



Landcare Research
Manaaki Whenua

Irrigation - Intensification - Illumination

Exploring Limits and Trade-Offs in Agricultural Intensification

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Outline

Objective

Ecosystem Services & Models

Identifying Trade-offs with LUMASS

Agricultural Intensification in the Ruamahanga

Black Creek

White Rock

Objectives

Assessing the impact of agricultural intensification on the provisioning of ecosystem services in the Ruamahanga catchment.

Identification of trade-offs between environmental and agricultural objectives of land management.

Guiding questions

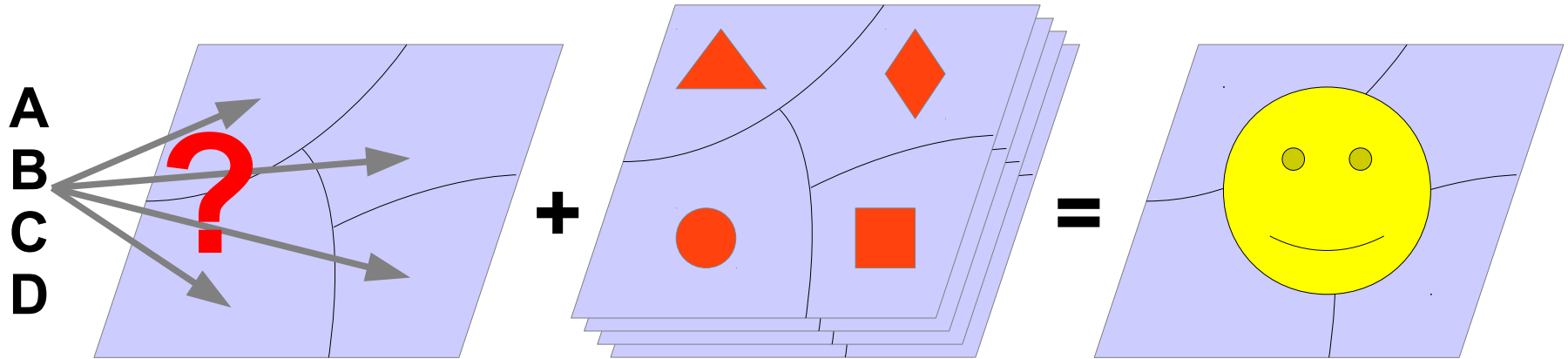
Do we make the best use of our natural resources?

Is there environmental headroom for agricultural intensification?

Ecosystem service	Process	Indicator	Model / Data
Global climate regulation	Carbon fixation	Carbon sequestration [t CO _{2eq.} / ha / yr]	CenW (Kirschbaum 1999)
	Greenhouse gas emission	Methane and nitrous oxide emissions [t CO _{2eq.} / ha / yr]	New Zealand greenhouse gas inventory emission factors (MfE 2010)
Erosion control	Soil erosion	Soil erosion [t sediment / km ² / yr]	NZeem(R) (Dymond et al. 2010)
Water-flow regulation	Water cycling	Water yield [mm/yr]	WATYIELD (Fahey et al. 2010)
Clean water provision	Nutrient cycling	Nitrate leached [kg N / ha / yr]	Overseer(R) (MAF et al. 2011), literature figures (Lilburne et al. 2010)
Food and fibre	Plant and animal growth	Wool, meat, milk, crop, grapes, timber production [kg / ha / yr]	Statistics NZ, Baker & Associates (2009)
Agricultural performance		Indicator	Model / Data
Farm profitability		Operating surplus [Mio. \$]	ANZ (2012, 2014), Baker & Associates (2009), Beef & Lamb (2014), Lewis & Bryant (n.d.), Laurie (2014)

(modified from Ausseil et al. 2013)

Multi-objective Spatial Optimisation



Resource

+

Criteria

=

Outcome

Land-Use

+

Productivity

=

max Revenue

Land-Use

+

Env. Indicator

=

min Env. Impact

Water

+

Spec. Efficiency

=

max Efficiency

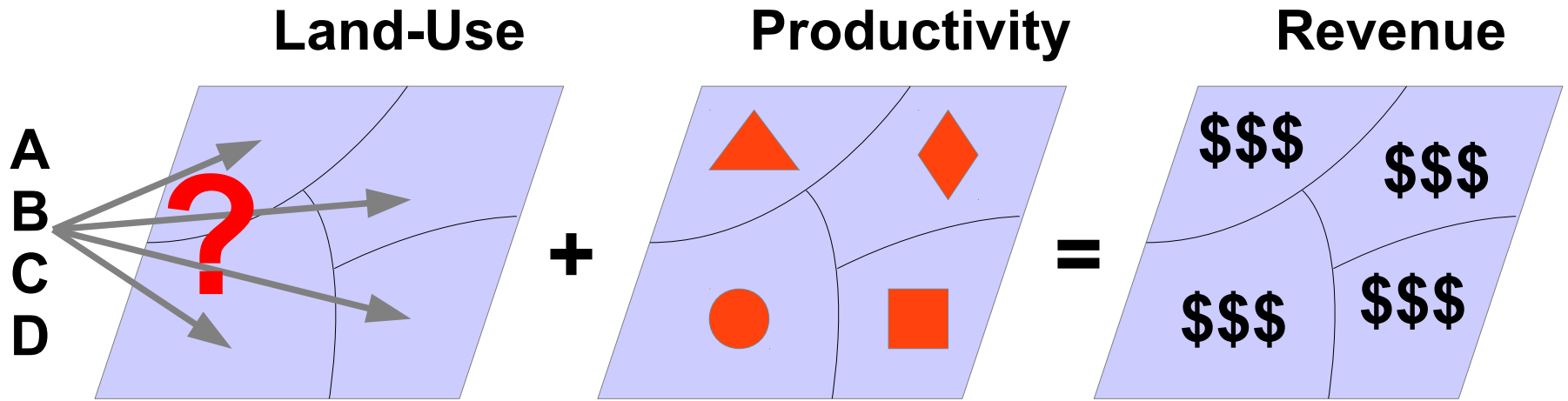
Habitat




+

Suitability

=

max Biodiversity



				
A	\$\$	\$\$\$	\$	\$\$
B	\$	\$	\$\$\$	\$\$
C	\$\$\$	\$\$	\$\$	\$
D	\$\$	\$\$	\$	\$\$\$

Land-Use Performance with Respect to Productivity

Allocation Constraints

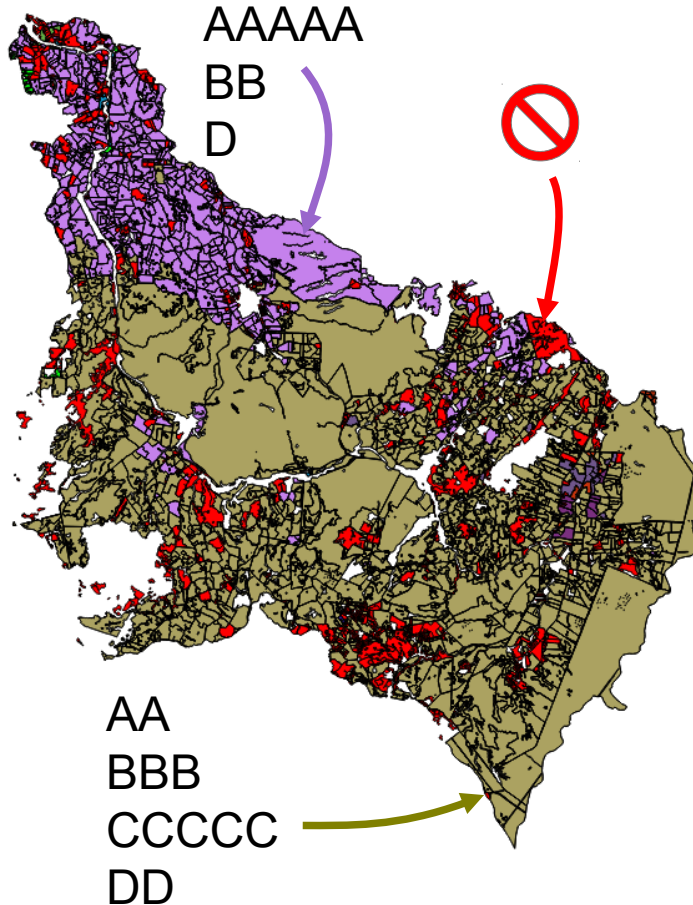
Where?
How much?

quantity per zone

total allocation:

AAAAAAA
BBBBB
CCCCC
DDD

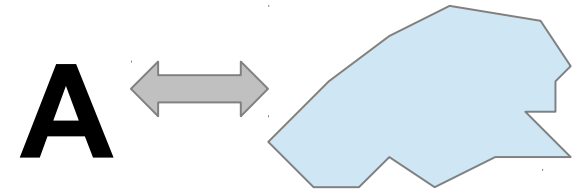
- ha dairy per region
- m3 water per irrigation zone
- no-go area



AAAAA
BB
D

AA
BBB
CCCCC
DD

proximity to stationary objects



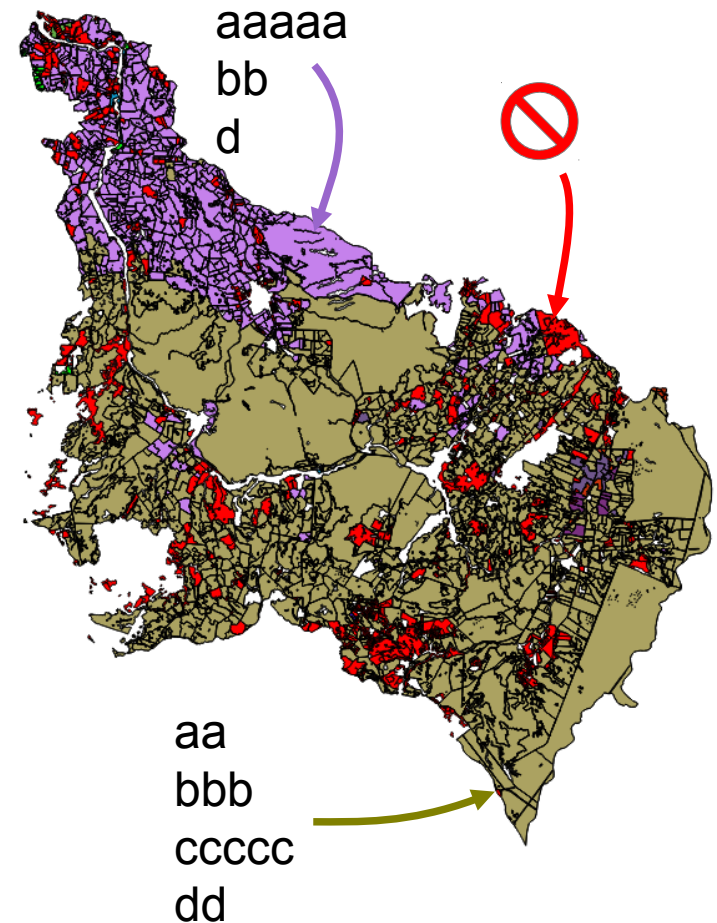
- nutrient cap depending on proximity to surface water
- housing suitability depending on proximity to industry
- business suitability depending on proximity to transport (road / rail)
- habitat suitability depending on proximity to settlement, road, river, lake, forest, etc.

Performance Constraints

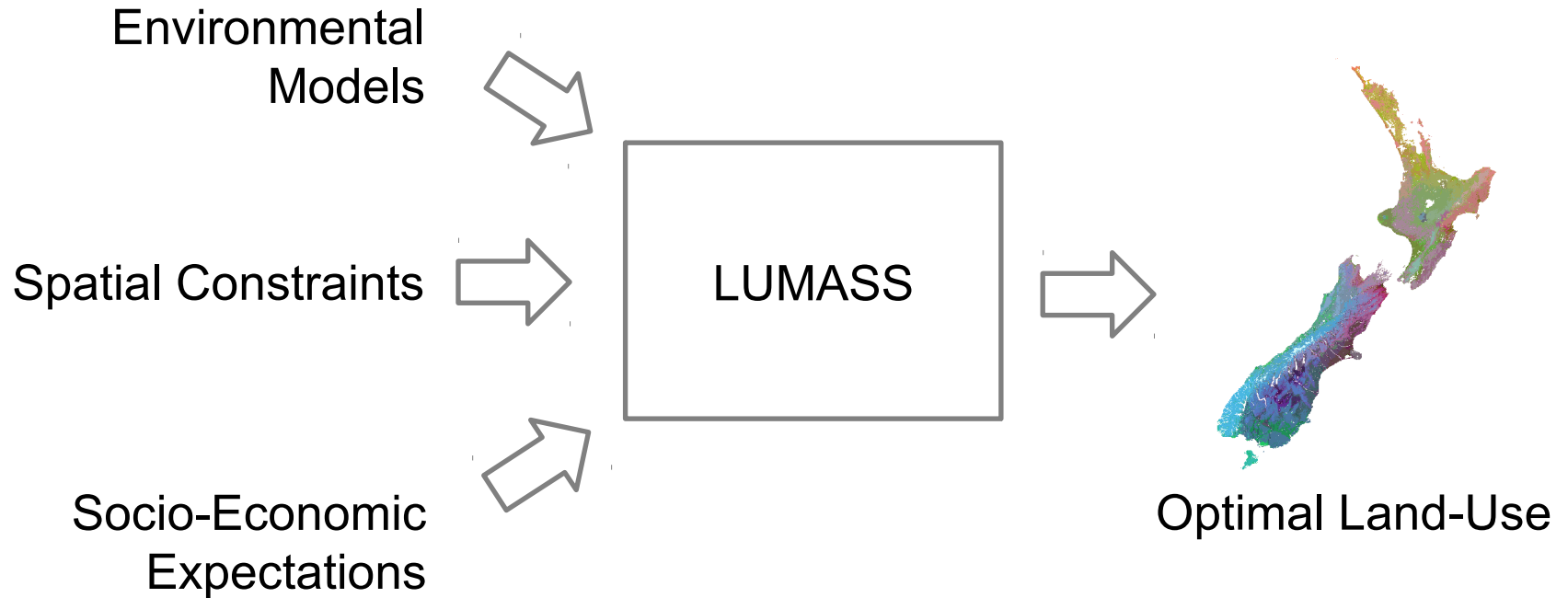
Desired Performance
Tolerated Impact

quantity per zone

- the overall nitrate leaching must not be greater than XXX kg N a-1
- the maximum nitrate leaching in zone X1 must not be greater than XXX kg N a-1
- the overall net revenue from dairy must be greater than \$XXX
- the total habitat value in zone X3 must be at least XXXX units



Spatial Optimisation with LUMASS



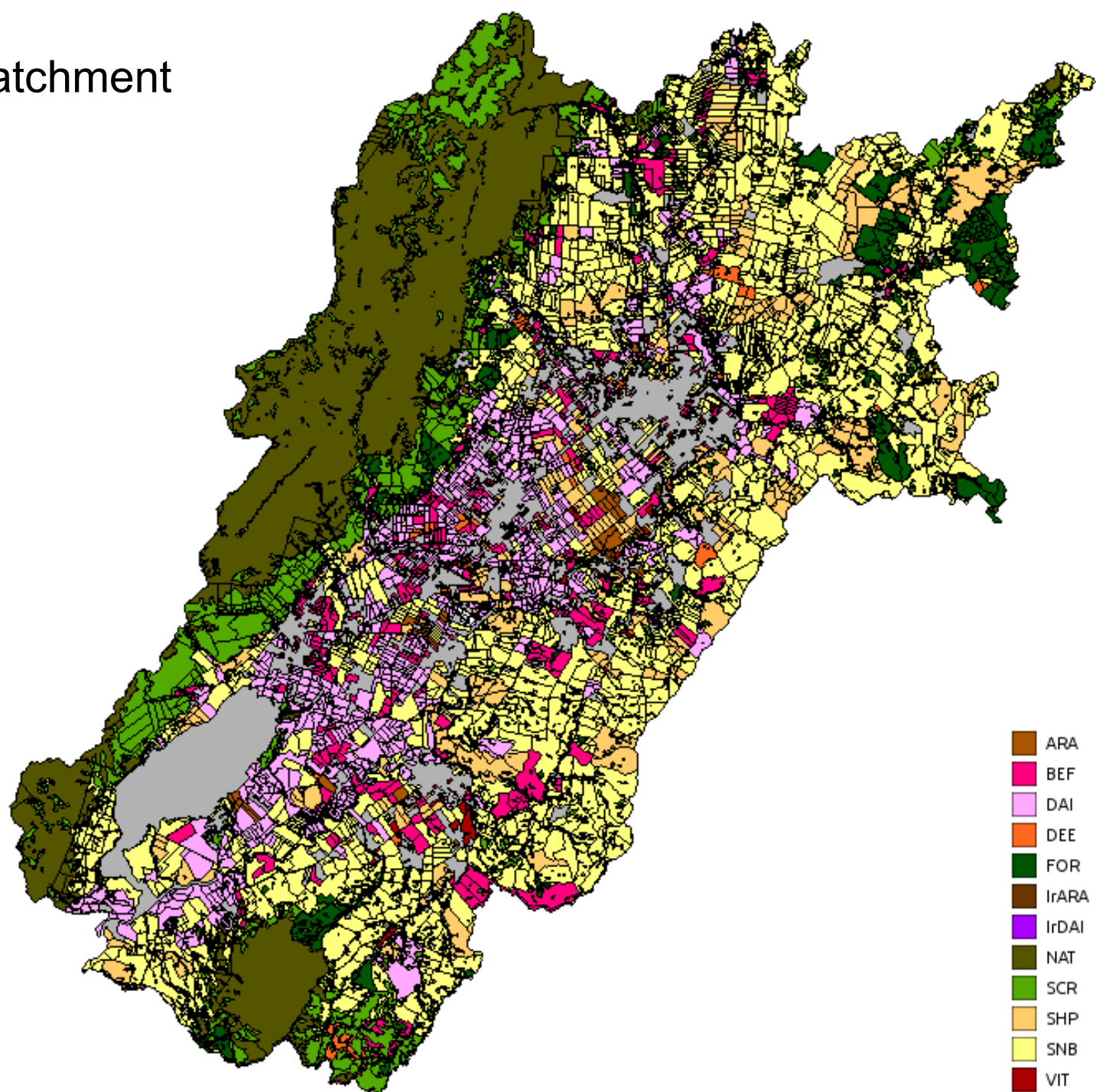
➤ Exploring Limits

➤ Identifying trade-offs

➤ Discovering Potentials

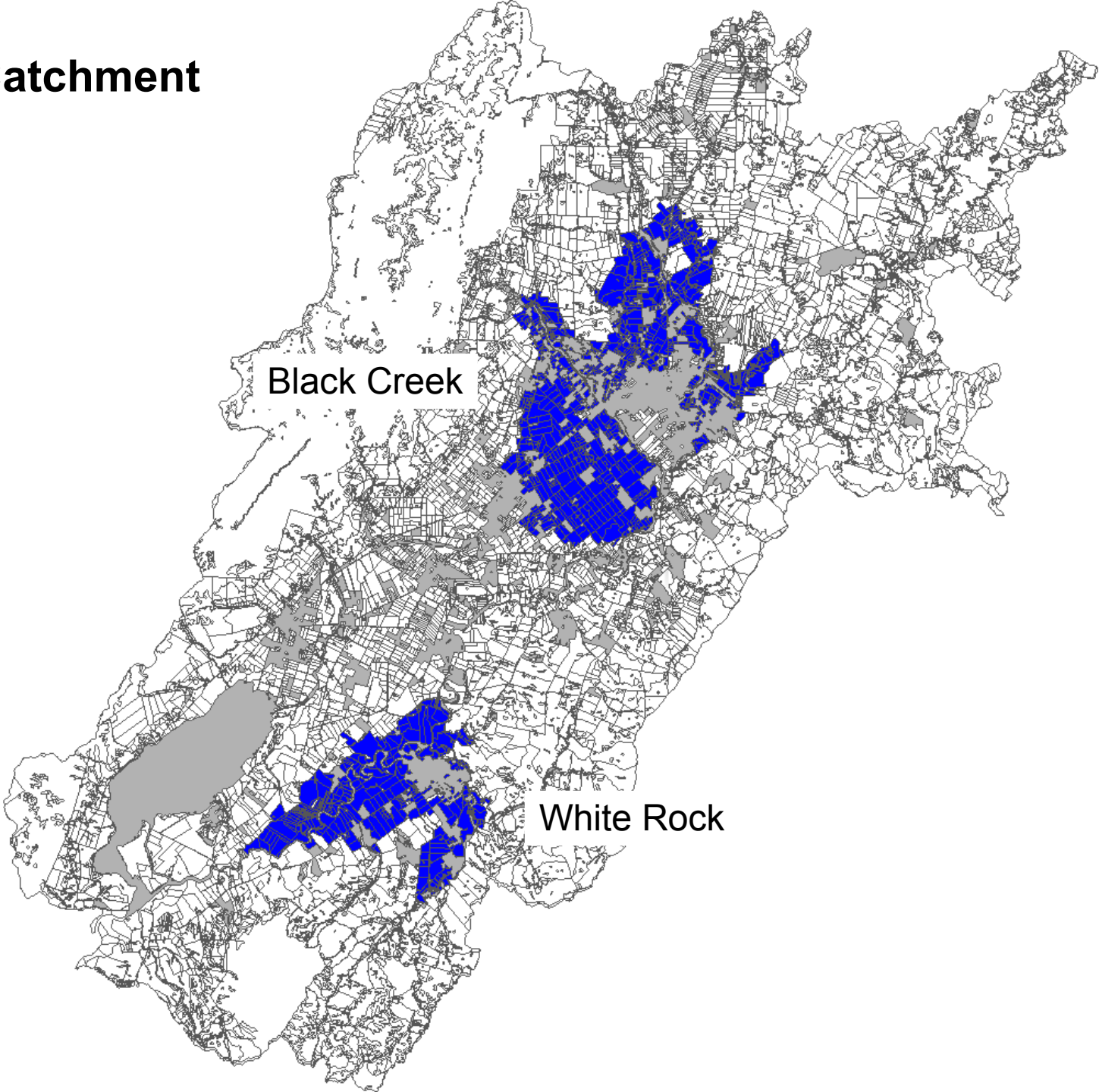
Ruamahanga Catchment

Land Use 2011



Ruamahanga Catchment

Irrigable Areas



Black Creek

White Rock

Agricultural Intensification Scenarios

land-use conversion constraints

S1 – land-use intensification

dairy → irrigated dairy
 arable → irrigated arable
 <x> → <x>

S2 – intensive dairy expansion

min nitrate leaching
 milk solids \geq S1 + 30%

{ sheep }
 { beef } → irrigated dairy
 { deer }

S3 – dairy, arable, viticulture expansion

min nitrate leaching
 milk solids \geq S1 + 30%
 crop yield \geq S1 + 30%
 grapes \geq yr2011 + {25%,8%} (Ruamahanga)

{ sheep } → irrigated dairy
 { beef } → irrigated arable
 { deer } → viticulture

S4 – dairy, arable, viticulture expansion

s. S3

S5 – surplus maximisation

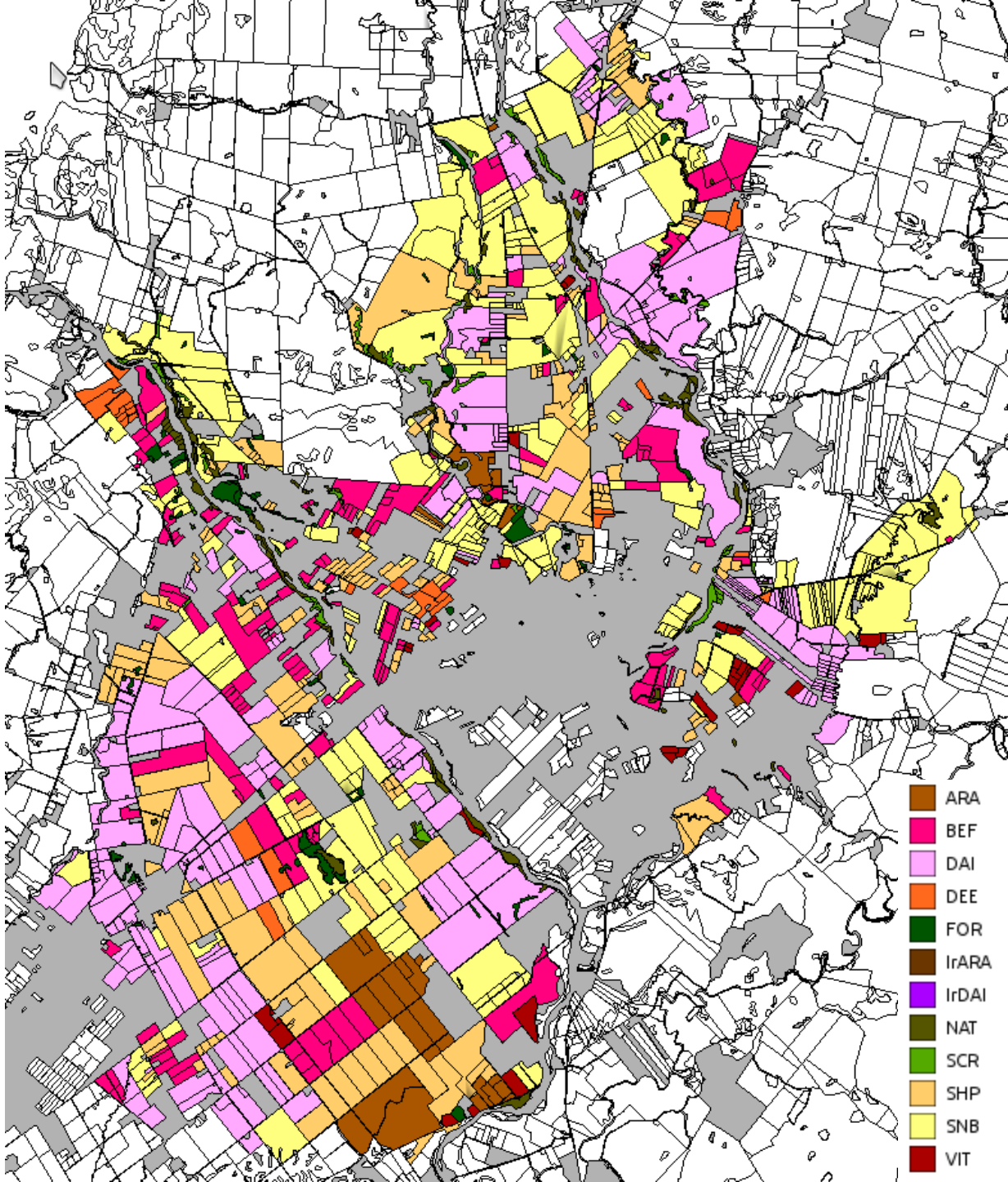
max operating surplus
 GHG \leq yr2011
 N leach \leq yr2011
 meat \geq 30% yr2011
 wool \geq 30% yr2011
 wood \geq 30% yr2011
 <x> \geq yr2011

viticulture → viticulture
 scrub → scrub
 native bush → native bush
 <x> → <y>



Black Creek

Land Use - 2011



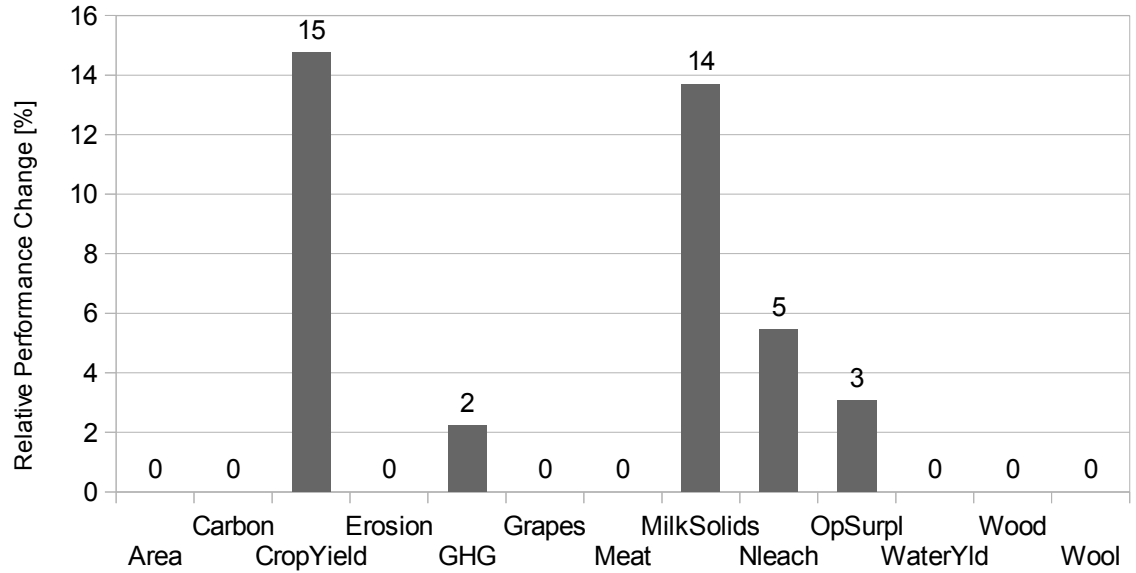
Black Creek

Land Use Intensification

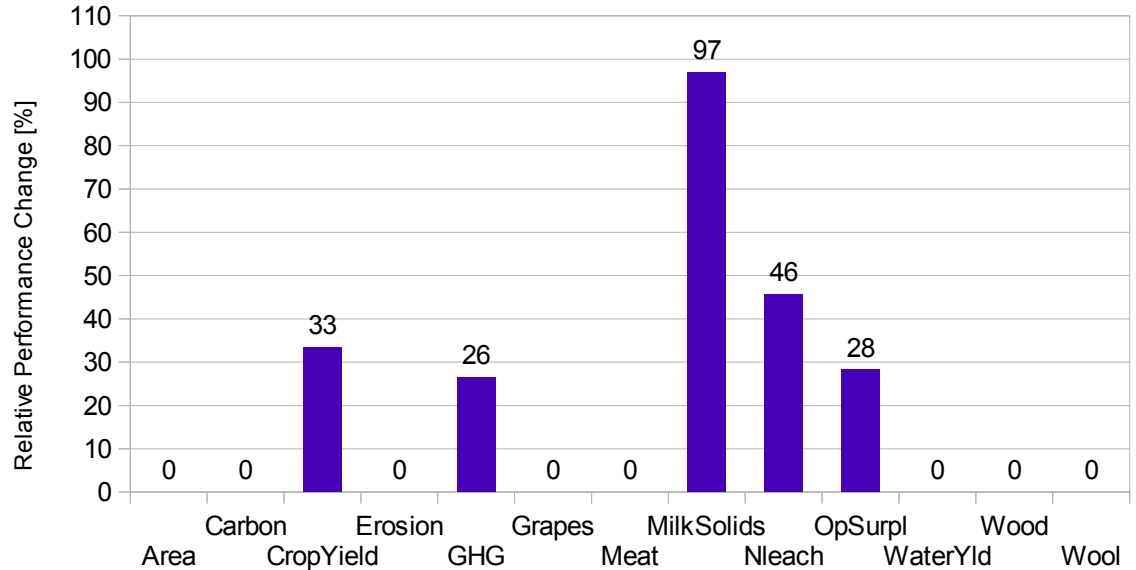
BC-S1

land-use conversion constraints

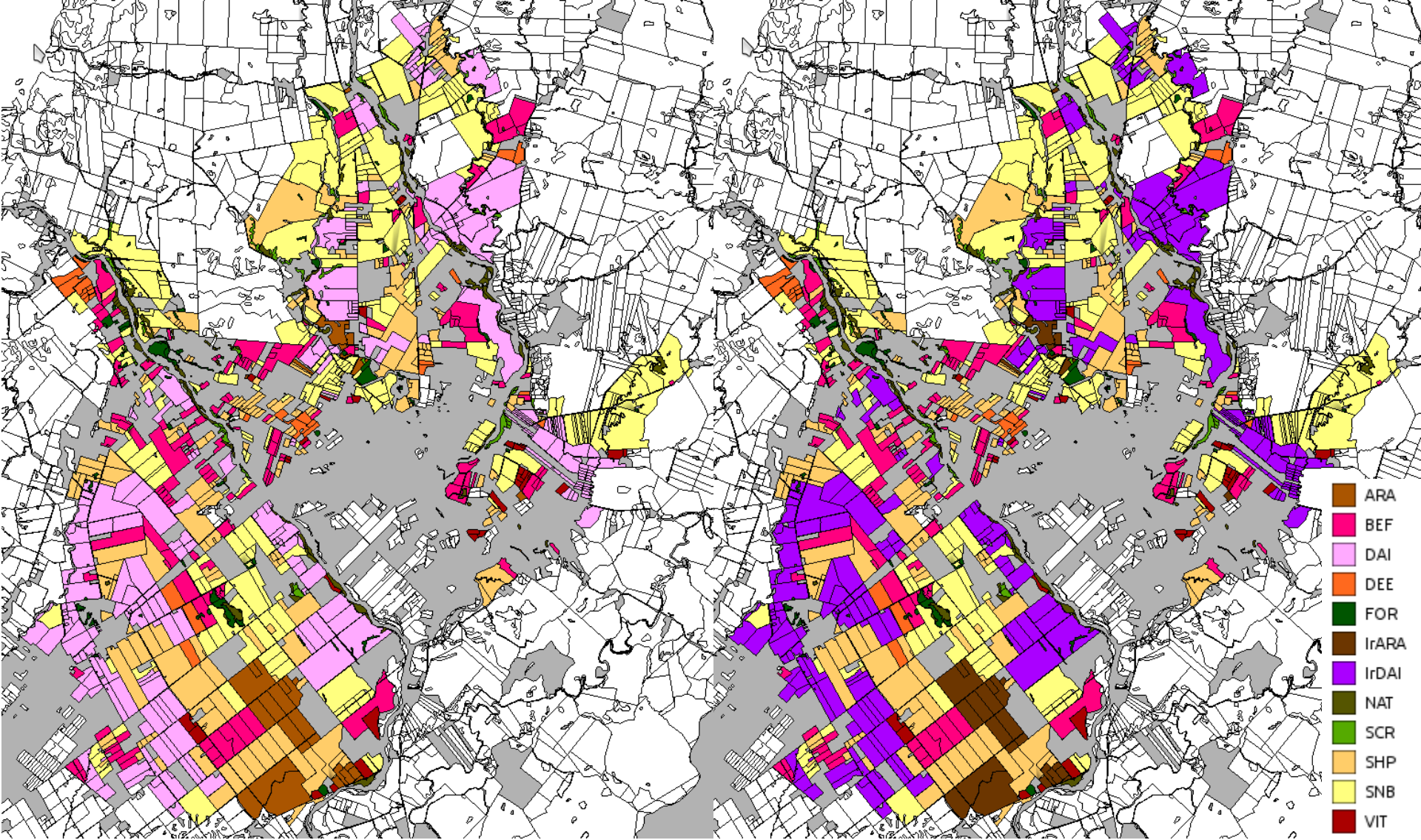
dairy → irrigated dairy
arable → irrigated arable
<x> → <x>



Ruamahanga



Black Creek



Land Use - 2011

Land Use Intensification

Black Creek

Intensive Dairy Expansion

BC-S2b

objective & performance constraints

min nitrate leaching
milk solids $\geq S1 + 30\%$

land-use conversion constraints

{ sheep
beef
deer }

→ irrigated dairy

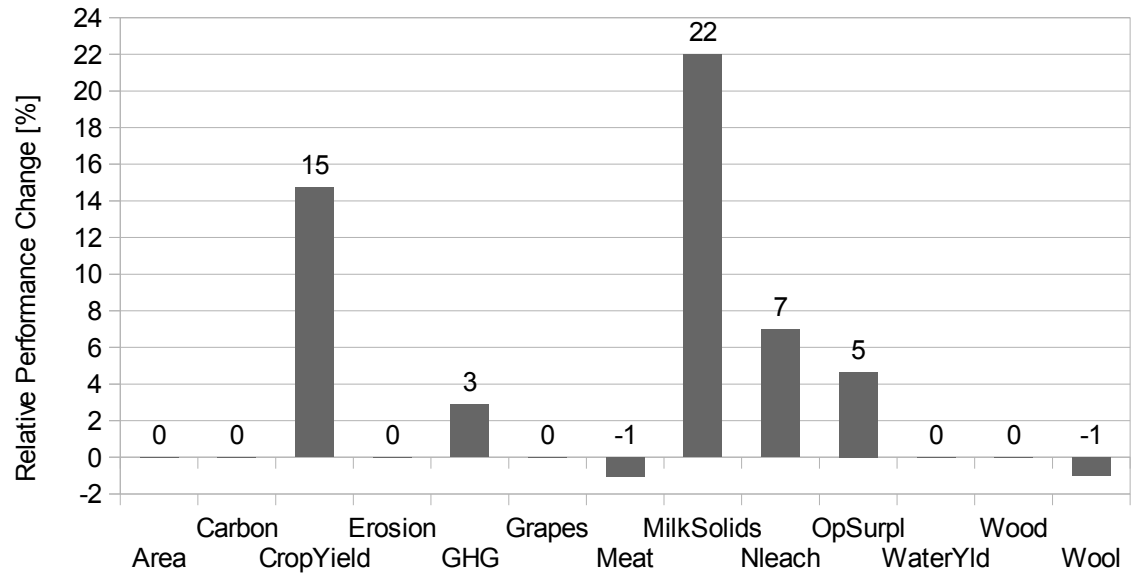
dairy
arable

→ irrigated dairy

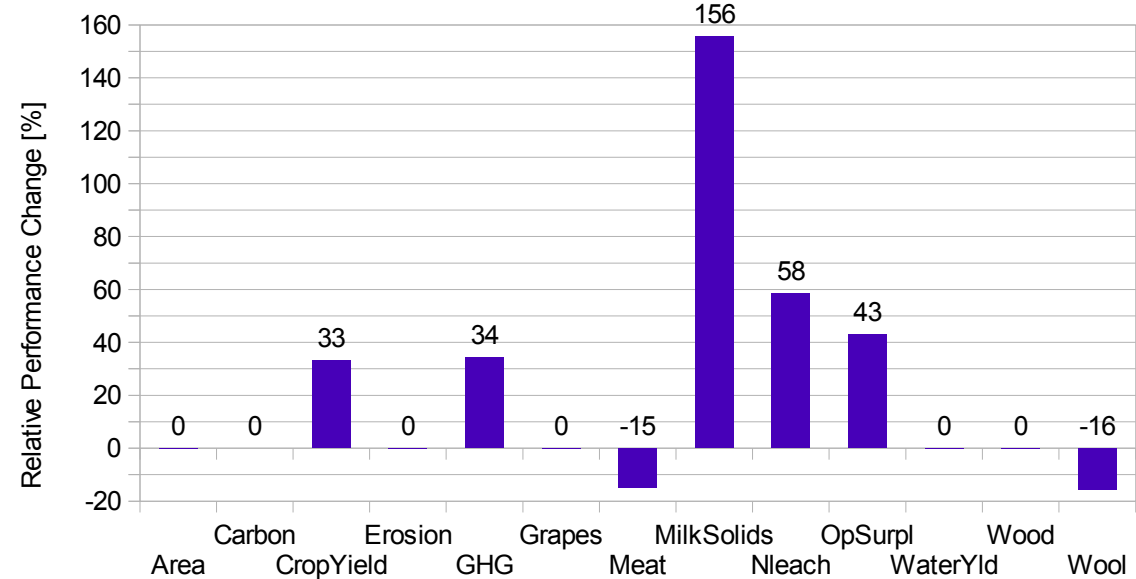
→ irrigated arable

<x>

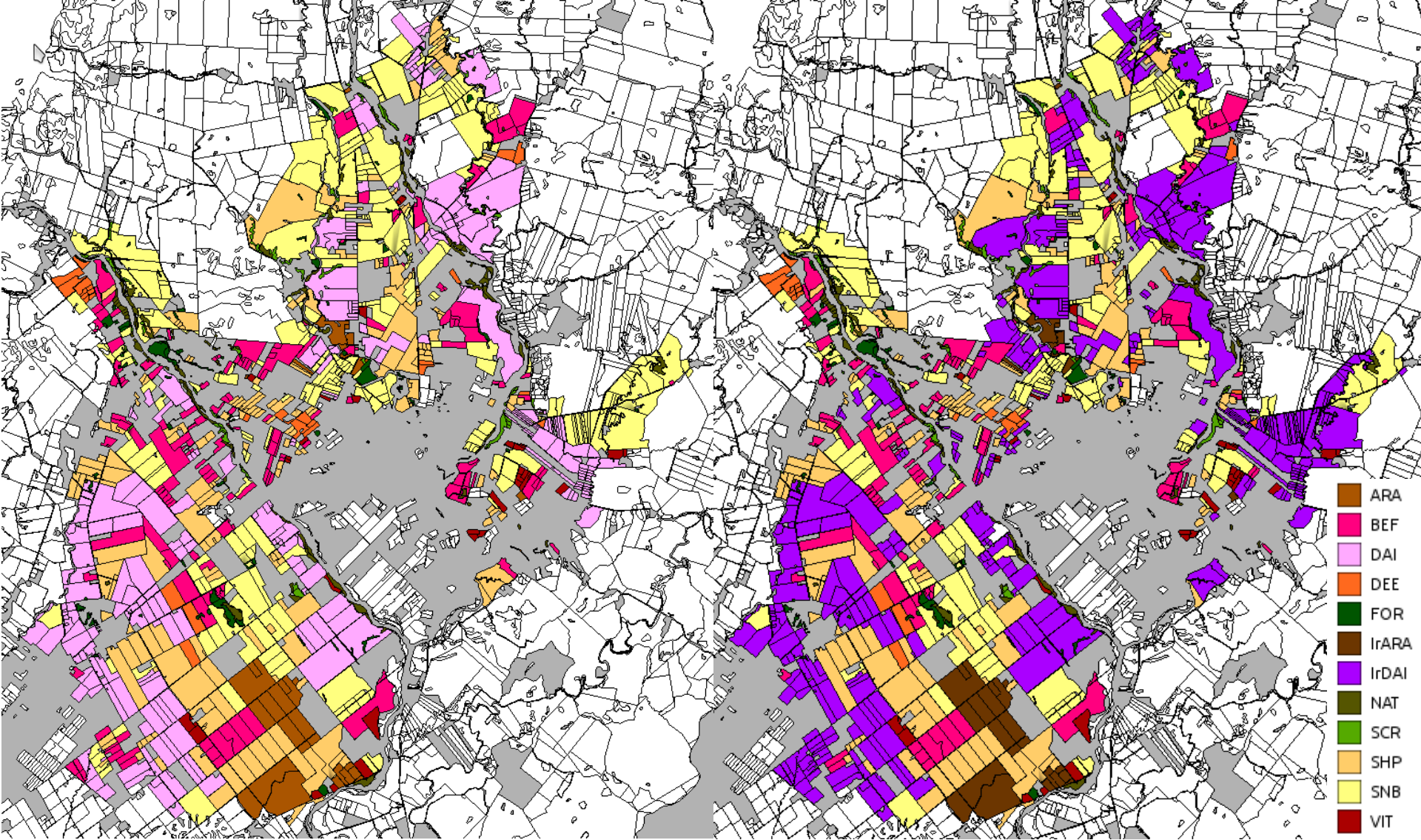
→ <x>



Ruamahanga

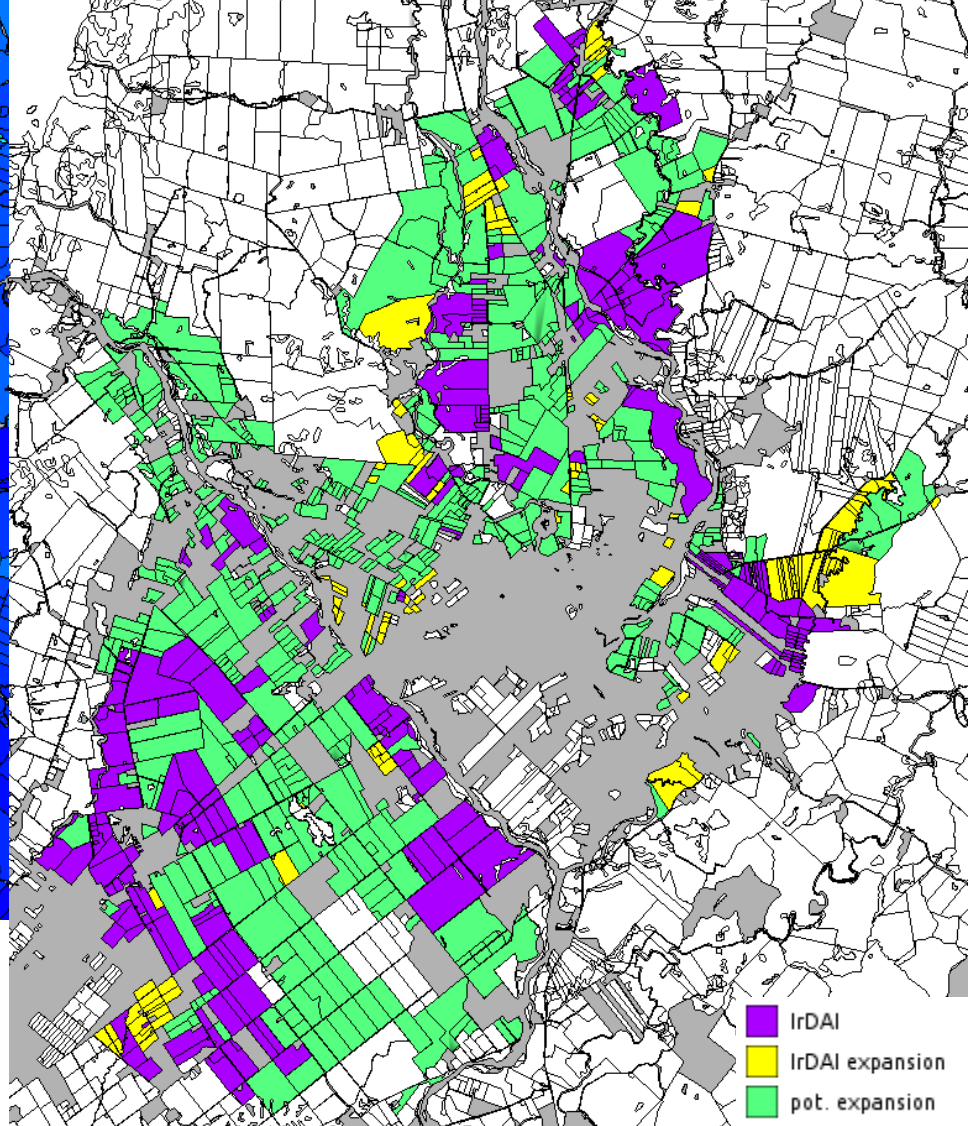
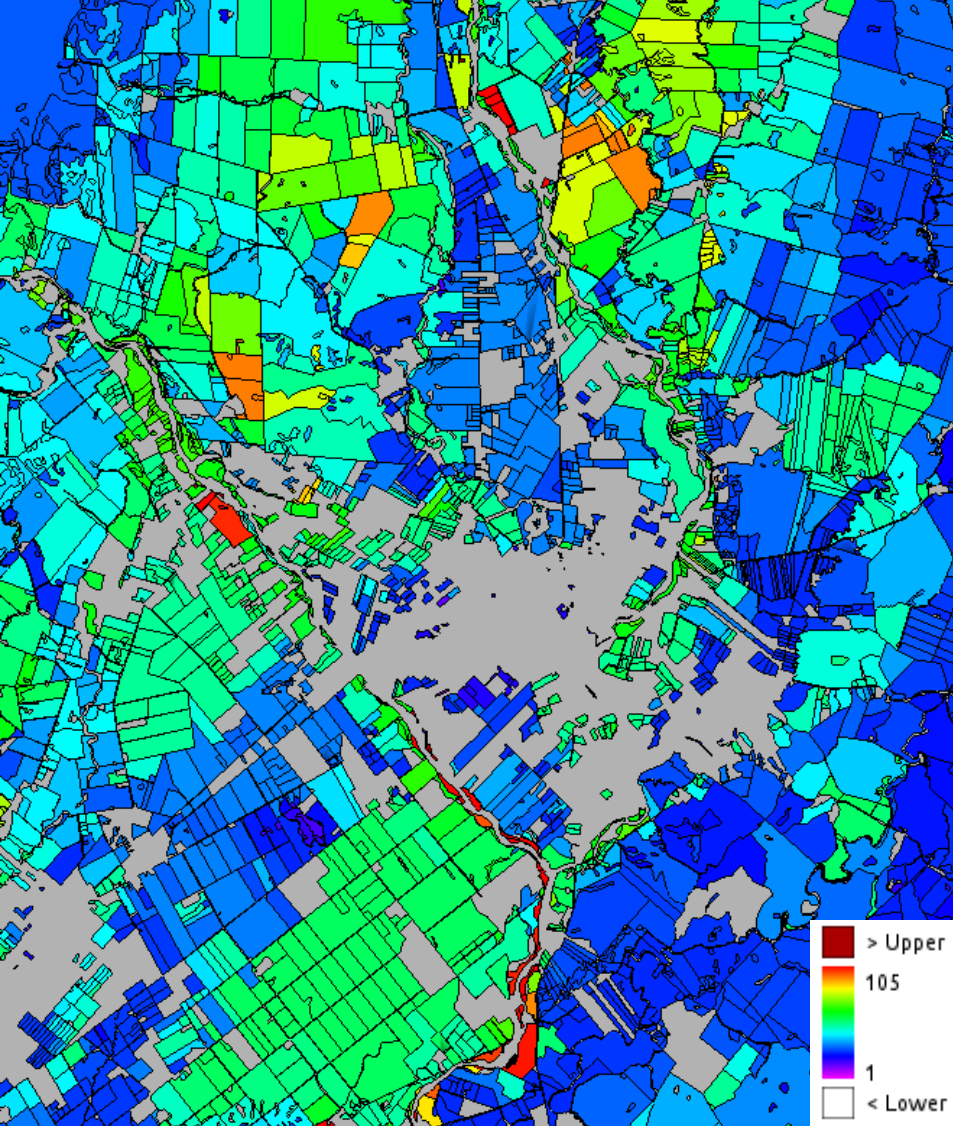


Black Creek



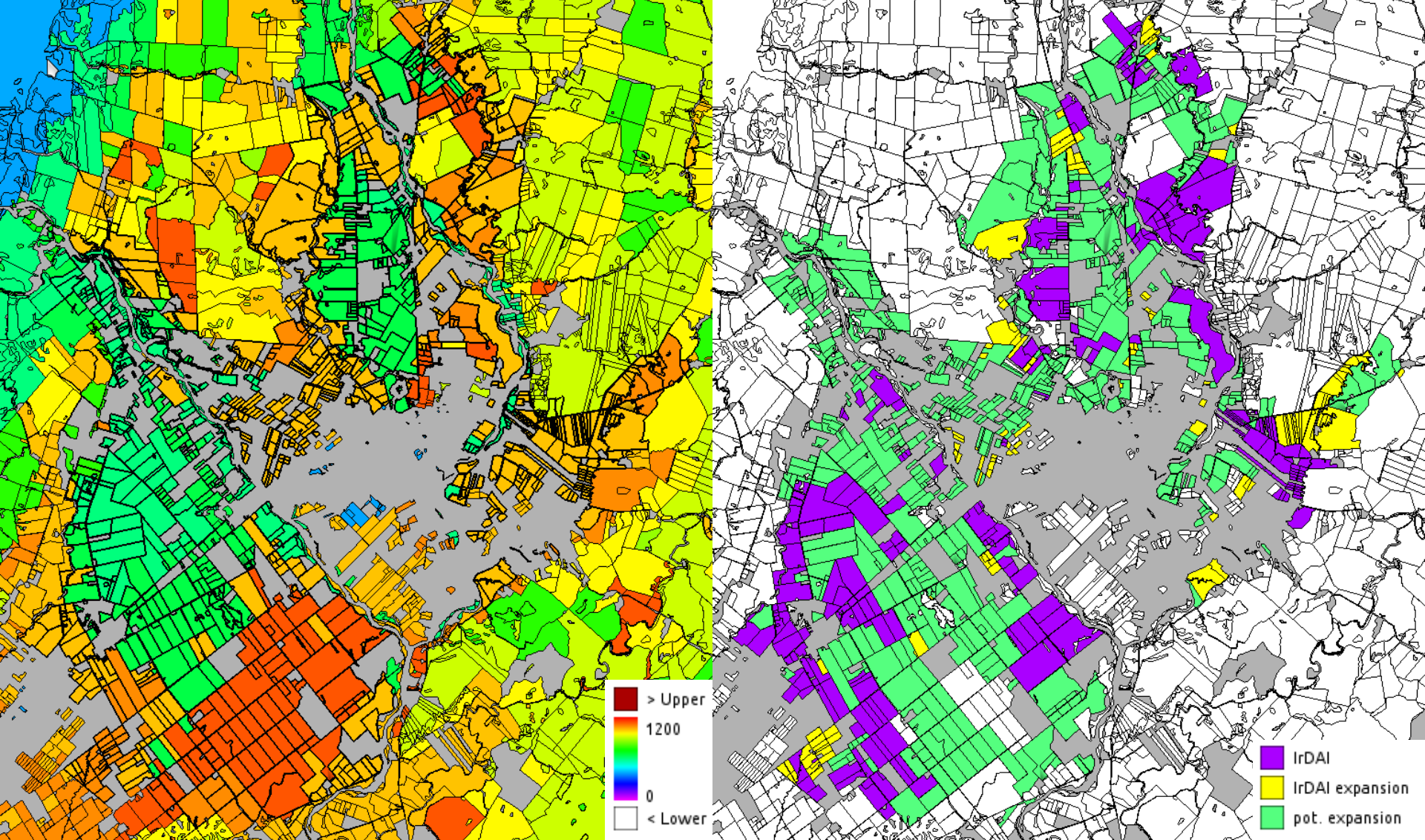
Land Use - 2011

Intensive Dairy Expansion



Potential nitrate leaching [kg N/ha/yr] for irrigated dairy farming

Optimal and potential locations of land use change to increase milk solids production by 30% while minimising nitrate leaching.



Potential production of milk solids [kg milk solids/ha/yr] for irrigated dairy farming

Optimal and potential locations of land use change to increase milk solids production by 30% while minimising nitrate leaching.

Black Creek

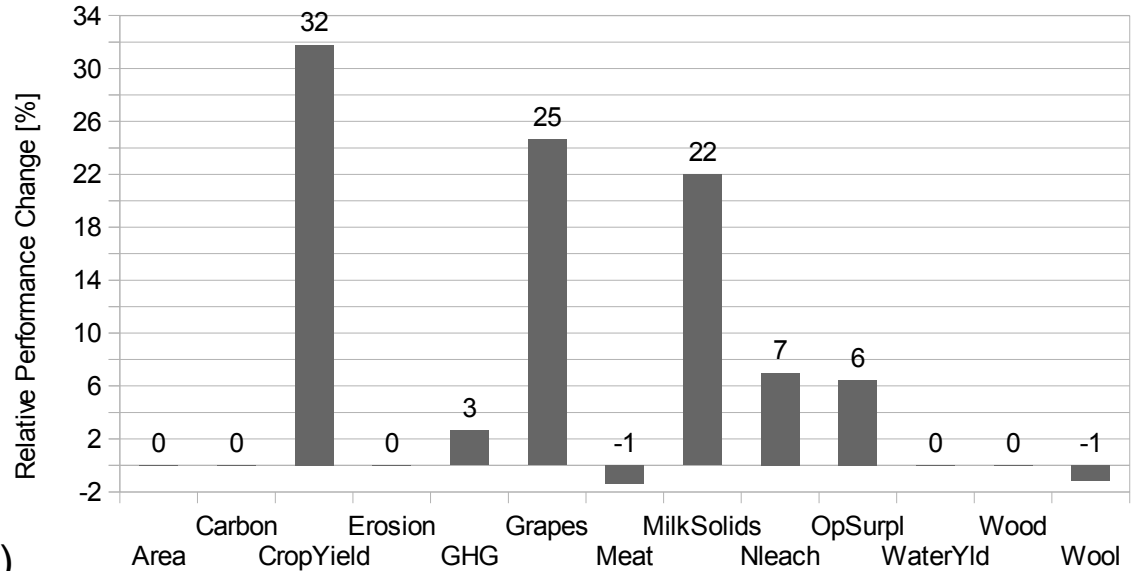
Dairy, Cropping, Viticulture Expansion (constrained) BC-S3b

objective & performance constraints

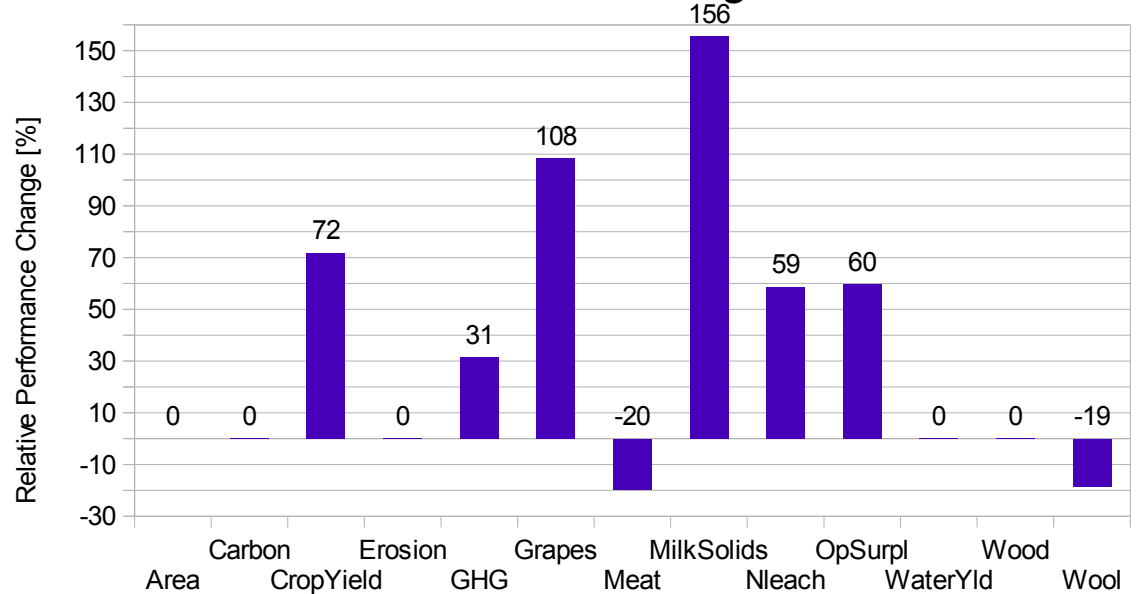
min nitrate leaching
 milk solids $\geq S1$ + 30%
 crop yield $\geq S1$ + 30%
 grapes $\geq yr2011$ + 25% (Rua.)

land-use conversion constraints

{ sheep beef deer }	→ irrigated dairy
	→ irrigated arable
	→ viticulture
dairy	→ irrigated dairy
arable	→ irrigated arable
<x>	→ <x>



Ruamahanga



Black Creek

Black Creek

Dairy, Cropping, Viticulture Expansion (constrained) BC-S3b

*objective &
performance constraints*

min nitrate leaching

milk solids $\geq S1$ + 30%

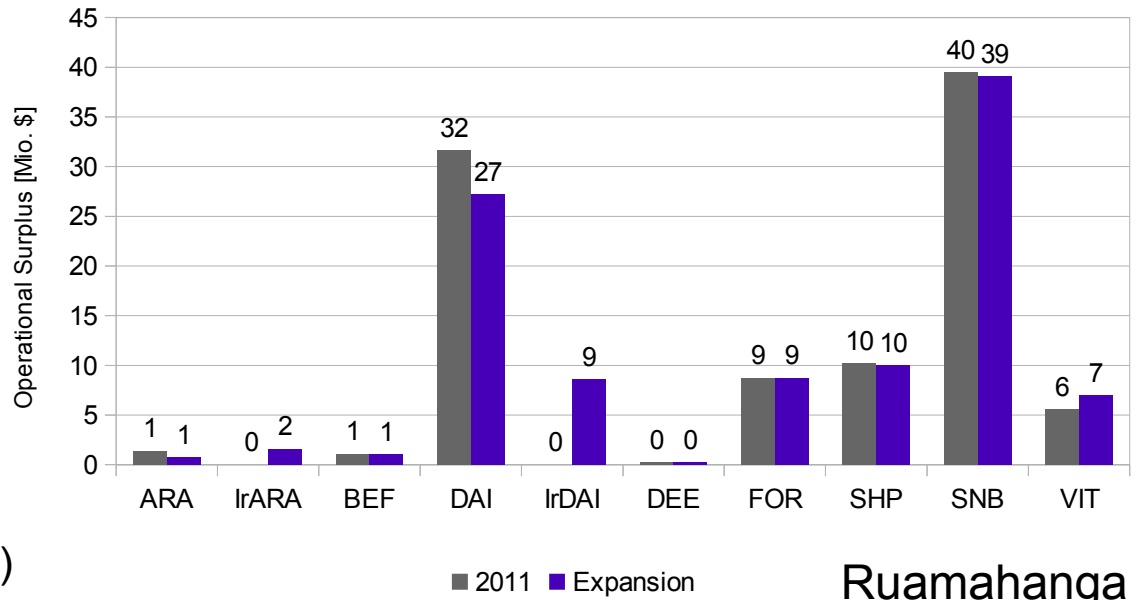
crop yield $\geq S1$ + 30%

grapes \geq yr2011 + 25% (Rua.)

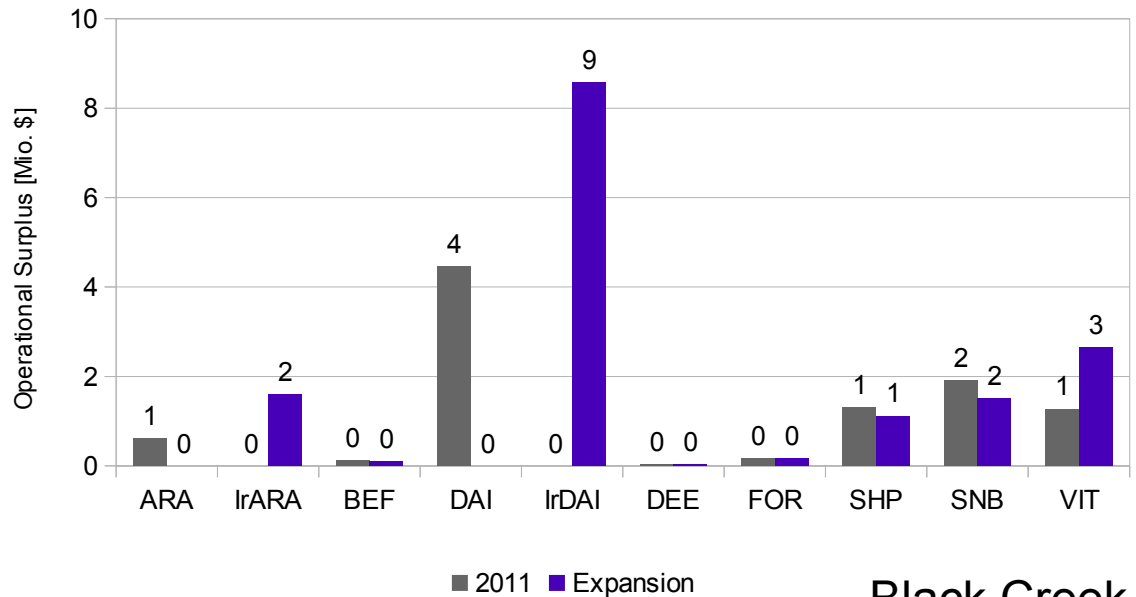
land-use conversion constraints

{ sheep } → irrigated dairy
 { beef } → irrigated arable
 { deer } → viticulture

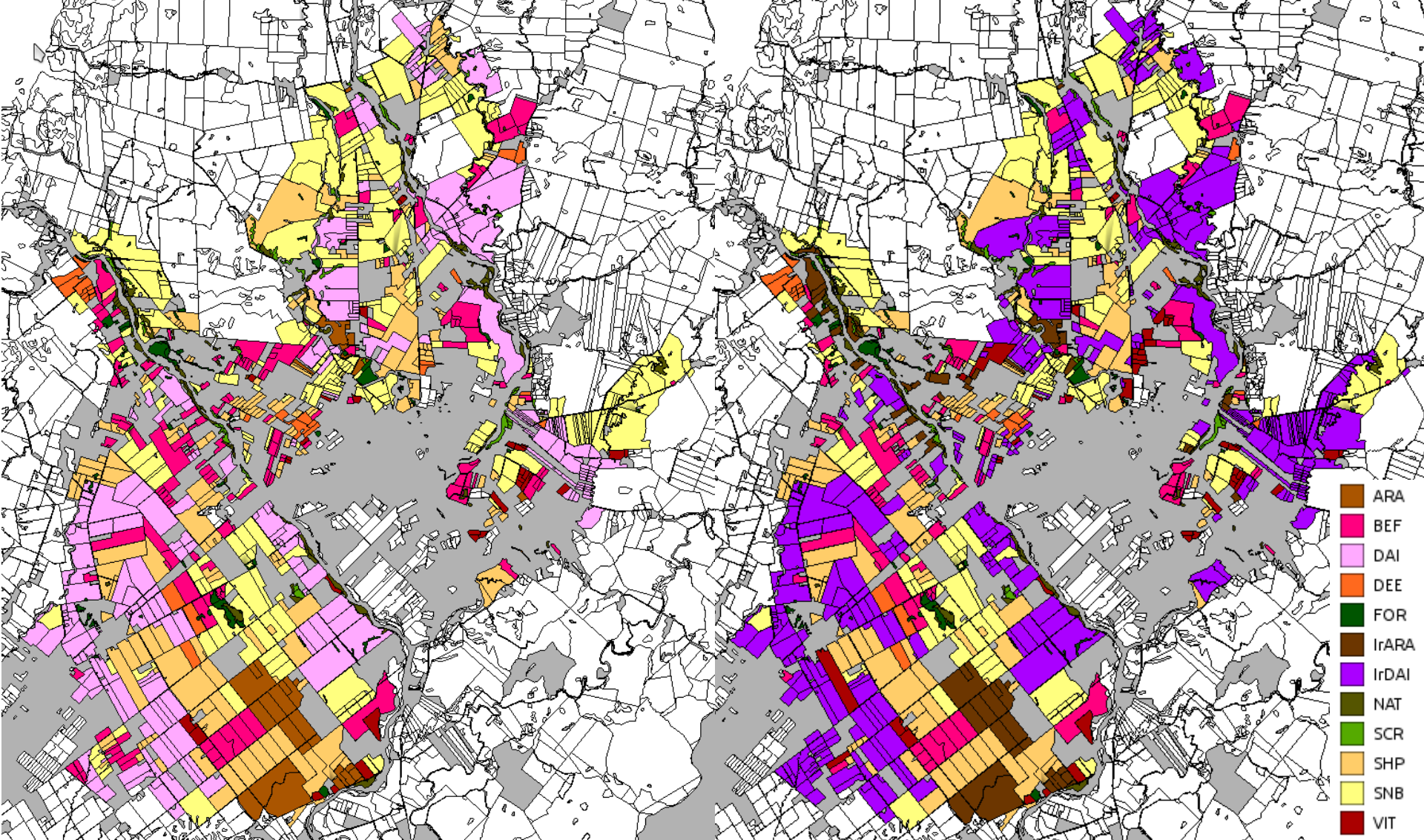
dairy → irrigated dairy
 arable → irrigated arable
 <x> → <x>



Ruamahanga



Black Creek



Land Use - 2011

**Dairy, Cropping, Viticulture Expansion
(constrained)**

Black Creek

Dairy, Cropping, Viticulture Expansion (unconstrained) BC-S4b

objective & performance constraints

min nitrate leaching

milk solids \geq S1 + 30%

crop yield \geq S1 + 30%

grapes \geq yr2011 + 25% (Rua.)

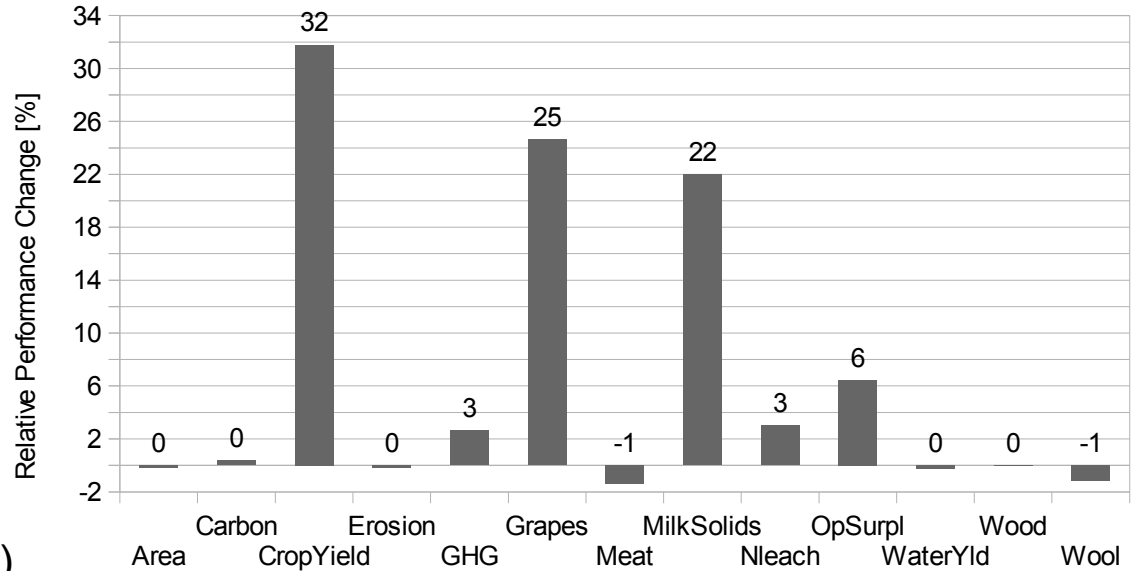
land-use conversion constraints

viticulture \rightarrow viticulture

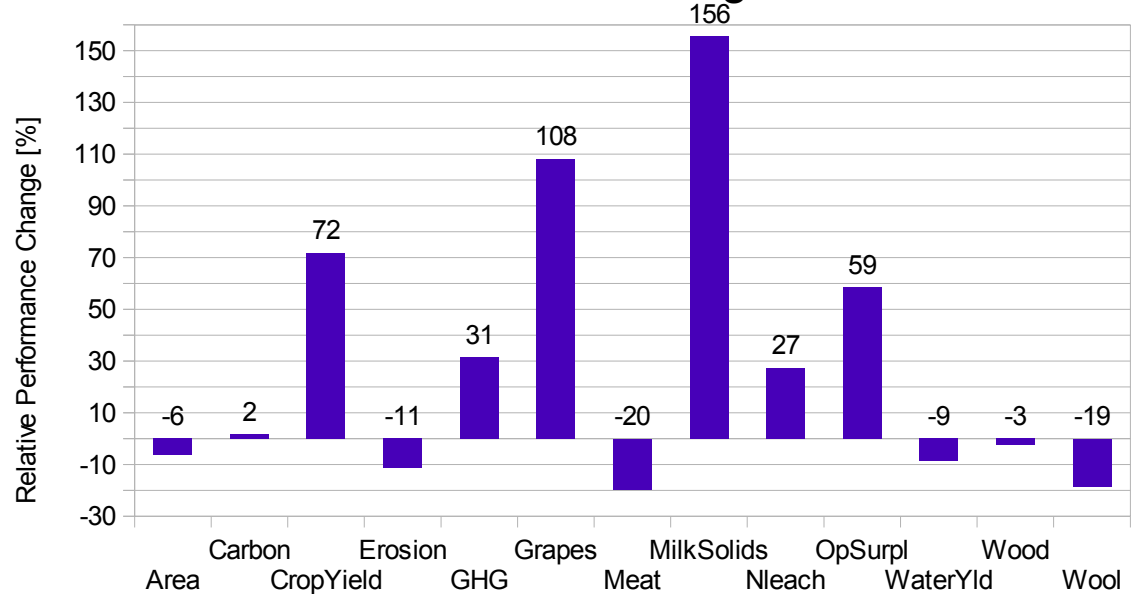
scrub \rightarrow scrub

native bush \rightarrow native bush

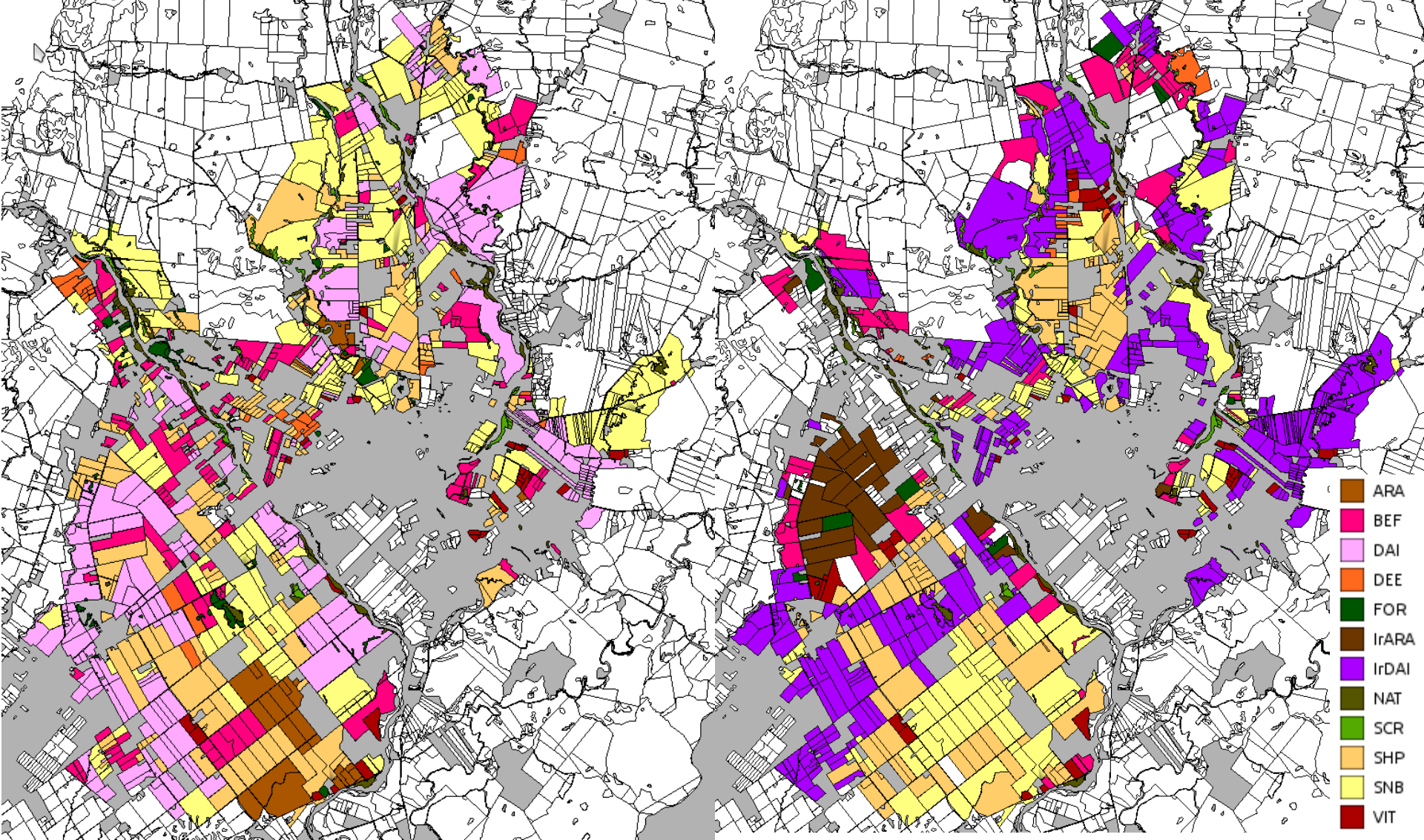
<x> \rightarrow <y>



Ruamahanga



Black Creek



Land Use - 2011

**Dairy, Cropping, Viticulture Expansion
(unconstrained)**

Black Creek

Surplus maximisation

(unconstrained) BC-S5

objective & performance constraints

max operating surplus

GHG \leq yr2011

N leach \leq yr2011

meat \geq 30% yr2011

wool \geq 30% yr2011

wood \geq 30% yr2011

<x> \geq yr2011

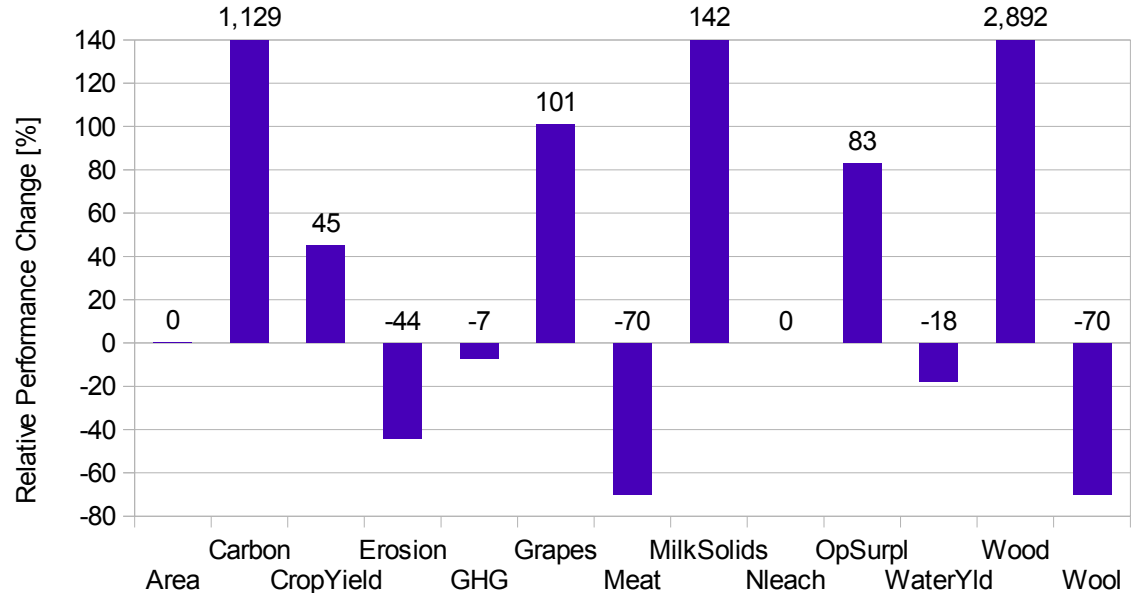
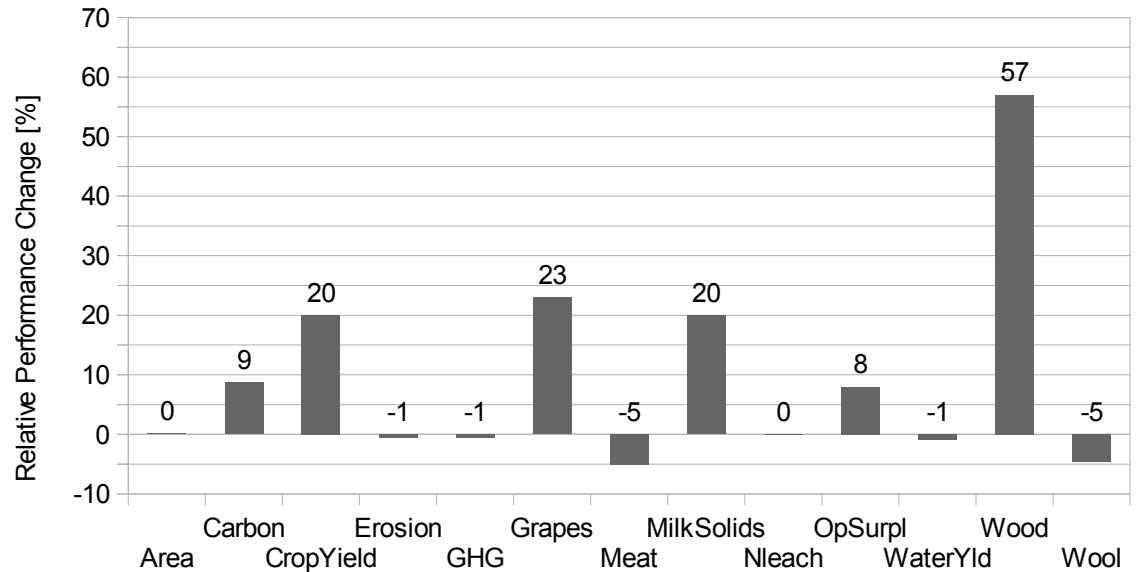
land-use conversion constraints

viticulture \rightarrow viticulture

scrub \rightarrow scrub

native bush \rightarrow native bush

<x> \rightarrow <y>



Black Creek

Surplus maximisation

(unconstrained) BC-S5

objective & performance constraints

max operating surplus

GHG ≤ yr2011

N leach ≤ yr2011

meat ≥ 30% yr2011

wool ≥ 30% yr2011

wood ≥ 30% yr2011

<x> ≥ yr2011

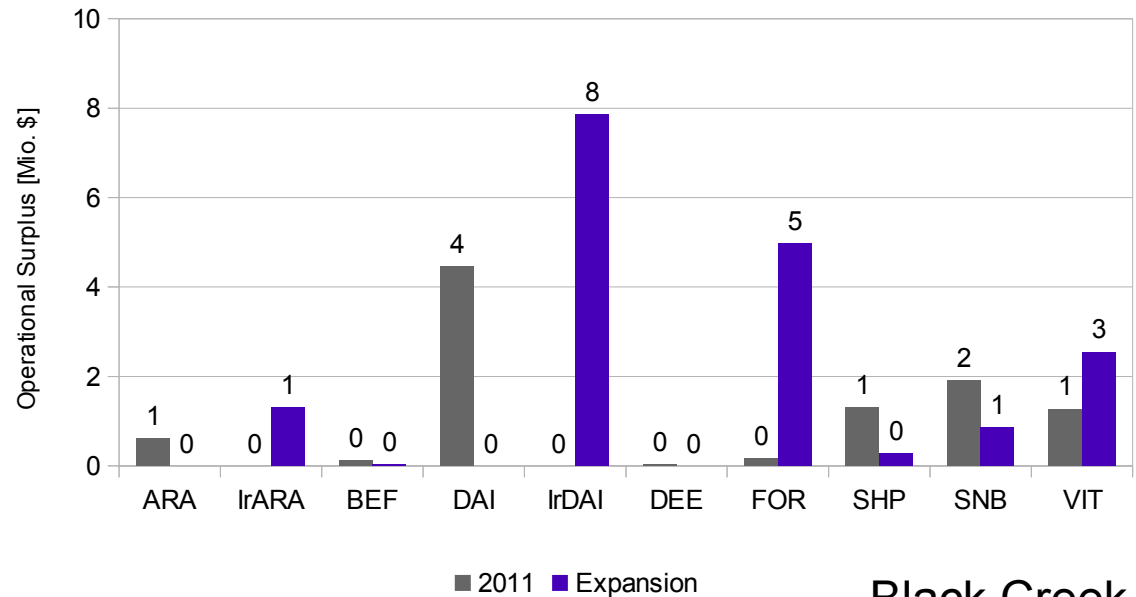
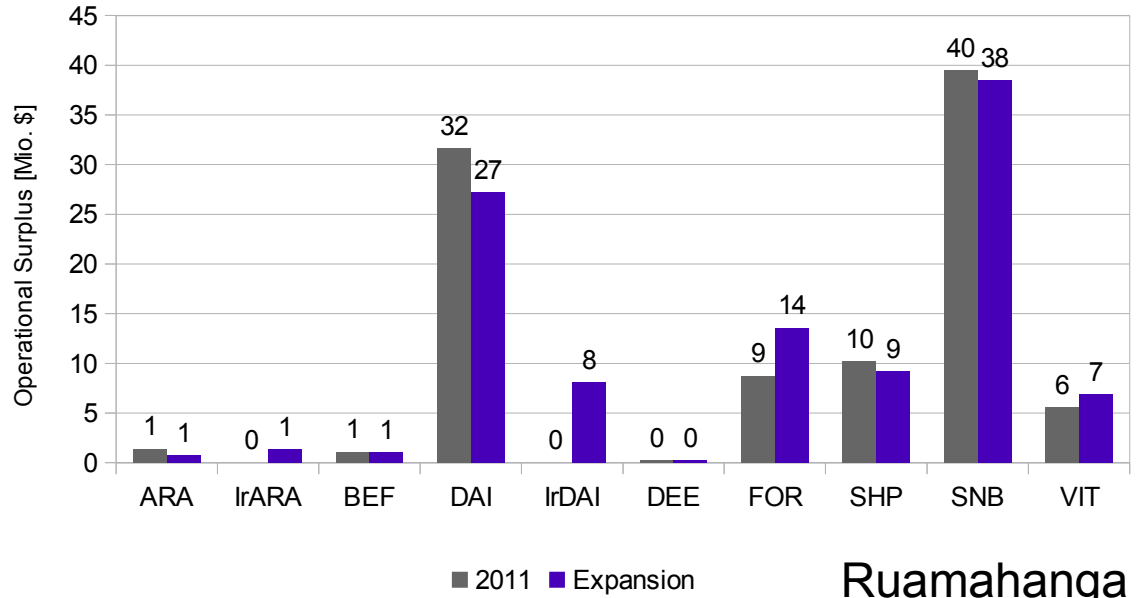
land-use conversion constraints

viticulture → viticulture

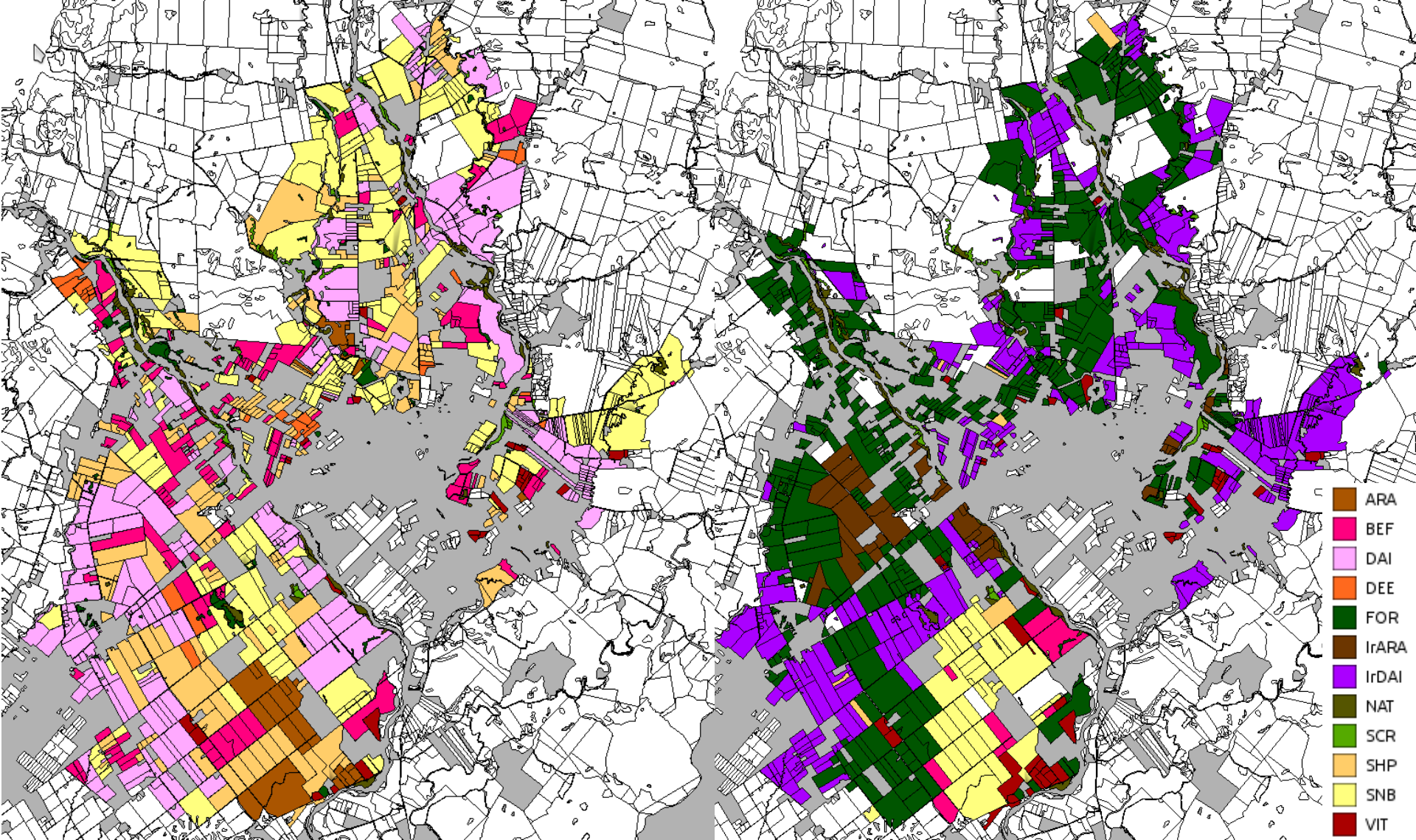
scrub → scrub

native bush → native bush

<x> → <y>



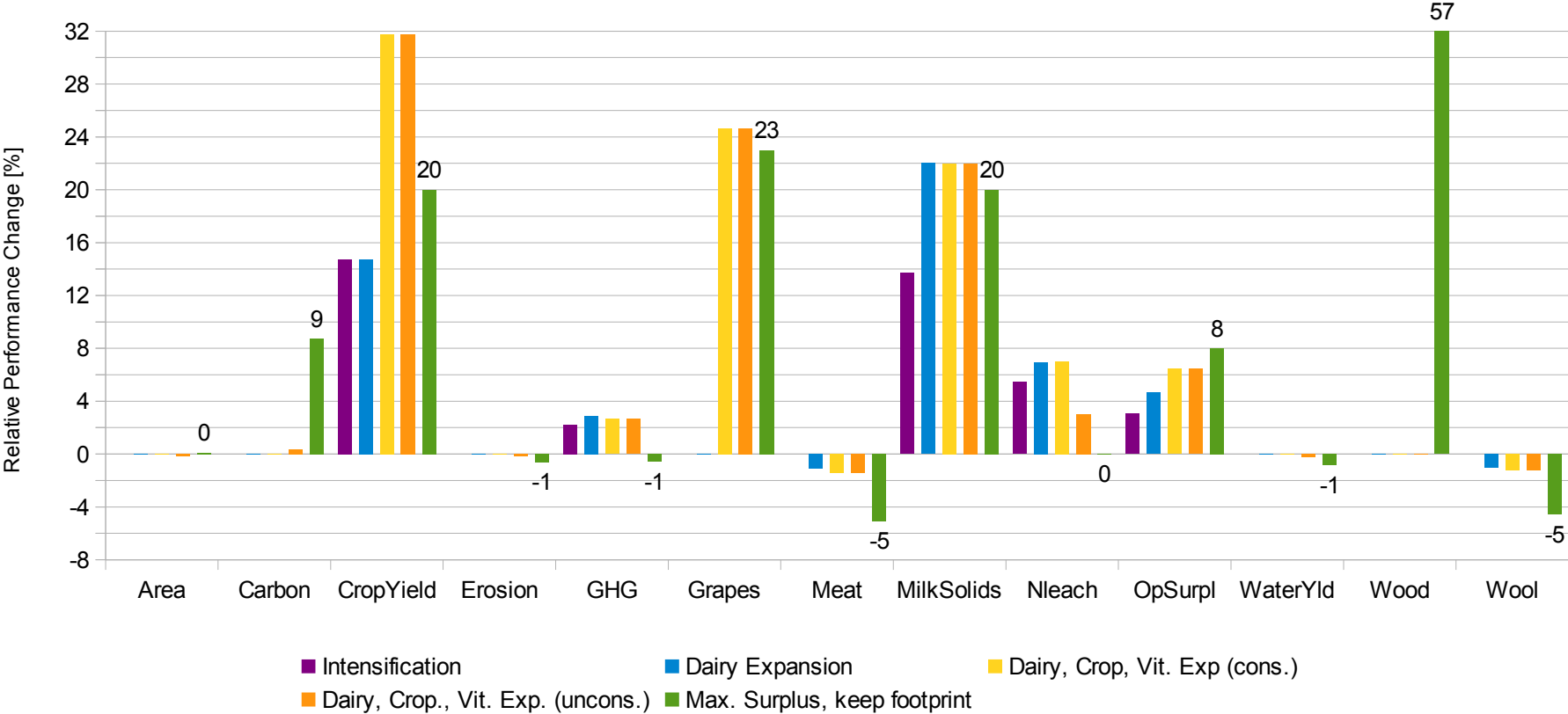
Black Creek



Land Use - 2011

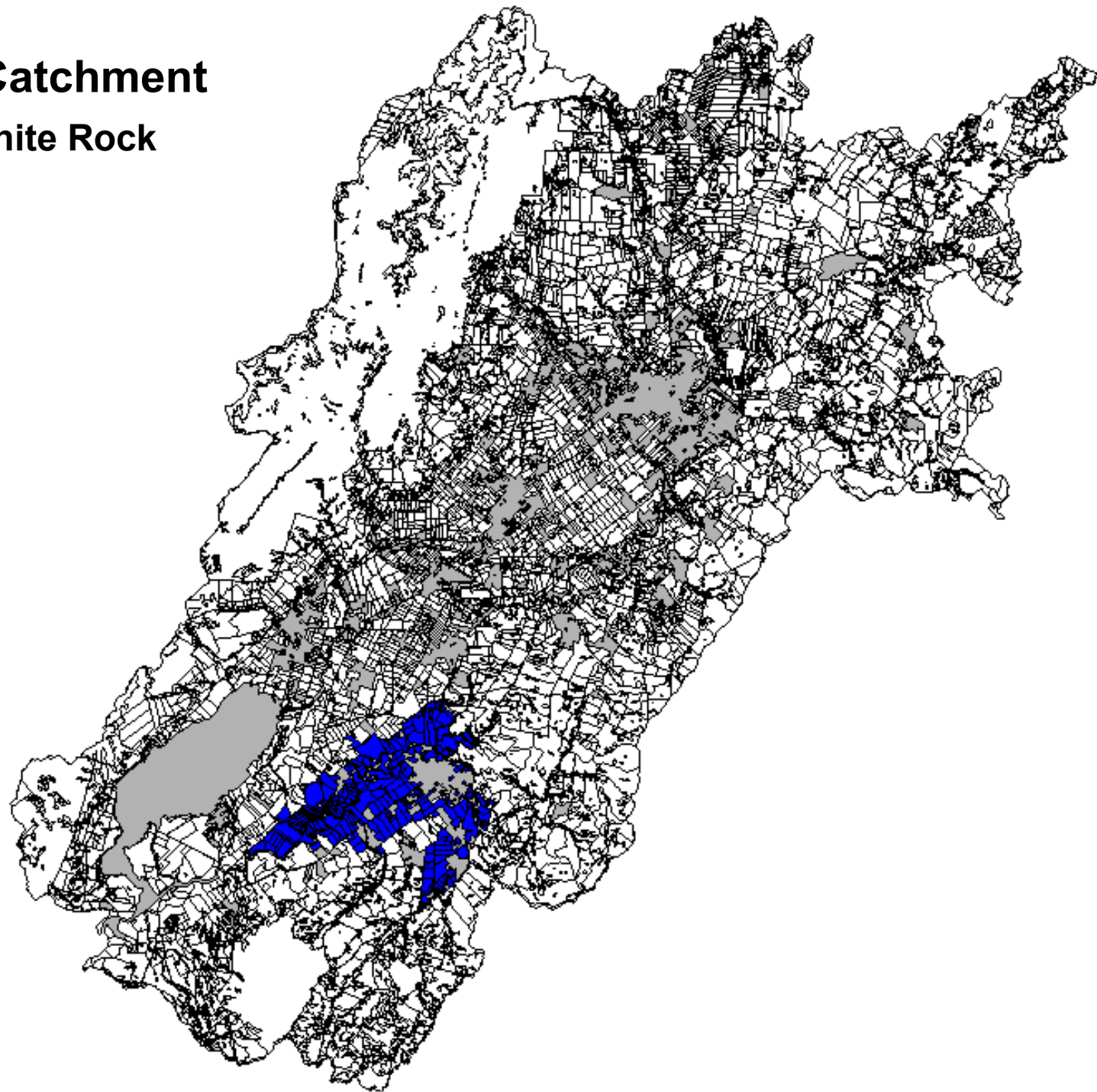
Max. Surplus, maintain Environmental Performance of Ruamahanga Catchm. (unconstrained)

Impact of Land Use Scenarios for the Black Creek Irrigable Area on Ecosystem Services Provision in the Ruamahanga Catchment



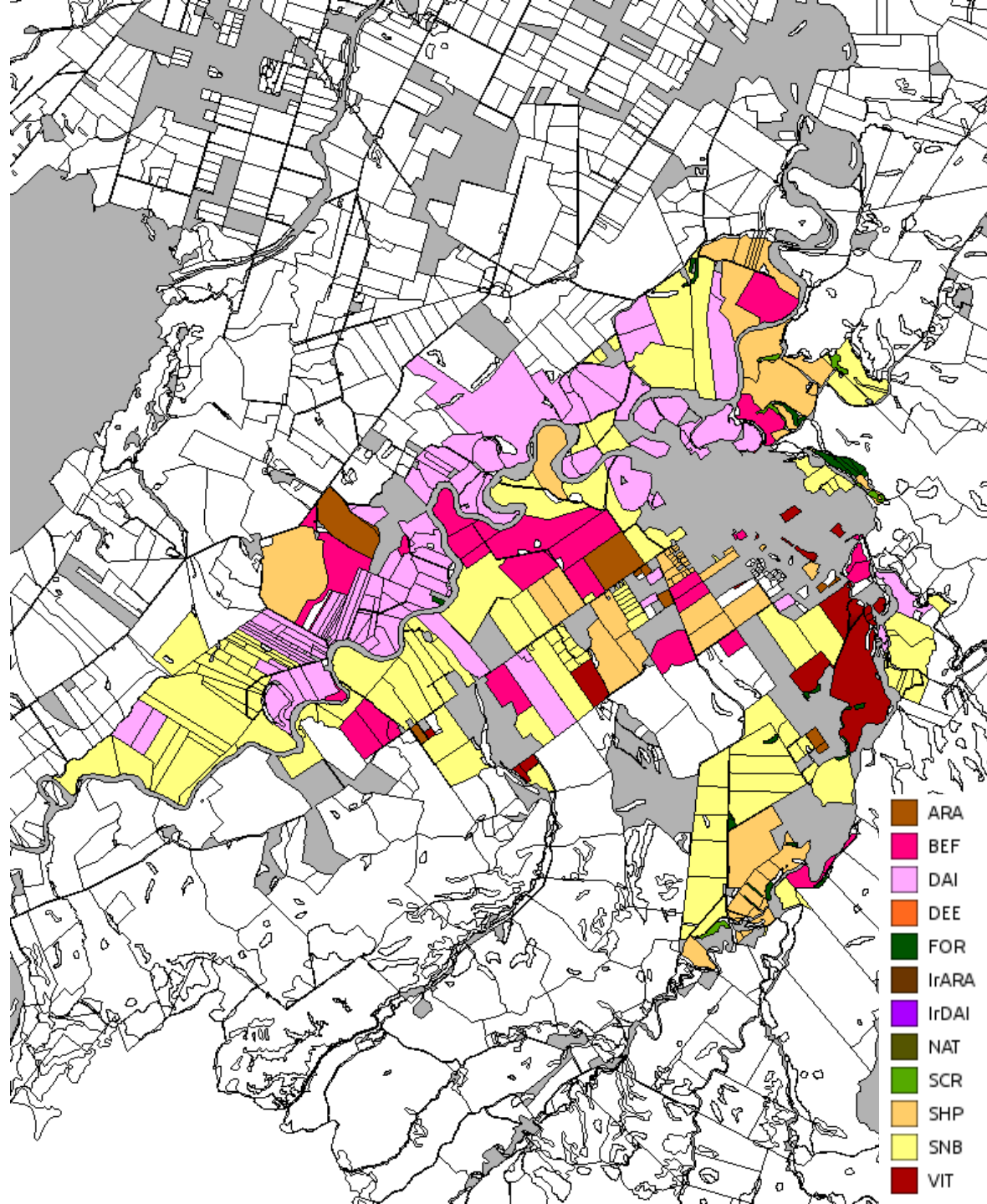
Ruamahanga Catchment

Irrigable Area – White Rock



White Rock

Land Use - 2011



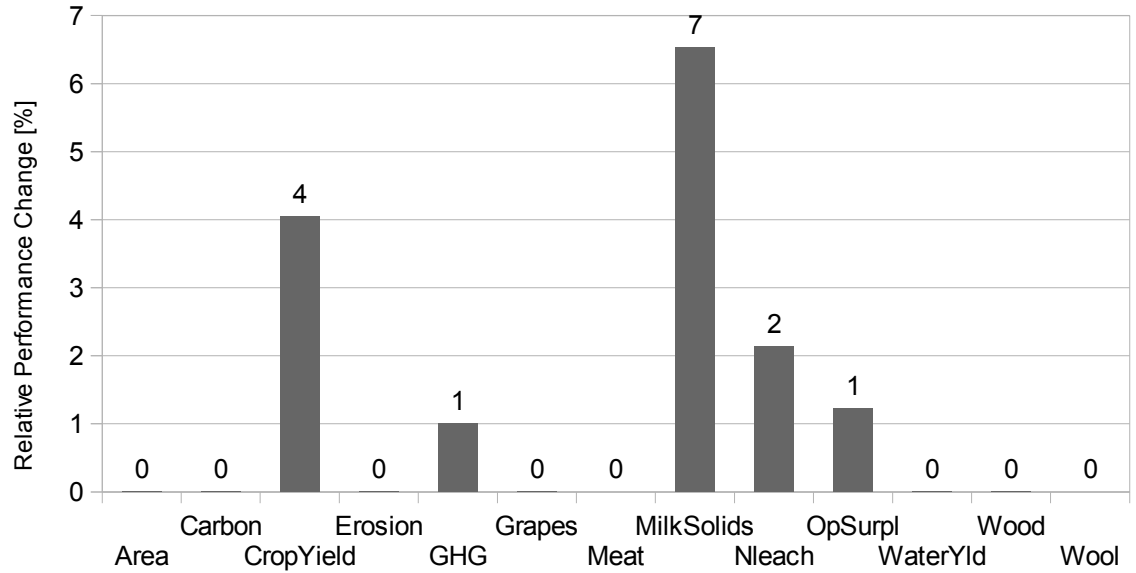
White Rock

Land Use Intensification

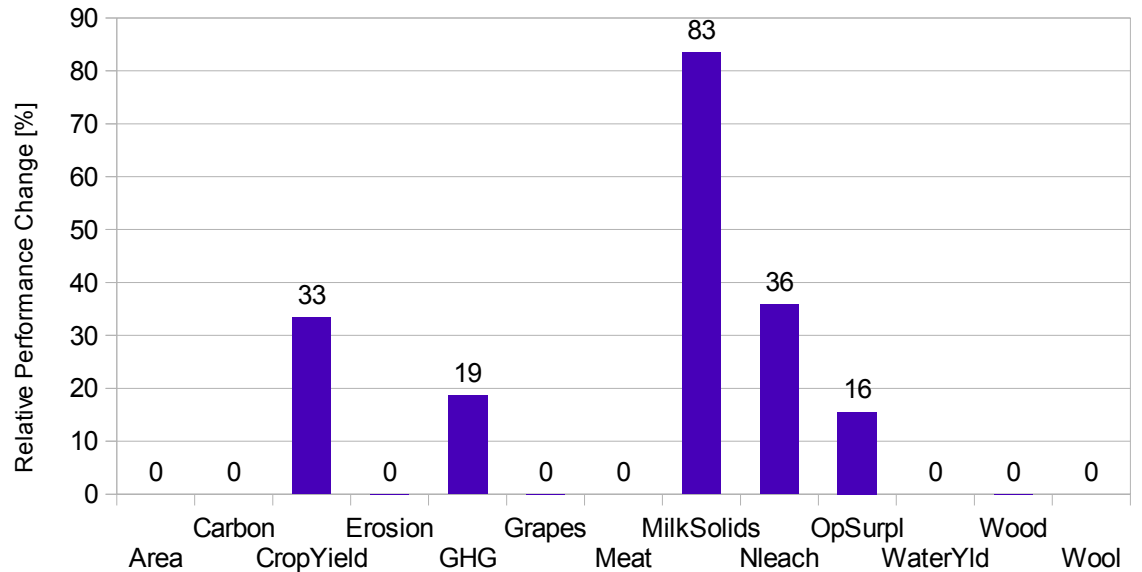
WR-S1

land-use conversion constraints

dairy → irrigated dairy
arable → irrigated arable
<x> → <x>



Ruamahanga



White Rock

White Rock

Dairy, Cropping, Viticulture Expansion (constrained) WR-S3b

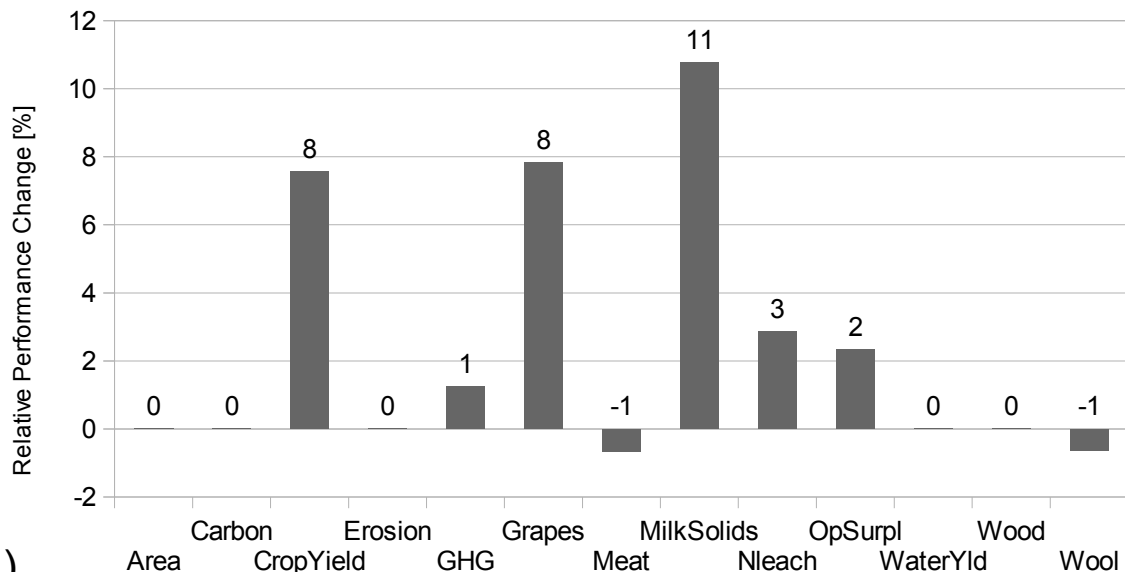
objective & performance constraints

- min nitrate leaching
- milk solids \geq S1 + 30%
- crop yield \geq S1 + 30%
- grapes \geq yr2011 + 8% (Rua.)

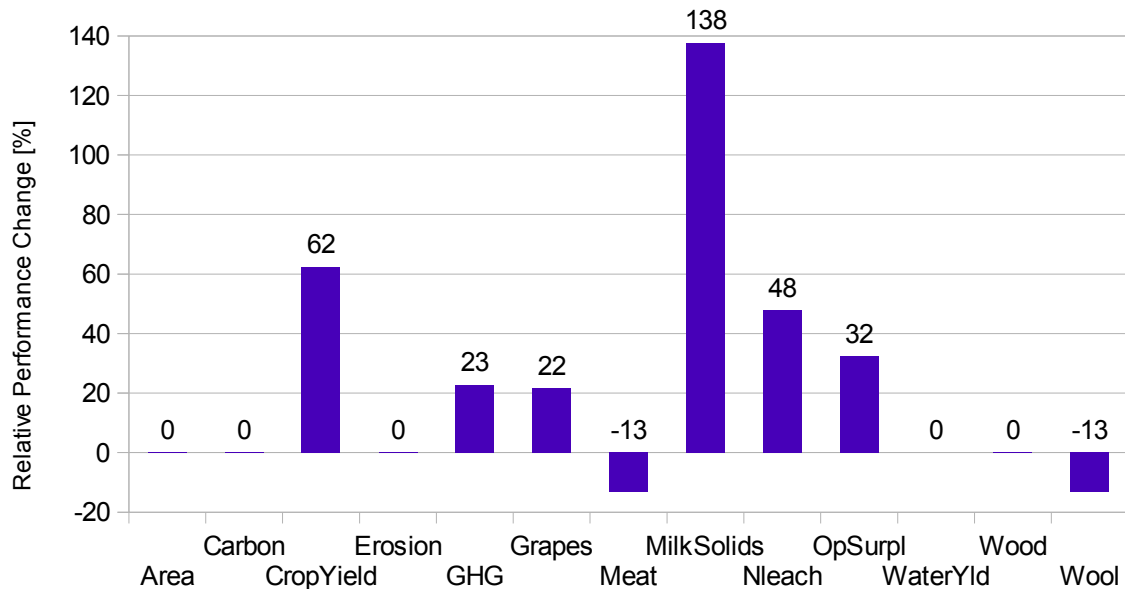
land-use conversion constraints

- { sheep } → irrigated dairy
- { beef } → irrigated arable
- { deer } → viticulture

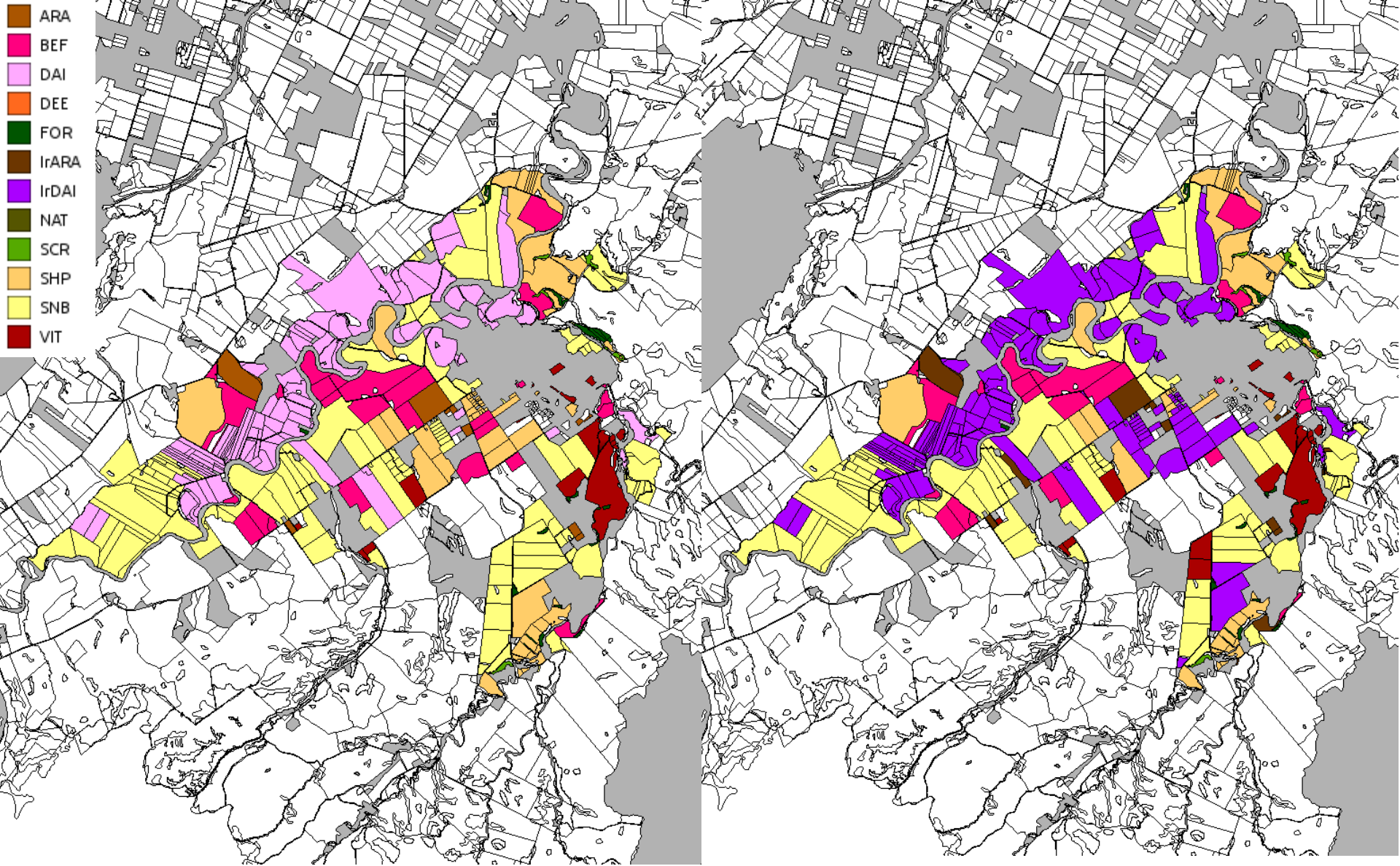
- dairy → irrigated dairy
- arable → irrigated arable
- <x> → <x>



Ruamahanga



White Rock



Land Use - 2011

Dairy, Cropping, Viticulture Expansion

White Rock

Surplus maximisation

(unconstrained) BC-S5

objective & performance constraints

max operating surplus

GHG ≤ yr2011

N leach ≤ yr2011

meat ≥ 30% yr2011

wool ≥ 30% yr2011

wood ≥ 30% yr2011

<x> ≥ yr2011

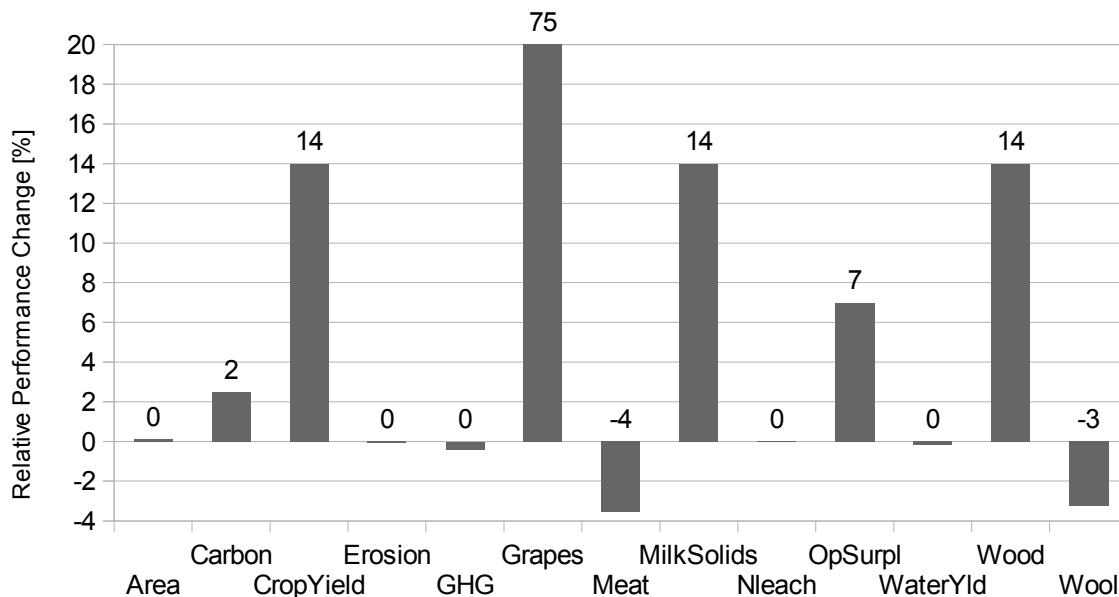
land-use conversion constraints

viticulture → viticulture

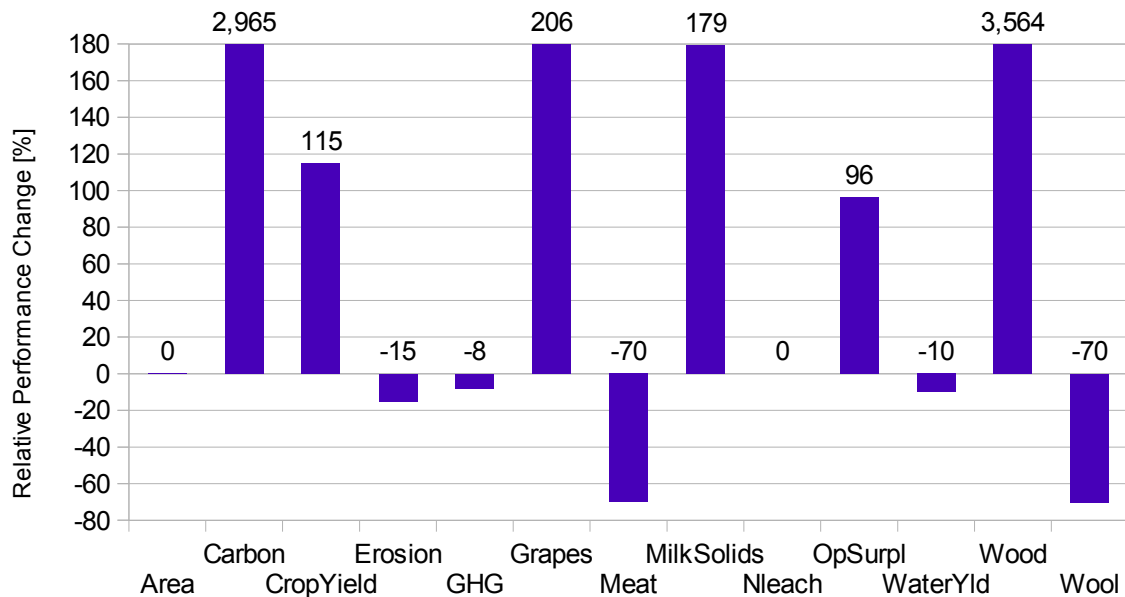
scrub → scrub

native bush → native bush

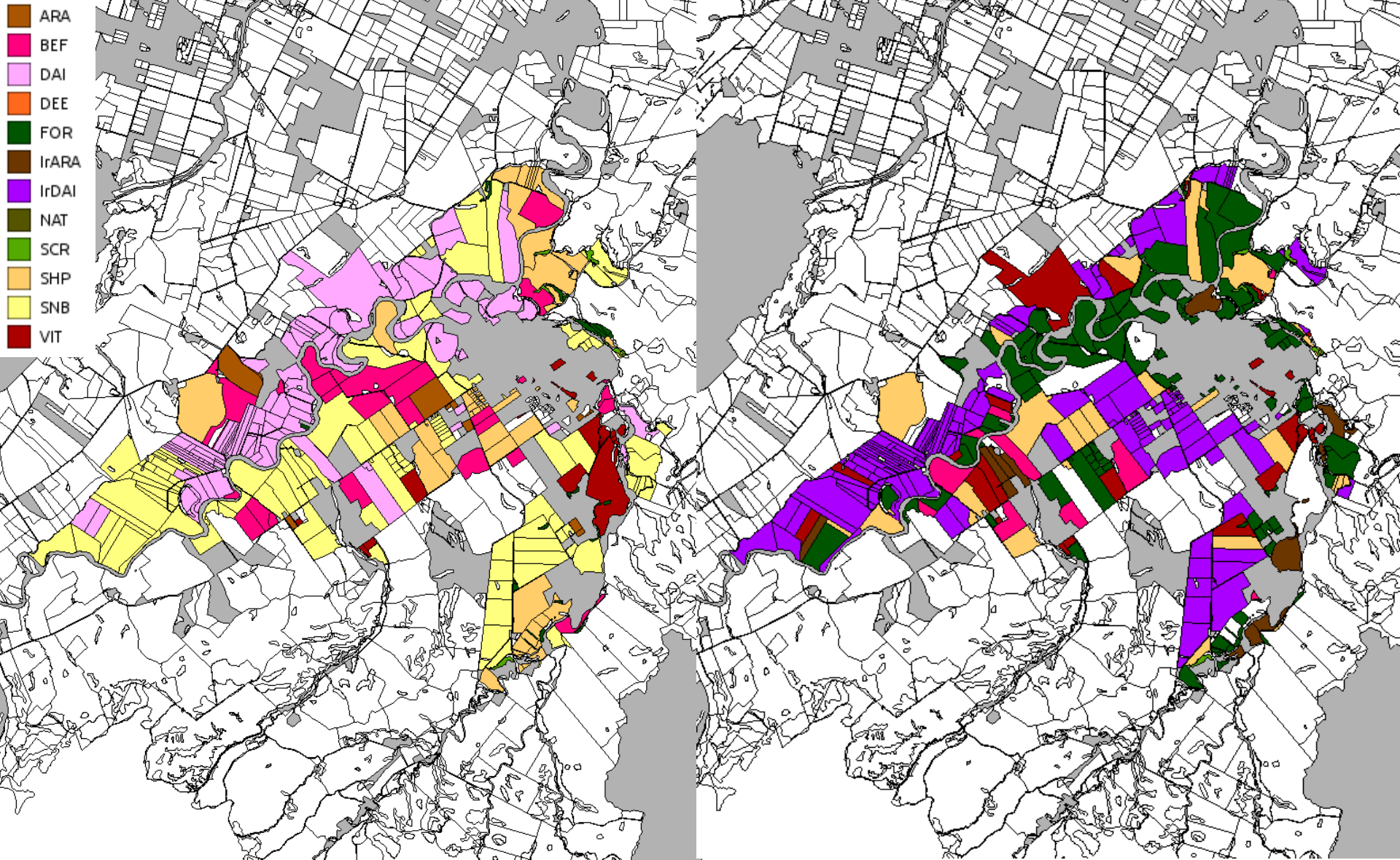
<x> → <y>



Ruamahanga



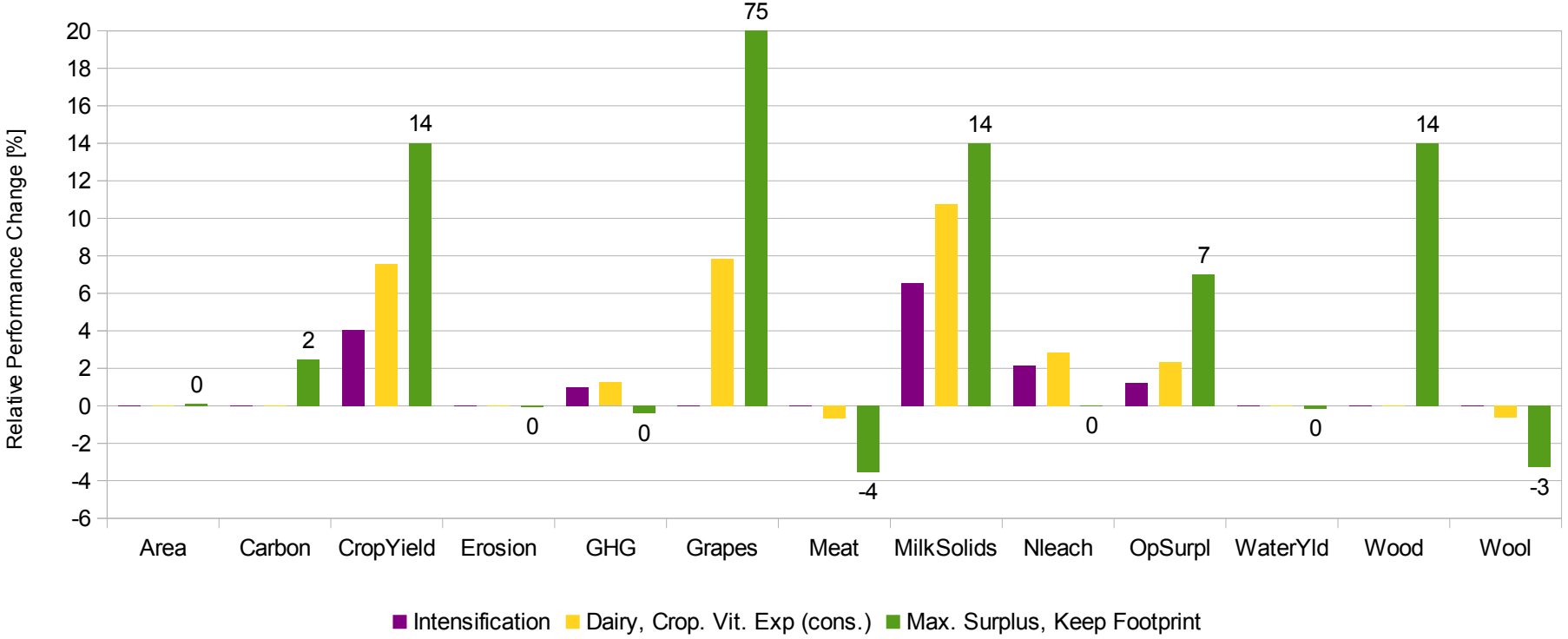
White Rock



Land Use - 2011

Max. surplus, maintain environmental performance of Ruamahanga catchm. (unconstrained)

Impact of Land Use Scenarios for the White Rock Irrigable Area on Ecosystem Services Provision in the Ruamahanga Catchment



Conclusions

- Agricultural intensification and expansion (S1-S3) increased the environmental footprint.
- The greater the expected production increase the greater the modelled environmental footprint.
- Relaxing the constraints on possible land-use conversions (S4) reduced the environmental footprint.
- The biggest increase in operating surplus, except for meat and wool, was modelled for scenario S5.
- The current land-use configuration does not use the full potential of the landscape to provide ecosystem services.
- The effect of agricultural intensification (S1-S5) in the Black Creek indicative irrigable area has a greater impact on the provisioning of ecosystem services in the Ruamahanga catchment than the effect of agricultural intensification in the White Rock indicative irrigable area.

Conclusions

LUMASS supports

- the integration of performance indicators from different models
- the integration of stakeholder objectives and expectations
- the exploration of landscape limits and potentials
- the identification of trade-offs between conflicting objectives
- evidence-based spatial decision-making and policy development



Landcare Research
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