Landcare Research
Manaaki Whenua

Irrigation - Intensification - Illumination

Exploring Limits and Trade-Offs in Agricultural Intensification

Alexander Herzig, John Dymond,
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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.

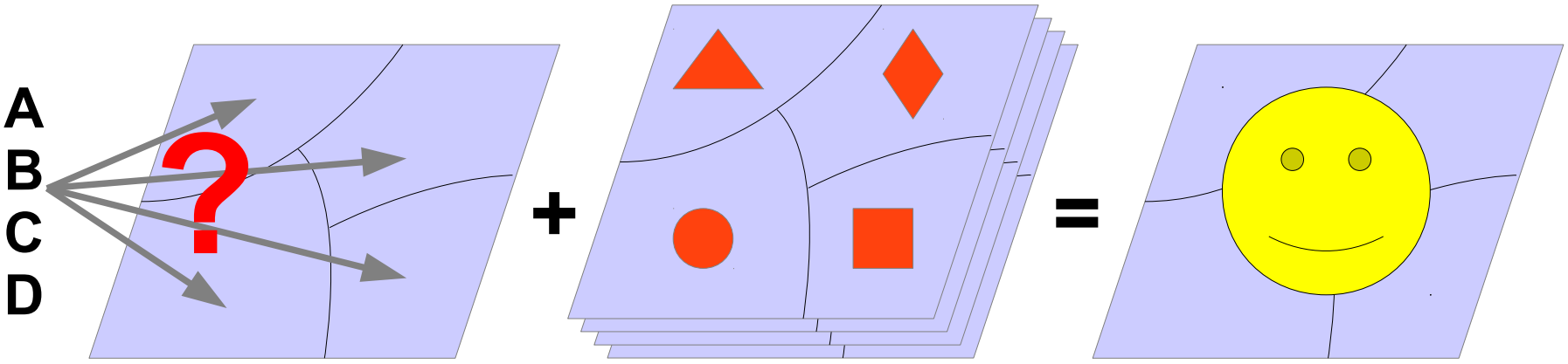
Guiding questions

- Do we make the best use of our natural resources?
- Is there environmental headroom for agricultural intensification?

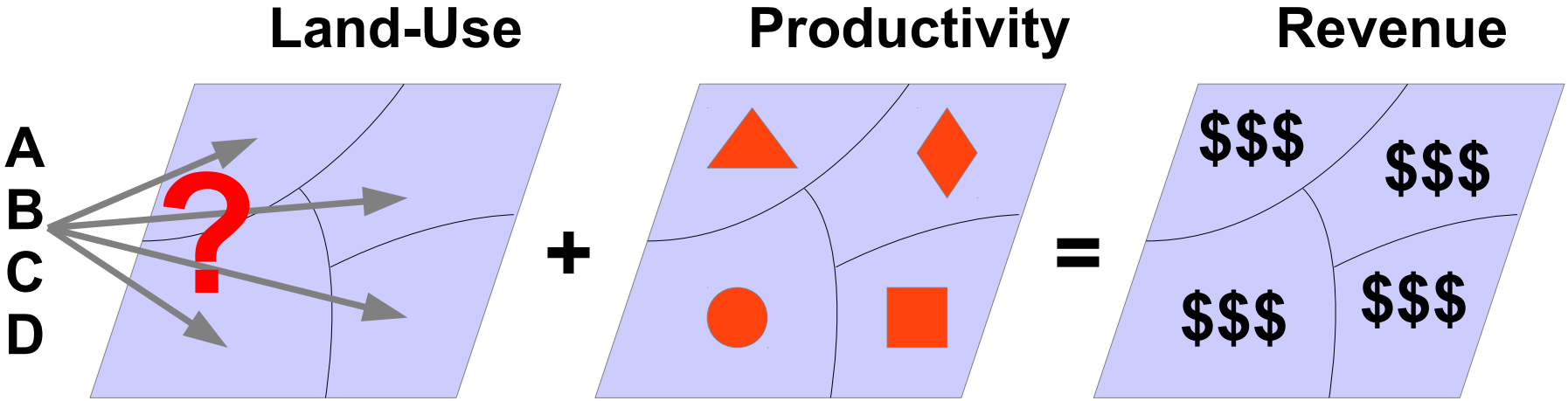
Ecosystem service	Process	Indicator	Model / Data
Global climate regulation	Carbon fixation	Carbon sequestration [t $CO_{2eq.}$ / ha / yr]	CenW (Kirschbaum 1999)
	Greenhosue gas emission	Methane and nitrous oxide emissions [t $CO_{2eq.}$ / ha / yr]	New Zealand greenhouse gas inventory emission factors (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. Imapct
Water	+	Spec. Efficiency	=	max Efficiency
Habitat	+	Suitability	=	max Biodiversity



	▲	●	■	♦
A	$$	$$$	$	$$
B	$	$	$$$	$$
C	$$$	$$	$$	$
D	$$	$$	$	$$$

Land-Use Performance with Respect to Productivity

Allocation Constraints

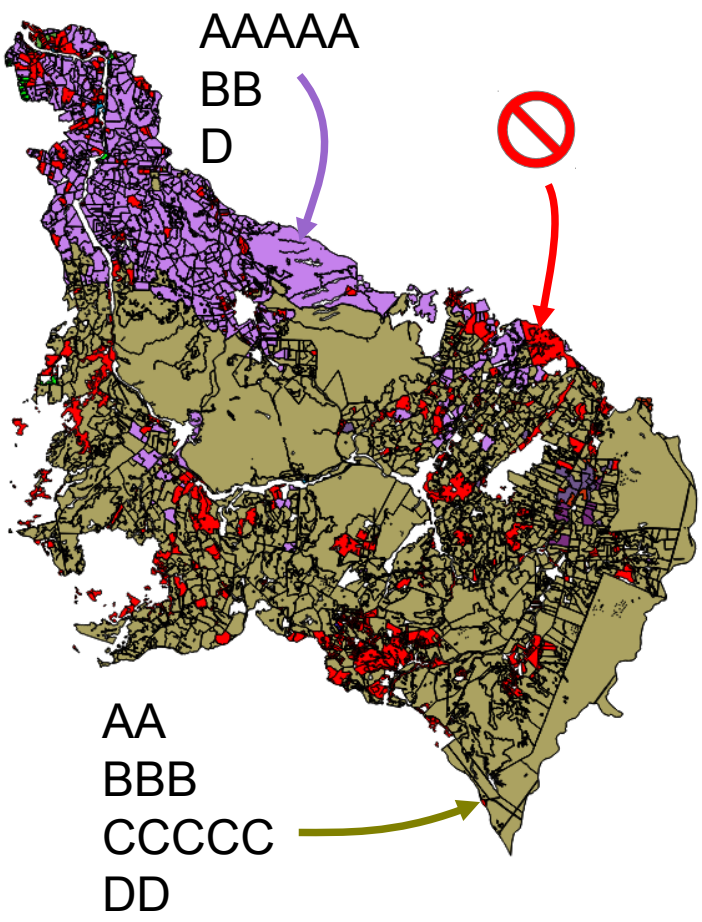
Where?
How much?

quantity per zone

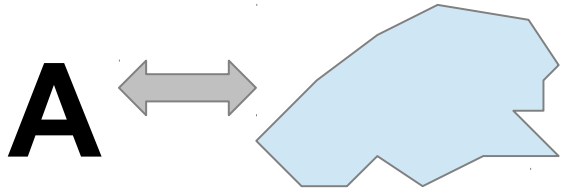
total allocation:

AAAAAAA
BBBBB
CCCCC
DDD

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



proximity to stationary objects



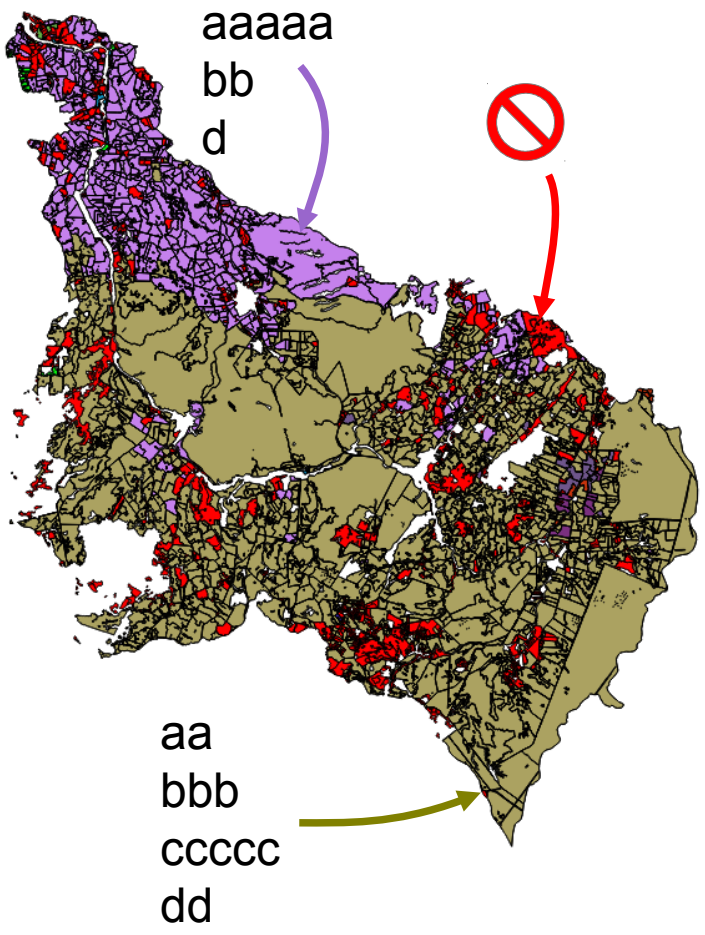
- nutrient cap depending on proximity to surface water
- housing suitability depending on proximity to industry
- business suitability depending proximity to transport (road / rail)
- habitat suitability depending on proximity to settlement, road, river, lake, forest, etc.

Performance Constraints

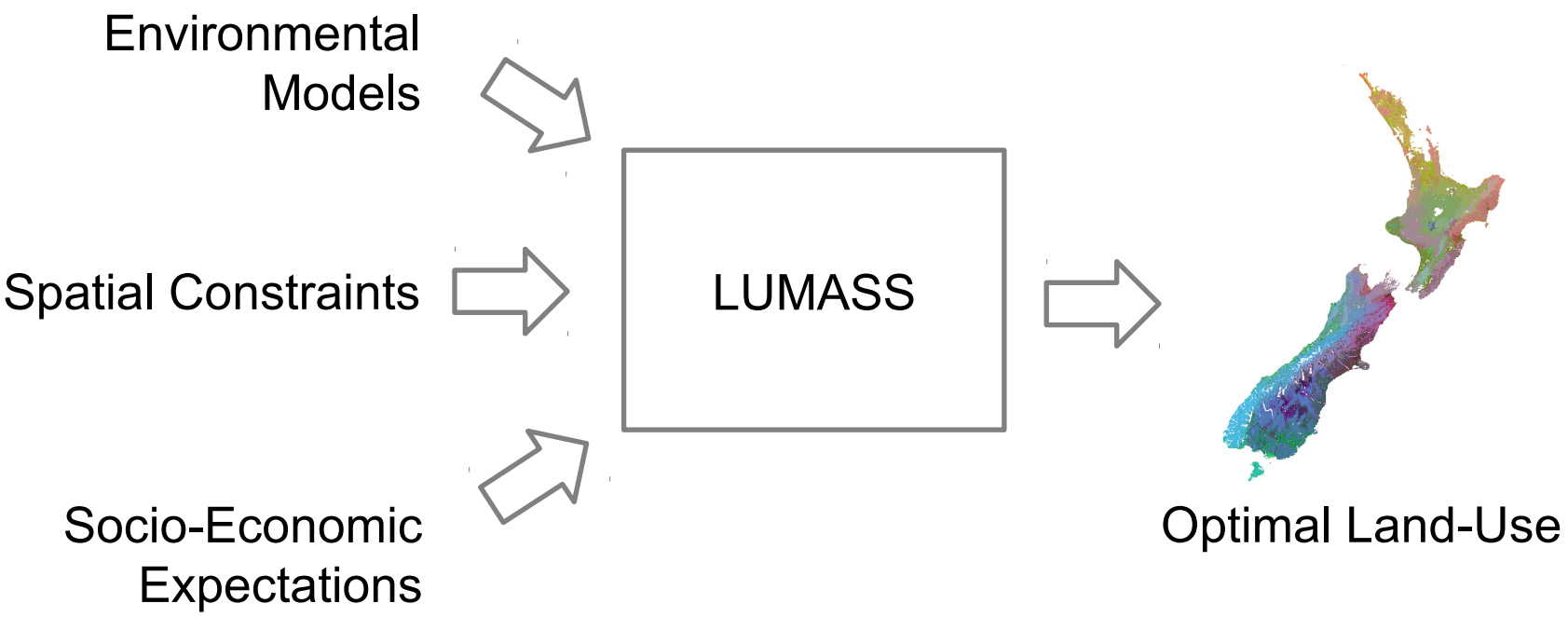
Desired Performance
Tolerated Impact

quantity per zone

- the overall nitrate leaching must not be greater then 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



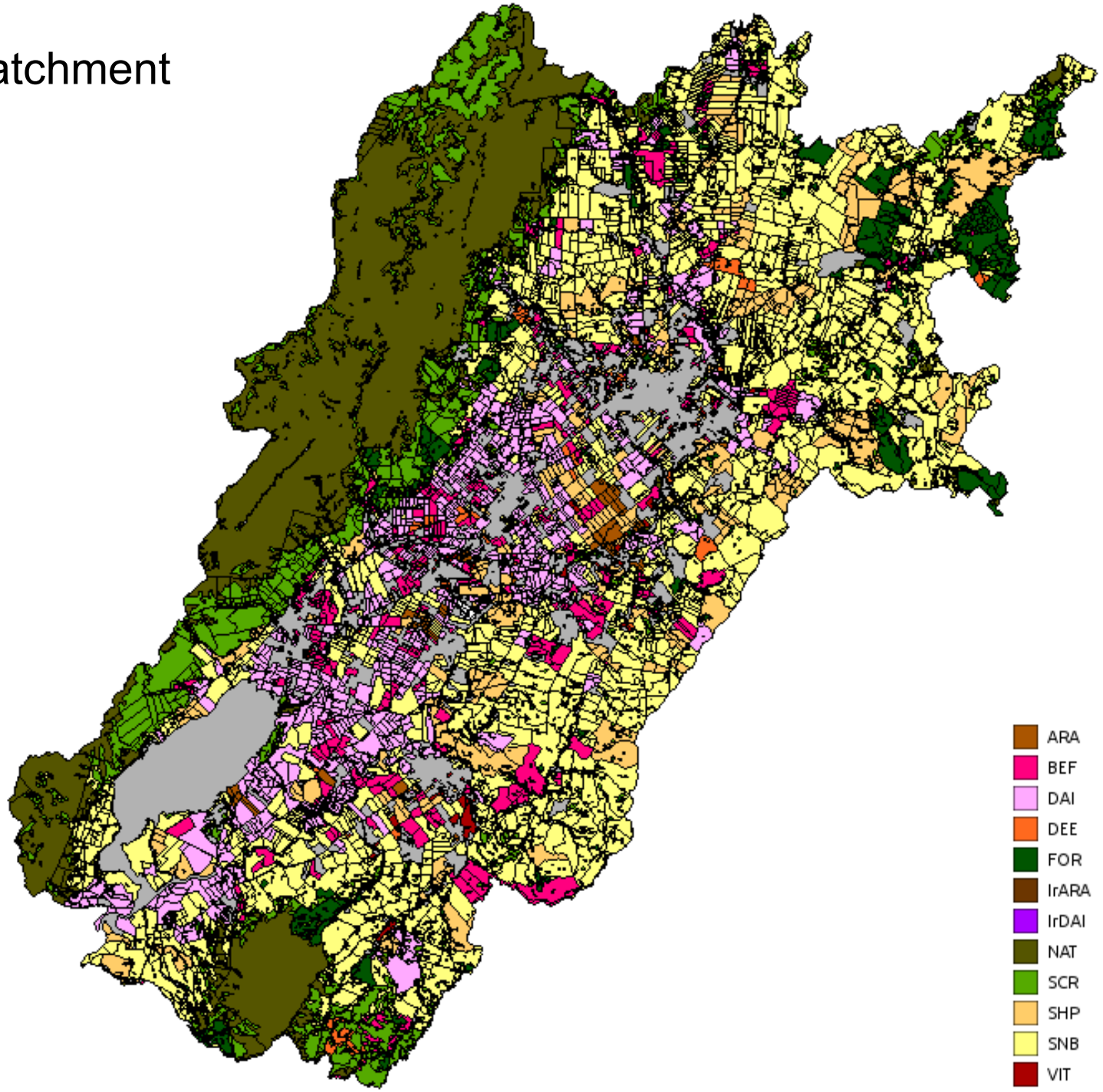
Spatial Optimisation with LUMASS



- Exploring Limits
- Identifying trade-offs
- Discovering Potentials

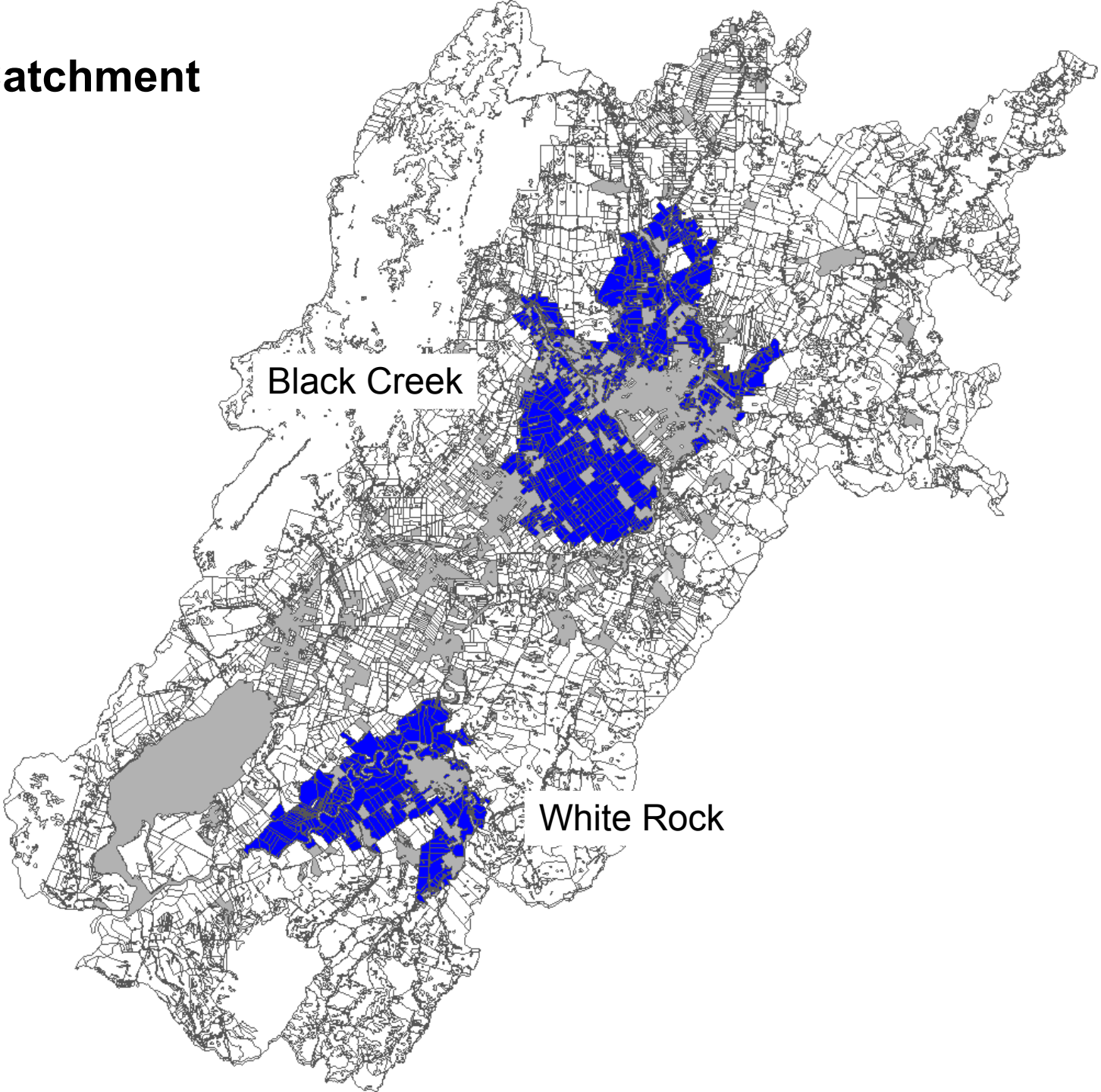
Ruamahanga Catchment

Land Use 2011



Ruamahanga Catchment

Irrigable Areas



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 >= S1 + 30%

{sheep, beef, deer} → irrigated dairy

S3 – dairy, arable, viticulture expansion

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

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

S4 – dairy, arable, viticulture expansion

s. S3

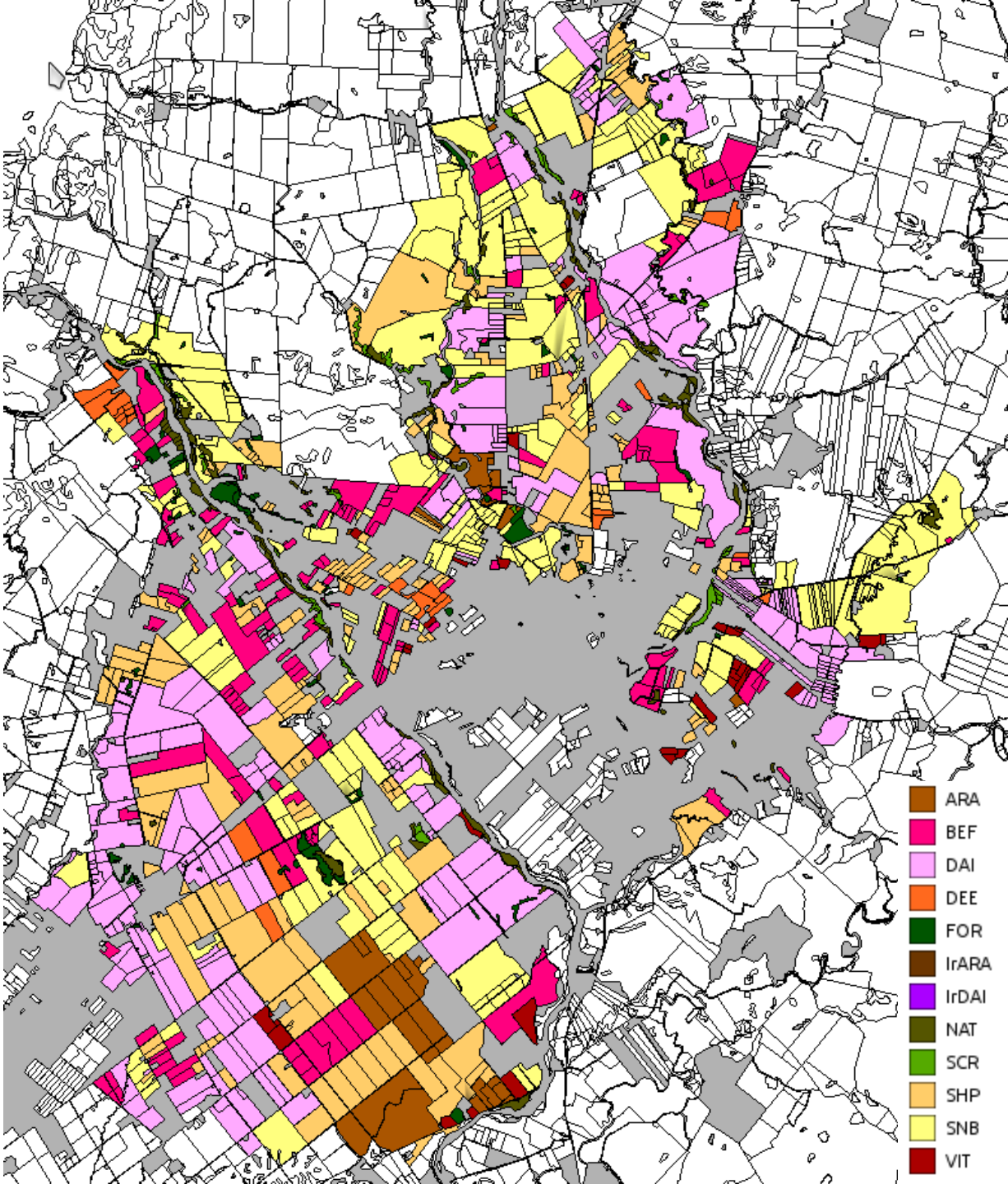
S5 – surplus maximisation

max operating surplus
GHG <= yr2011
N leach <= yr2011
meat >= 30% yr2011
wool >= 30% yr2011
wood >= 30% yr2011
<x> >= yr2011

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

Black Creek

Land Use - 2011



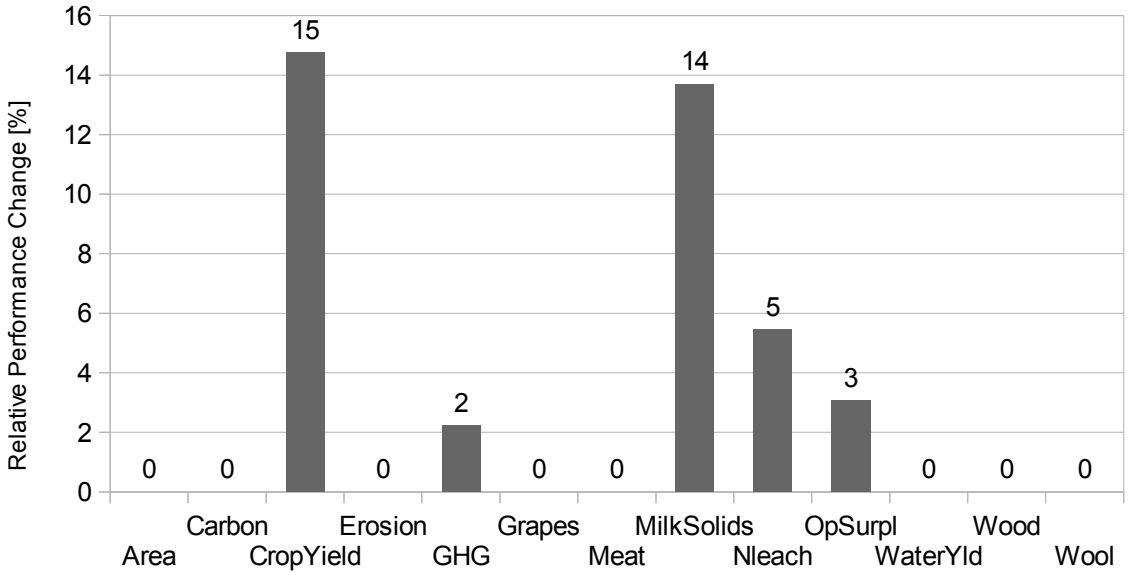
Black Creek

Land Use Intensification

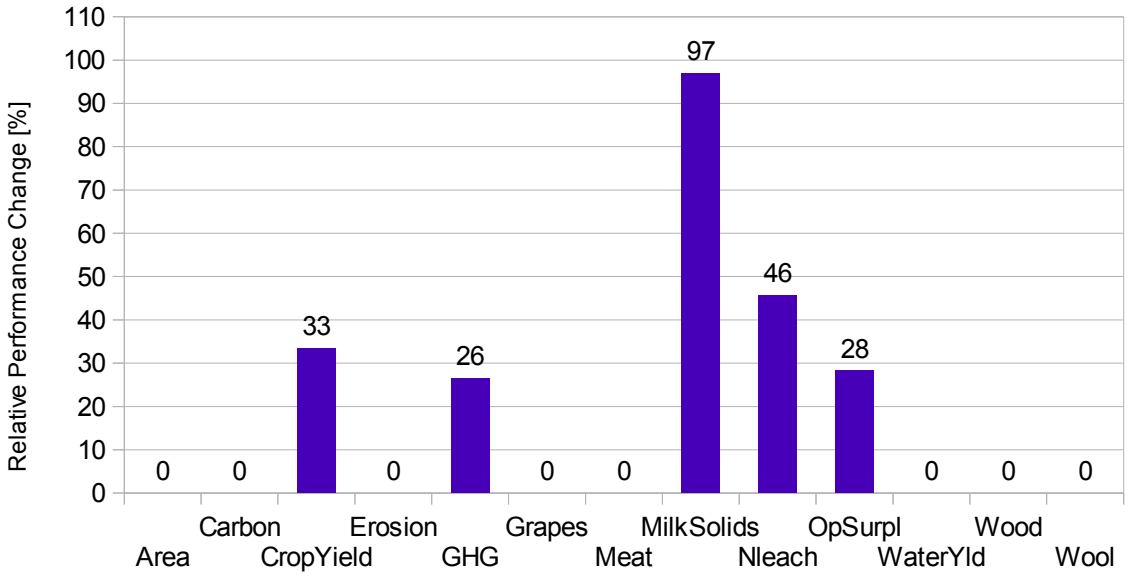
BC-S1

land-use conversion constraints

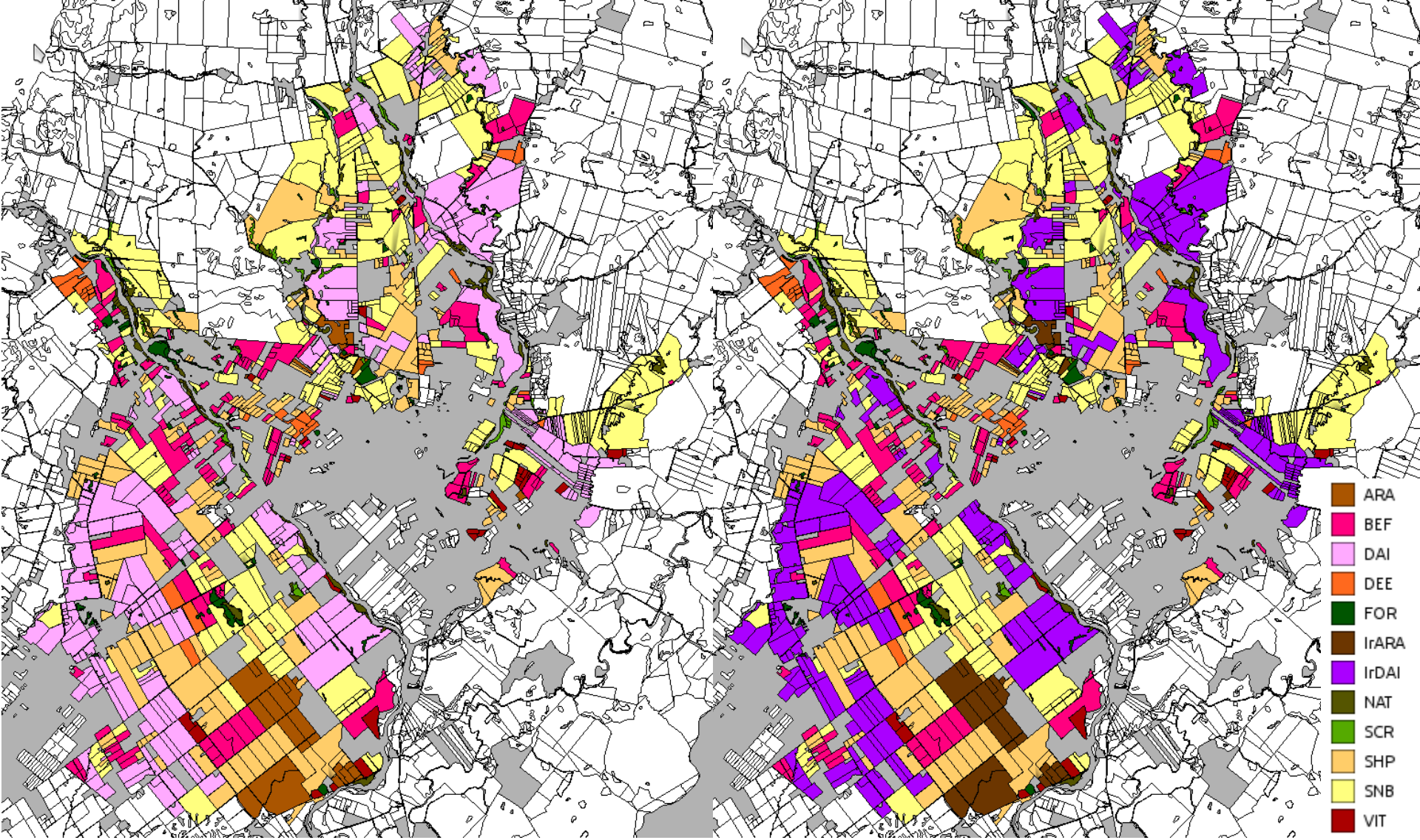
dairy	→ irrigated dairy
arable	→ irrigated arable
<x>	→ <x>



Ruamahanga



Black Creek



Land Use - 2011

Land Use Intensification

Black Creek

Intensive Dairy Expansion

BC-S2b

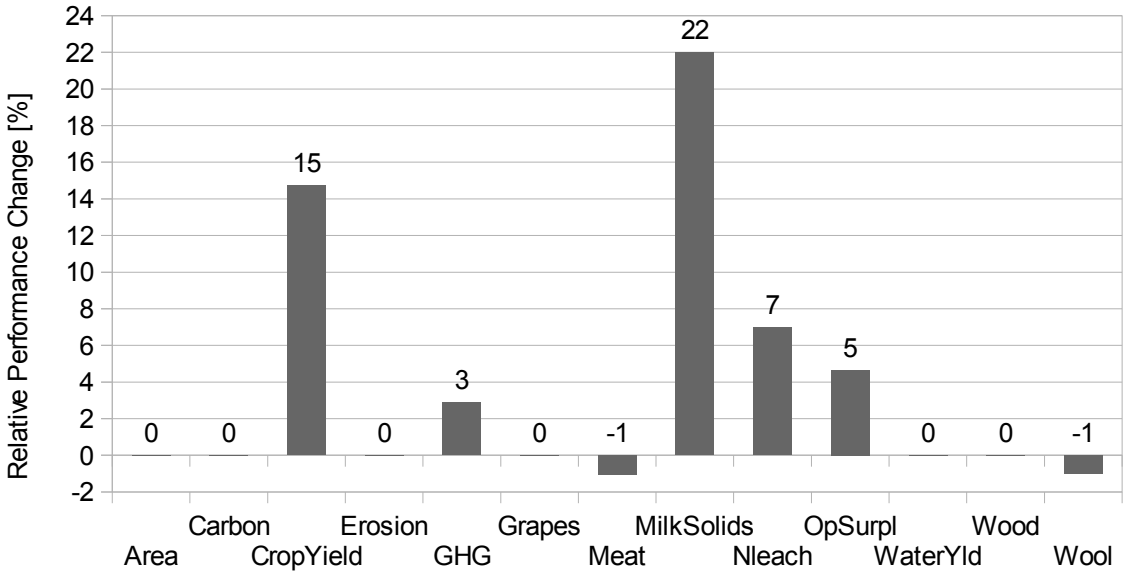
objective & performance constraints

min nitrate leaching
milk solids >= S1 + 30%

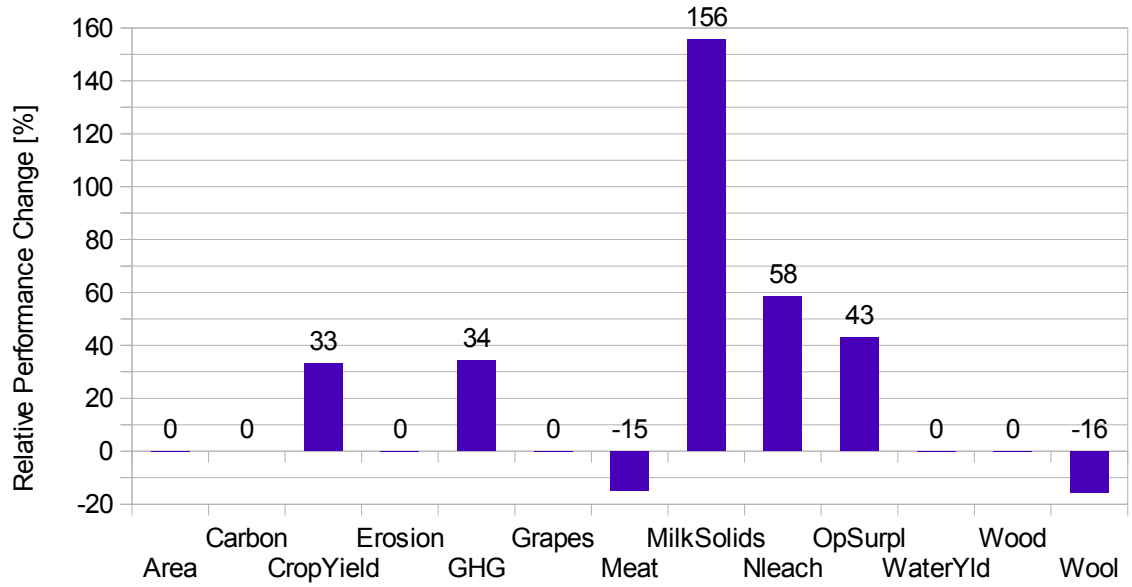
land-use conversion constraints

{ sheep, beef, deer } → irrigated dairy

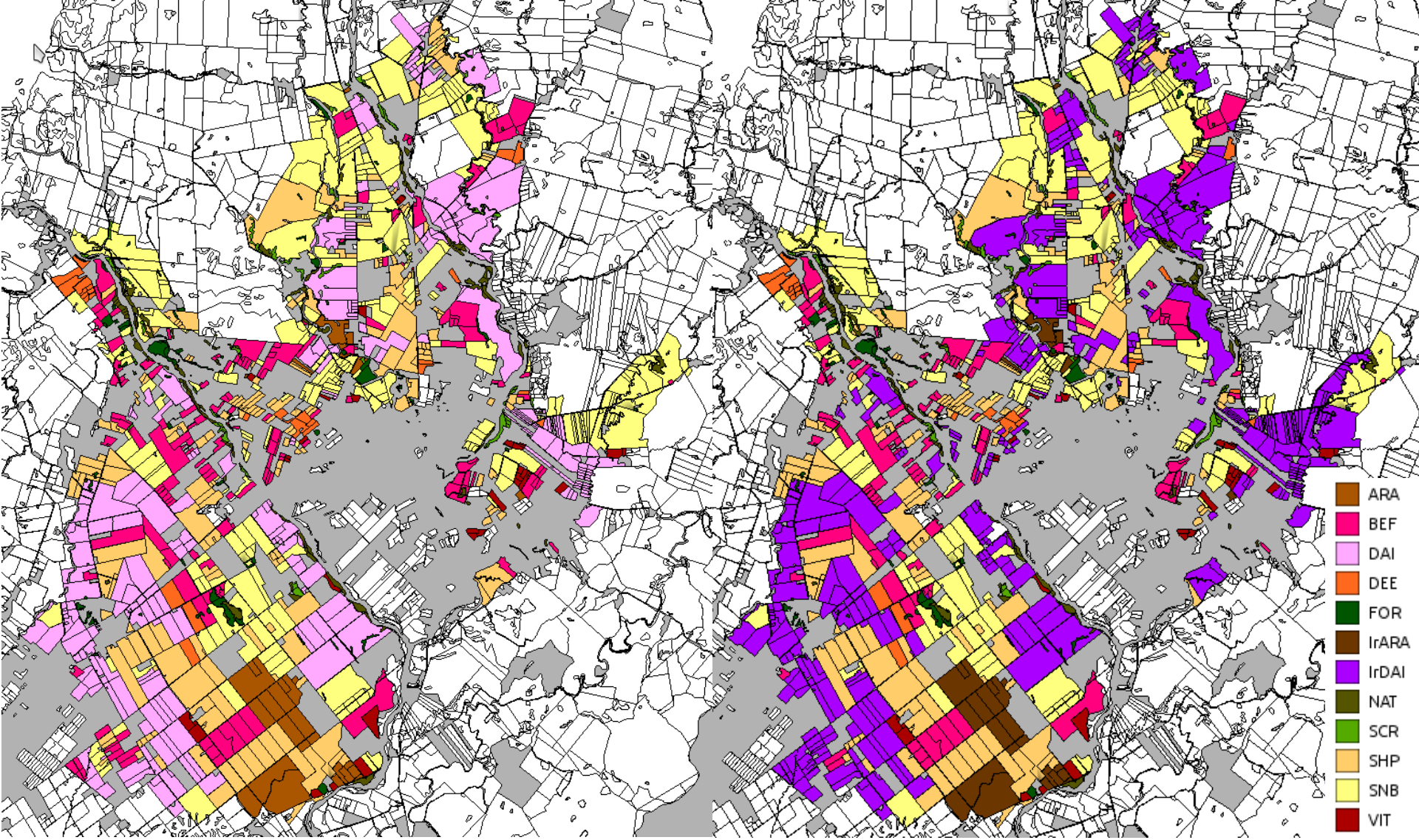
dairy → irrigated dairy
arable → irrigated arable
<x> → <x>



Ruamahanga

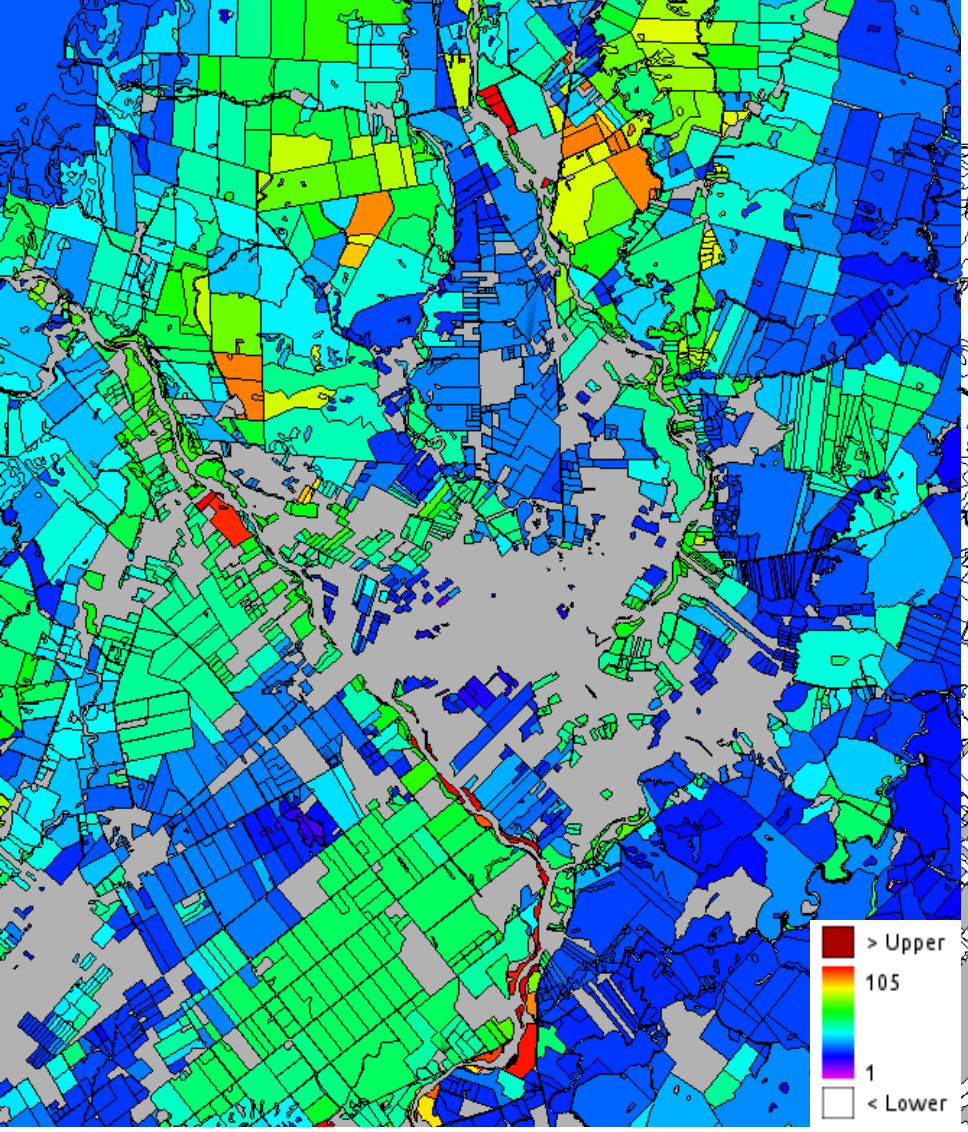


Black Creek

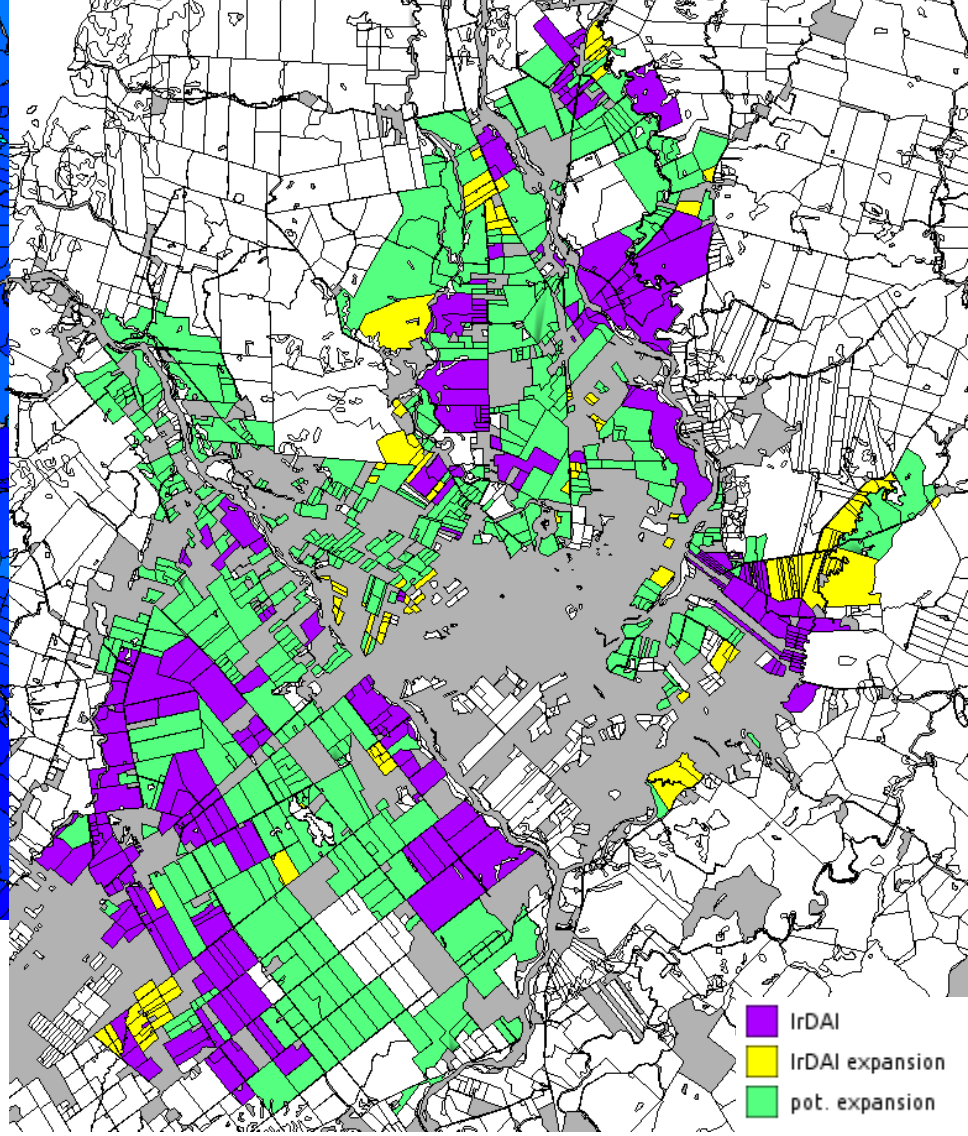


Land Use - 2011

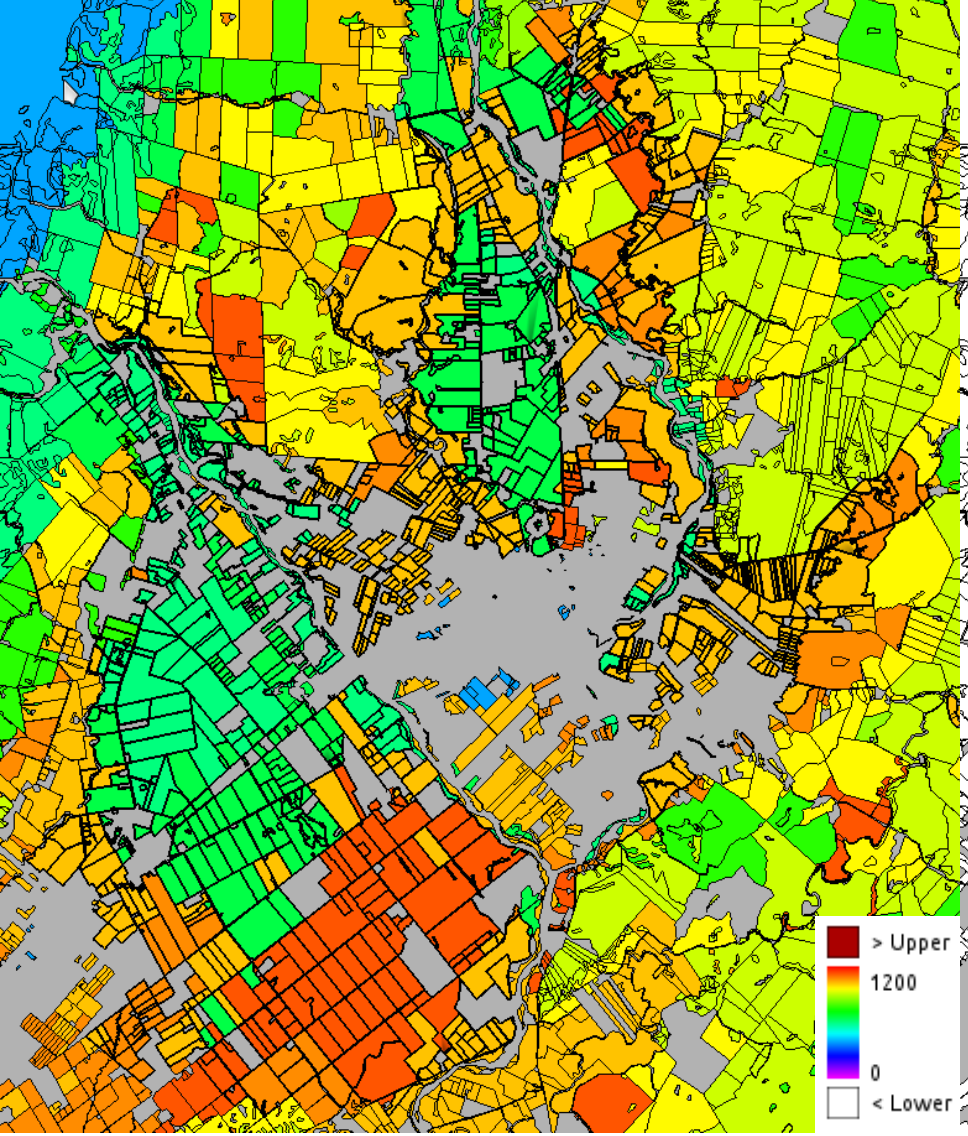
Intensive Dairy Expansion



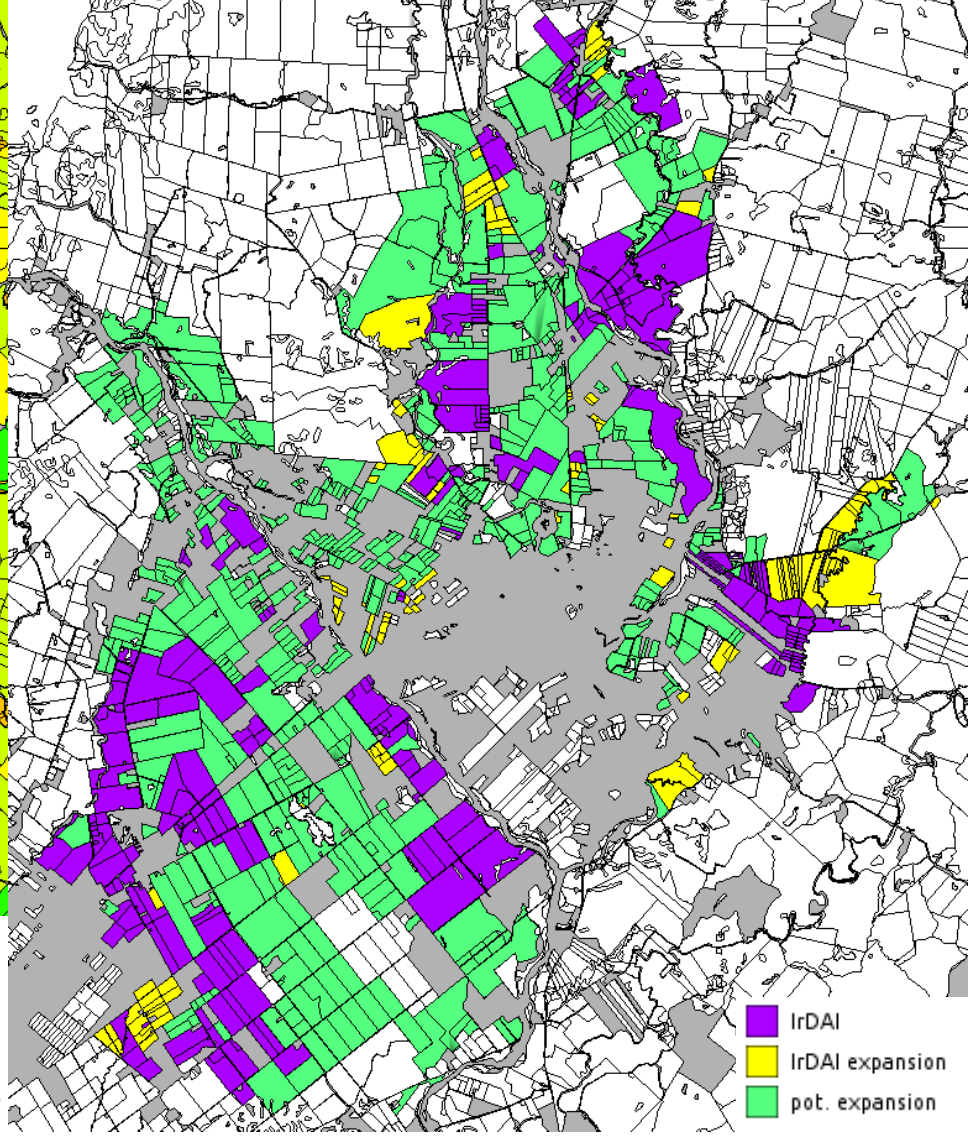
Potential nitrate leaching [kg N/ha/yr] for irrigated dairy farming



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

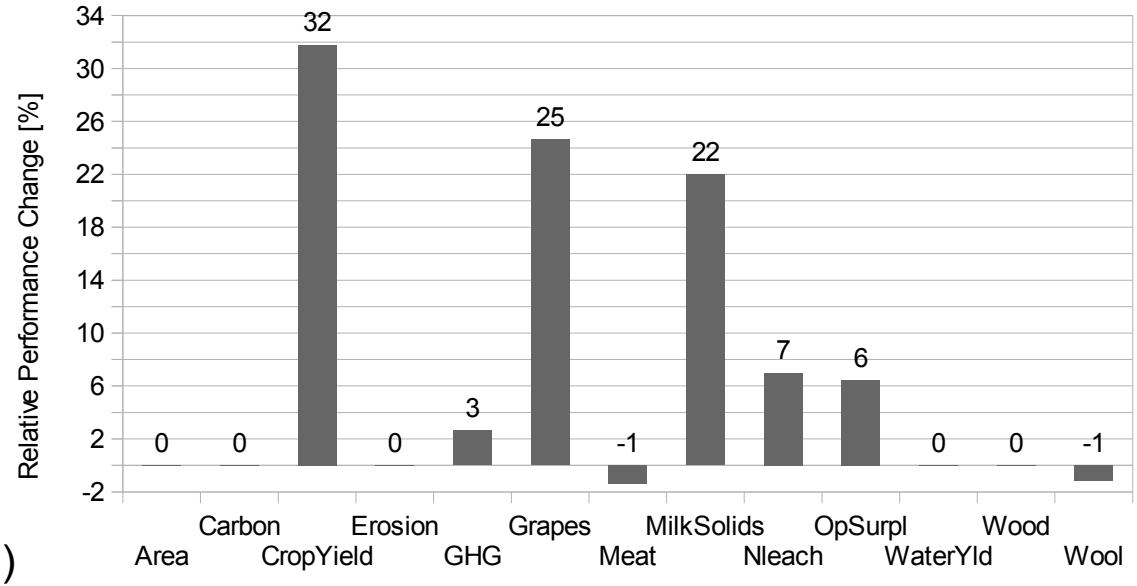
objective & performance constraints

min nitrate leaching
milk solids >= S1 + 30%
crop yield >= S1 + 30%
grapes >= yr2011 + 25% (Rua.)

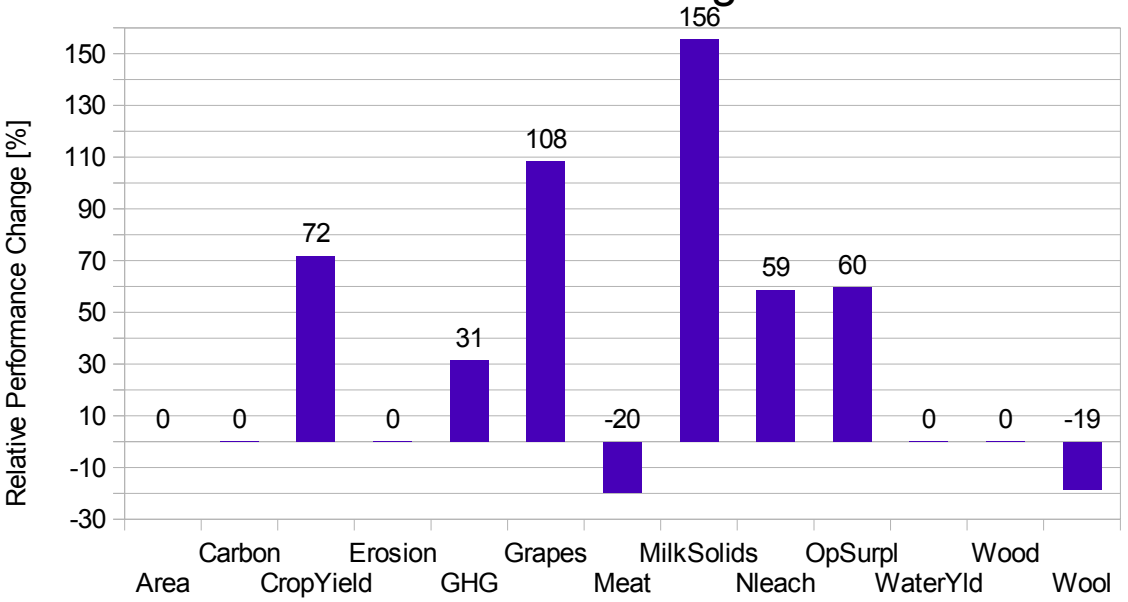
land-use conversion constraints

{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

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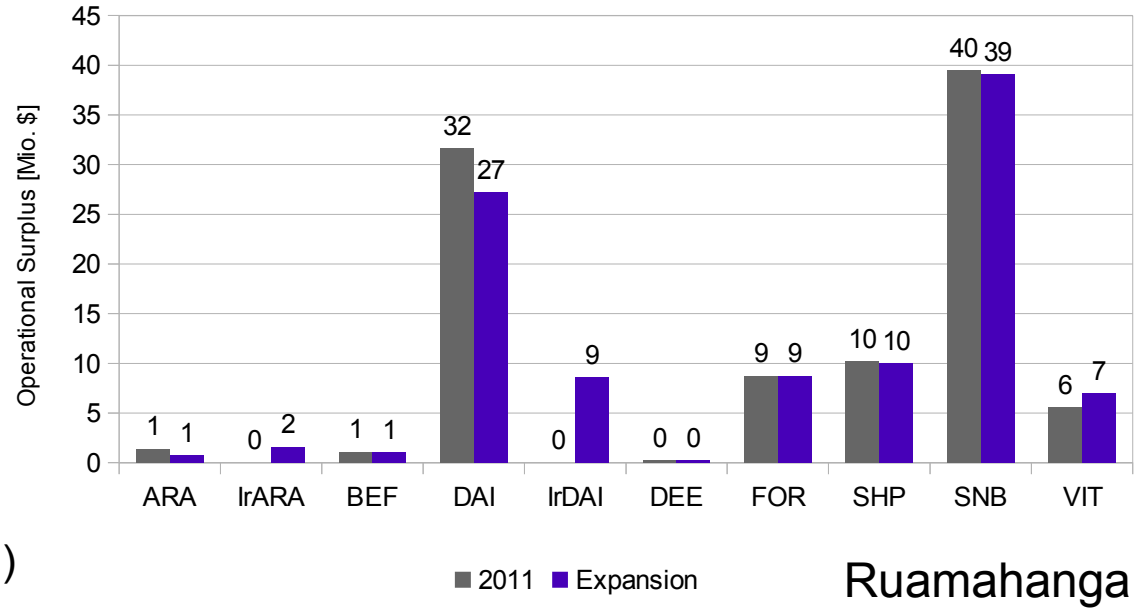
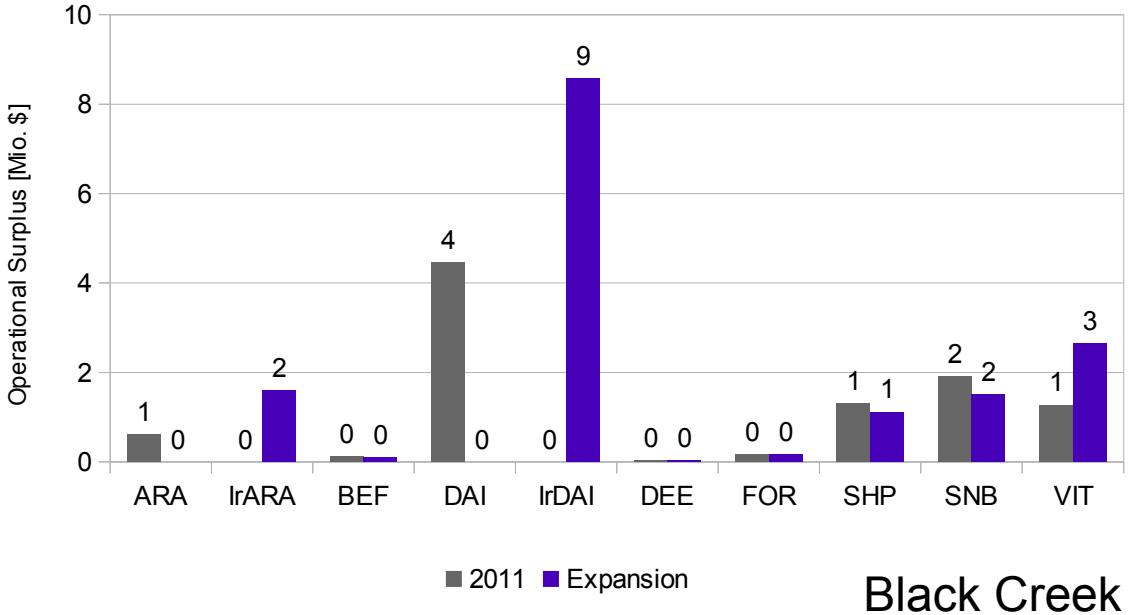
land-use conversion constraints

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

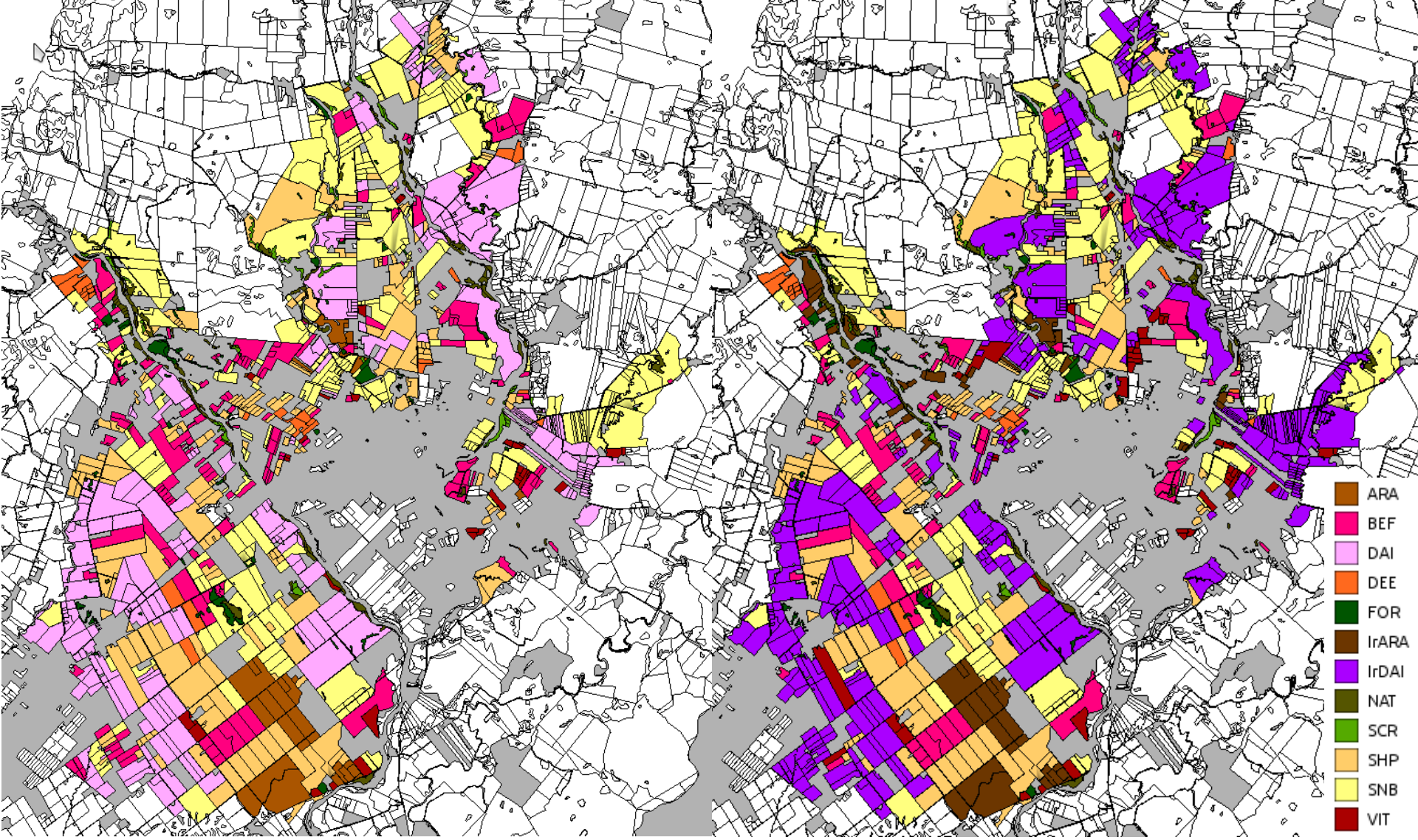
dairy → irrigated dairy
arable → irrigated arable
<x> → <x>



Ruamahanga



Black Creek



Land Use - 2011

Dairy, Cropping, Viticulture Expansion (constrained)

Black Creek

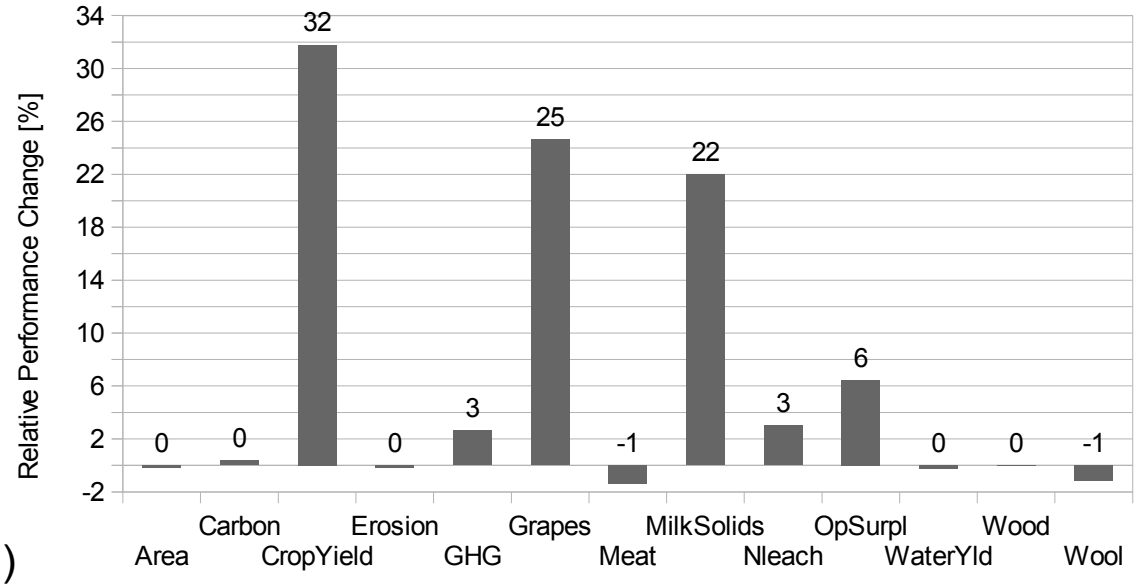
Dairy, Cropping, Viticulture Expansion (unconstrained) BC-S4b

objective & performance constraints

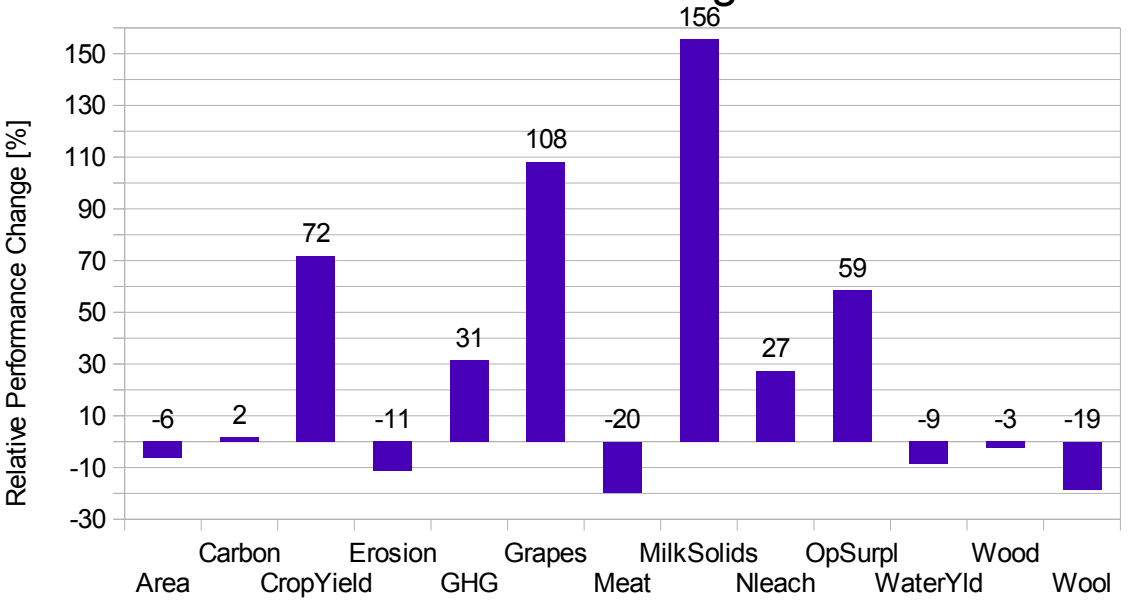
min nitrate leaching
milk solids >= S1 + 30%
crop yield >= S1 + 30%
grapes >= yr2011 + 25% (Rua.)

land-use conversion constraints

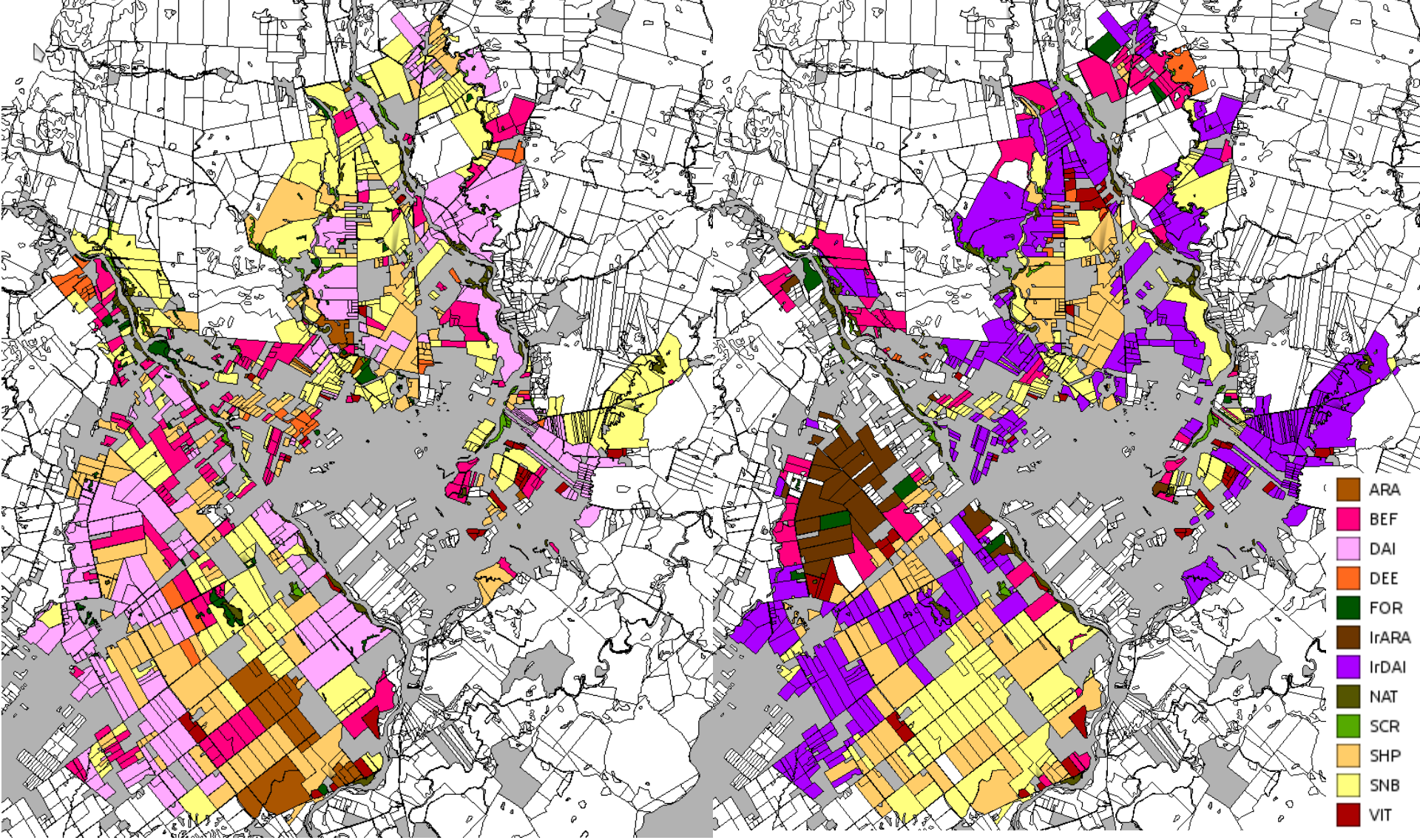
viticulture → viticulture
scrub → scrub
native bush → native bush
<x> → <y>



Ruamahanga



Black Creek



Land Use - 2011

Dairy, Cropping, Viticulture Expansion (unconstrained)

Black Creek

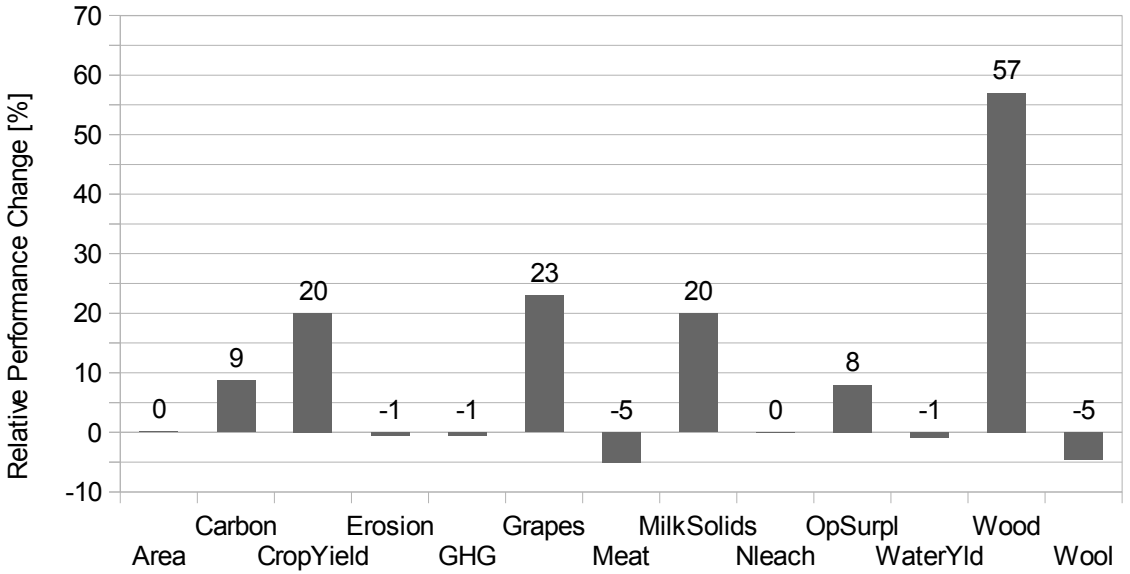
Surplus maximisation
(unconstrained) BC-S5

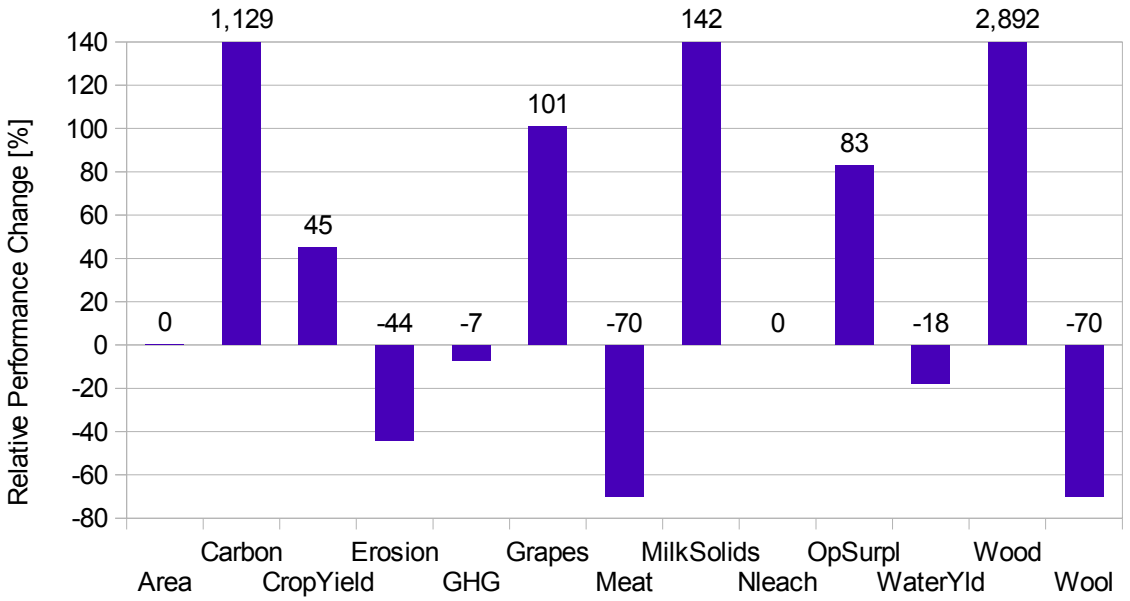
objective & performance constraints

max operating surplus
GHG <= 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

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

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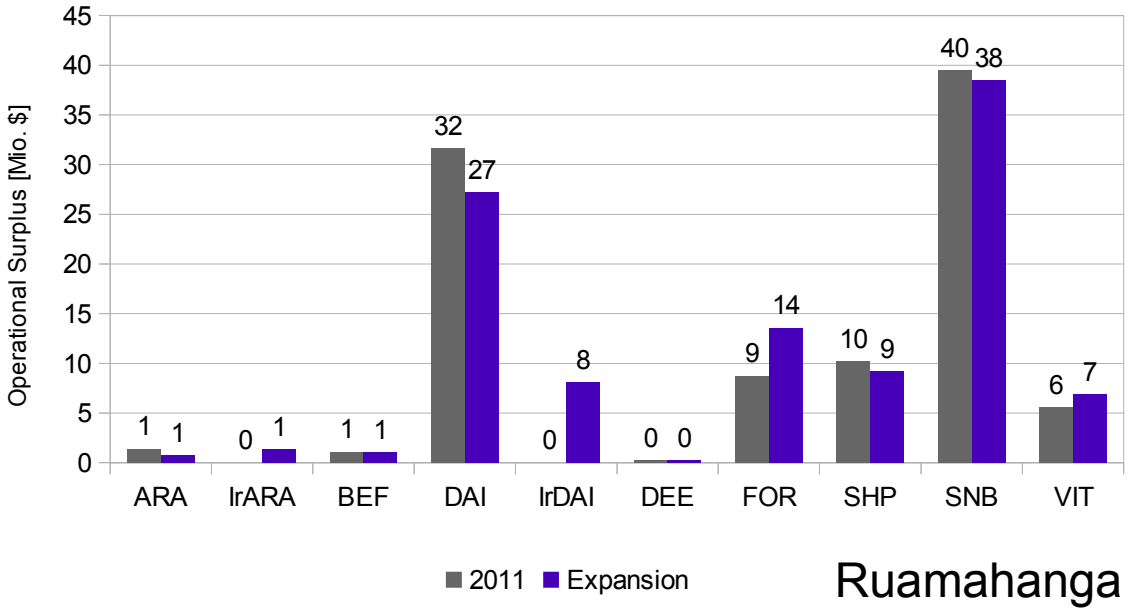
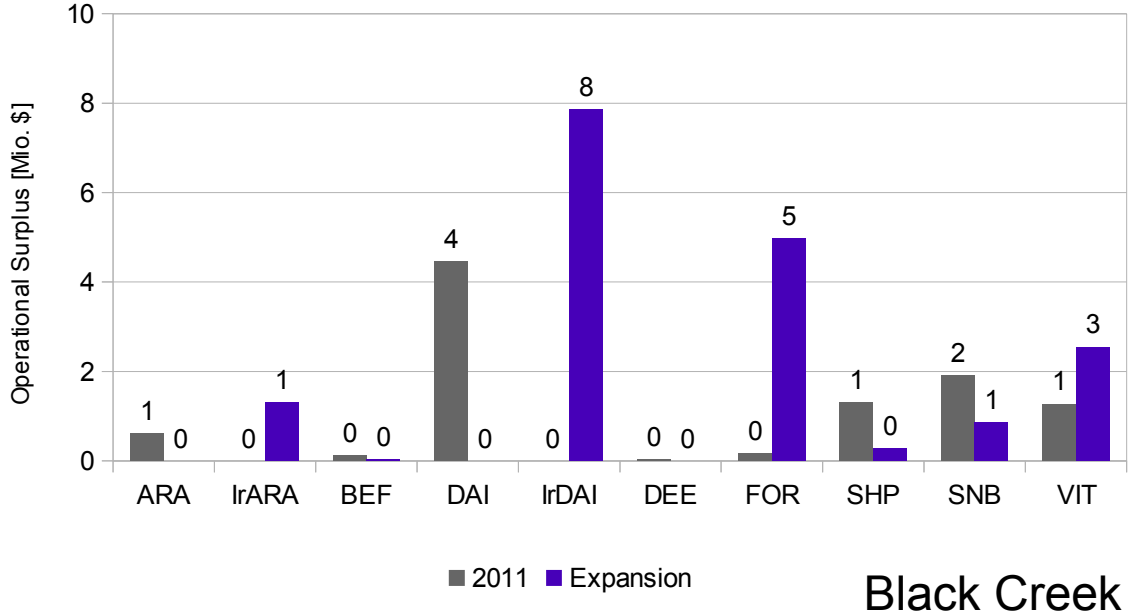
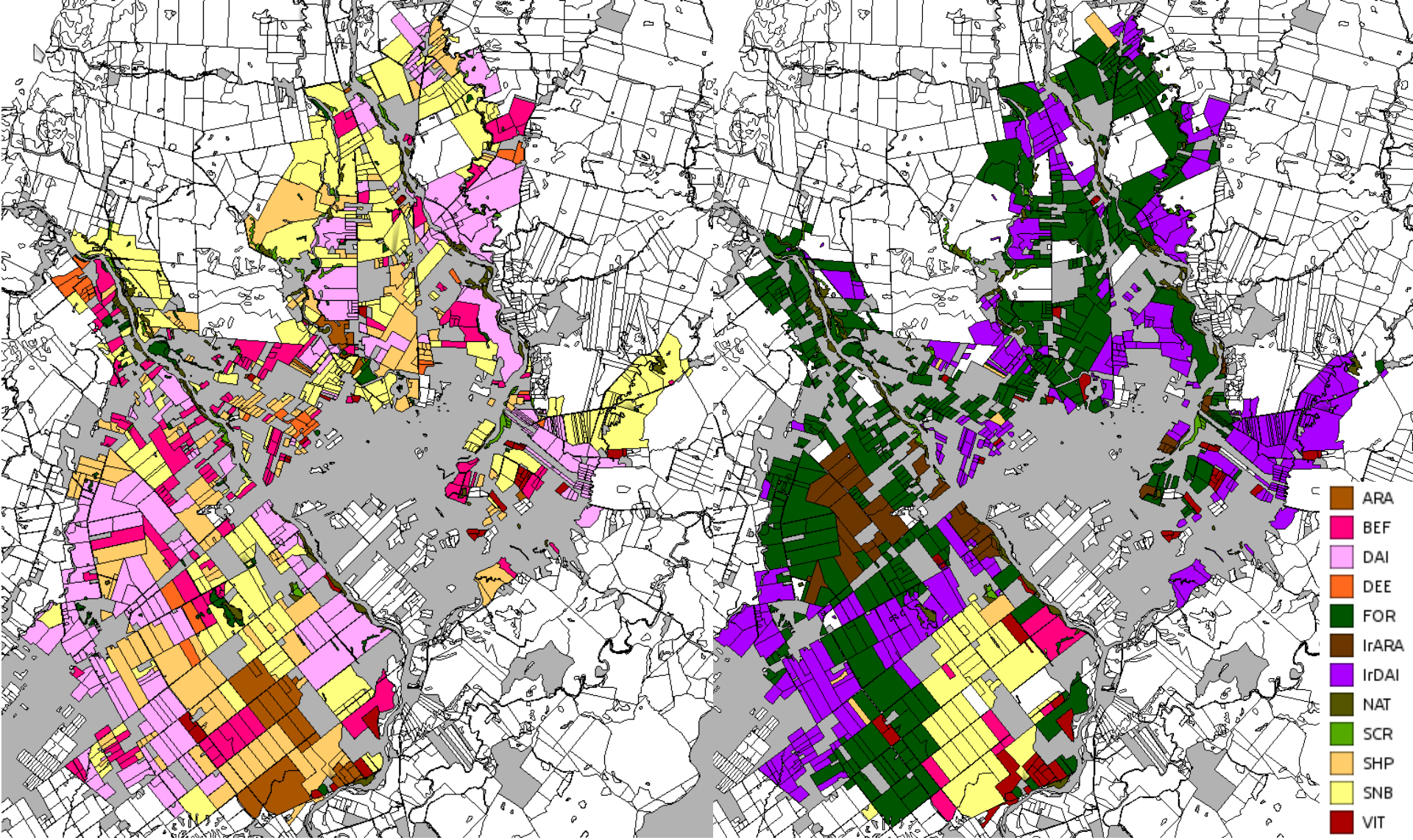


Ruamahanga



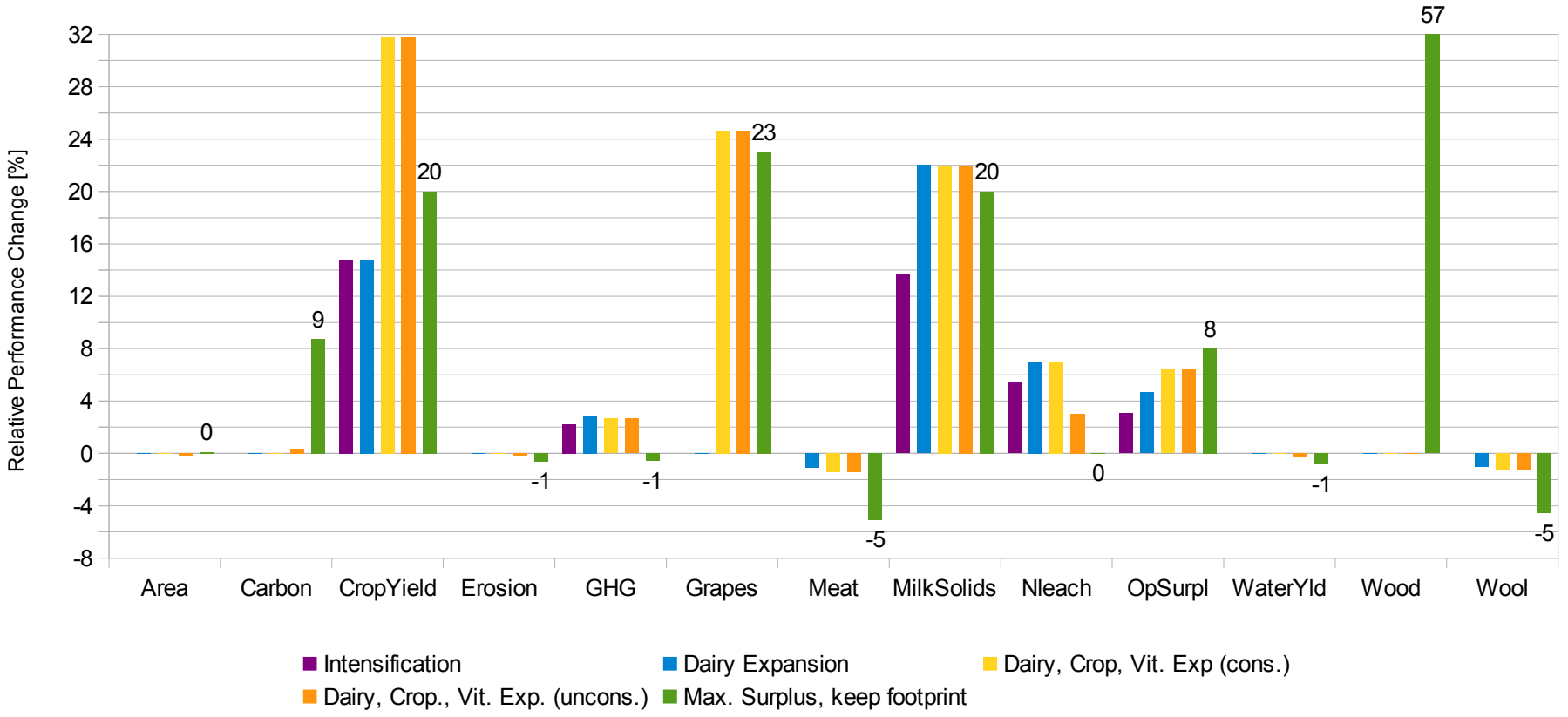
Black Creek



Land Use - 2011

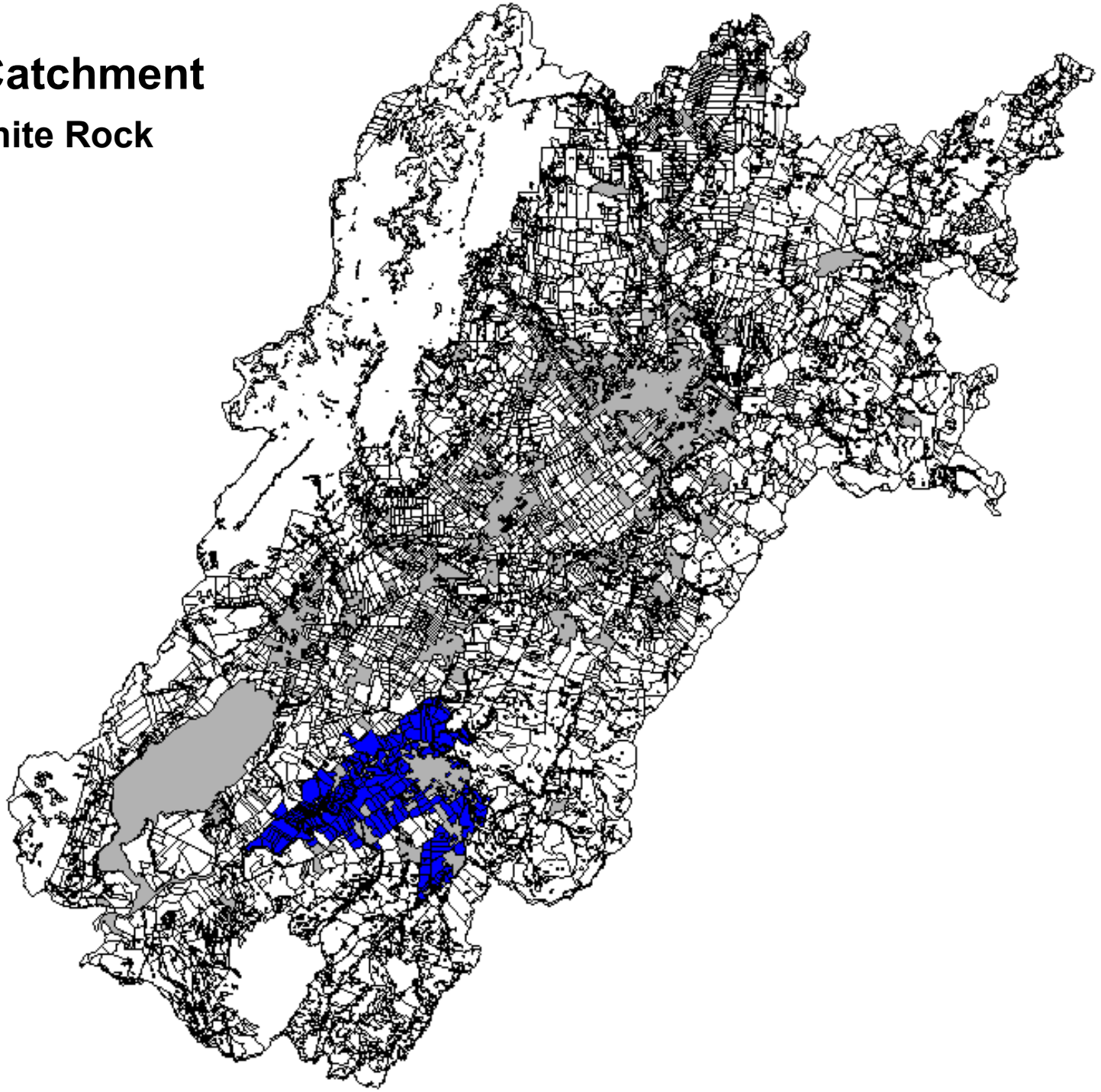
Max. Surplus, maintain Environmental Performance of Ruamahanga Catchm. (unconstrained)

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



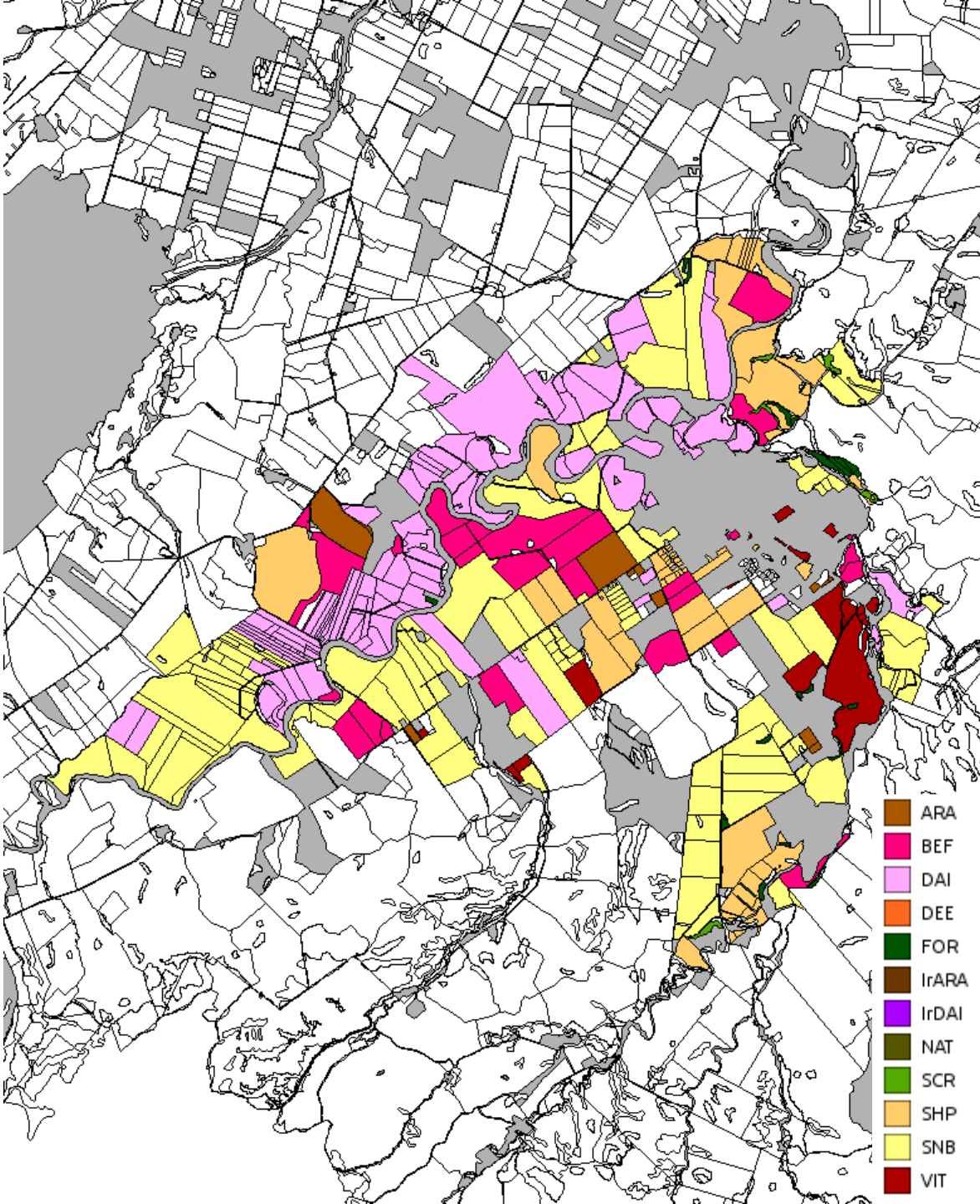
Ruamahanga Catchment

Irrigable Area – White Rock



White Rock

Land Use - 2011



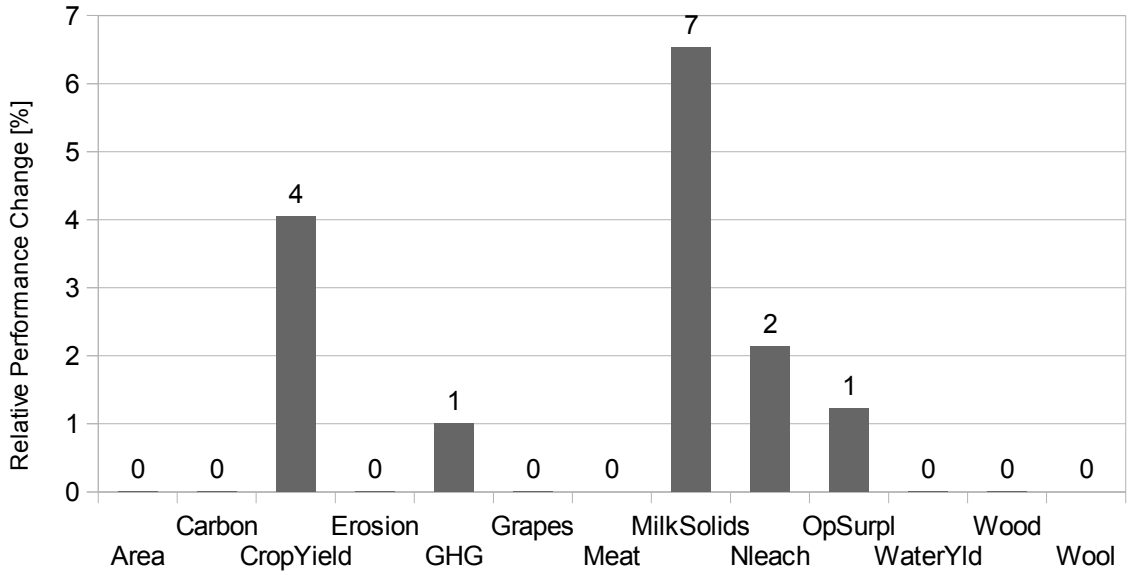
White Rock

Land Use Intensification

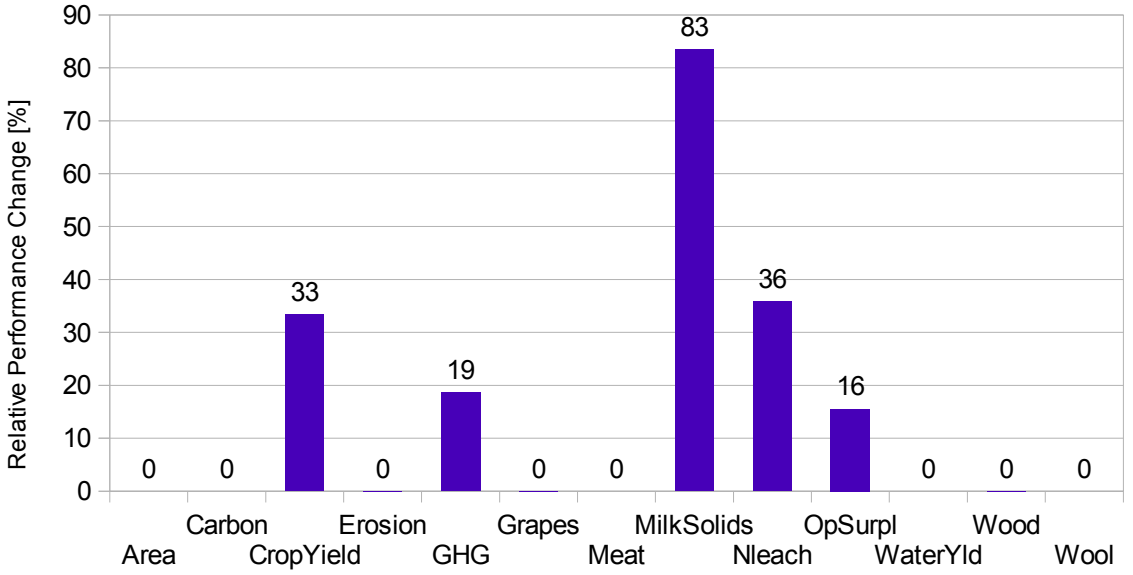
WR-S1

land-use conversion constraints

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



Ruamahanga



White Rock

White Rock

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

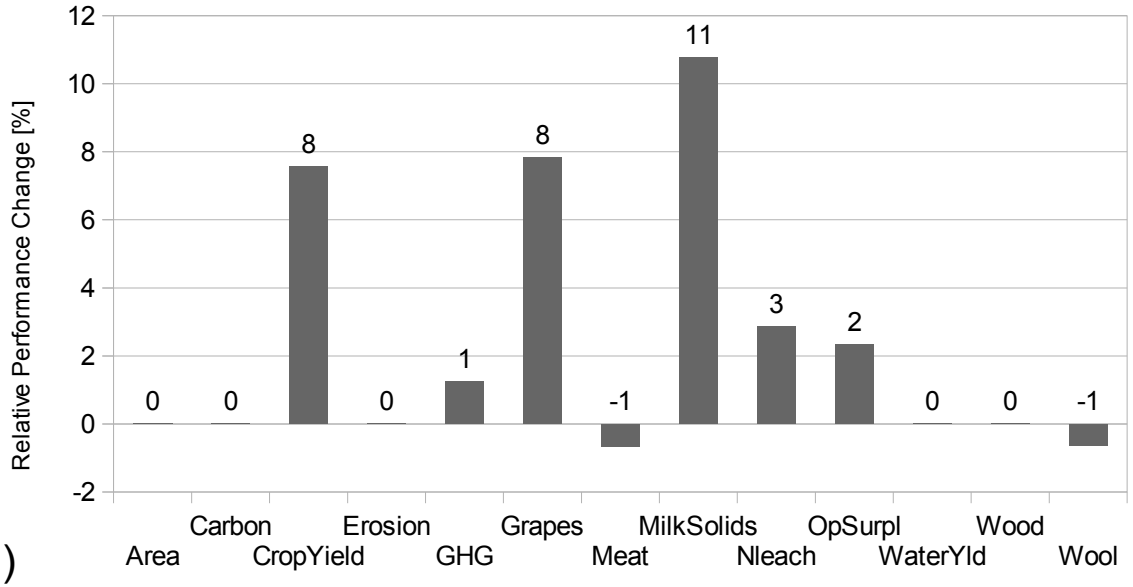
objective & performance constraints

min nitrate leaching
milk solids >= S1 + 30%
crop yield >= S1 + 30%
grapes >= yr2011 + 8% (Rua.)

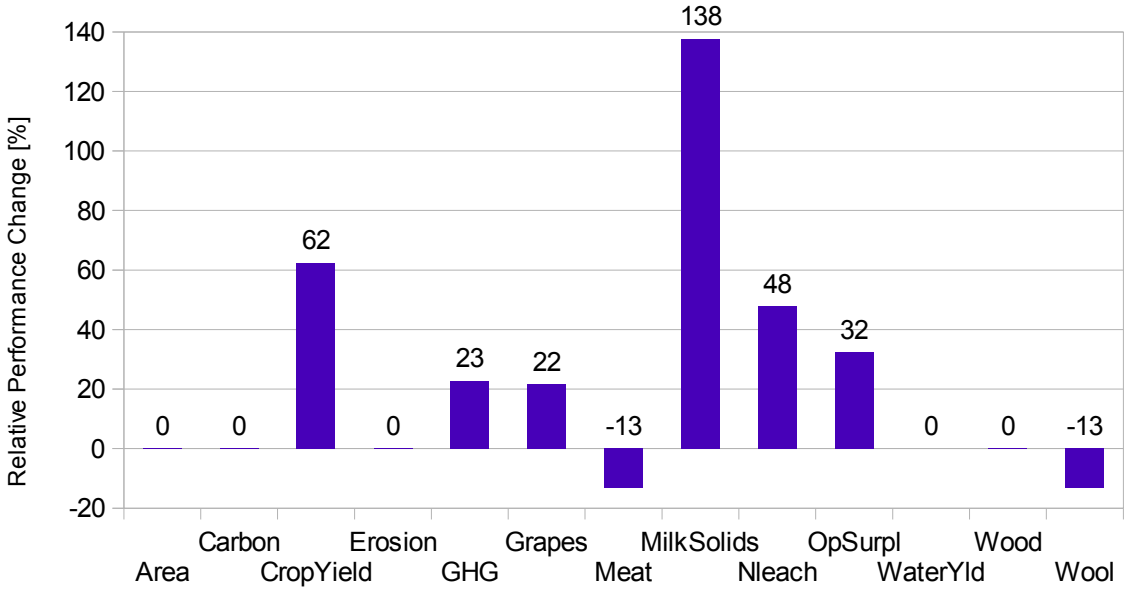
land-use conversion constraints

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

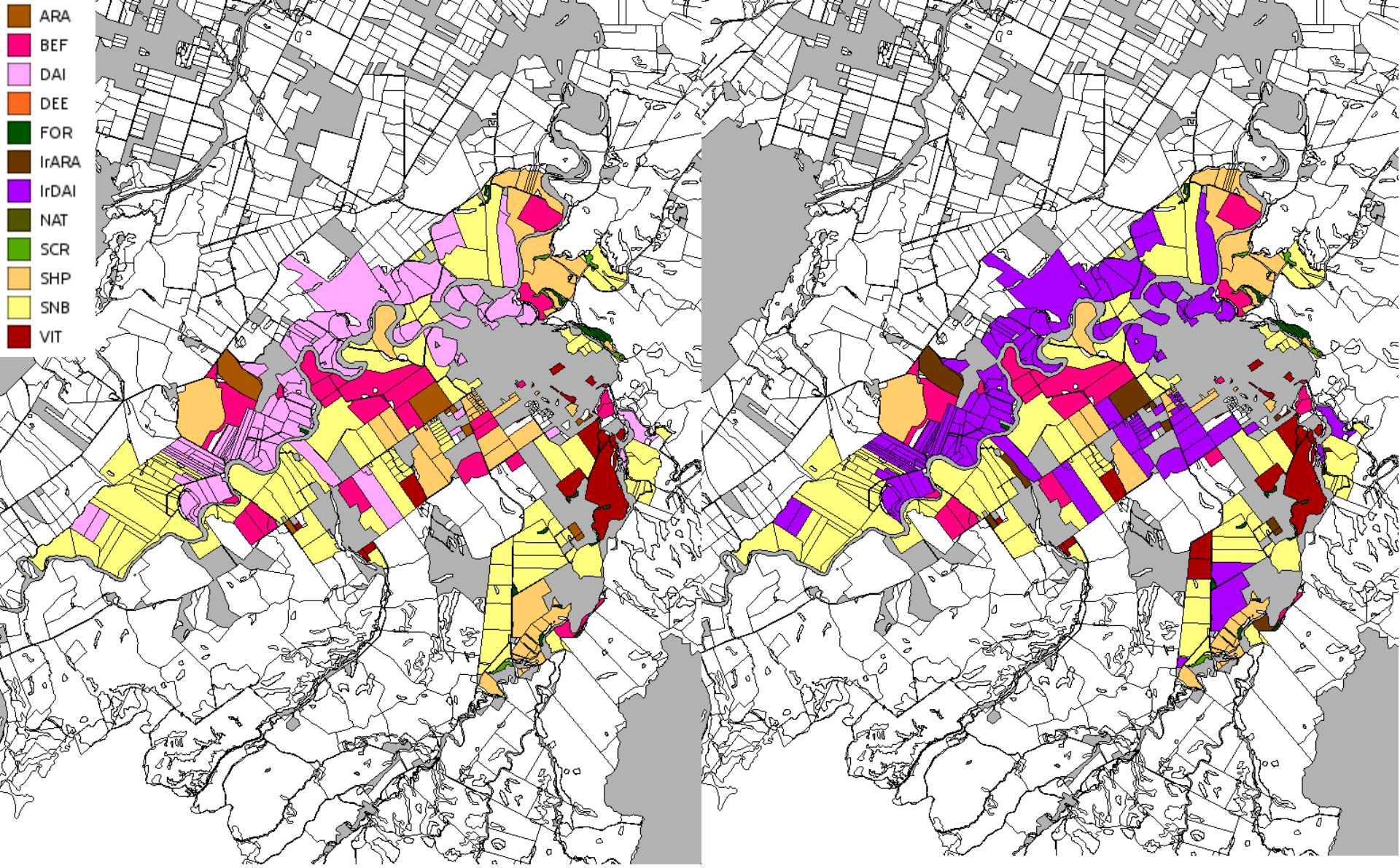
dairy → irrigated dairy
arable → irrigated arable
<x> → <x>



Ruamahanga



White Rock



Land Use - 2011

Dairy, Cropping, Viticulture Expansion

White Rock

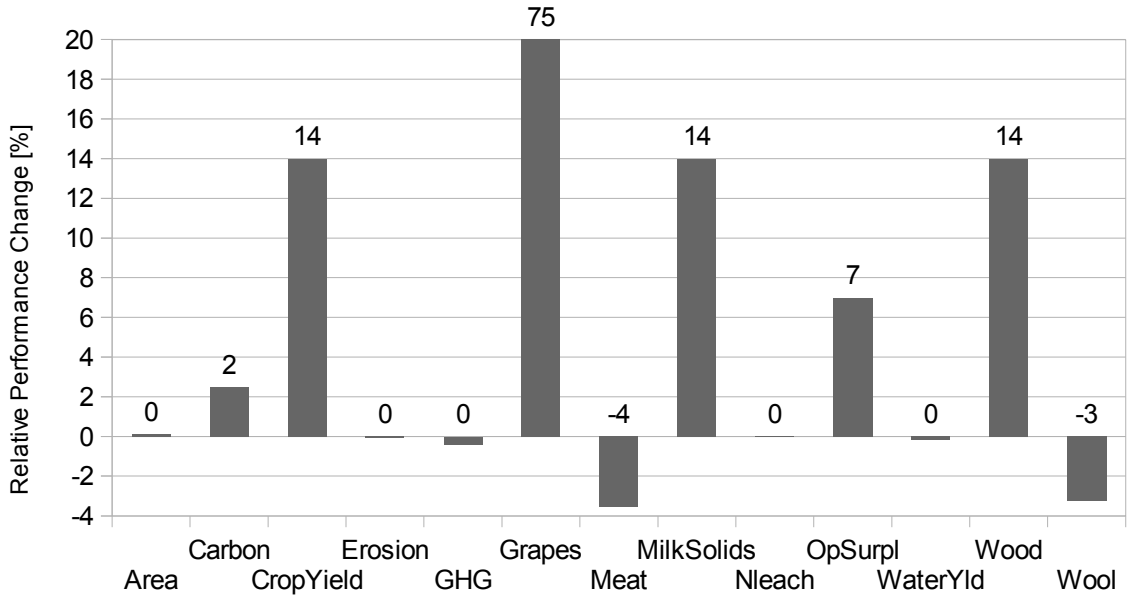
Surplus maximisation
(unconstrained) BC-S5

objective & performance constraints

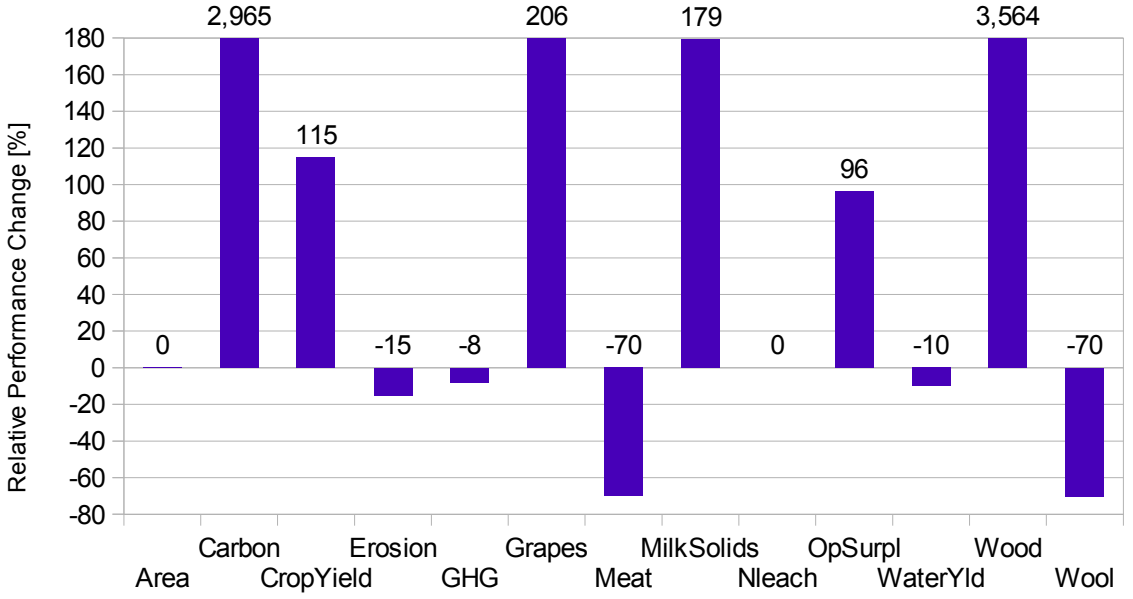
max operating surplus
GHG <= yr2011
N leach <= yr2011
meat >= 30% yr2011
wool >= 30% yr2011
wood >= 30% yr2011
<x> >= yr2011

land-use conversion constraints

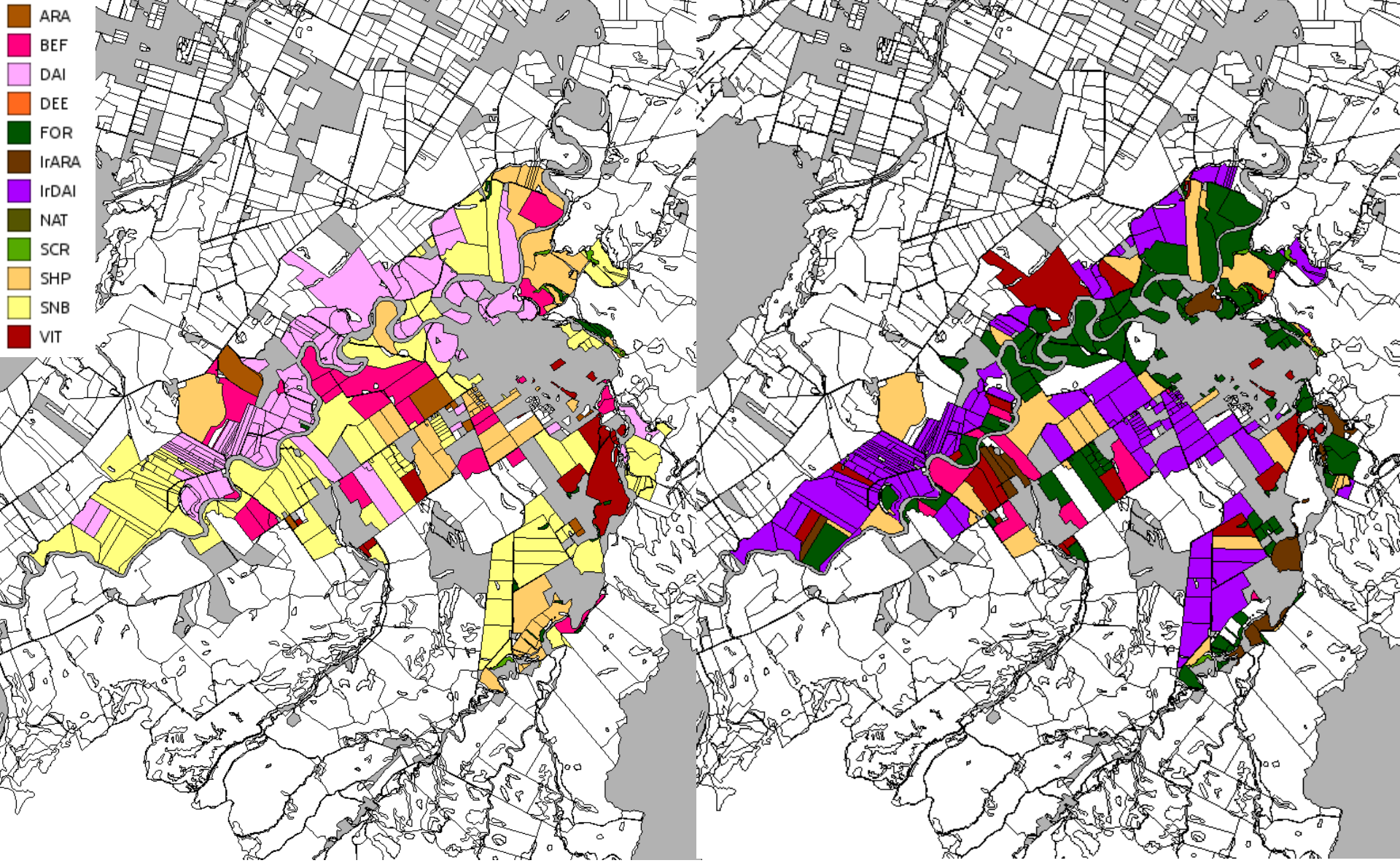
viticulture → viticulture
scrub → scrub
native bush → native bush
<x> → <y>



Ruamahanga



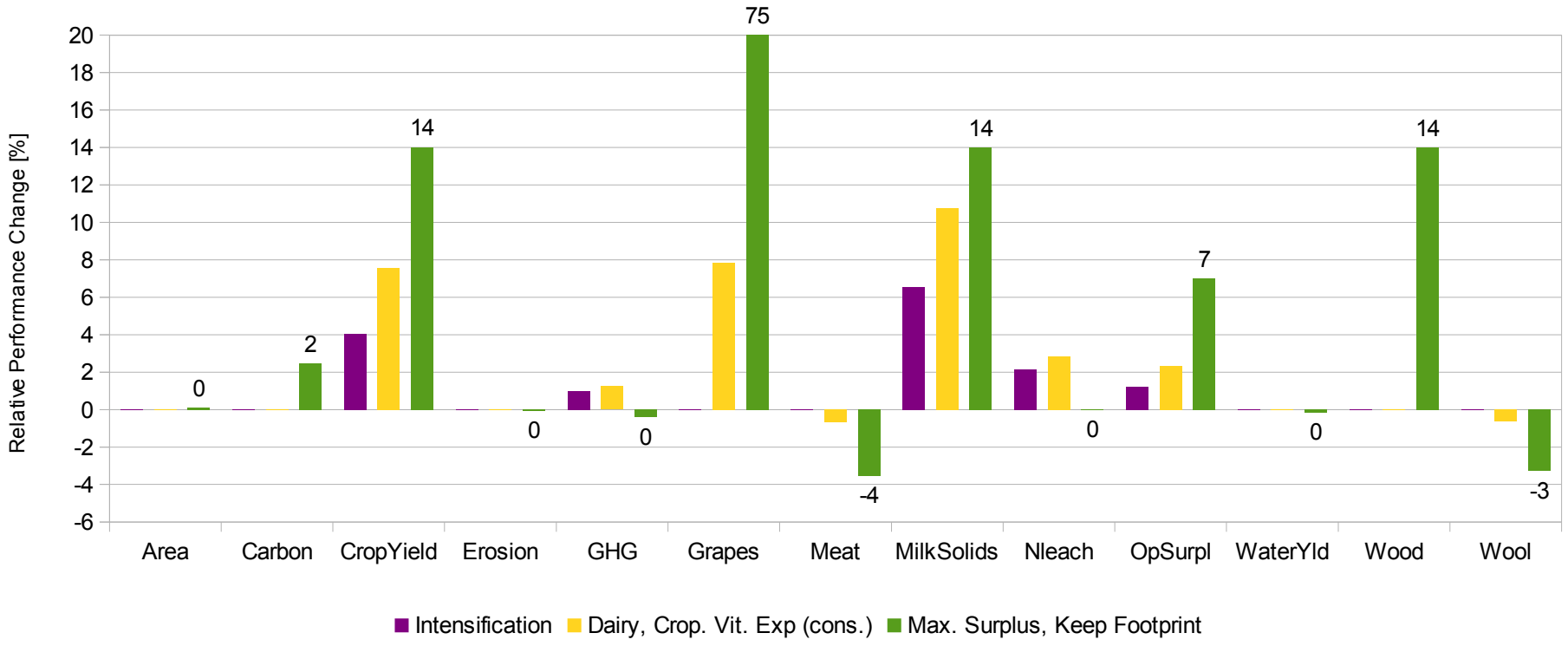
White Rock



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

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