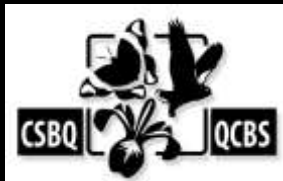


# Un réseau d'infrastructures vertes pour la biodiversité et les services écologiques



Andrew Gonzalez  
@bio\_diverse

McGill University & Centre de la Science de la Biodiversité du Québec

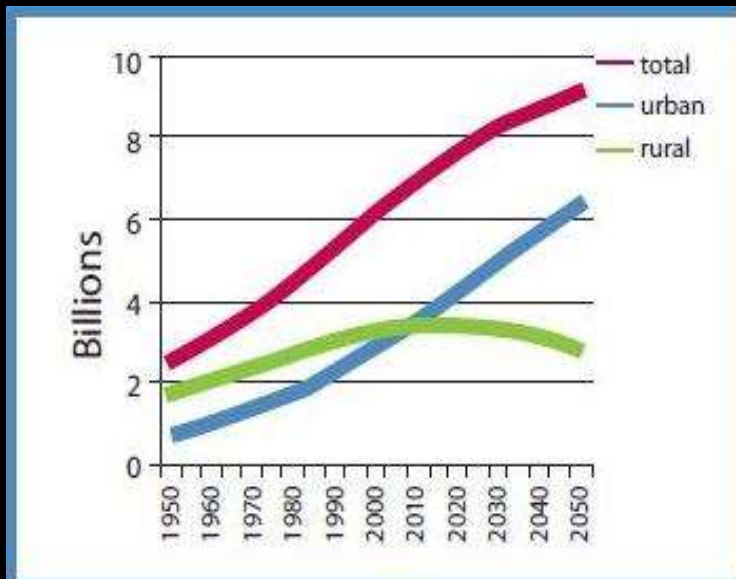


# *Un nexus de 3 tendances majeures:*

*1. Population urbaine*

*2. Changement climatique*

*2. Changement de Biodiversité*



*World Population: Urban and Rural 1950-2050*

*(source: UN Dept of Economic and Social Affairs, 2007)*



*Biodiversité*



*Qualité de vie*

*Thérapeutiques*

*Maladies  
Infectieuses*

*Ecosystèmes*

*Santé*

*Bien être*

# Fragmentation de l'habitat sur l'île de Montréal

Montréal 1650



Montréal 1700

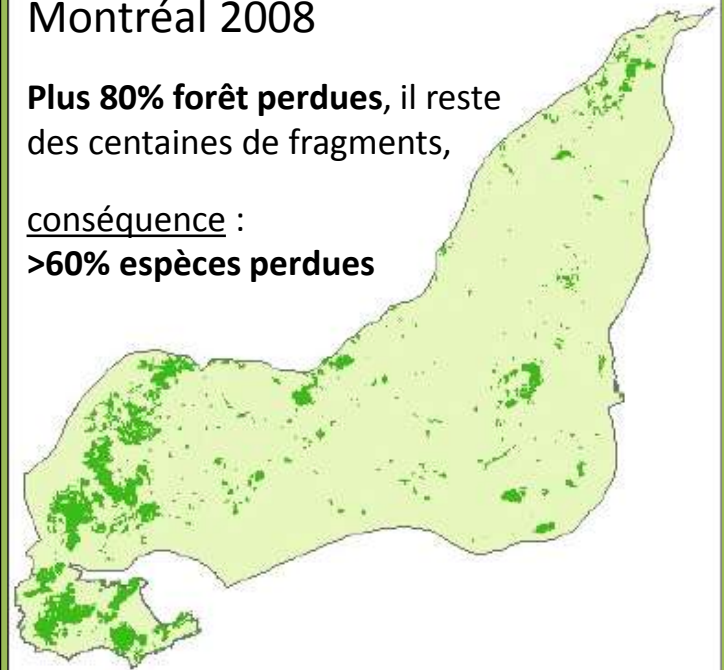


Montréal 2008

Plus 80% forêt perdues, il reste des centaines de fragments,

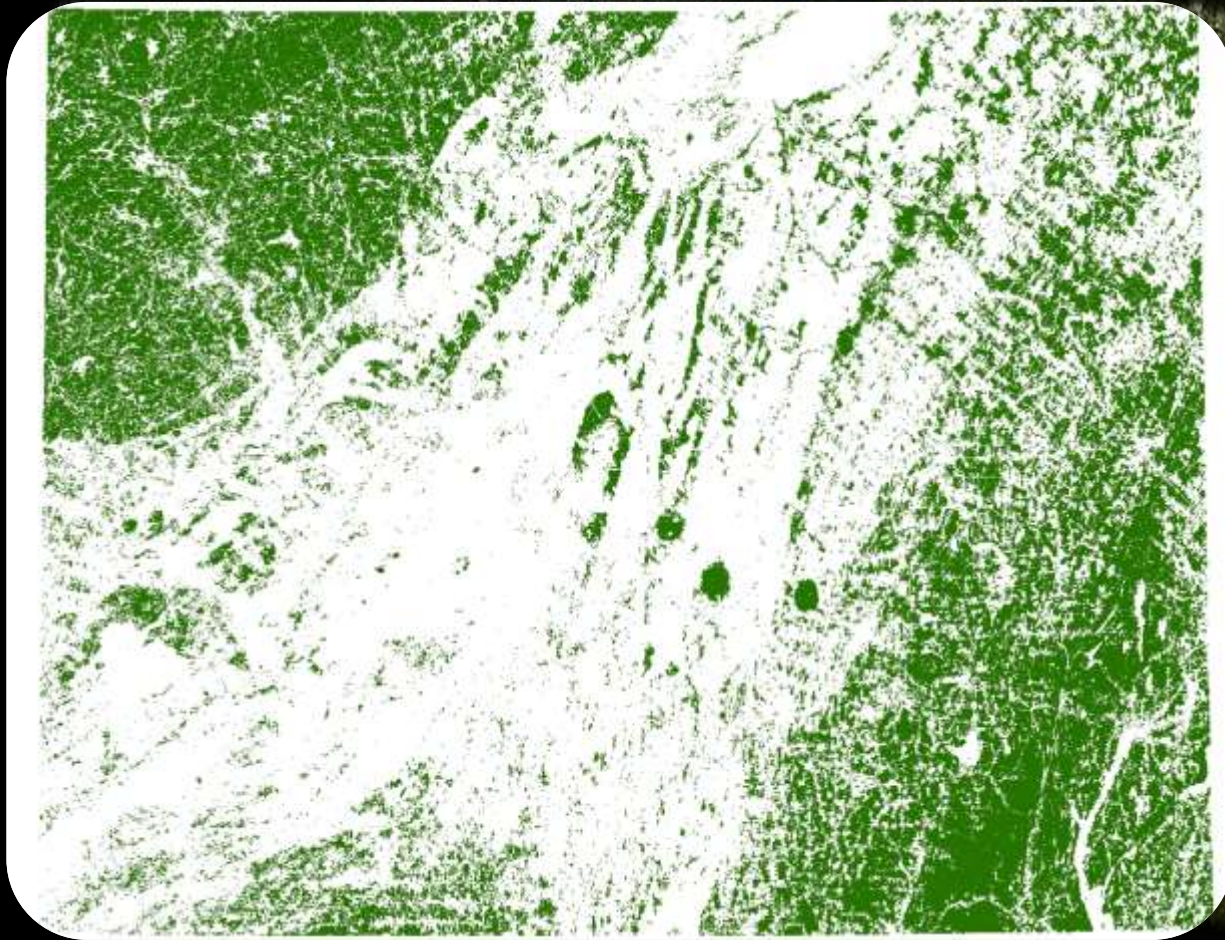
conséquence :

**>60% espèces perdues**



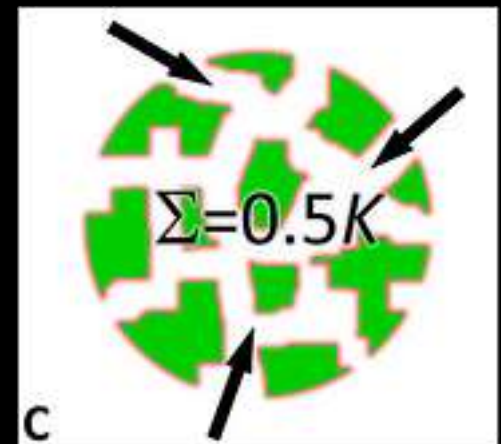
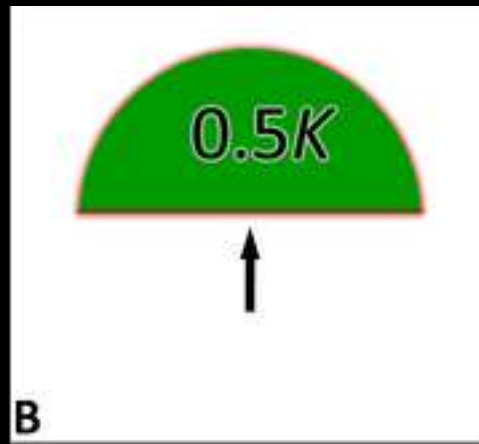
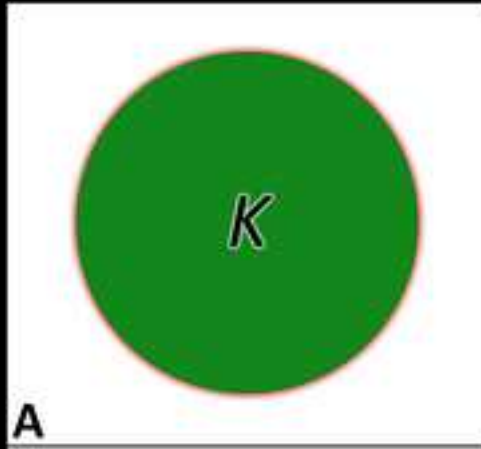
Base de données topographiques du Québec

# La viabilité écologique de la région est menacée.



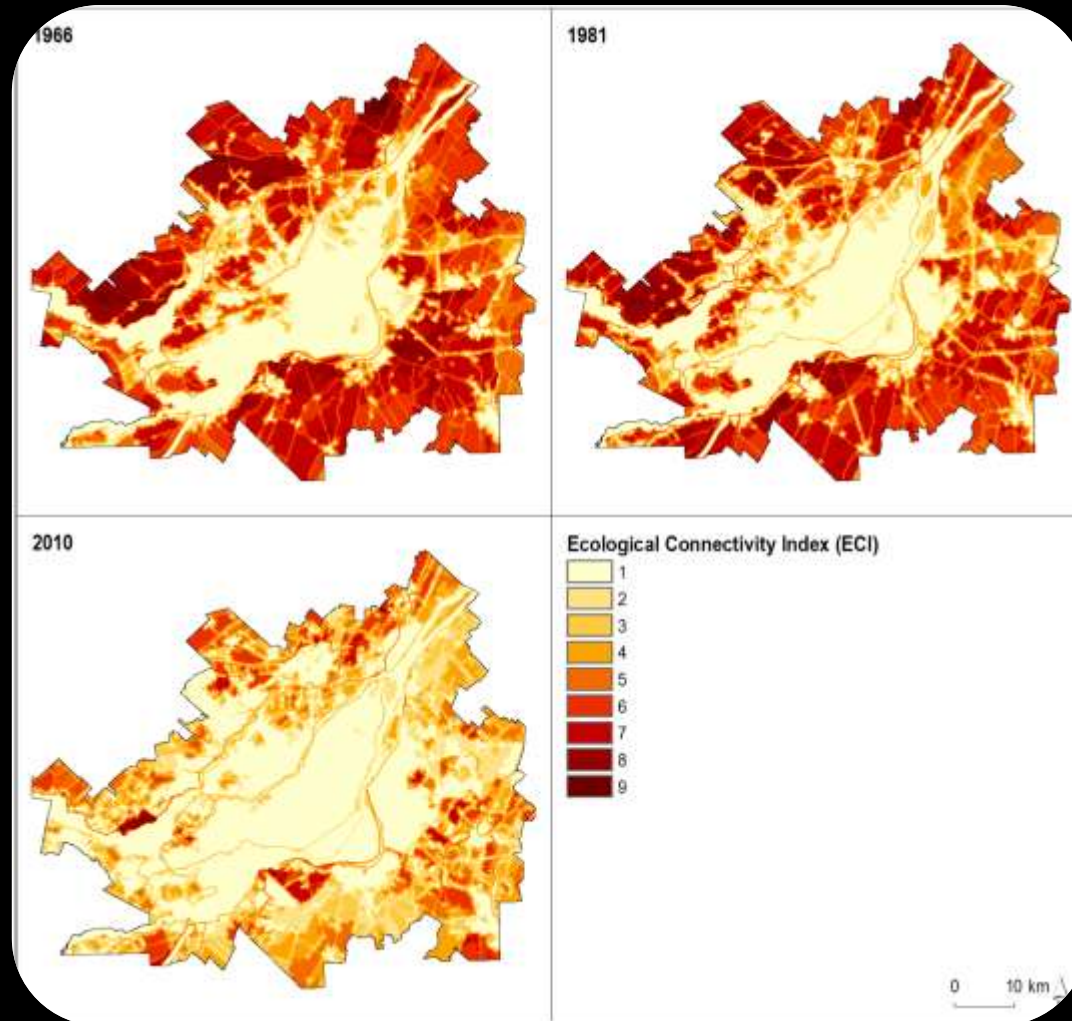
- Augmentation de  $\sim 2.6^{\circ}\text{C}$  prévu pour 2070
- 40% des espèces en situation précaire.
- Seulement 1% du milieu terrestre est protégé.

# Fragmentation d'écosystèmes



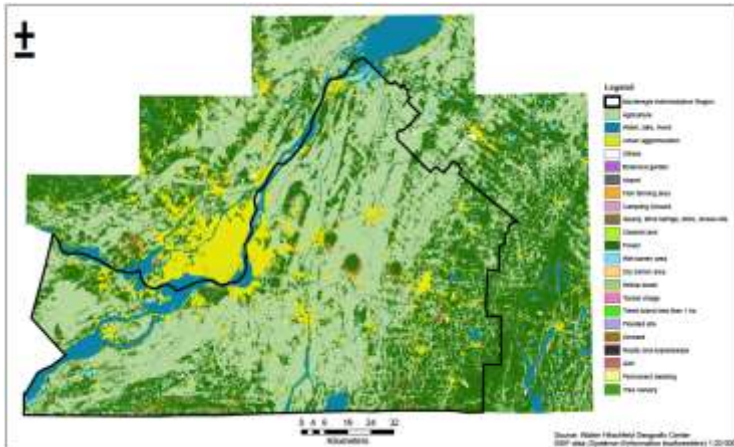
- 1) Loss of total area.
- 2) Increased number of small habitat fragments.
- 3) Increased edge.
- 4) Fragments increasingly isolated (connectivity lost).

# La connectivité érodé

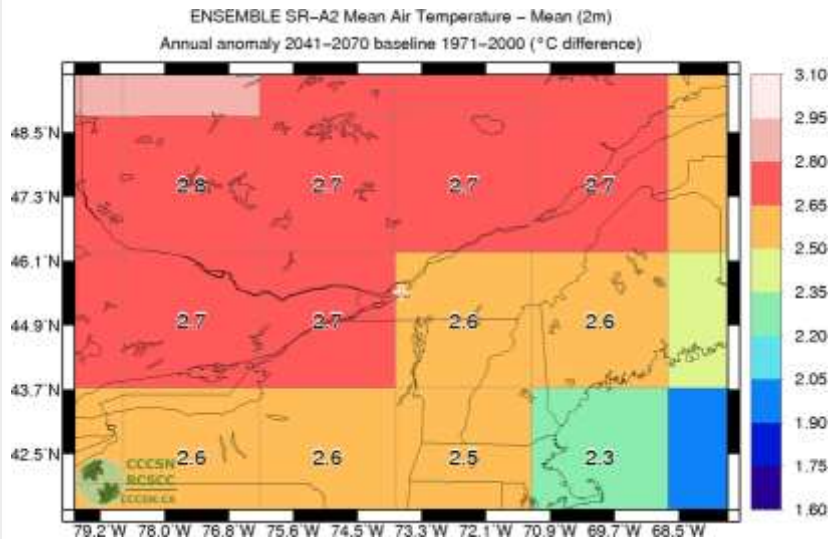


# Changements environnementaux

## Utilisation des terres (déboisement)



## Changements climatiques régionaux



<http://atlantic.cccsn.ca/>

# Écosystèmes perturbés

## La diversité biologique

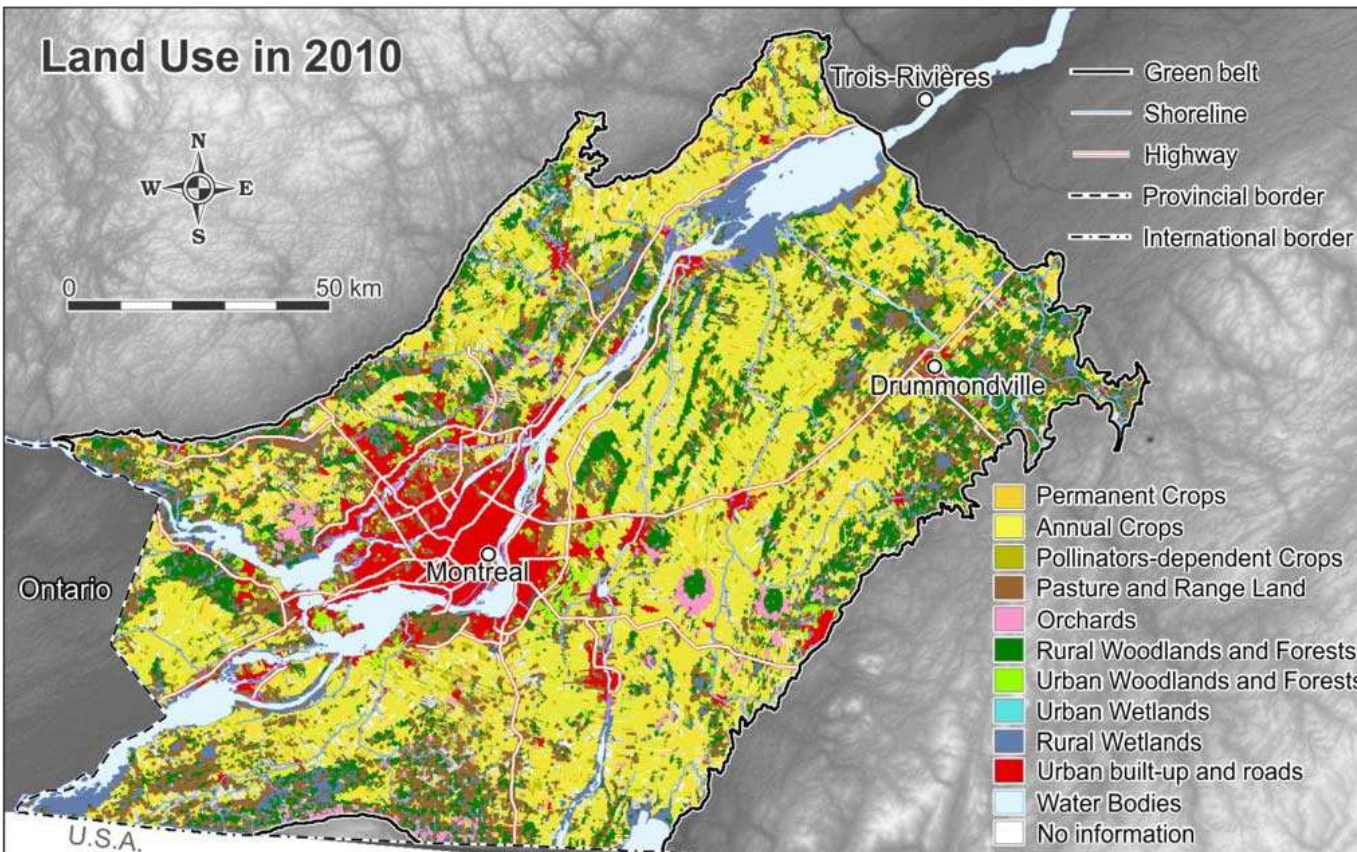


## Les services écologiques



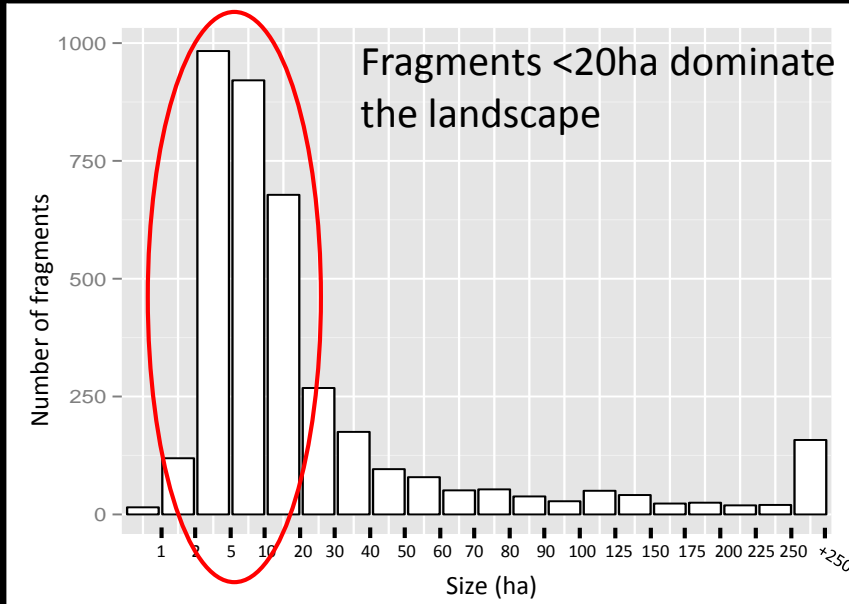


# Greater Montreal ES Valuation – Green Network



Ecosystem Service	Total Value (\$M)/y
	2173.3
Global Climate Regulation	17.8
Air Quality	366.4
Water Provisioning	220.9
Waste Treatment	122.2
Erosion Control	16.2
Pollination	26.0
Biodiversity Habitat	910.5
Disturbance Prevention	34.9
Nutrient Cycling	21.9
Aesthetics	54.1
Recreation	382.4

# Small fragments, big contribution...



C stored  
(aboveground)  
in forest fragments  
<20 h

## Montreal's annual emissions

All  
transportation

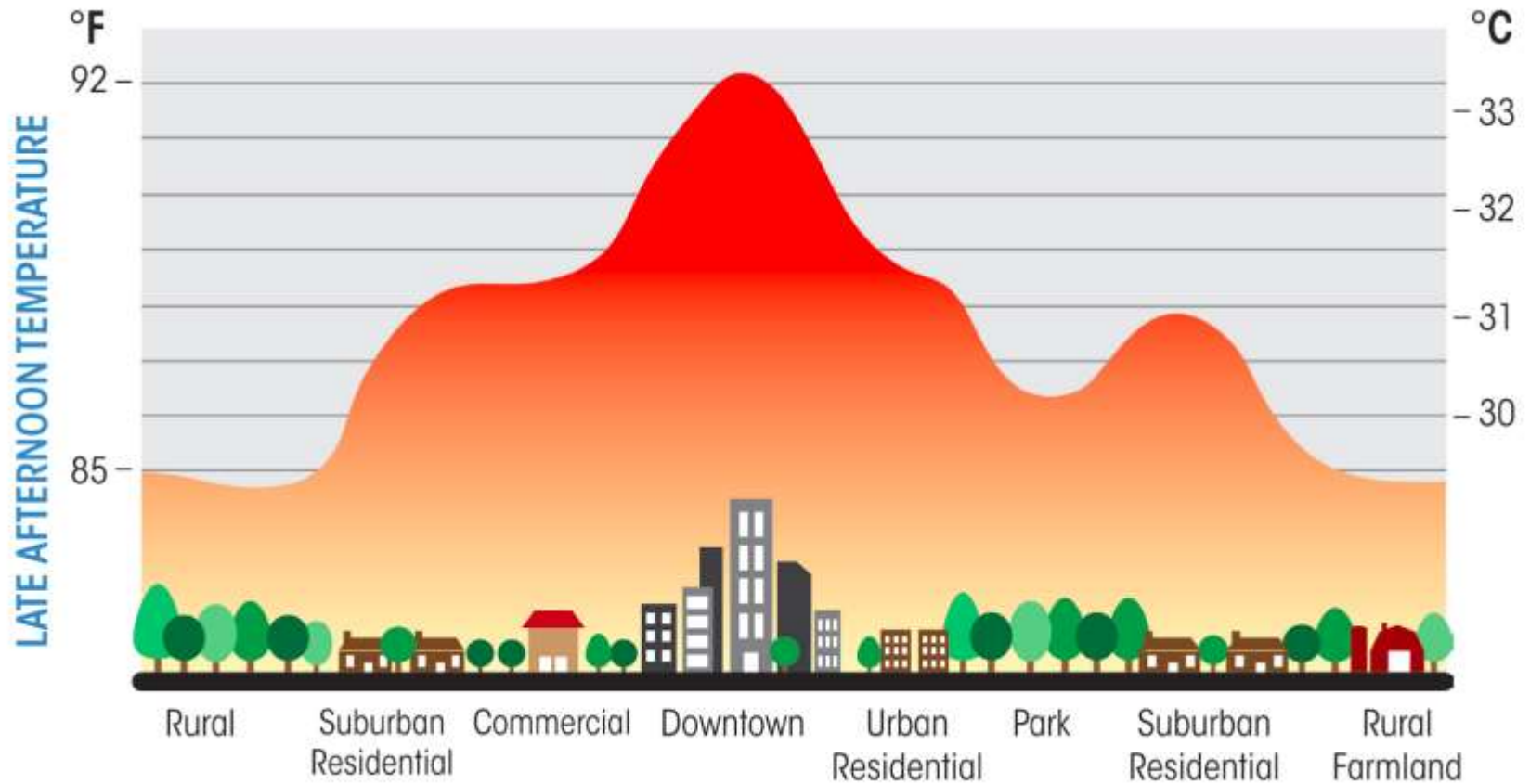
All  
industry

All  
buildings

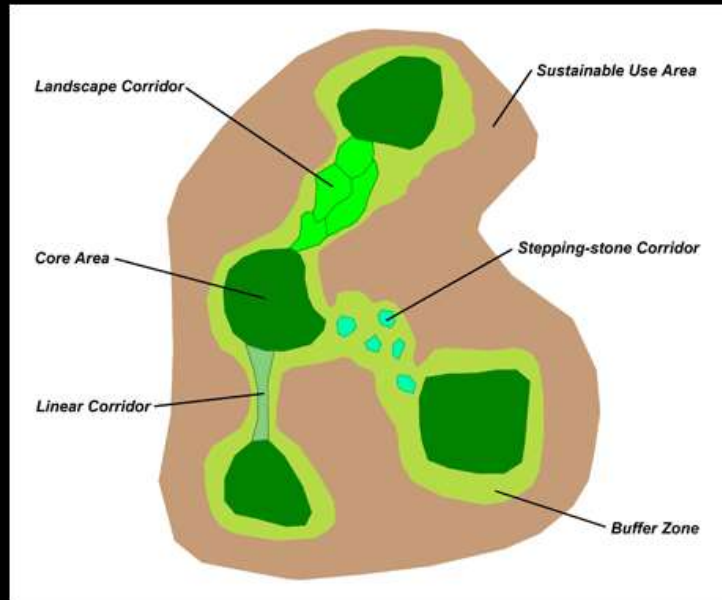
... on the Island of Montréal

# Îlots de chaleur a Montréal

FIGURE 7 : MODÉLISATION DE LA TEMPÉRATURE DE SURFACE DANS LES ZONES URBAINES DE LA CMM AVEC UNE DENSITÉ DE POPULATION SUPÉRIEURE À 100 HABITANTS PAR KILOMÈTRE CARRÉ



# Les infrastructures vertes



Corridor riverain



Corridor urbain (planifié)

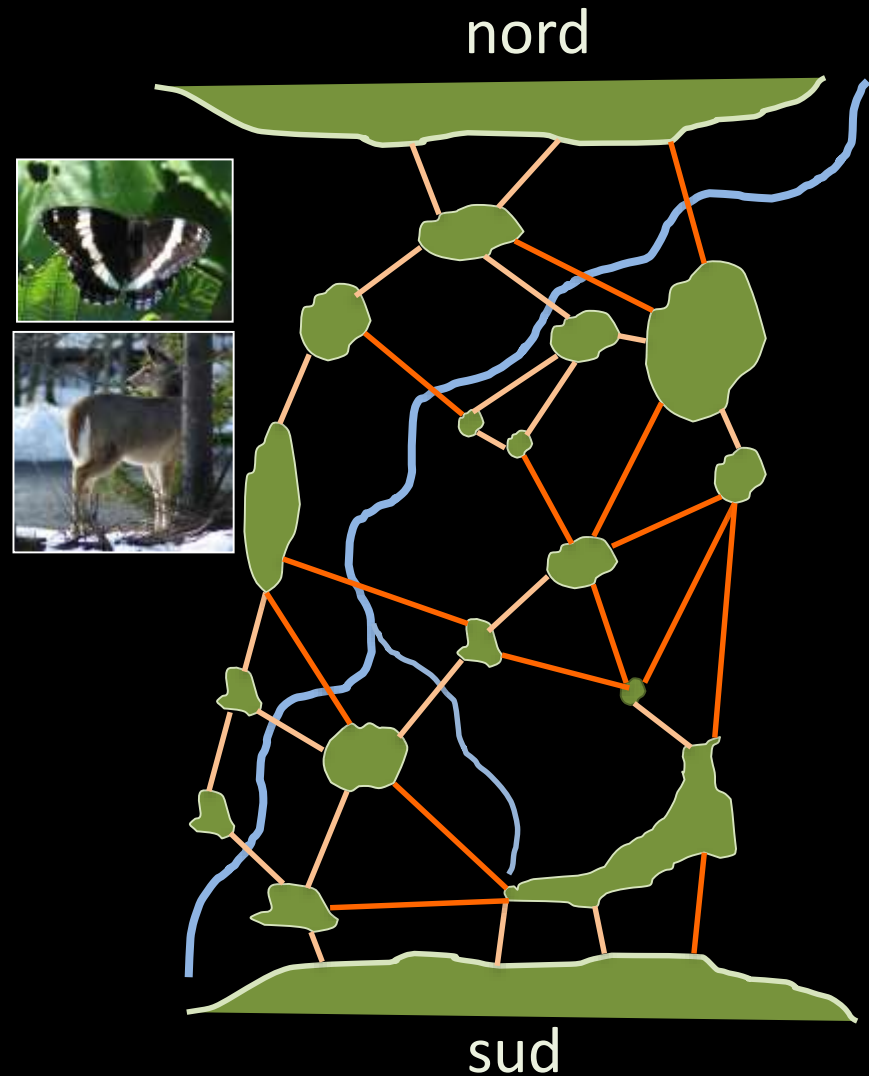


Corridors à usages multiples:  
Corridors urbains  
Corridors riverains  
Corridors continentaux (migratoires)

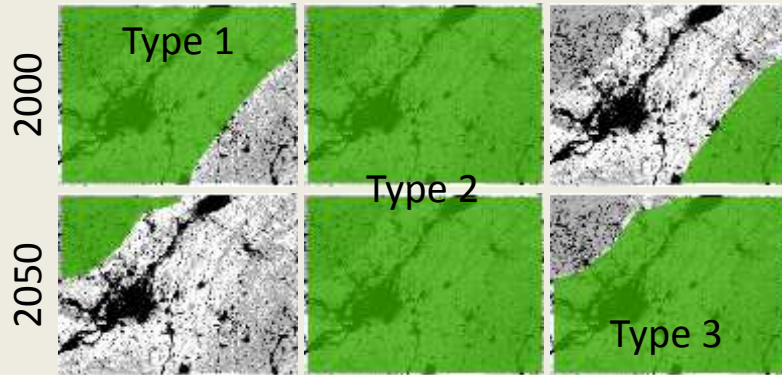
# Réseaux écologiques

**1) Assurent les mouvements des organismes**

**2) Maintiennent la biodiversité et le fonctionnement des écosystèmes.**



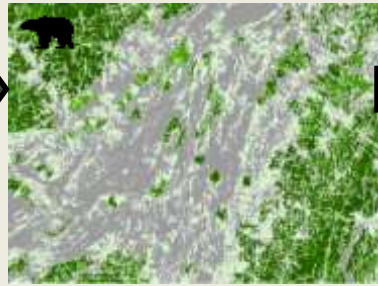
## Climate suitability



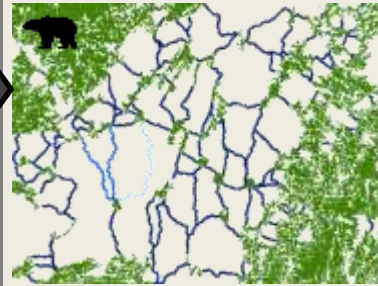
## Species selection



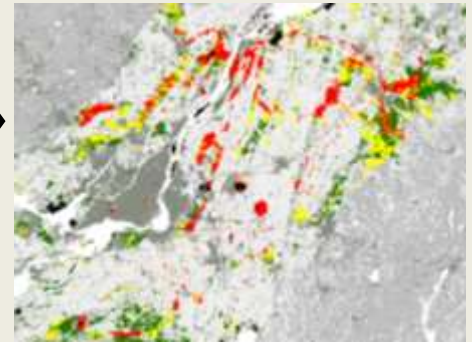
## Habitat quality



## Species' network

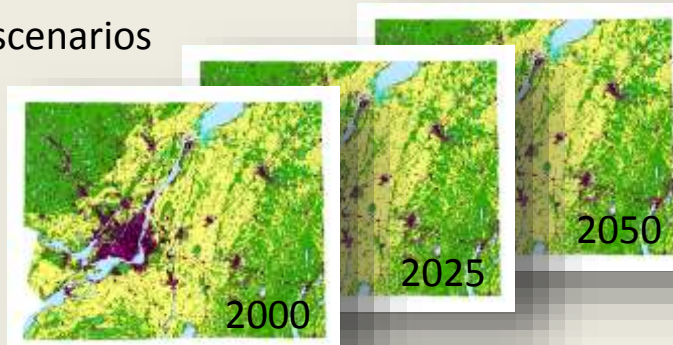


## Spatial prioritization



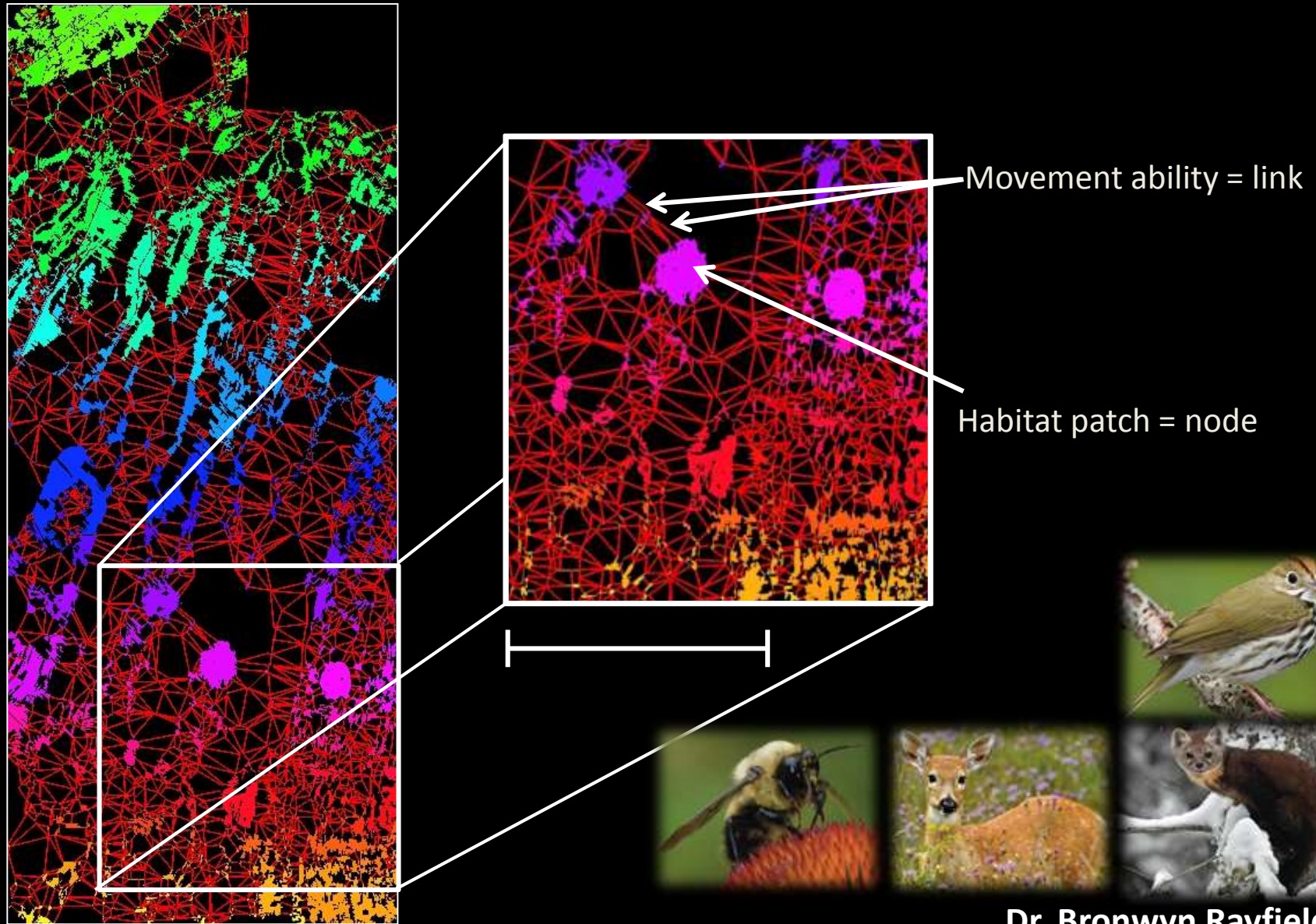
## Land use change simulations

x scenarios



Conservation  
scenarios

# Defining an Ecological Network



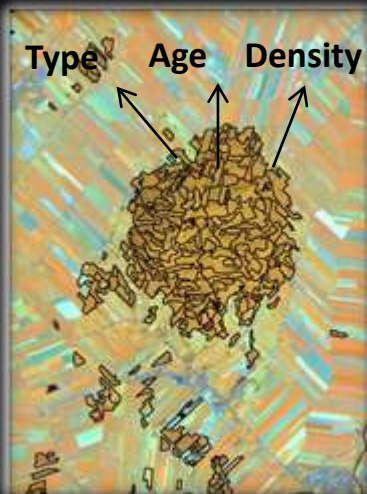
# Habitat quality of a single node, across species



representative species of mature and old deciduous dominated forests



Ovenbird



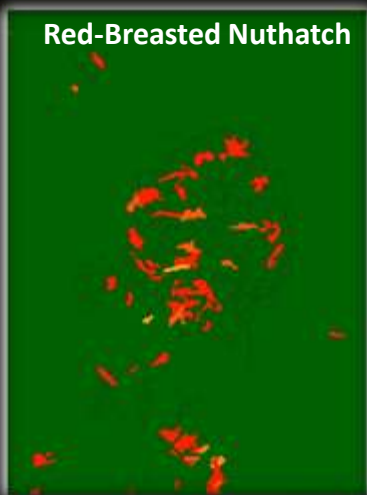
American Marten



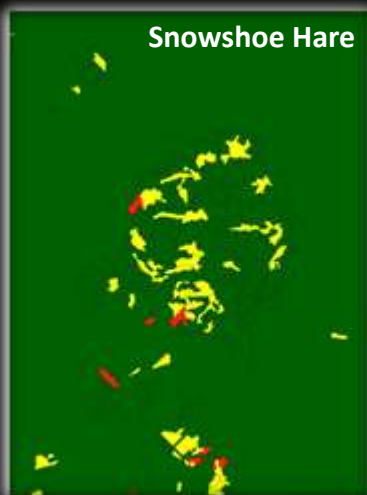
associated with forests old and mature coniferous dominated forests



representative species of mature and old coniferous dominated forests



Red-Breasted Nuthatch



Snowshoe Hare



Pileated Woodpecker



old and mature deciduous and mixed forests

Value

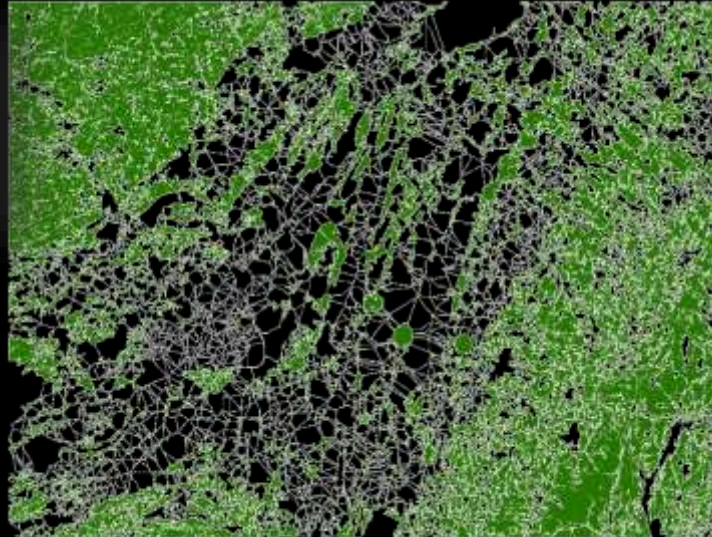


High

Low

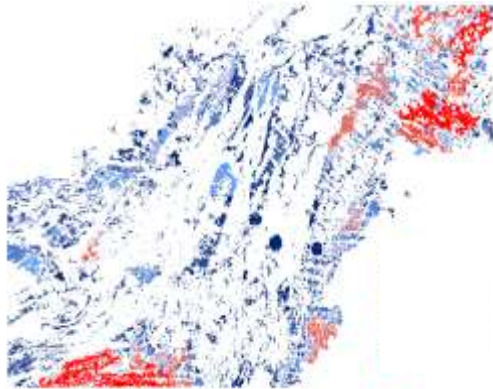


# *Le réseau d'habitat pour chaque espèce*

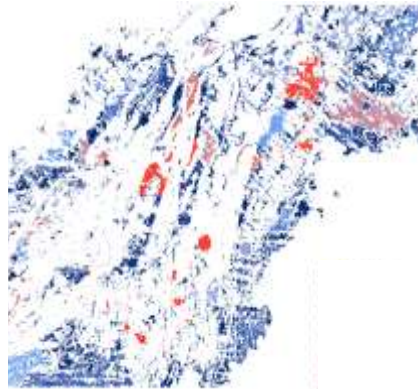


# Network Optimization: ranking the contribution of each fragment to the network

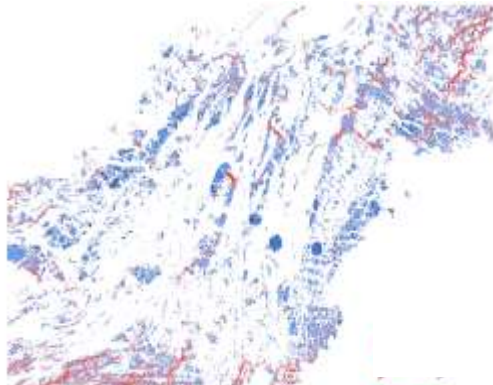
**Metapop. Capacity**



**Centrality**



**Current density**



**Habitat Quality**



## The value of the $i$ -th fragment

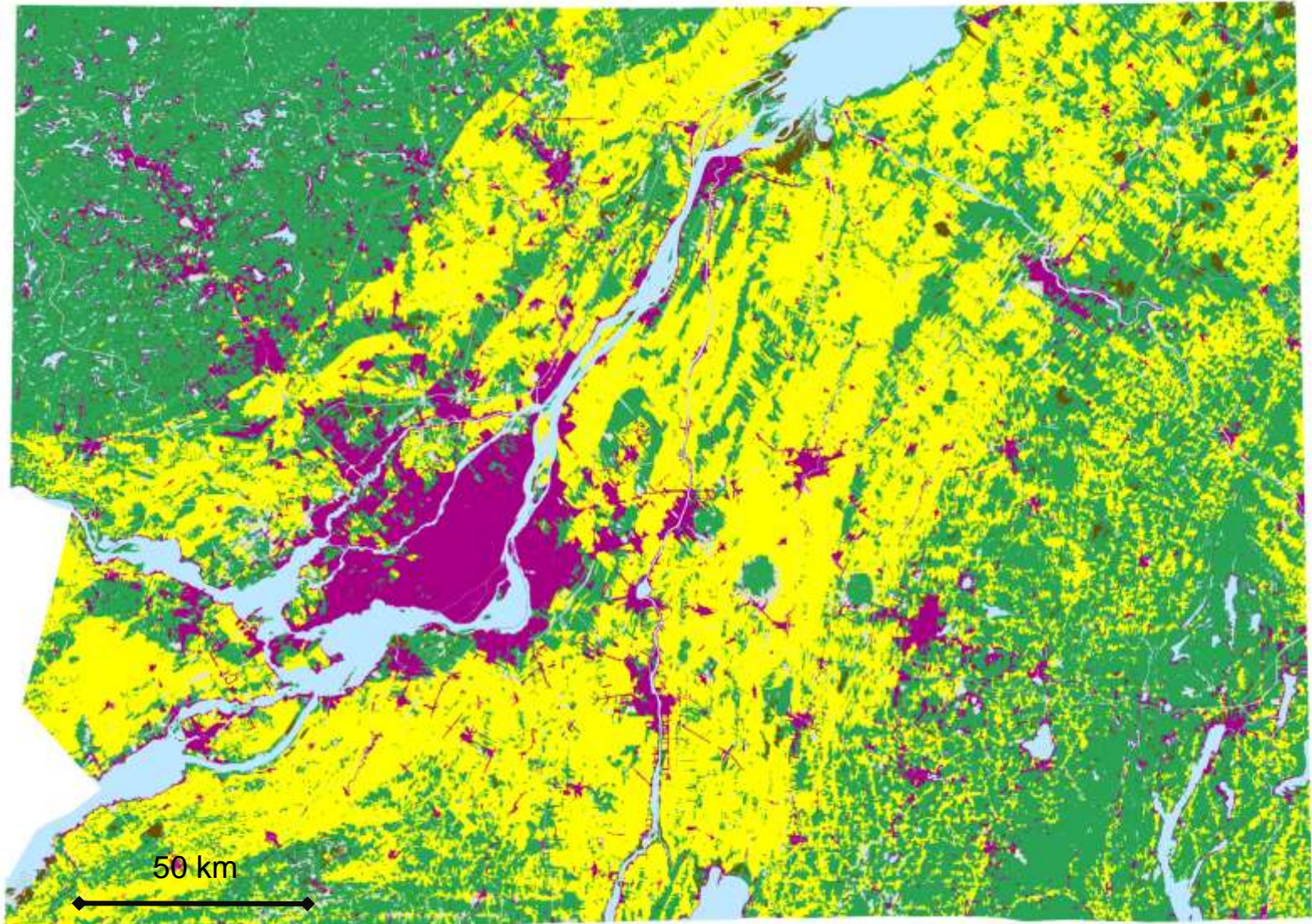
Additive benefit function

- Calculate the change for each metric when the  $i$ -th pixel is removed
- Repeat for all pixels
- Sum the change



Moilanen (2007)

# Présent



Forest

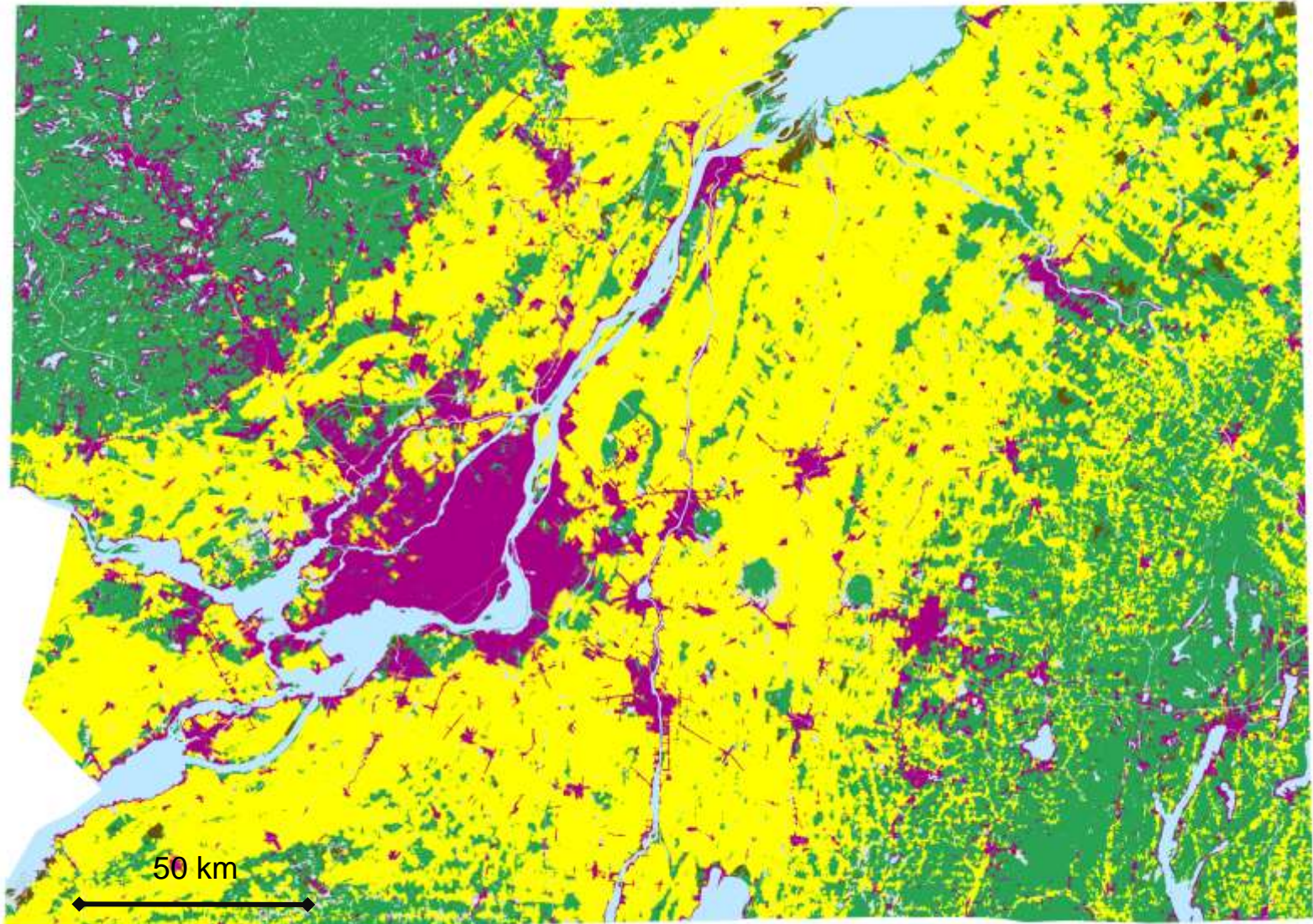


Agriculture



Urban

# Status Quo pour 2050



Forest

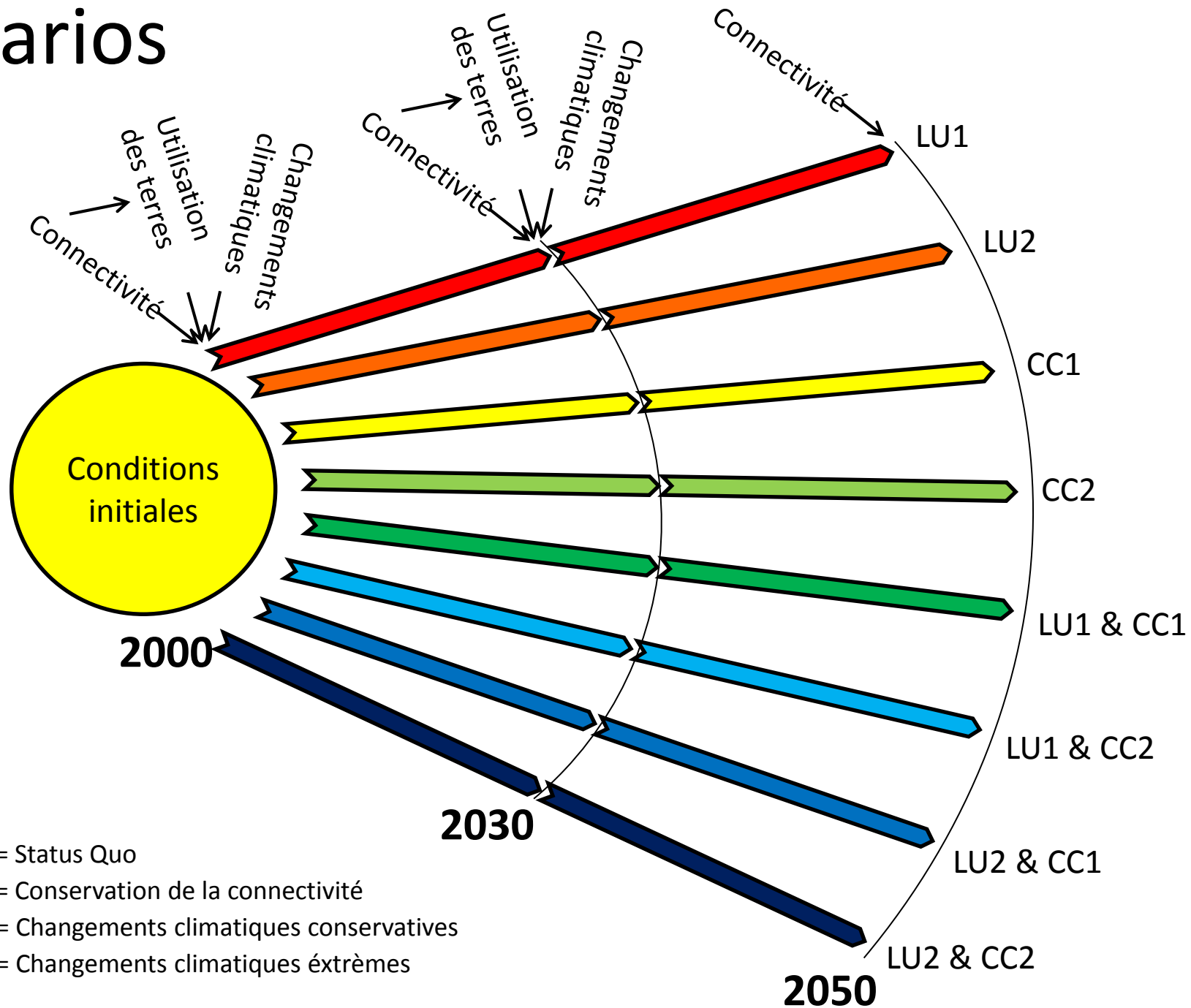


Agriculture



Urban

# Scénarios



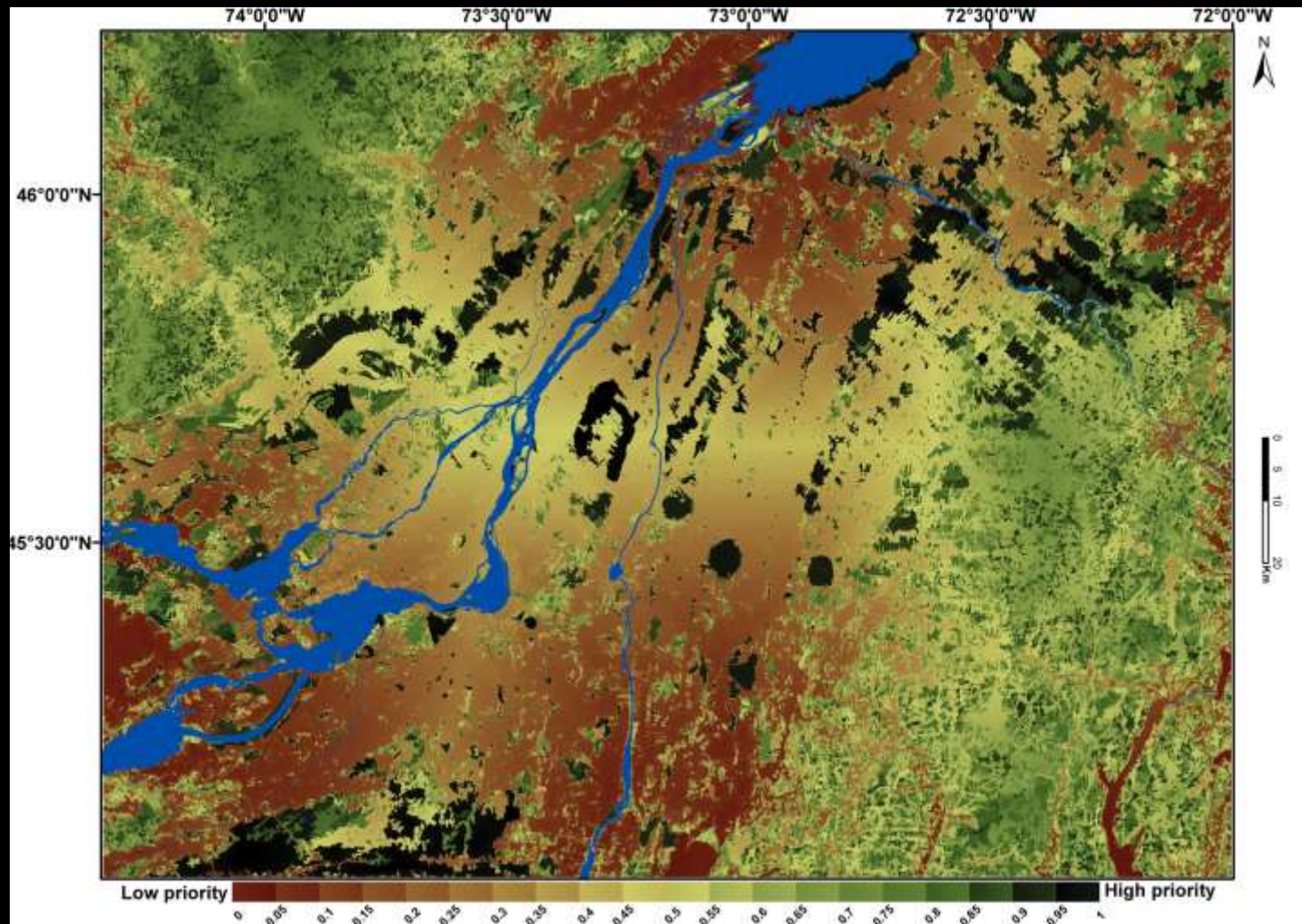
LU1 = Status Quo

LU2 = Conservation de la connectivité

CC1 = Changements climatiques conservatives

CC2 = Changements climatiques extrêmes

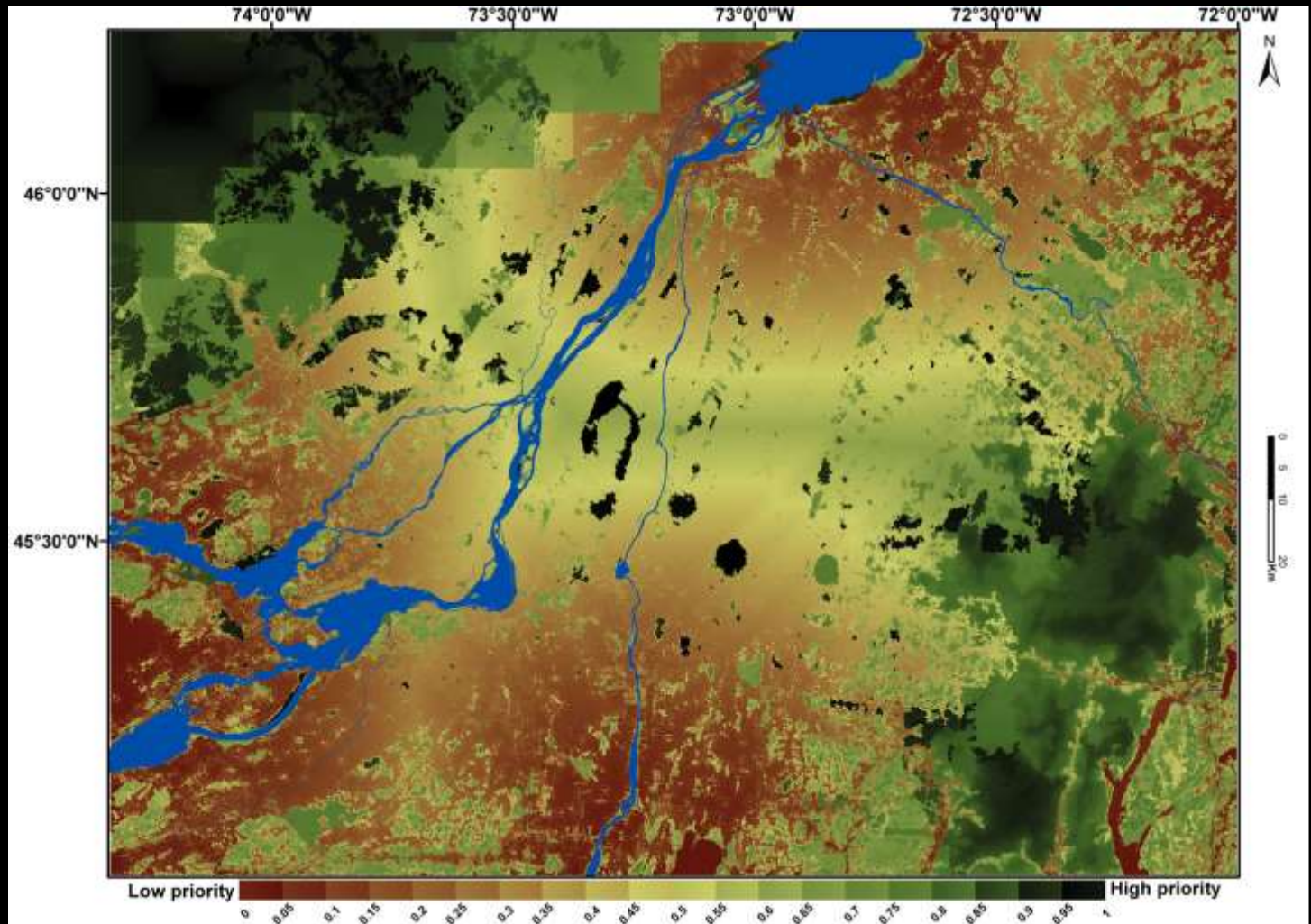
# Network Prioritisation for 2010



4 input layers with equal weighting (NB, ECA, HQ, CD) for 5 species

# Network Prioritisation for 2050, BAU only

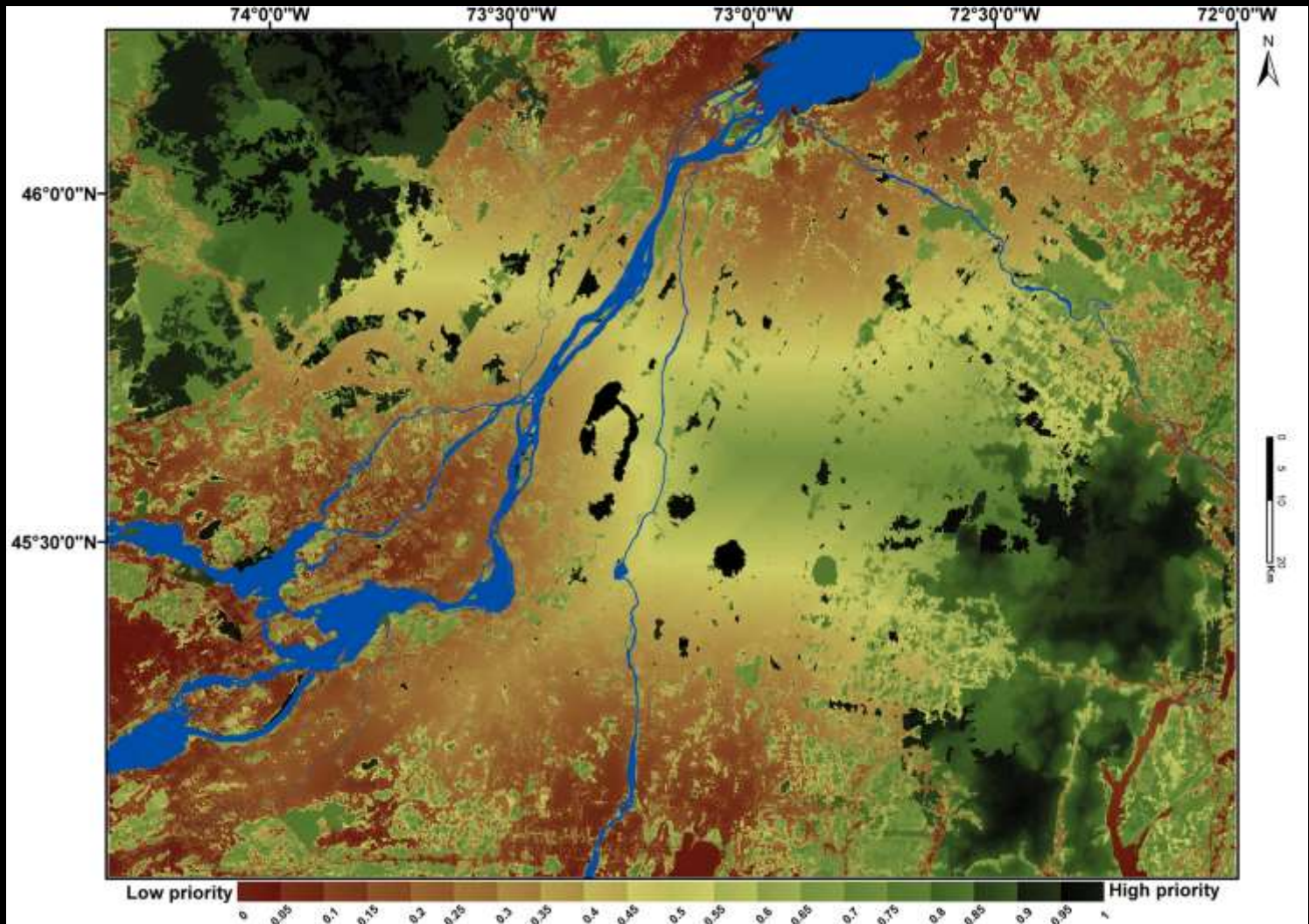
(Zonation v3.1, Moilanen et al. 2005)



Considerable erosion of the network, but prioritization similar

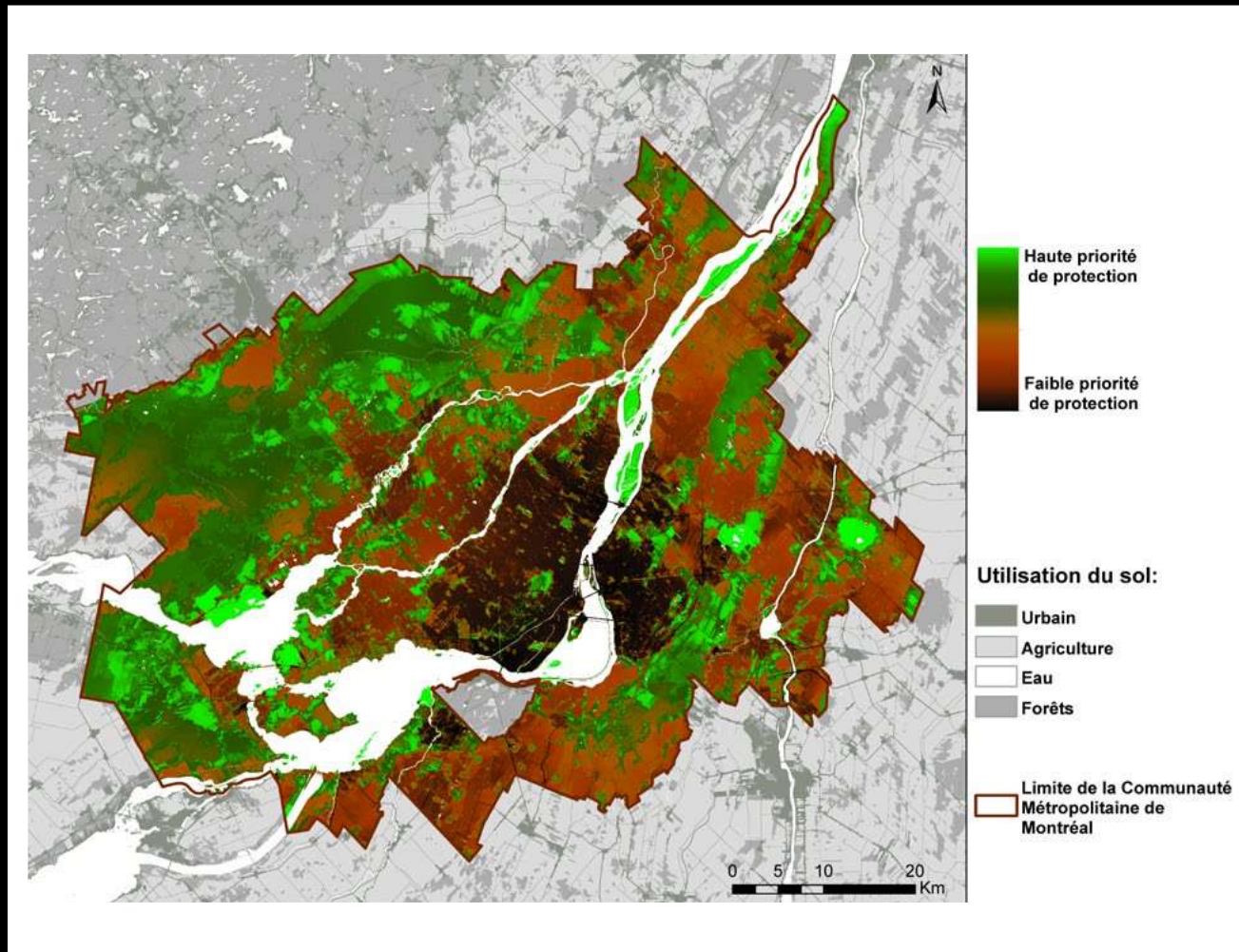
# Network Prioritisation for 2050, BAU + Clim 1

(Zonation v3.1, Moilanen et al. 2005)

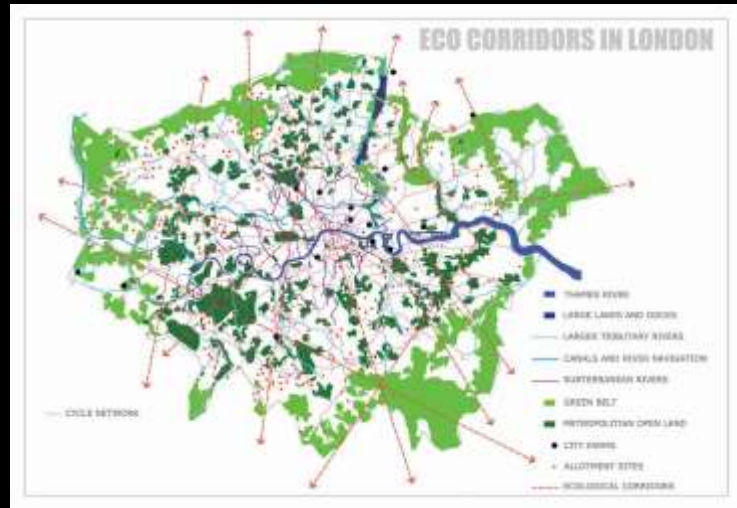




*Carte des priorités de conservation pour la connectivité, la qualité d'habitat, le climat, et la réduction des îlots de chaleur.*



# Infrastructure Verte



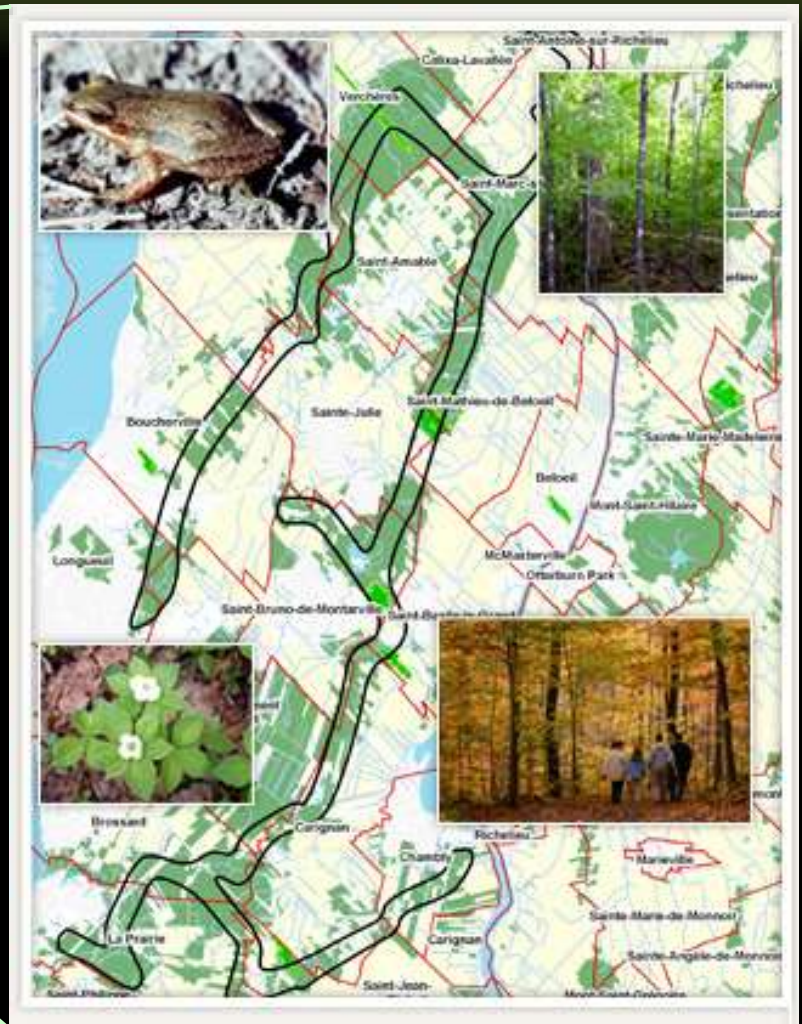
<http://ecocorridorsinlondon.blogspot.ca>



<http://worldlandscapearchitect.com>

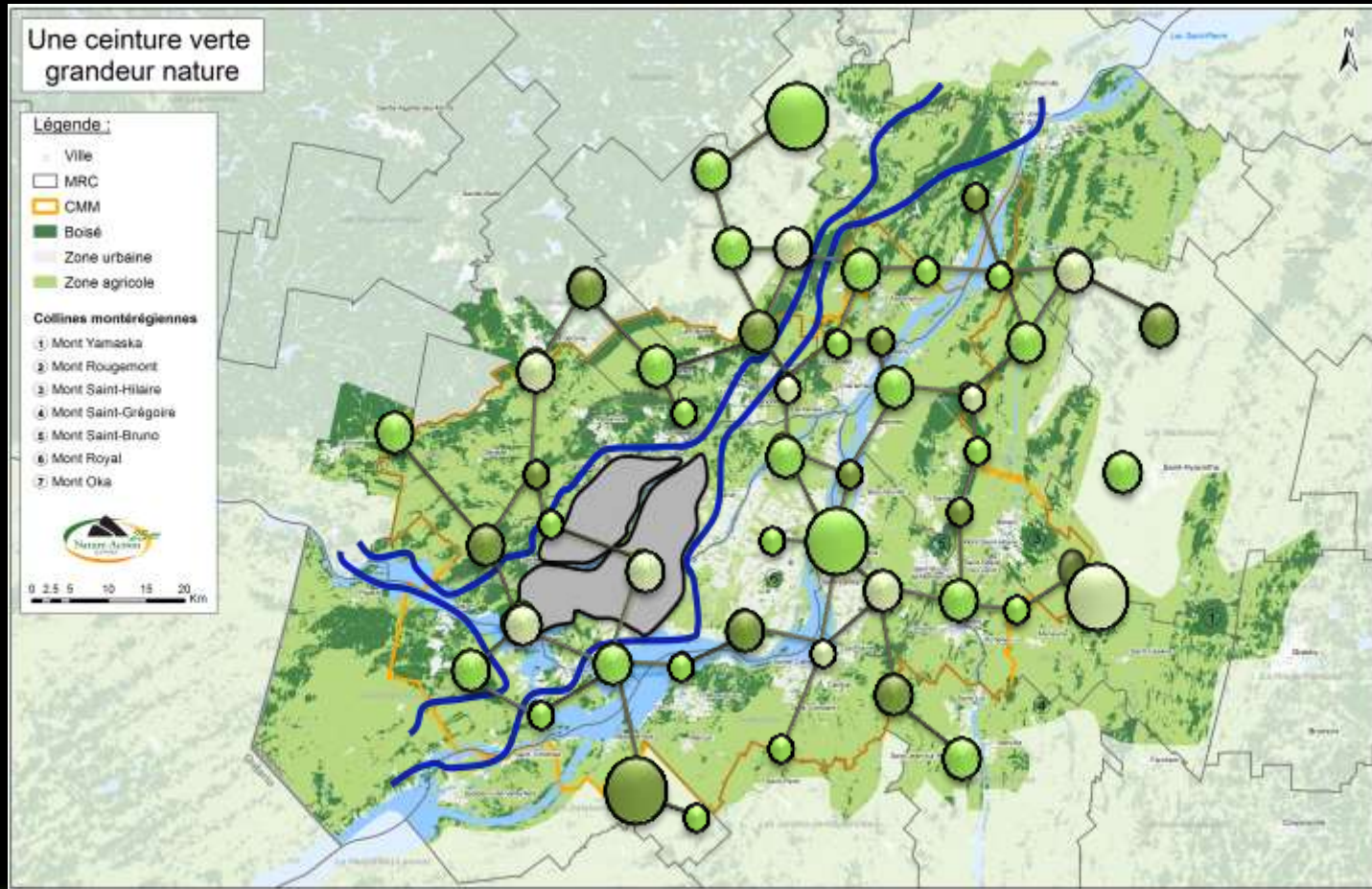


# Ecological planning for the region



NGO-driven conservation efforts to create corridors

# Science meets policy: Montreal greenbelt



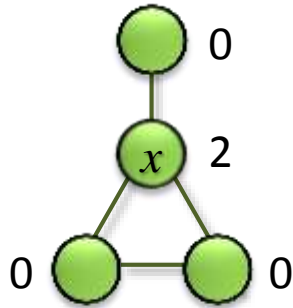
# Merci à vous et à nos partenaires...



# Analyse

## A. Priorisation des éléments

- Mesures de la centralité



### Centralité betweenness de noeud $x$

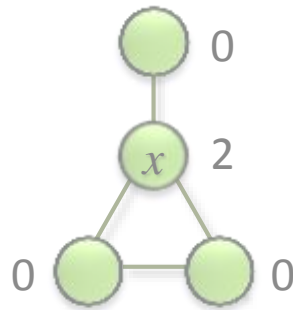
= le nombre de chemins de moindre coût reliant tous les noeds qui inclus  $x$

Freeman (1977)

# Analyse

## A. Priorisation des éléments

- Mesures de la centralité

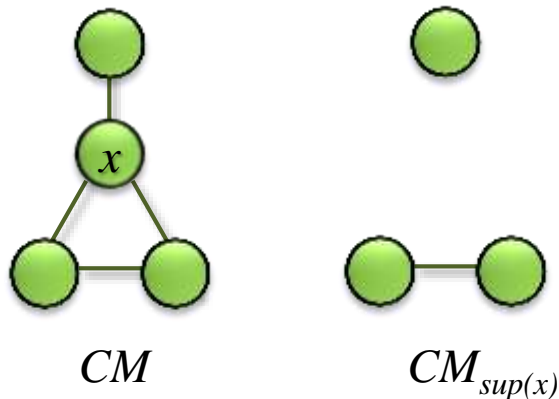


**Centralité betweenness de noeud  $x$**

= le nombre de chemins de moindre coût reliant tous les noeds qui inclus  $x$

Freeman (1977)

- Importance des éléments calculer par suppression



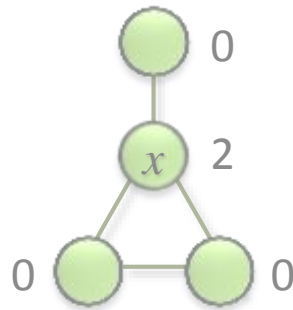
$$\Delta CM_x = 100 \times \frac{CM - CM_{sup(x)}}{CM}$$

Urban et Keitt (2001)  
Bodin et Saura (2010)

# Analyse

## A. Priorisation des éléments

- Mesures de la centralité

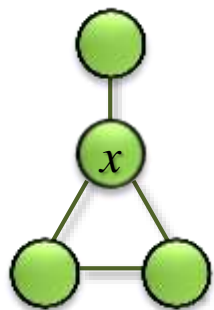


**Centralité betweenness de noeud  $x$**

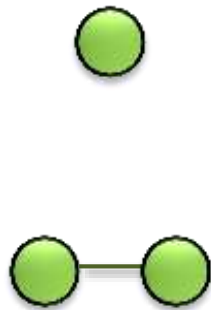
= le nombre de chemins de moindre coût reliant tous les noeds qui inclus  $x$

Freeman (1977)

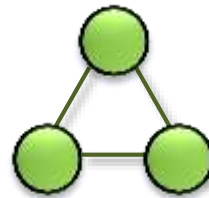
- Importance des éléments calculer par suppression



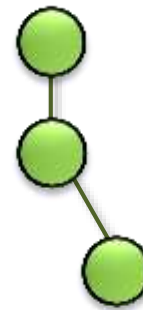
$CM$



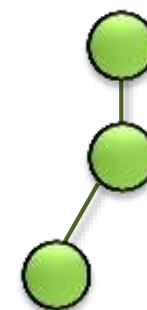
$CM_{sup(1)}$



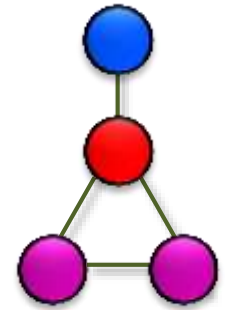
$CM_{sup(2)}$



$CM_{sup(3)}$



$CM_{sup(4)}$



Importance des noeuds



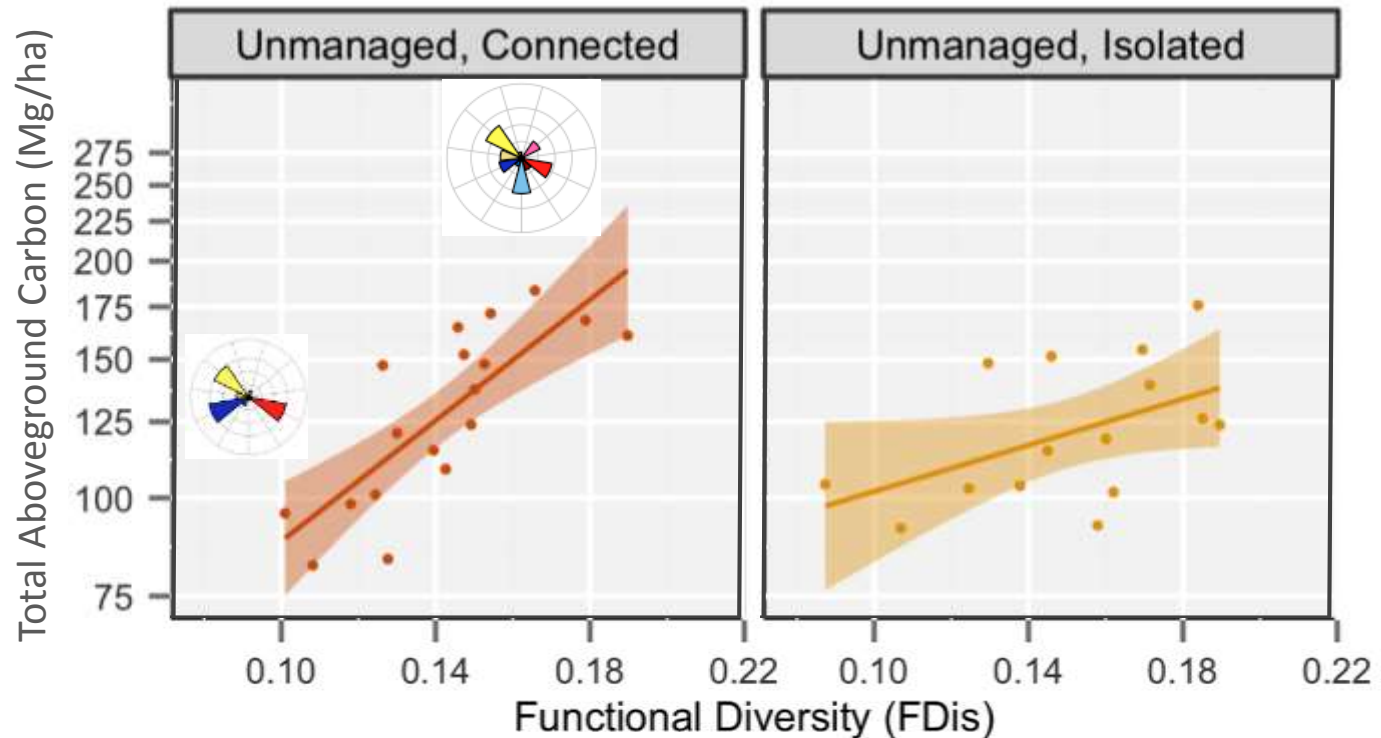
# Connectivity matters

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- 1) Connectivity mediates stability & trophic complexity  
(Loreau, Mouquet and Gonzalez 2003; Pillai, Gonzalez and Loreau 2011).
- 2) Connectivity maintains ecosystem function (Staddon et al. 2010).
- 3) Connectivity increases the probability of evolutionary rescue in metapopulations (Bell & Gonzalez 2011 Science).
- 4) Connectivity mediates range shifts under climate change



# Connectivity strengthens the biodiversity-carbon relationship in forest fragments



Ziter, Bennett and Gonzalez (2013) *Ecosphere*

# Les corridors ralentissent la perte de la biodiversité

