



**Landcare Research**  
**Manaaki Whenua**

# Estimating the Impacts of A Multi-Policy Initiative at the Catchment Level

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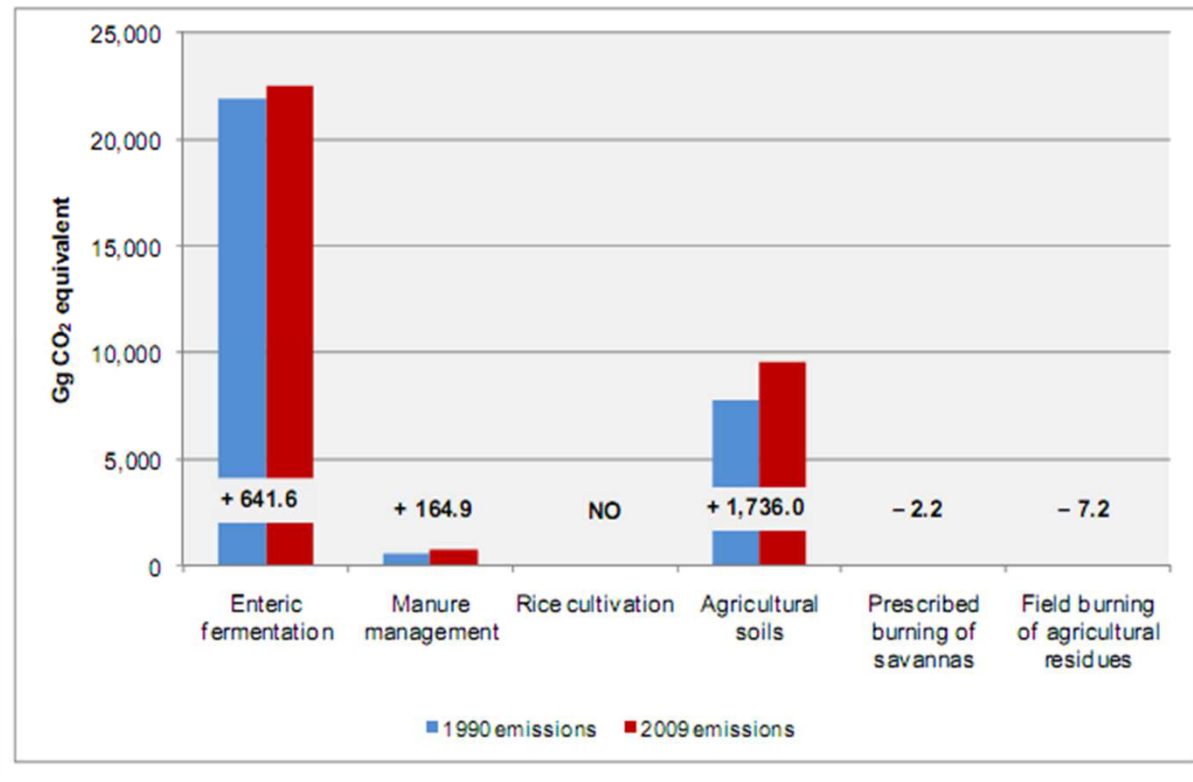
# Overview

- Agriculture is key sector of New Zealand's economy
  - Global market pressures to enhance farm output through intensive farming practices (e.g., fertilizer, irrigation, etc.)
- Intensive land-based enterprises also a large contributor of greenhouse gases (GHGs), nutrient and sediment runoff to waterways, etc.
  - 32.8 MtCO<sub>2</sub>e/yr of emissions from agriculture (47% of total)
  - Net sequestration from land use in 2009 was nearly 27 Mt CO<sub>2</sub>e
- Growing concern to assess impacts from implementing policies at regional scale
- Landcare developed NZ-FARM model capable of estimating impacts at sub-catchment level
  - This paper focuses on impacts in the Hurunui catchment
  - Alternative work on Waiau and Manawatu catchments

# Motivation of Study

- NZ-ETS to cover agriculture in 2015
- Increase in production intensity could increase sector's GHGs
- Current net removals from land use could be reduced from land use change

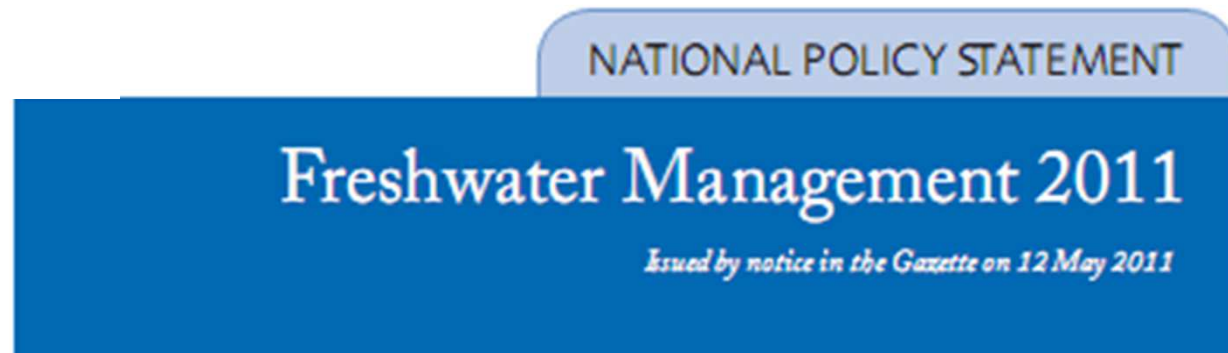
Figure 6.1.2 Change in New Zealand's emissions from the agriculture sector from 1990 to 2009



Source: Ministry for Environment, 2011.

# Motivation of Study

- National/regional measures to improve water quality *and* increase water quantity



## Objective B1

To safeguard the life-supporting capacity, ecosystem processes and indigenous species including their associated ecosystems of fresh water, in sustainably managing the taking, using, damming, or diverting of fresh water.

- But, can **both** of these objectives be achieved feasibly?
- What is the impact of imposing GHG price on agriculture?

# Questions

1. How do these objectives impact land use?
2. Can we feasibly increase water quantity without affecting water quality?
3. What are impacts of GHG emissions price on land use and production?
4. How does a price on agricultural GHG emissions alter nutrient leaching levels?
5. Can additional irrigation enhance economic output without increasing GHG emissions *and* nutrient leaching within a catchment?

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

- Objective: Maximize total net revenue from all potential farm enterprises in catchment
- Subject to regional/zone (R) constraints :
  - $\text{Inputs}_R \leq \text{Inputs Available}_R$
  - $\text{Area Land Use}_R \leq \text{Land Available}_R$
  - $\text{Area Irrigated Enterprises}_R \leq \text{Water Available}_R$
  - $\text{Environmental Outputs}_R \leq \text{Regulated Output}_R$
- Change in enterprise/land use constrained by constant elasticity of transformation (CET) fns
- Method: comparative-static, partial equilibrium, non-linear programming model solved in GAMS



# NZ-FARM – Key Components

- Land-use/enterprises:
  - Pastoral: dairy, sheep, beef, deer, pigs
  - Arable: wheat, barley, maize
  - Horticultural: potatoes, grapes, berryfruit
  - Forestry: pine, eucalyptus, native
  - Other: scrub and Dept of Conservation land
- Environmental outputs:
  - Nutrients: Nitrogen and Phosphorous
  - Water use
  - GHGs for farm and forest activities
  - Exploring water yield, sediments & pollination
- Endogenous farm practices:
  - Change enterprise or land use
  - Adjust fertilizer and stocking rates
  - Add dairy feed pad or apply nitrate inhibitors
  - Enter forest carbon sequestration programme



# Structure of NZFARM Nest and CET Functions

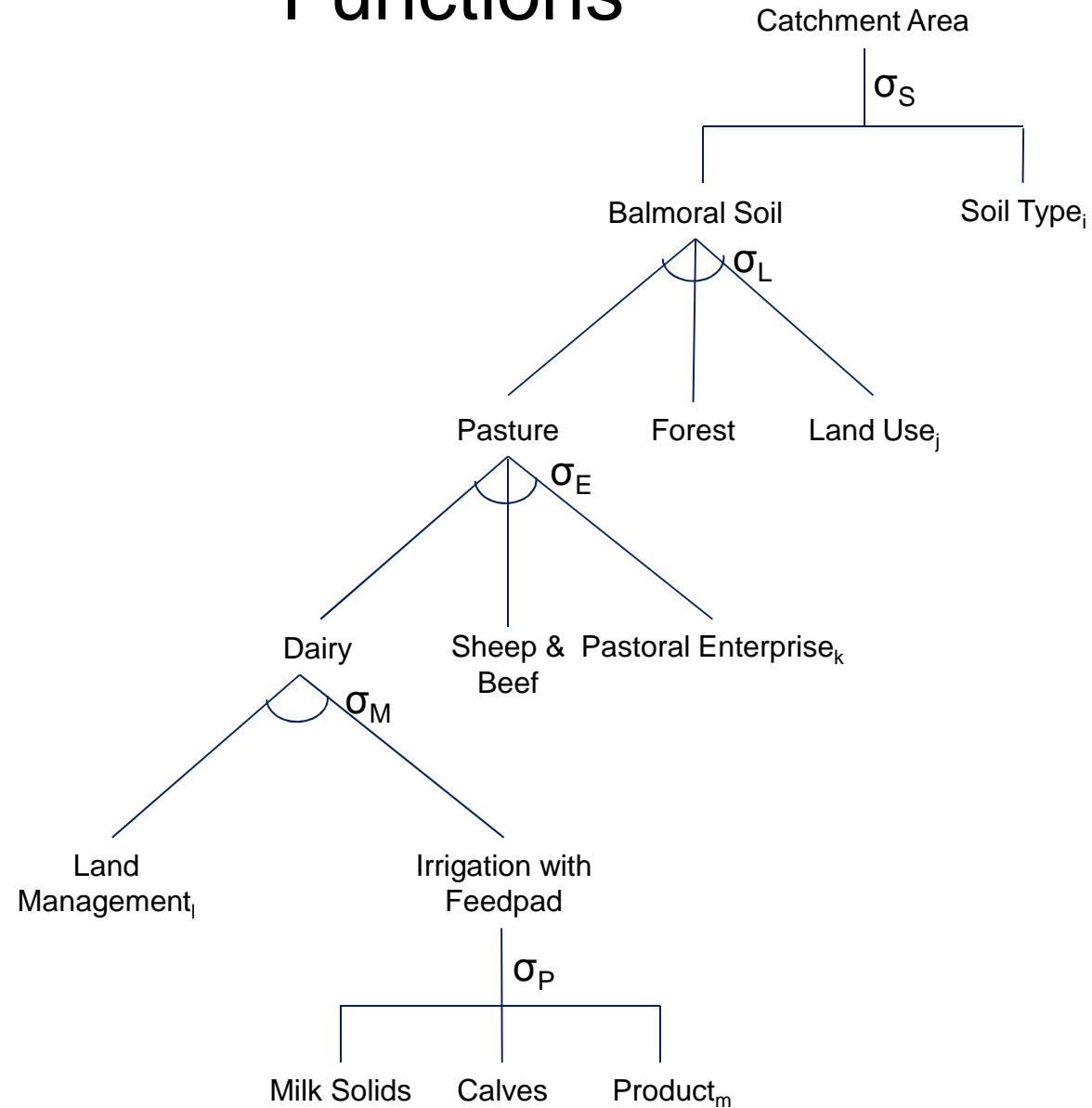
Soil Type

Land Use

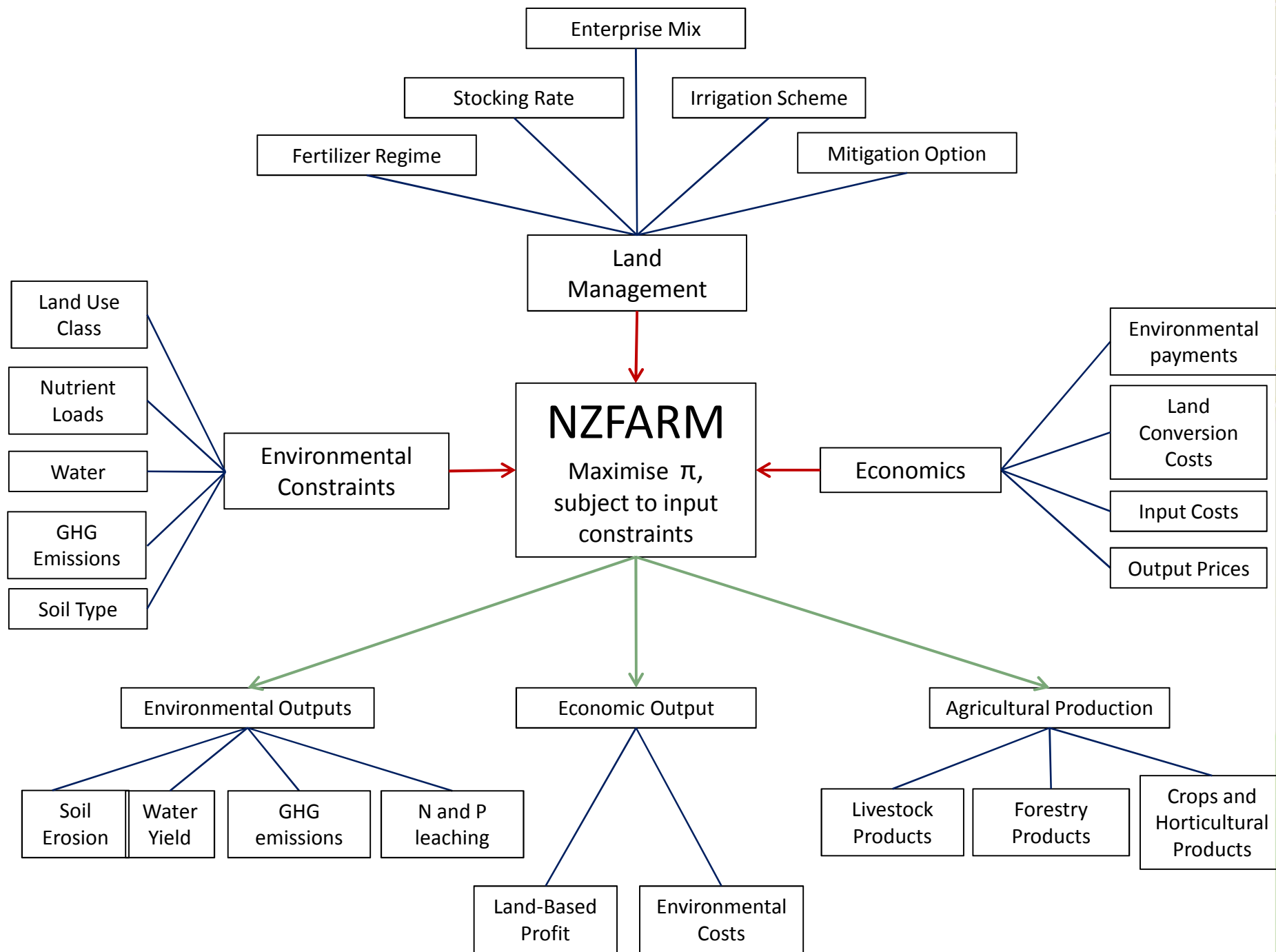
Enterprise

Land Management

Agricultural Production

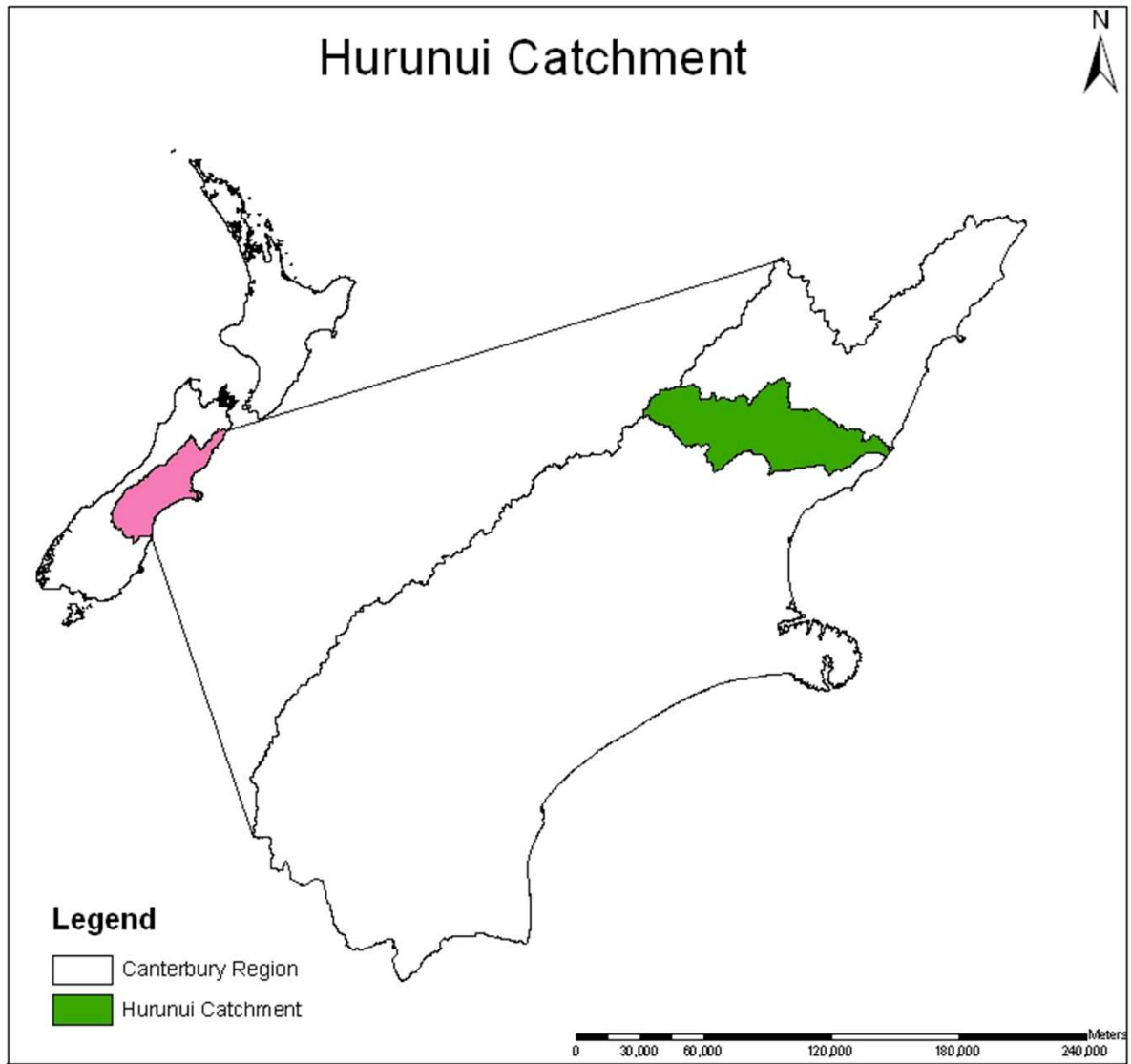






# Application to Hurunui Catchment

- NZ-ETS to cap agriculture emissions in 2015
  - Assume carbon prices of \$20 and \$40/tCO<sub>2</sub>e
- Concern over water use and environmental flows in region
  - Proposed Hurunui Water Project (HWP) would nearly double area of land that can be irrigated
  - Opponents contest that added irrigation would harm local ecosystem and impact recreation opportunities
- Regional Council currently considering nutrient leaching constraints in same catchment
  - Includes both Nitrogen (N) and Phosphorous (P) caps

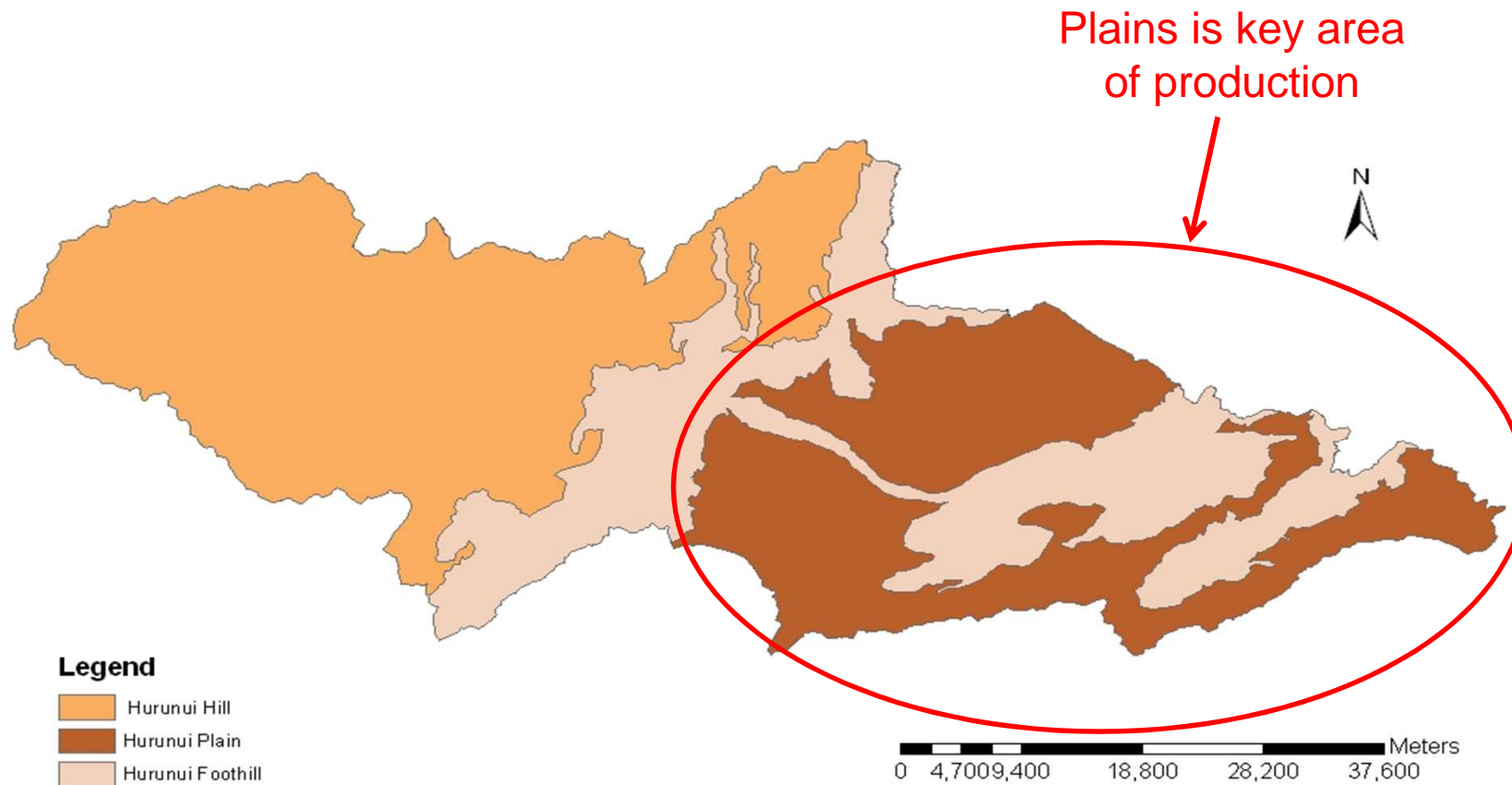


Total Area:  
260,000 HA

Dryland Area:  
237,800 HA

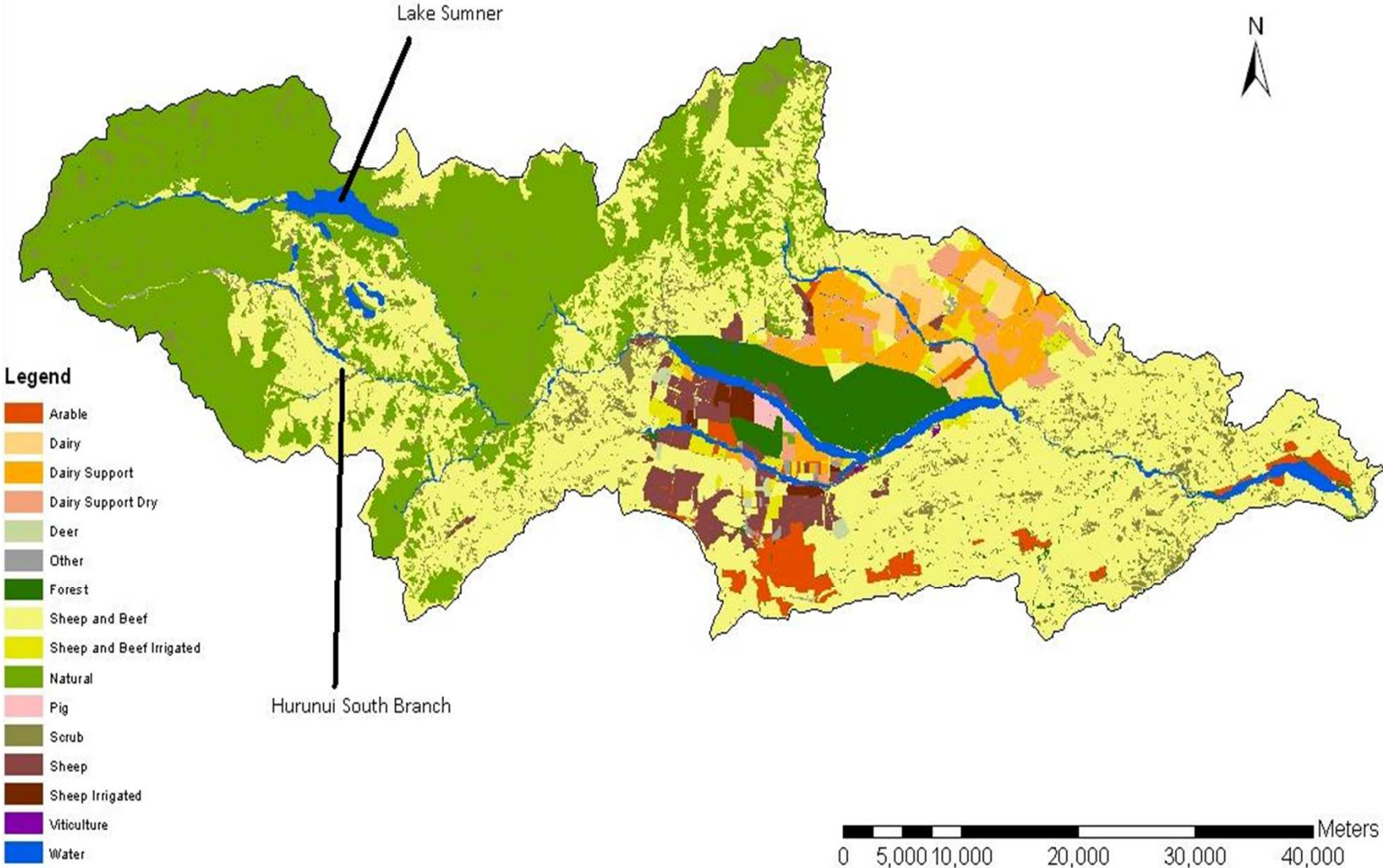
Irrigated Area:  
22,200 HA

# Sub-Zones within Hurunui Catchment



Note: area differentiated by productive capability/land use classification

# Baseline Enterprise Mix



# Baseline and Policy Scenarios

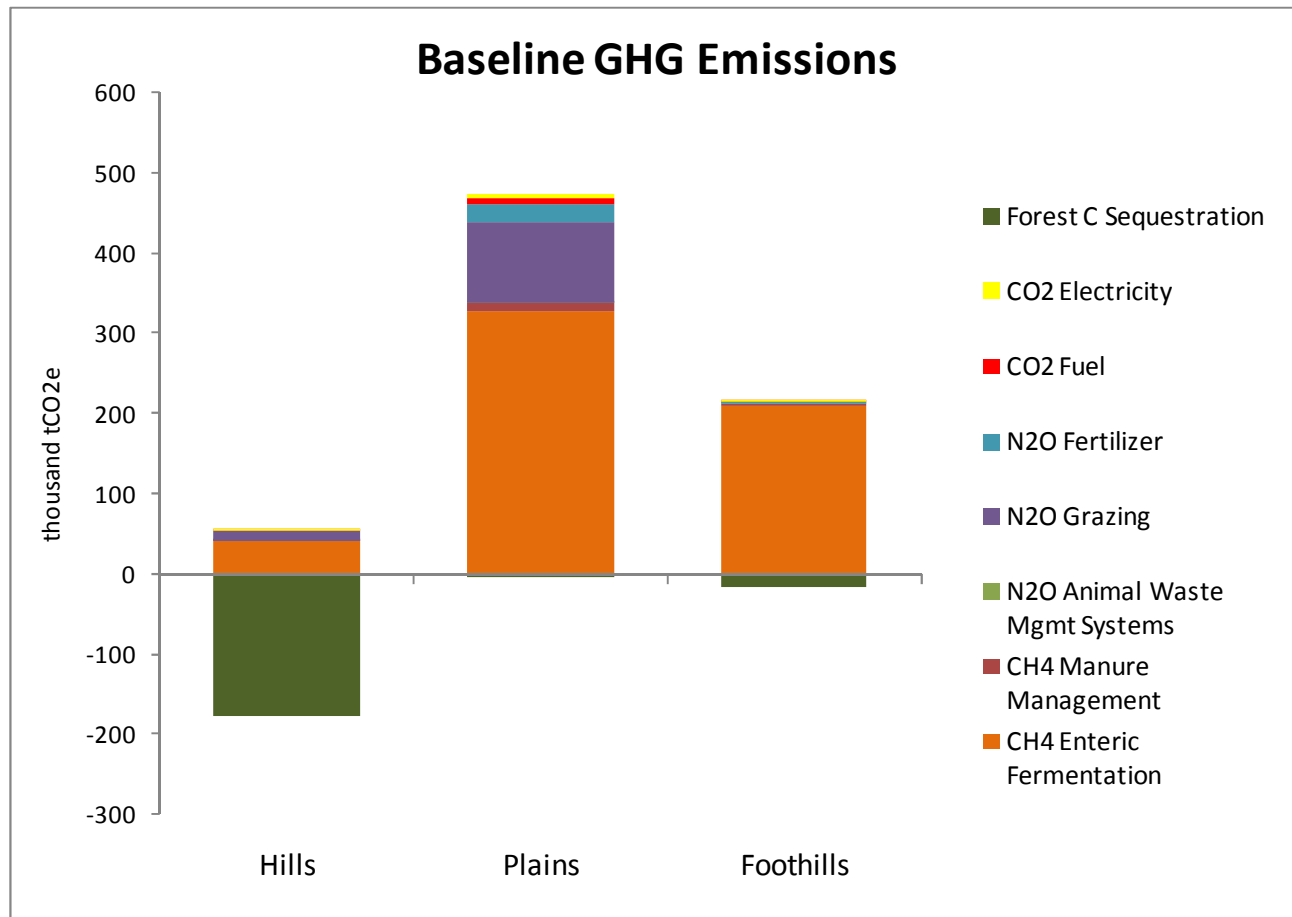
- Analysis assesses trade off of economic returns, GHG emissions and nutrient loads under several policy scenarios:
  - Baseline irrigation with no carbon price
  - Baseline irrigation with carbon price
  - Hurunui Water Project irrigation with no carbon price
  - Hurunui Water Project with carbon price
  - Hurunui Water Project with no carbon price, but nutrient cap

| Scenario  | Maximum Irrigated Area (ha) | Carbon Price on Ag GHGs (\$/tCO <sub>2</sub> e) | Nitrogen Cap (tons) | Phosphorous Cap (tons) |
|---|-----------------------------|---|---------------------|------------------------|
| Baseline  | 22,000                      | None  | None                | None                   |
| Baseline + GHG Price of \$20/tCO <sub>2</sub> e                   | 22,000                      | \$20  | None                | None                   |
| Baseline + GHG Price of \$40/tCO <sub>2</sub> e                   | 22,000                      | \$40  | None                | None                   |
| HWP with no GHG Price   | 41,400                      | None  | None                | None                   |
| HWP + GHG Price of \$20/tCO <sub>2</sub> e                        | 41,400                      | \$20  | None                | None                   |
| HWP + GHG Price of \$40/tCO <sub>2</sub> e                        | 41,400                      | \$40  | None                | None                   |
| HWP + Nitrogen and Phosphorous Leaching Capped at Baseline levels | 41,400                      | None  | Baseline Levels     | Baseline Levels        |



# Baseline Results

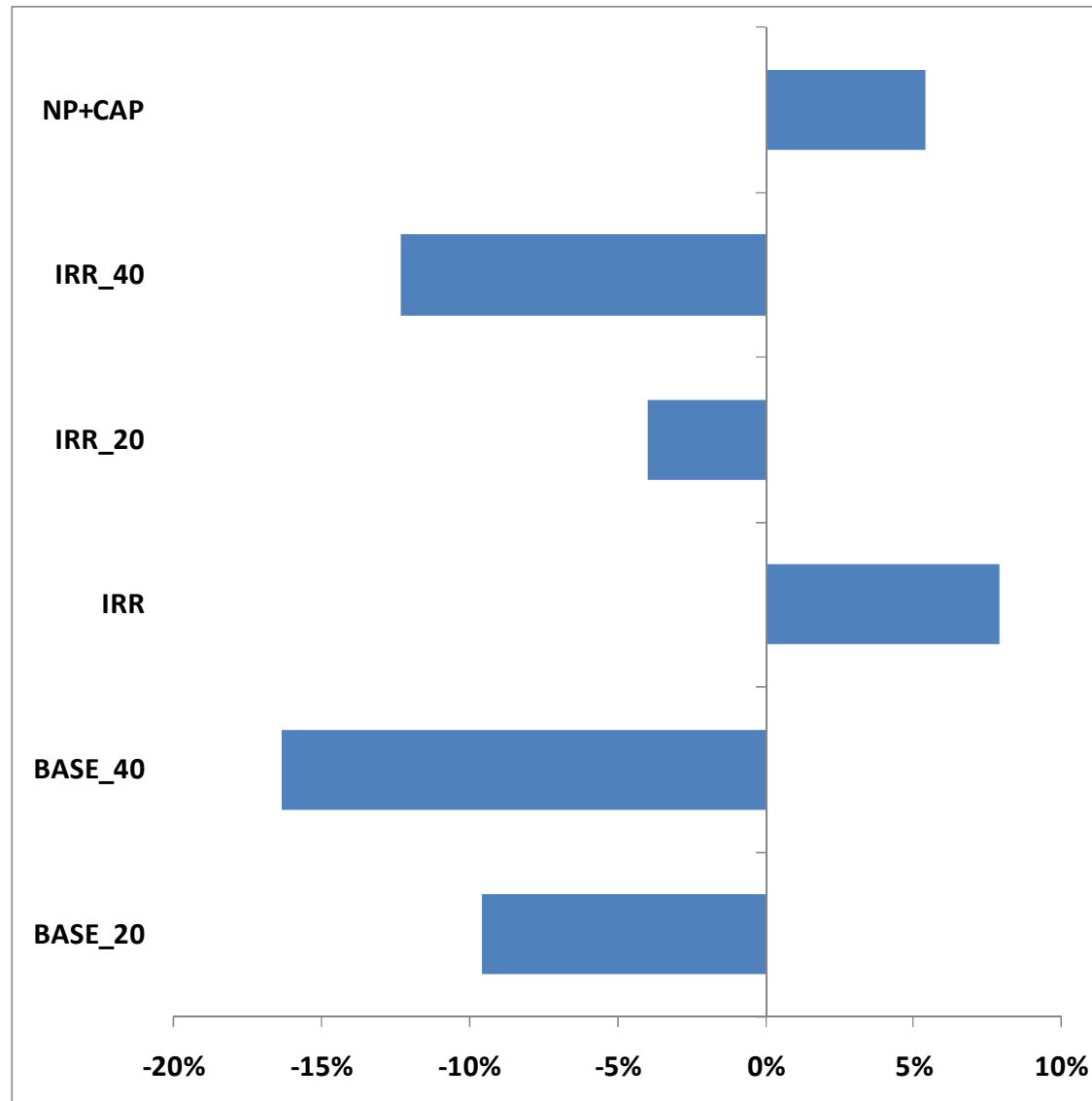
| Net Revenue (\$) | Total GHGs (tons) | Net GHGs (tons) | N Leaching (tons) | P Leaching (tons) |
|------------------|-------------------|-----------------|-------------------|-------------------|
| \$153,191,968    | 804,148           | 606,509         | 1,752             | 22.5              |



- Nearly all irrigation in plains
- Sheep and beef dominant enterprise
- Dairy and pine plantations in plains
- Net GHGs reduce emissions from catchment because of sequestration in native vegetation on scrub

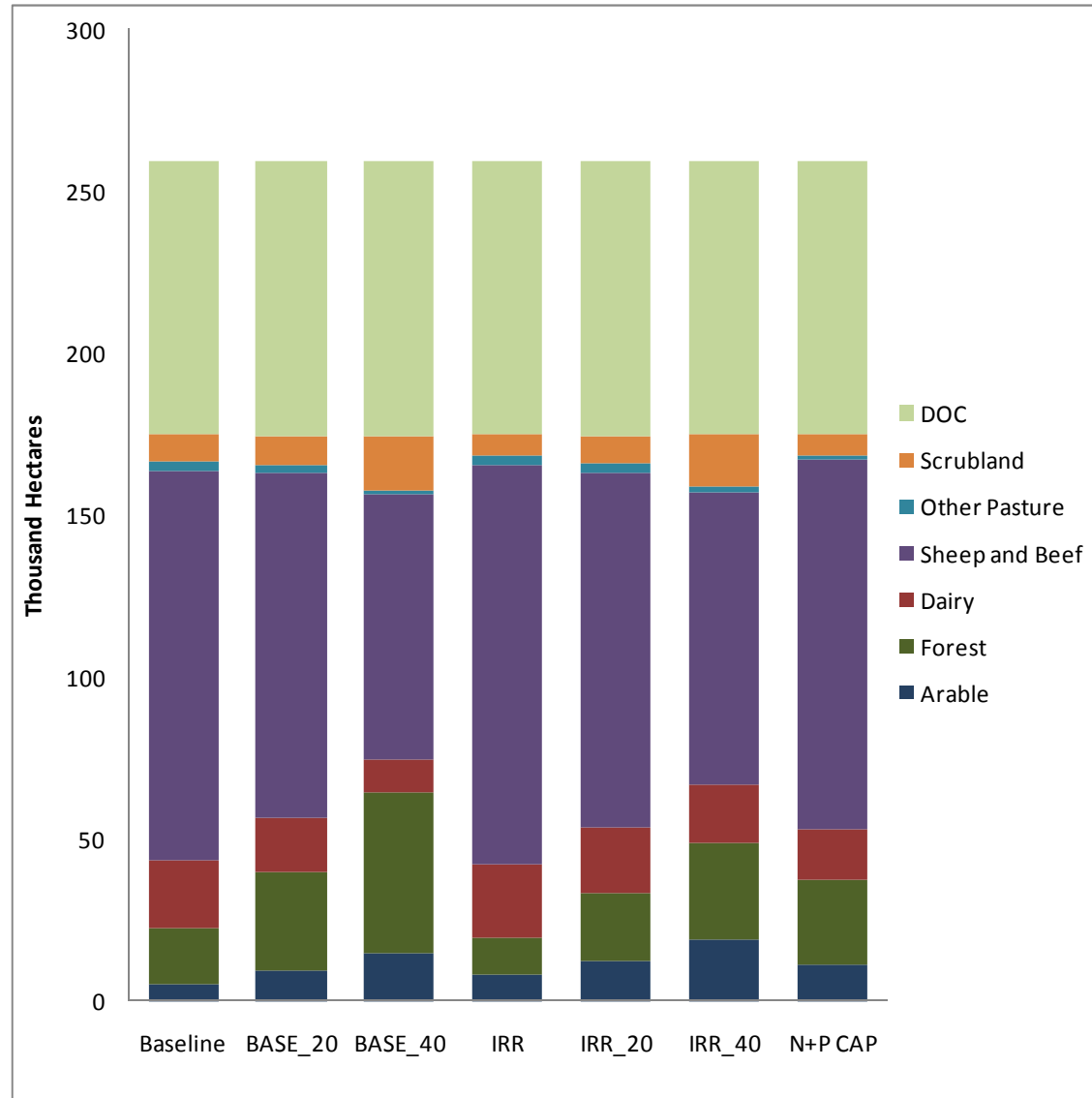


# Net Catchment Revenue Impacts



- Carbon price reduces revenue for all scenarios
- Irrigation scheme increases revenue relative to baseline
- Capping N and P at baseline levels with irrigation scheme still results in economic gains

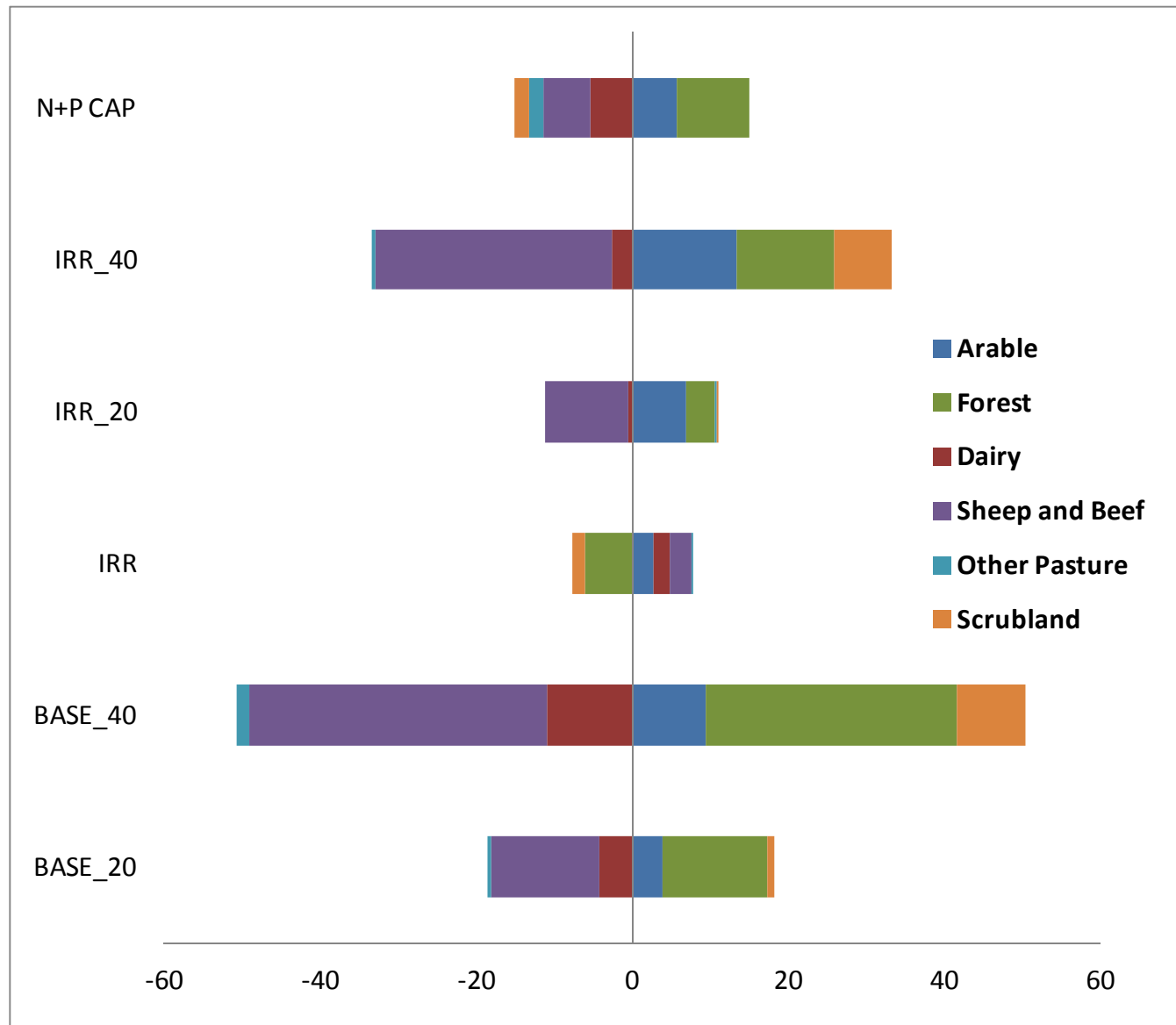
# Aggregate Enterprise Area



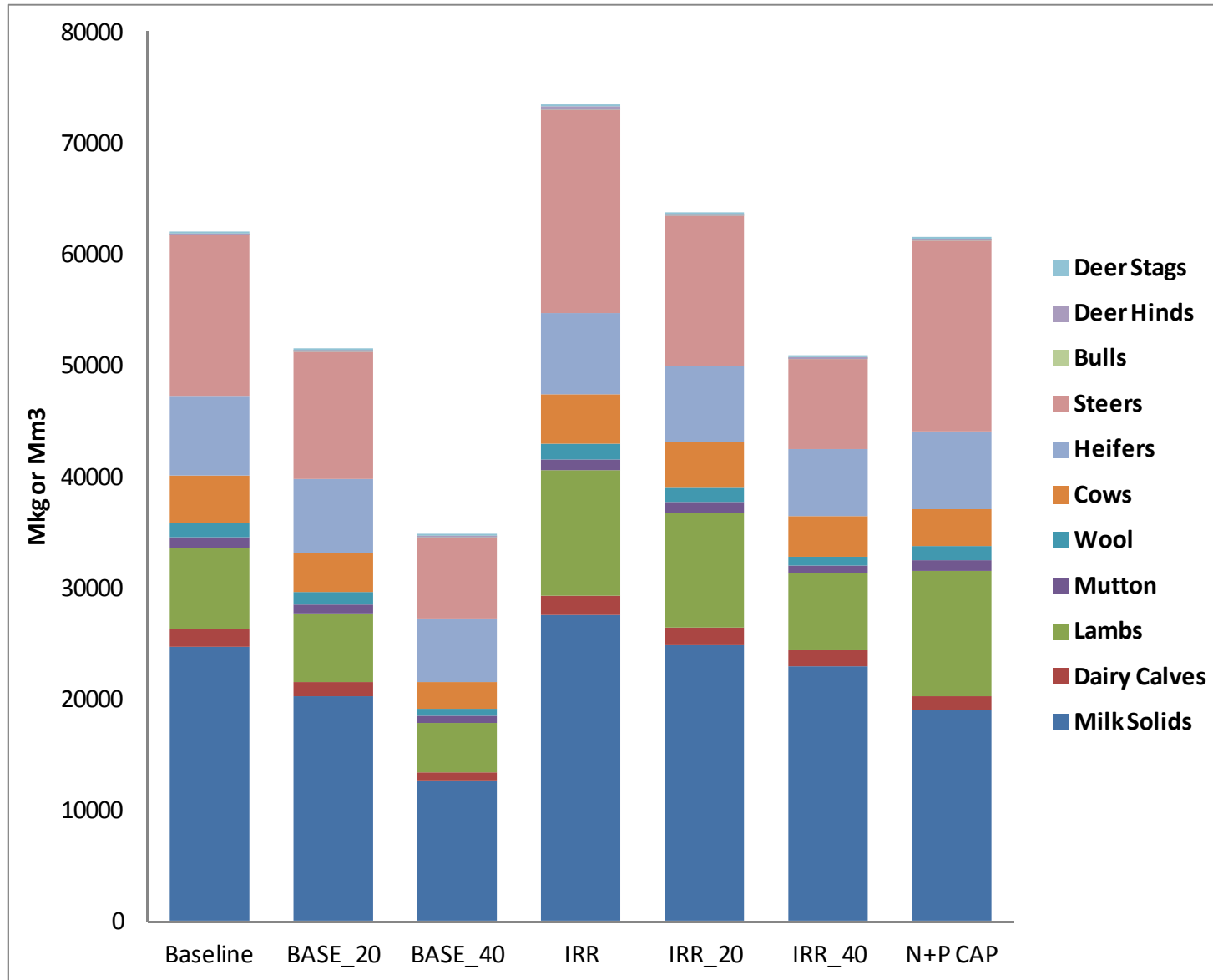
- Irrigation scheme shifts forest and scrub to dairy and arable land
- Carbon prices promotes expansion of forests and scrub
- Pastoral enterprises reduced with carbon price
- Arable crops still viable option for irrigation scheme as less GHG intensive



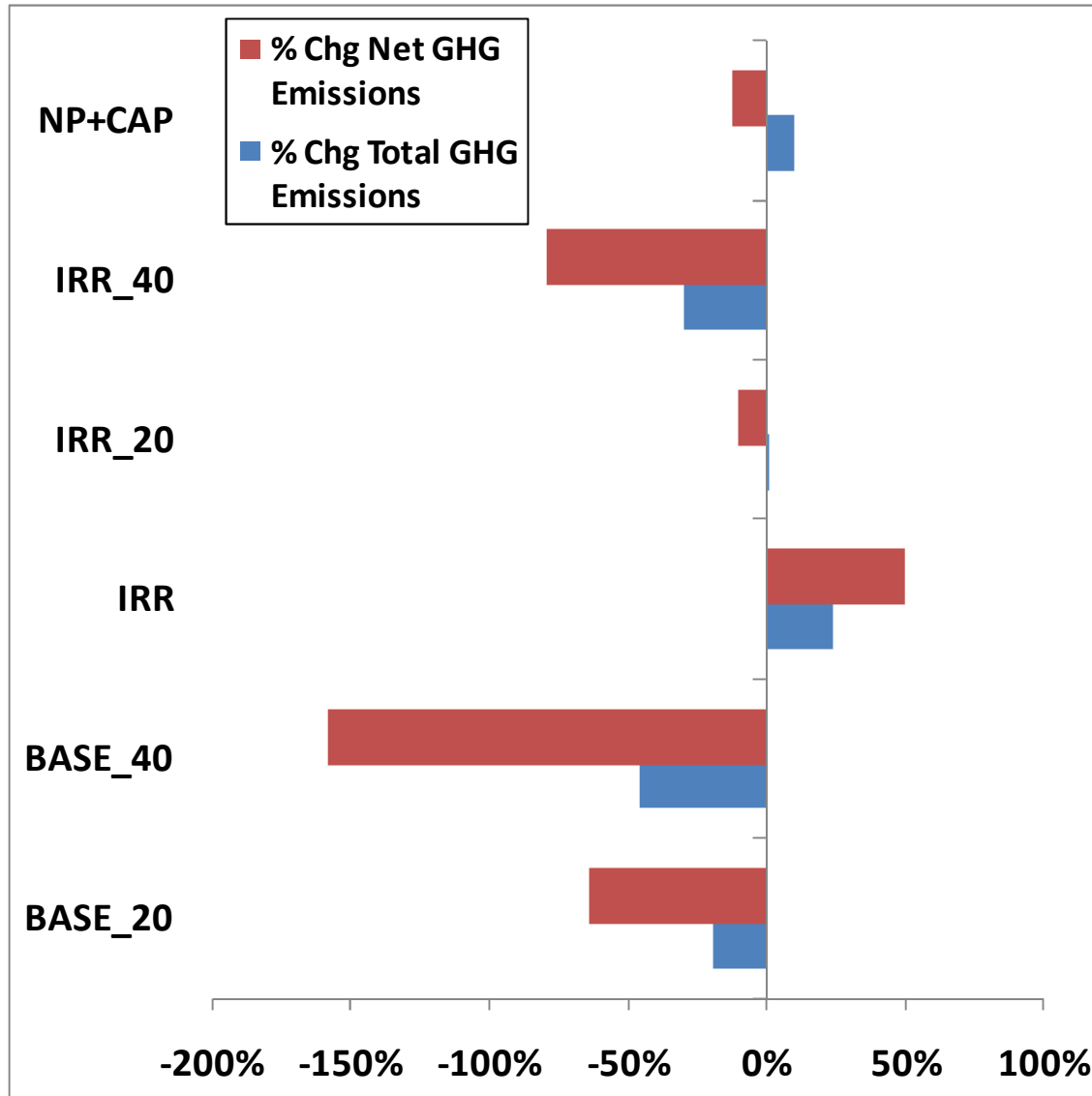
# Change in Aggregate Enterprise Area



# Pastoral Production



# Catchment-level GHG Impacts

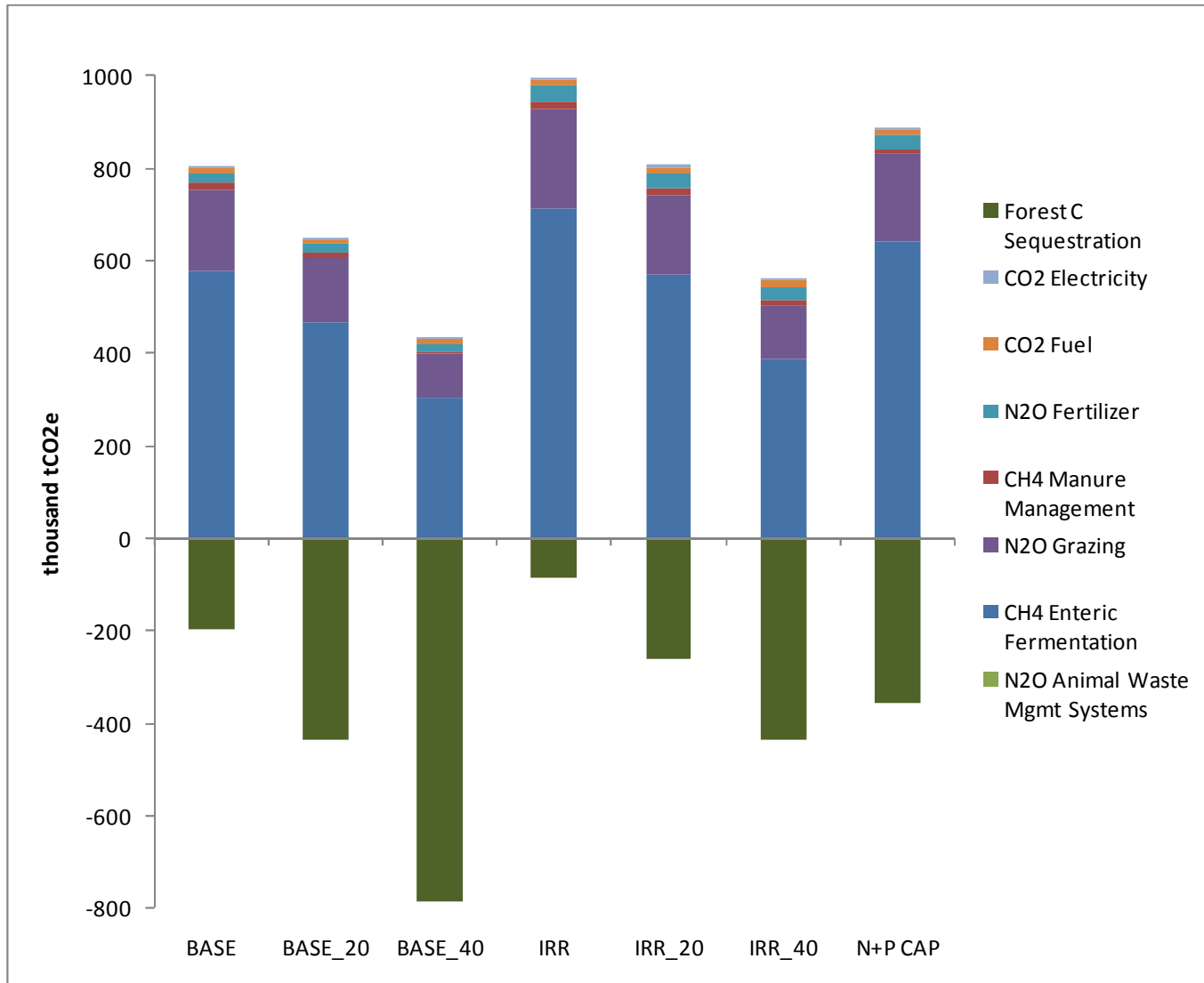


- Implementing irrigation scheme increases emissions by 19% to 64% (net)
- Adding carbon price reduces emissions below baseline for all scenarios
- Capping N and P at baseline levels results in net GHG emission reductions

**Note:** Net GHGs account for change in forest carbon sequestration



# Breakout of GHGs (tons CO<sub>2</sub>e)

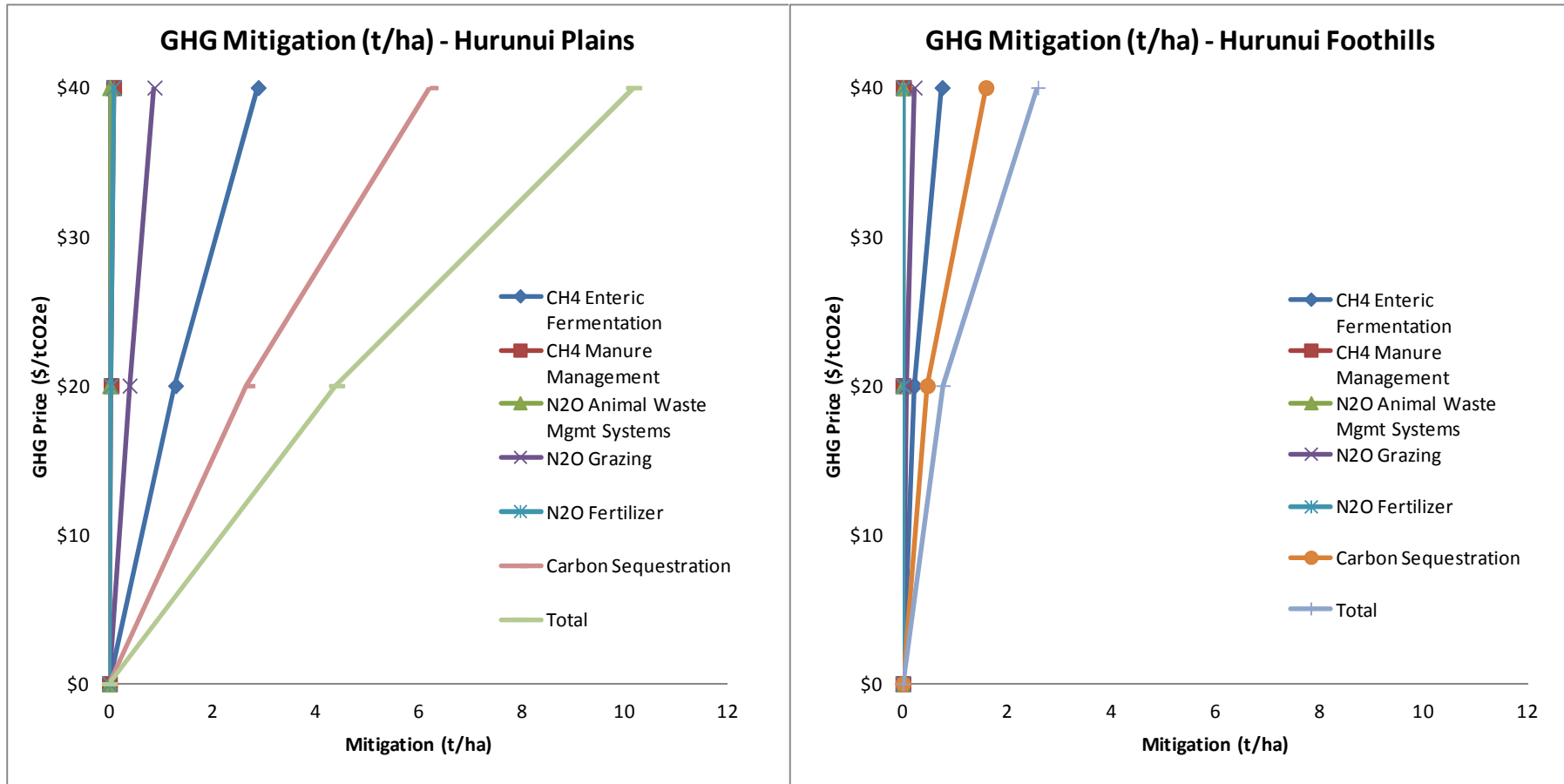


- Proportion of emissions roughly match latest national GHG inventory figures
- Emissions are dominated by pastoral production
- Forest carbon seq. in baseline from native vegetation
- Forest sequestration in policies from new pine or less conversion of scrub to pasture



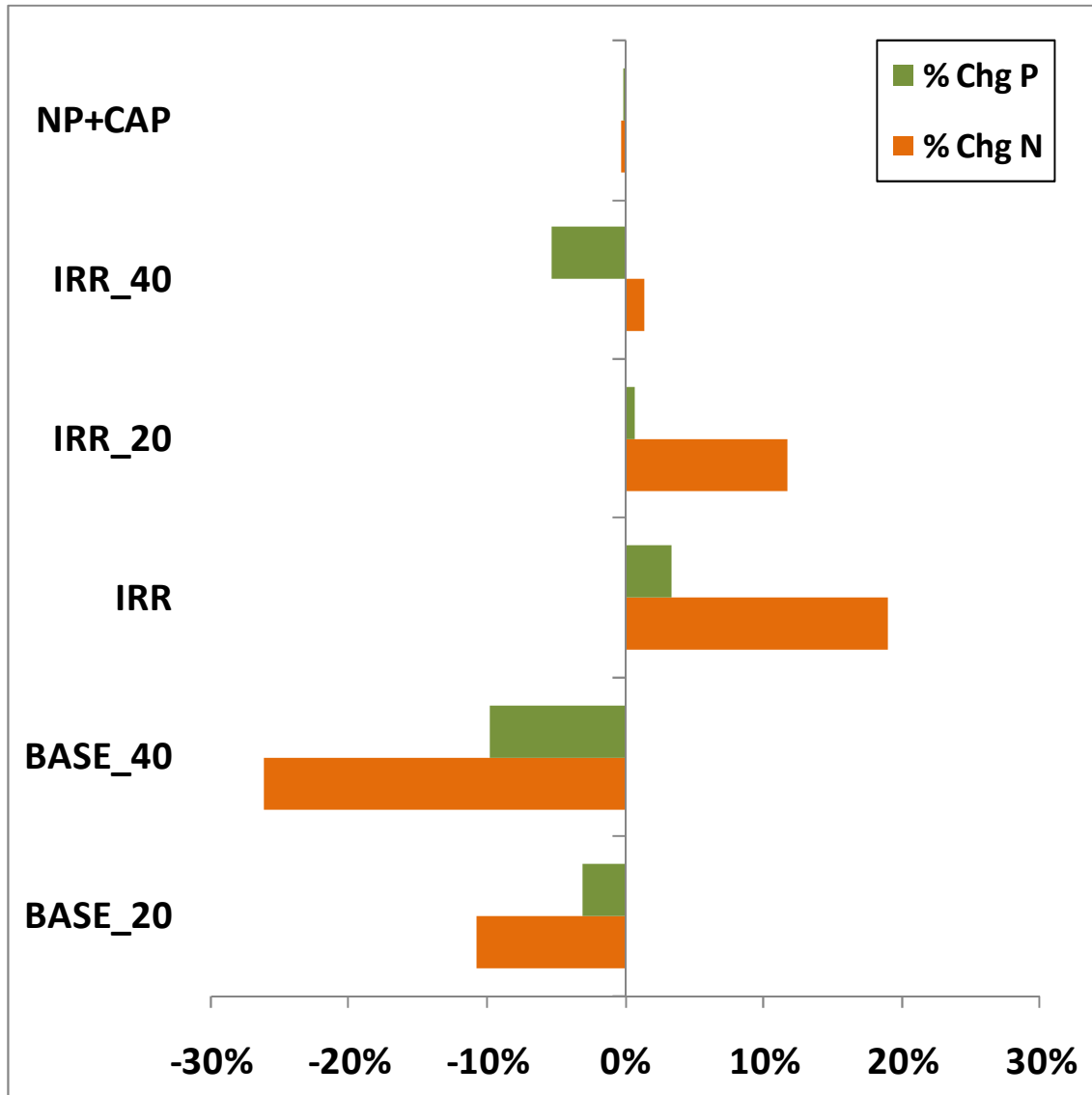
# Marginal Abatement Costs

## Baseline Irrigation + GHG Price



- Level of per hectare abatement varies across regions and mitigation options.
- Carbon sequestration, enteric fermentation are lowest cost options
  - Most mitigation from tree planting, reducing stocking and fertilizer app. rates
  - Additional mitigation from DCDs and feed pads for dairy

# Nutrient Impacts



- Implementing irrigation scheme increases N by 19% and P by 3% from more intensive land use
- Adding carbon price reduces nutrient loadings for all scenarios
- Require ~\$40/tCO<sub>2</sub>e to get near baseline levels for increased irrigation scenarios



# Answers to Questions

Q1 How do these objectives impact land use?

A1: Depends on the policy.

Constraint on output → Less pastoral enterprises

Increase in irrigation → Less forest and scrub

Q2. Can we feasibly increase water quantity without affecting water quality?

A2. No, unless we place constraints on enviro outputs

Q3. What are impacts of GHG price on land use and production in the catchment?

A3. Pasture converted to forest, arable, scrub



# Answers to Questions

Q4. How does a price on agricultural GHG emissions affect nutrient leaching levels?

A4. Benefit is that it reduces nutrient leaching for all scenarios

Q5. Can additional irrigation enhance economic output without increasing GHG emissions and nutrient leaching within a catchment?

A5. Yes, if we count net carbon sequestration from increase in forests



# Summary

- Co-benefits of Agriculture GHG emissions reduction policy do exist at catchment level
- Analysis shows that there may not be a ‘win-win’ scenario for more irrigation and improved water quality
  - Results driven by enterprise and mitigation options in model
- Model currently tracks water use, nutrients, and GHGs, but more environmental outputs/services could be considered as reliable data becomes available
  - Soil erosion, water yield, pollination etc.
- Alternative analysis of Manawatu Catchment produced similar results, but with varying magnitudes



# Questions? Contact Us:

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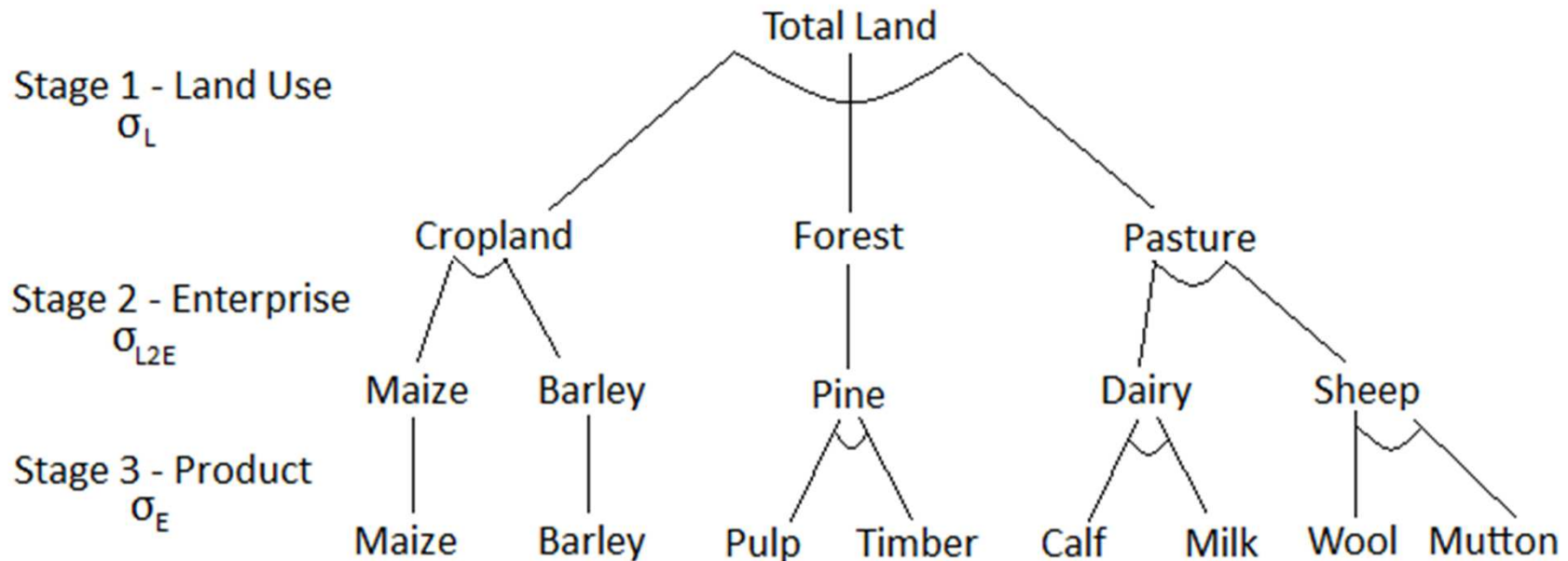
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# Structure of Nest in NZ-FARM

Given land area and soil type, landowner *simultaneously* chooses:

- (a) Land Use Mix
- (b) Enterprise Mix
- (c) Product Output



Transformation across these choices is constrained by constant elasticity of transformation (CET) functions with parameter,  $\sigma_i$ , where  $i = \{L, L2E, E\}$