	-10%
\$25/tCO_2e	23%	-37%	-281%	4%	-28%
\$37.50/tCO_2e	26%	-48%	-367%	2%	-38%
\$50/tCO_2e	17%	-61%	-461%	-12%	-54%

Experimental outputs

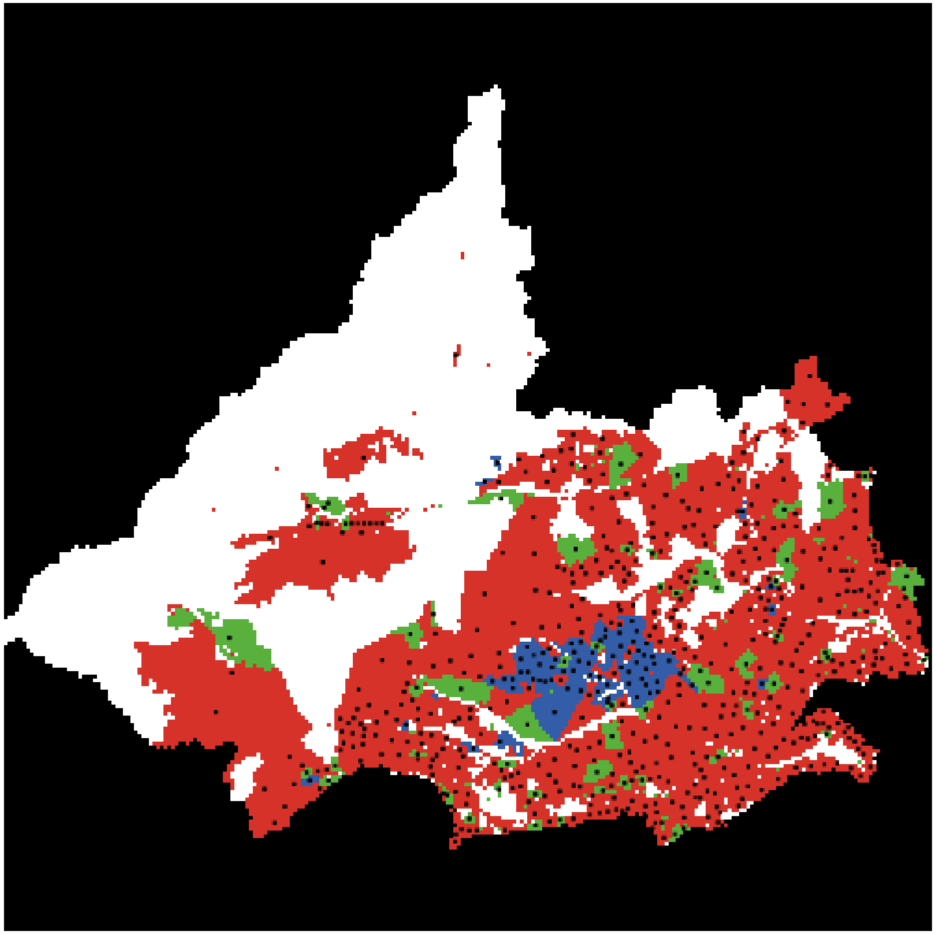




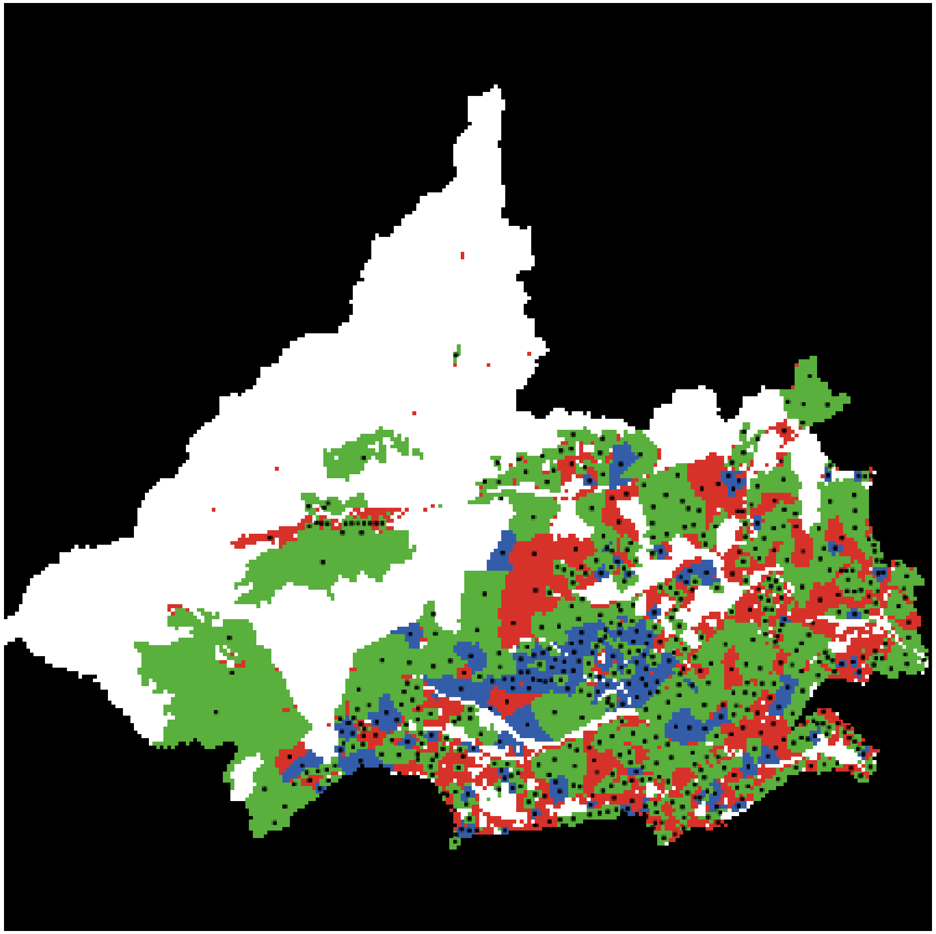


Experimental outputs

GHG price = $\$0/tCO_2e$



GHG price = $\$50/tCO_2e$



Conclusions / Future work

- Integrating modelling approaches is difficult
  - Understanding
  - Coupling
    - Nightmare
    - Although once well defined, it is relatively robust
- Future questions
  - Social changes (Succession changes)
  - Role of social networks in LUCC
  - Combination of economic and geographic questions

Questions & Thanks

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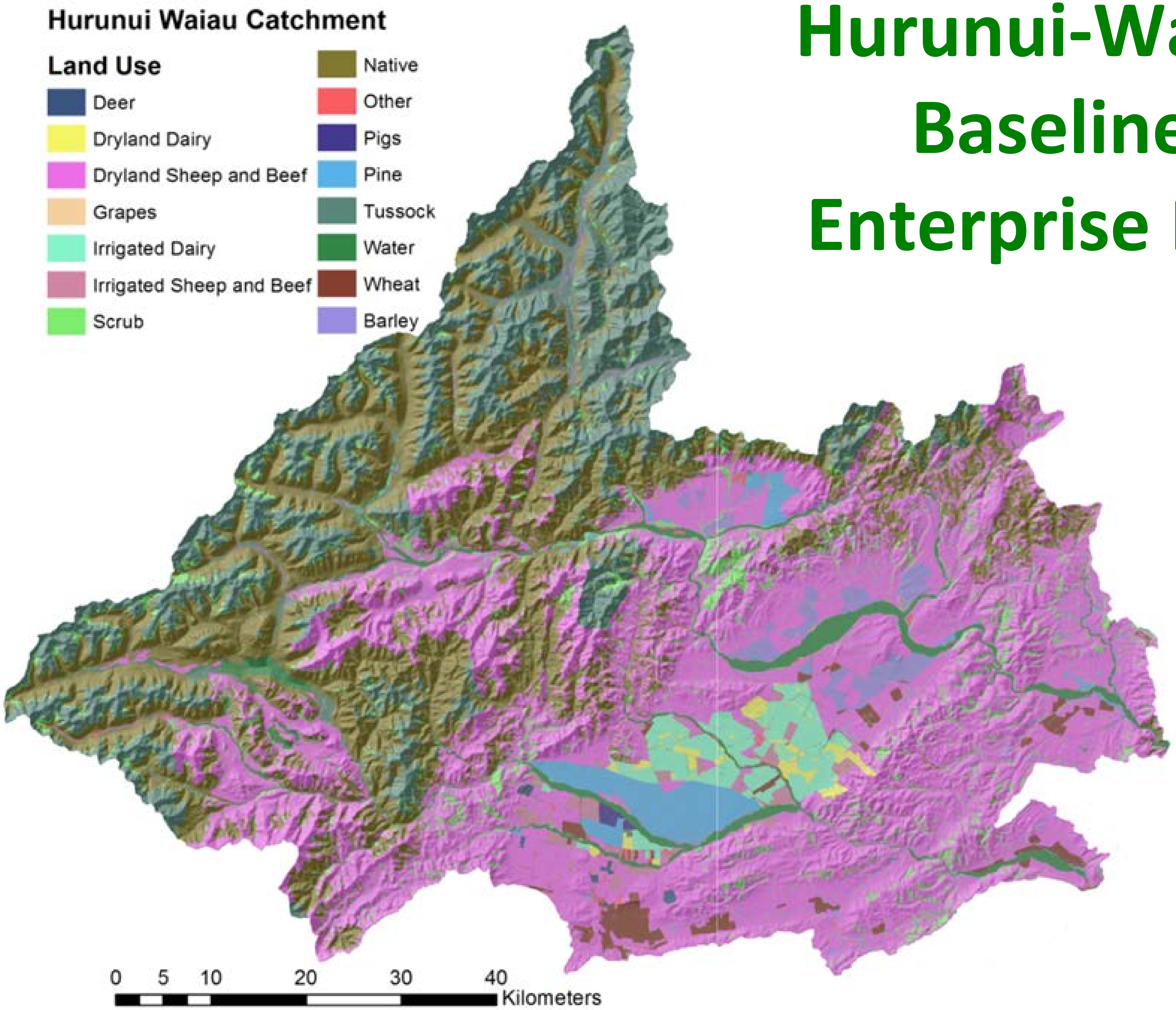
Where NZ-FARM has been applied

- Increases in water storage from infrastructure projects
- Proposed water quality caps or limits & allocation of limits
- Mandatory good management practices for agriculture
- Input & output taxes
- Implementation of NZ-ETS on the forestry & ag sectors
- Regional afforestation schemes
- Implementation of new farm technology and good management practices,
- Increases in farm input costs and/or product prices
- Combinations of the above options.

Application to GHG Policy

- Still debates about agricultural emissions being covered by NZETS
- Due for inclusion in 2015
- Points of obligation being considered
  - Processor-level (currently favoured by govt)
  - Farm-level
- Main concern is GHG emissions but co-benefits are important (e.g., water quality)
- Looked at impacts of:
  - Prices ($5, $15 & $25/t CO2e)
  - Different points of obligation

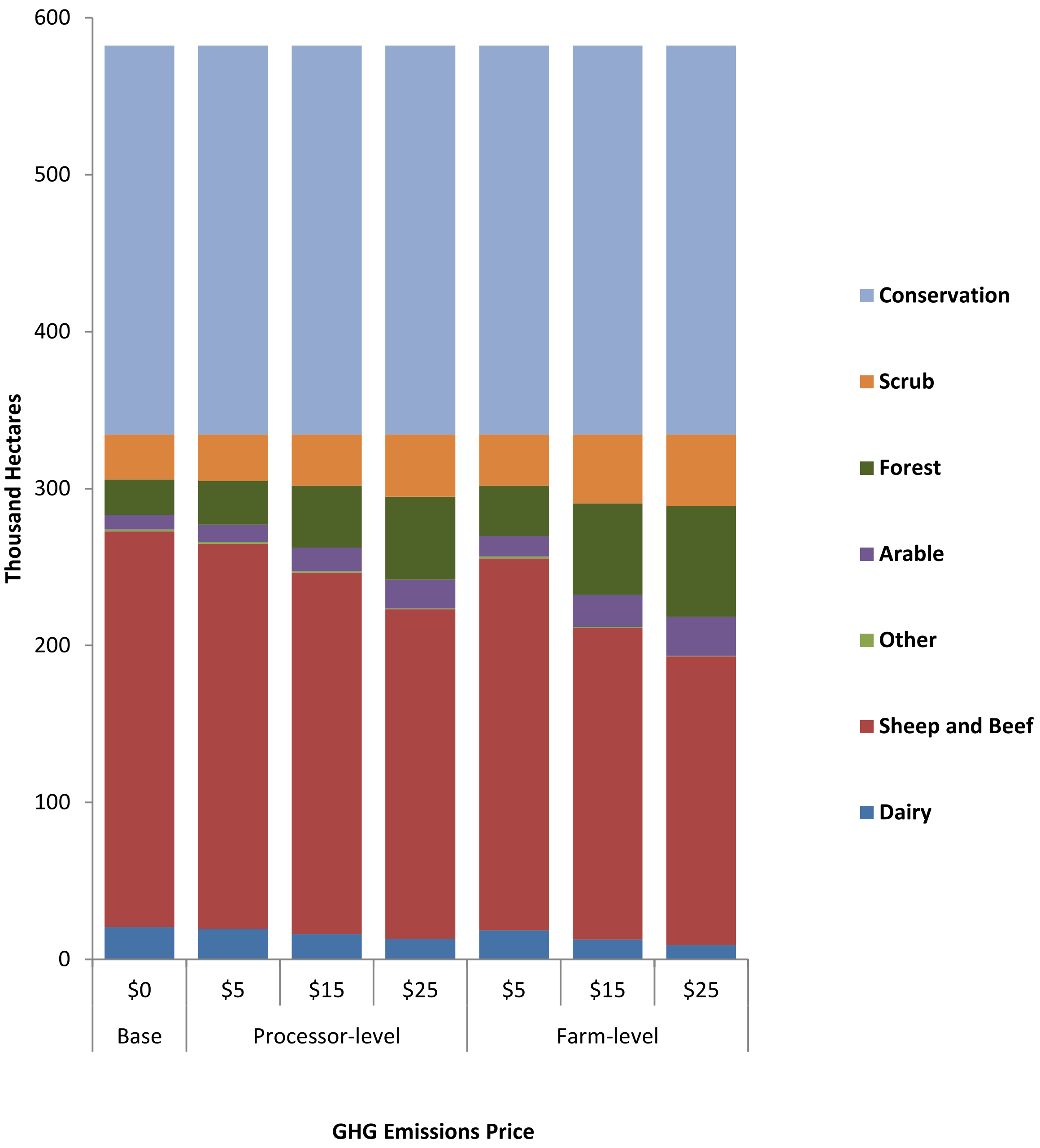
Hurunui-Waiau Baseline Enterprise Mix

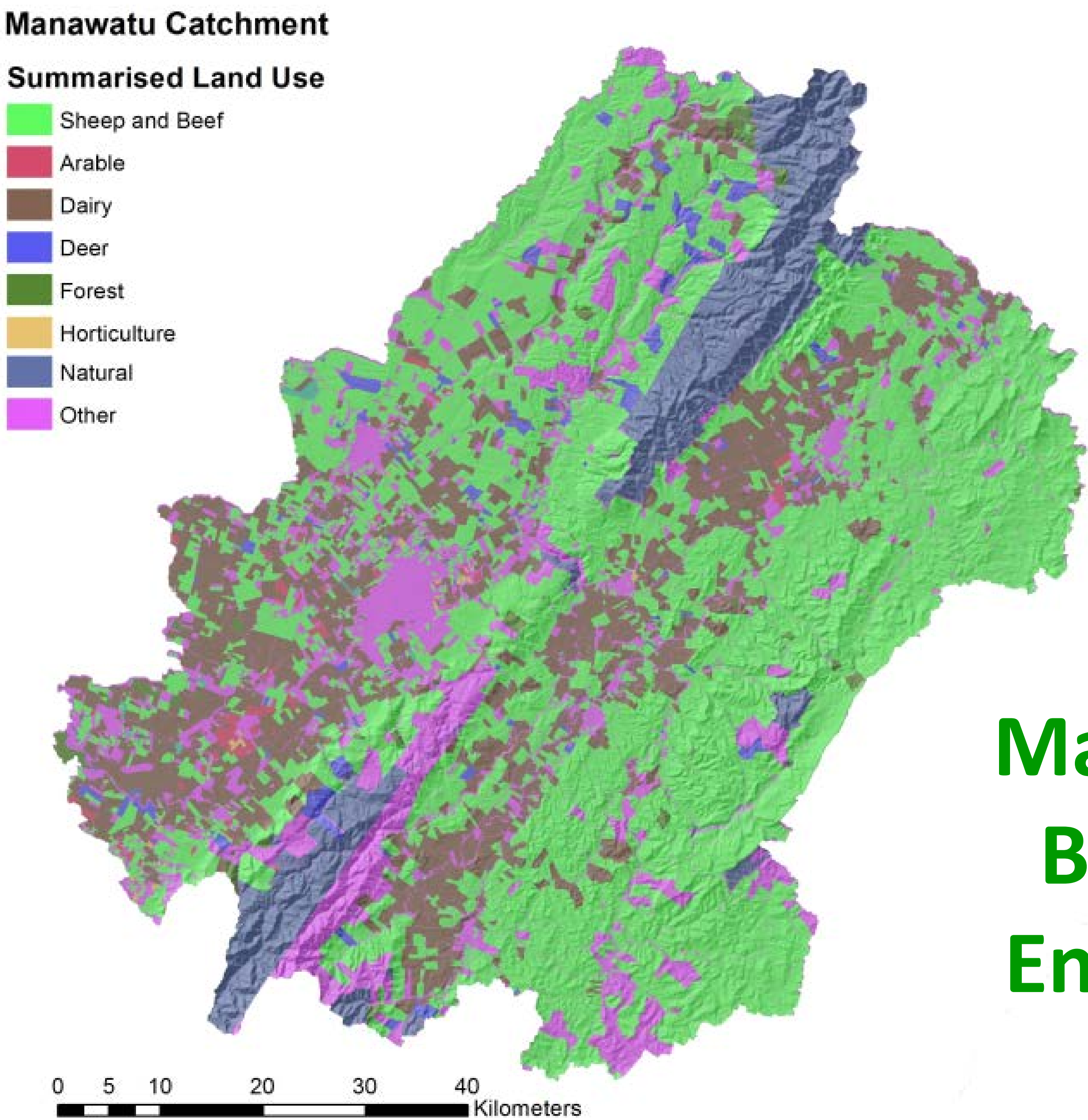


Results: Hurunui-Waiau

Scenario	Net Revenue (million $)	Total GHG emissions (tonnes)	Net GHGs (tonnes)	N Leaching (tonnes)	P Loss (tonnes)
Processor-level point of obligation					
$5/tCO_2e$	–1%	–4%	–17%	–1%	0%
$15/tCO_2e$	–4%	–14%	–56%	–6%	–2%
$25/tCO_2e$	–7%	–24%	-99%	-11%	–5%
Farm-level point of obligation					
$5/tCO_2e$	–3%	–10%	–37%	–3%	–1%
$15/tCO_2e$	–8%	–30%	-119%	–12%	–7%
$25/tCO_2e$	–12%	–38%	–156%	–17%	–9%

Hurunui-Waiau



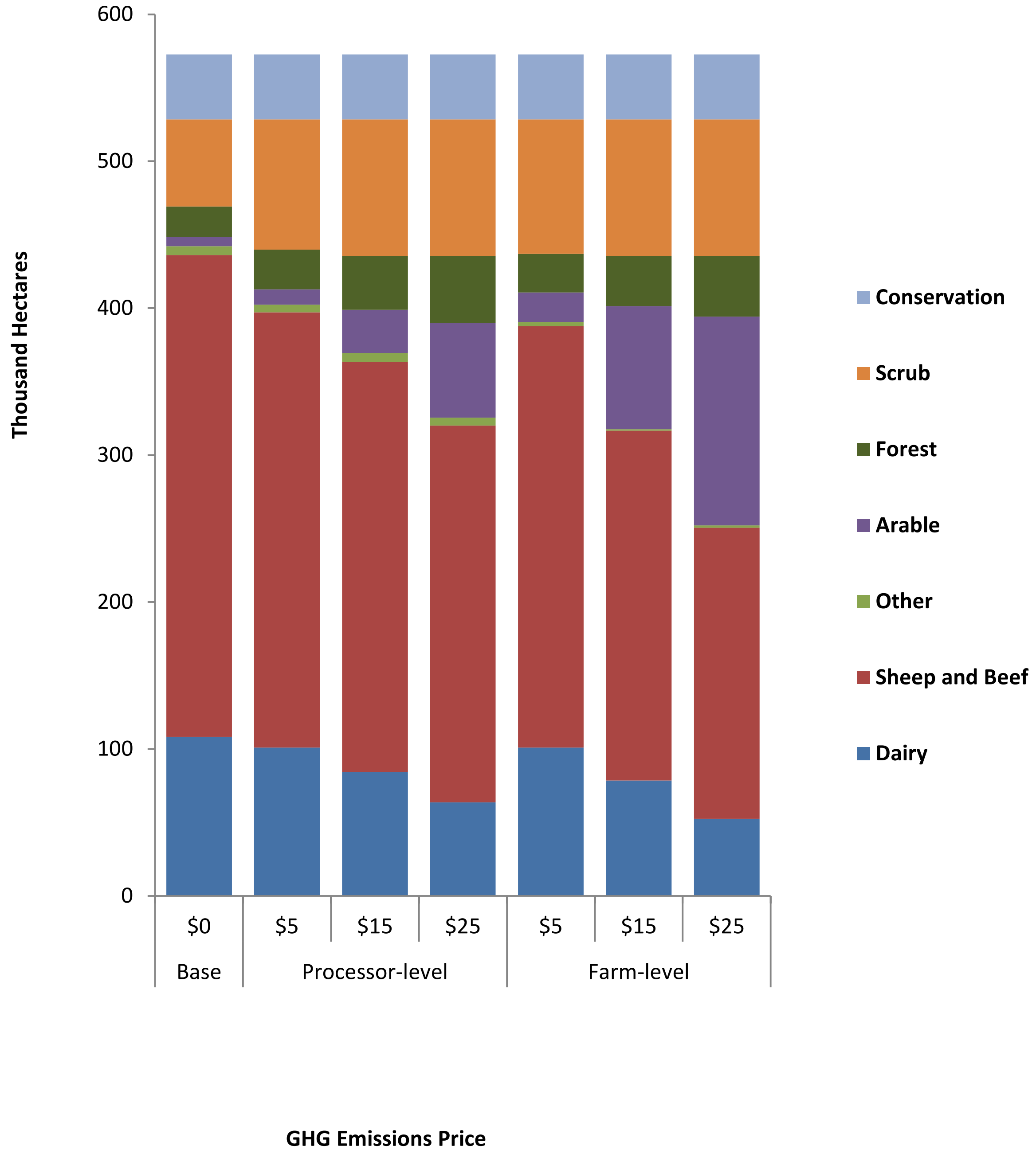


Manawatu Baseline Enterprise Mix

Results: Manawatu

Scenario	Net Revenue (million $)	Total GHGs emissions (tonnes)	Net GHGs (tonnes)	N Leaching (tonnes)	P Loss (tonnes)
Processor-level point of obligation					
$5/tCO$_2$e	–3%	–8%	–25%	–3%	–8%
$15/tCO$_2$e	–8%	–16%	–51%	4%	–12%
$25/tCO$_2$e	–13%	–25%	-78%	21%	–18%
Farm-level point of obligation					
$5/tCO$_2$e	–5%	–12%	–29%	5%	–11%
$15/tCO$_2$e	–13%	–29%	–65%	45%	–25%
$25/tCO$_2$e	–20%	–43%	–96%	77%	–35%

Results: Manawatu



However

NZFARM only accounts for economic behaviour

HENCE……

Linking the economic modelling to an agent-based model