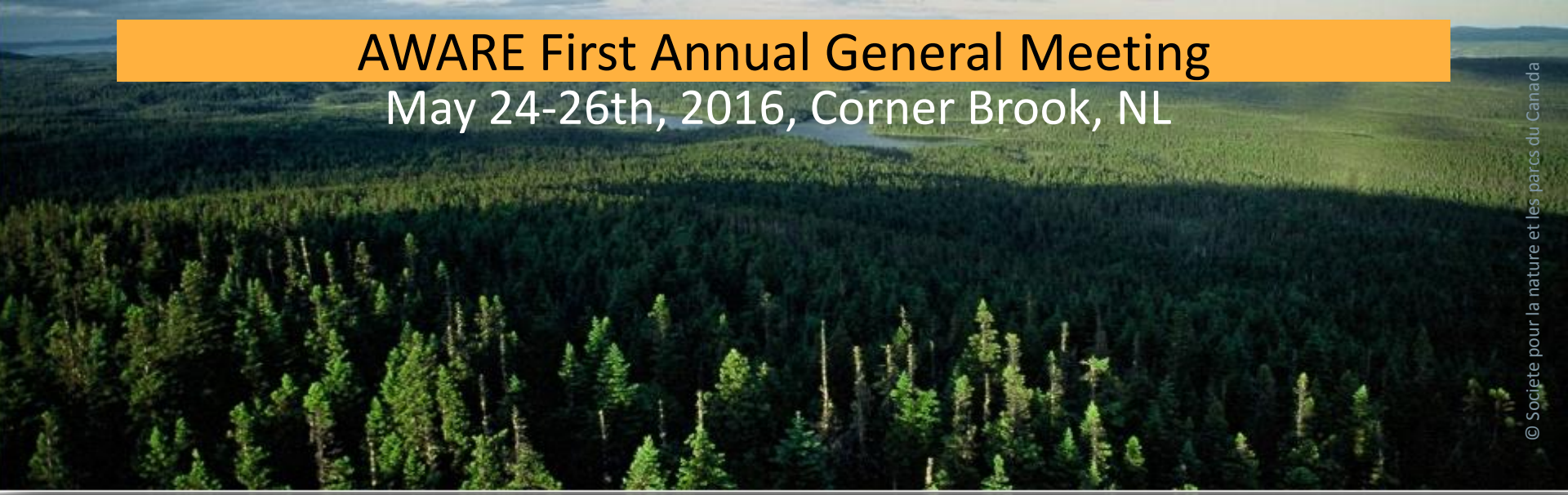


AWARE First Annual General Meeting

May 24-26th, 2016, Corner Brook, NL

Mapping the impacts of forest management activities on aquatic ecosystem services provided by forest

A. Schmidt[1] et *al.**

*R. A. Fournier[1], J. E. Luther[2], D. Harris[2], B. Pittman[3], B. Elkins[4], B. Hearn[2], O. van Lier[5]

[1] Université de Sherbrooke (QC), [2] Canadian Forest Service, Corner Brook (NL),
[3] Forestry and Agrifoods Agency (NL) , [4] Corner Brook Pulp and Paper Ltd (NL), [5] Canadian Wood Fibre Centre (NL)

UNIVERSITÉ DE SHERBROOKE

CRSNG NSERC

Kruger Industrial

Natural Resources Canada

Newfoundland Labrador

Newfoundland Island

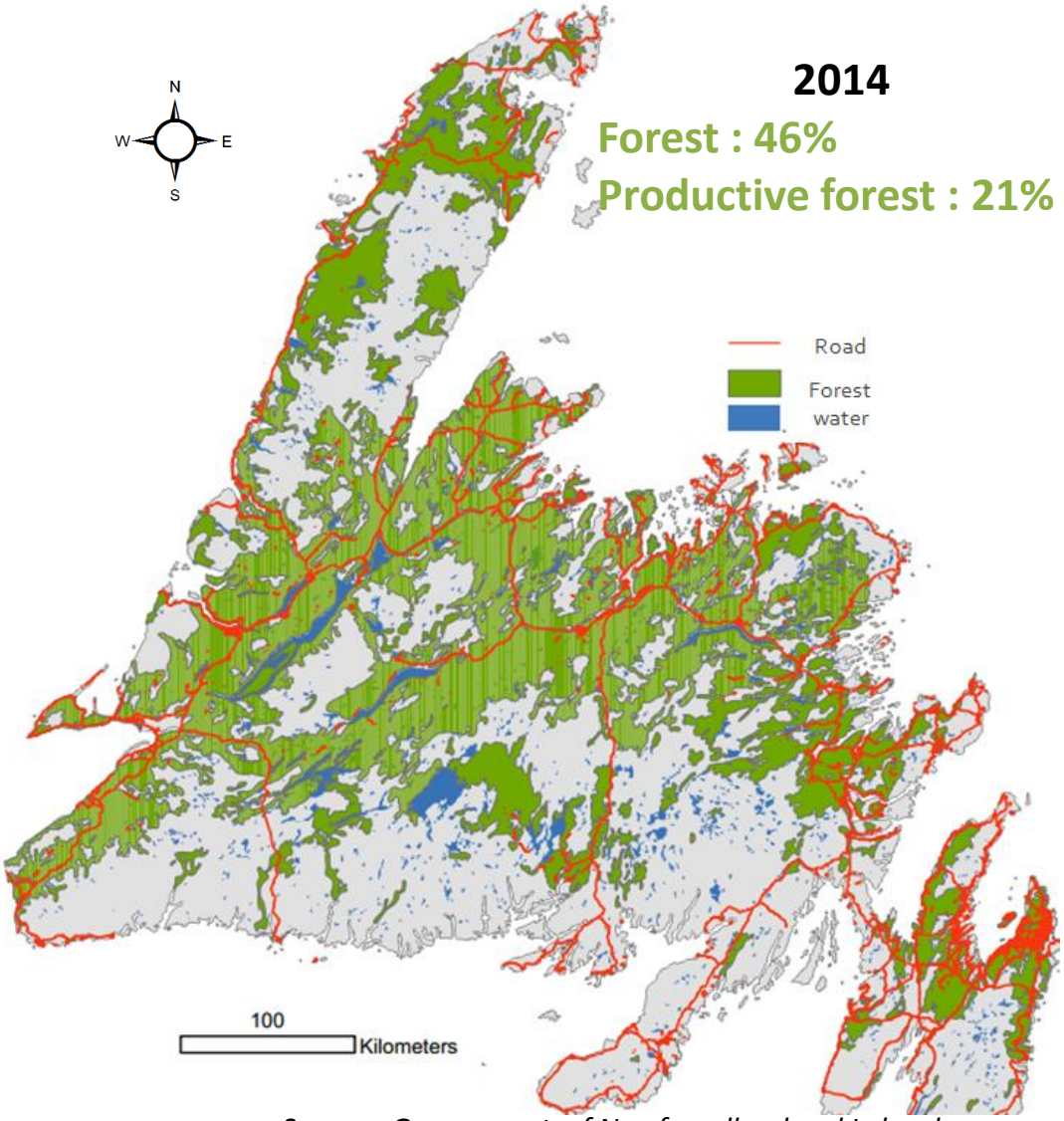
Forest

Forest industry

↓

an important component of the economy of Newfoundland

"The forest industry used around 1.3 million m^3 of local timber to produce wood products valued at $259 million"
(2012)



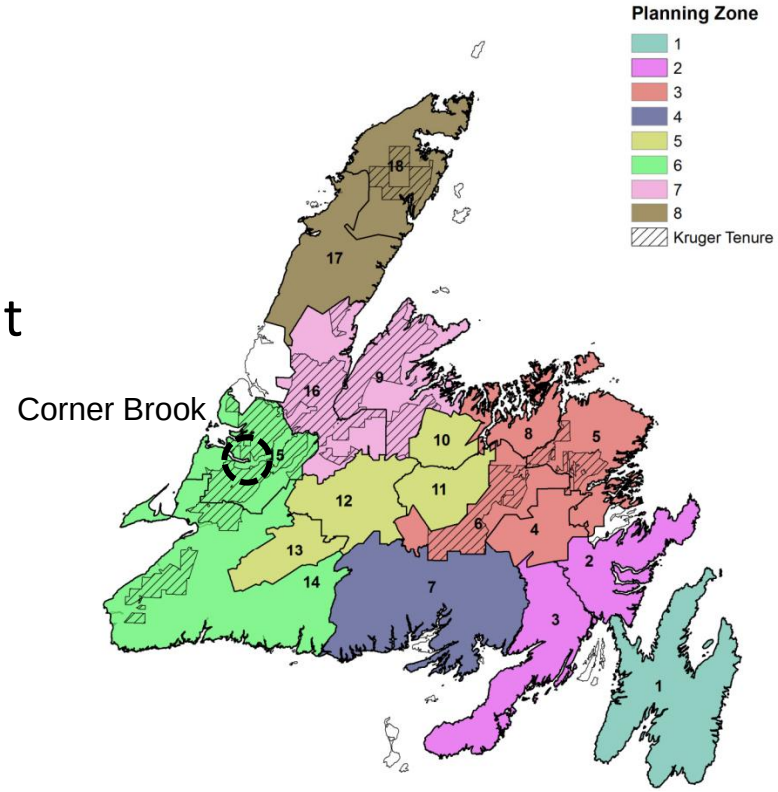
Source : Government of Newfoundland and Labrador

Newfoundland Island

Forest management

Main contributors to forest management in Newfoundland:

- Provincial Government
- Corner Brook Pulp and Paper Ltd



Source : Government Newfoundland and Labrador

Trend *:* Since 2014, forest management emphasizes ecological sustainability and protection of the environment in order to limit impacts on forest ecosystem.

Newfoundland Island

Impacts on forest ecosystems

- **Forest industry** requires significant wood resources
- Resulting in **forest activities**

Harvest

Logging

Infrastructure

Potential impacts on ecosystem services

- Forest loss
- Biodiversity loss
- Water cycle disturbance
- Landscape fragmentation
- Soil disturbance

Ecosystem Services

Definition

" Benefits that humans obtain from ecosystems directly or indirectly " *(Millennium Ecosystem Assessment report, 2005)*

Services = Benefits

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Newfoundland Island

Water component

- **Water: an essential component of the forest ecosystem**

Research Question

#Question 17a of Theme 2

How can effects of forest management activities on aquatic ecosystem services be quantified using available geospatial data?

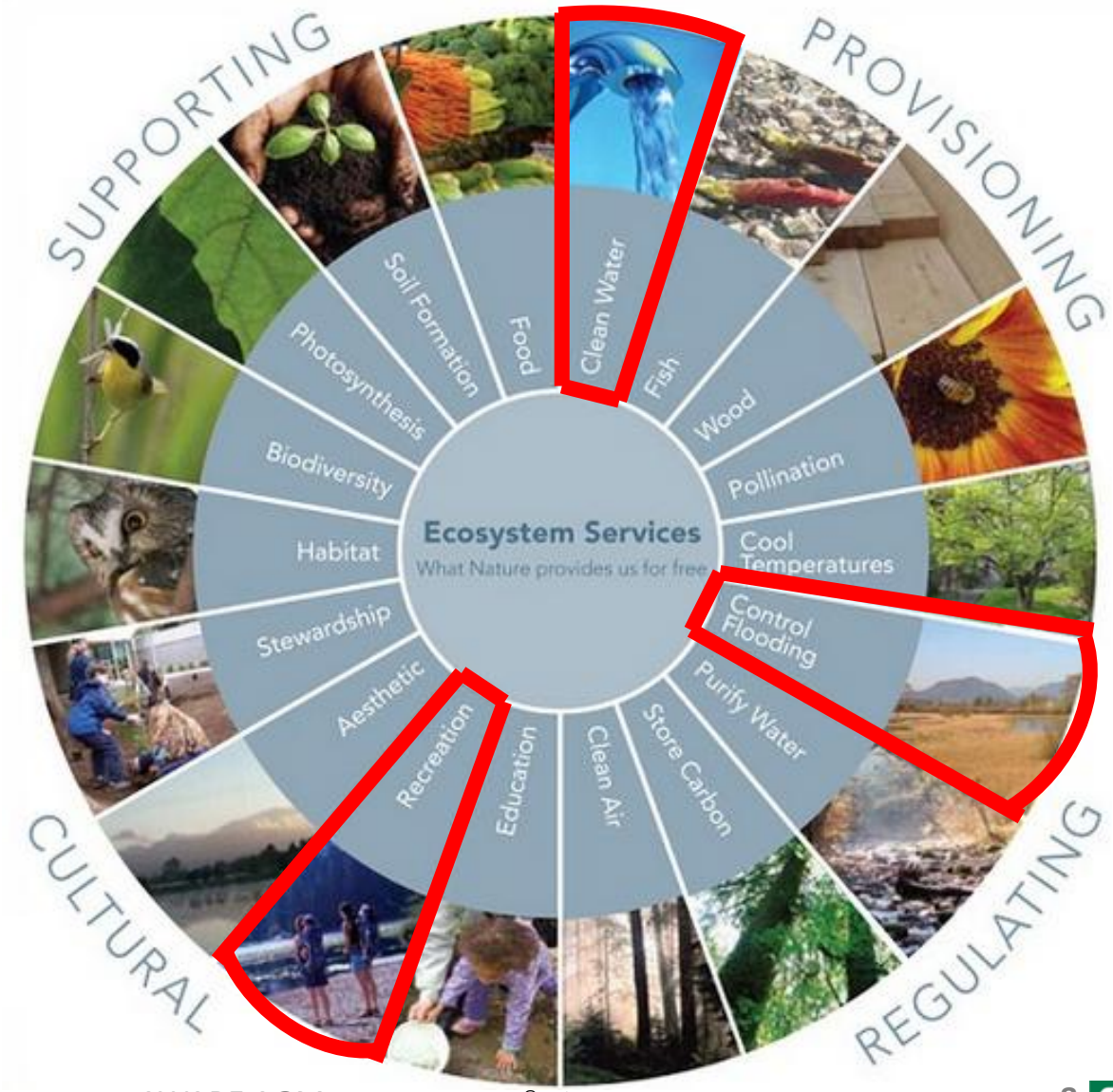
Studied Ecosystem Services

Identification

Focus on Aquatic Ecosystem Services (AES) :

- Water quality service
- Regulation flow
- Recreation fisheries

Services = Benefits



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Aim of the project

- Develop a **methodological framework** to **quantify Aquatic Ecosystem Services** (AES) provided by boreal forests and to **map impacts of forest activities** on AES using an **index** based on **spatial indicators**.

  - We focus only on mapping at the watershed scale in Western, Newfoundland.

  - Our results are designed to develop guidelines or recommendations for forest management activities regarding their impacts on AES.

Key definitions

- **Index**
  - Combination of all the selected indicators using a predefined mathematical relationship.
  - An index allows mapping a single aquatic ecosystem service

Index = Several indicators

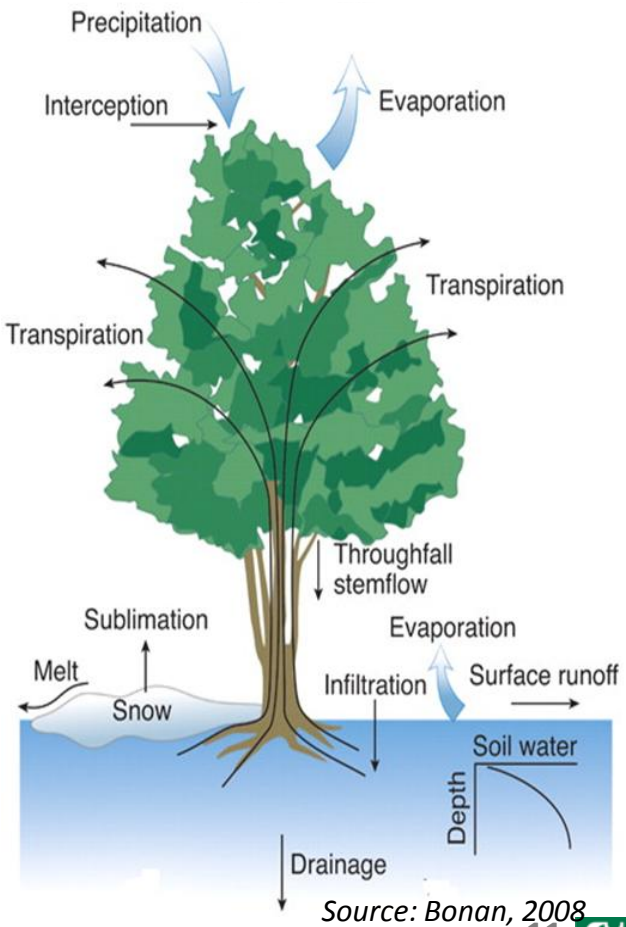
Key definitions

- **Indicators**
  - Indicators allow an **indirect assessment** of the ability for a forest area to fulfill its **function**.
  - Each **indicator** represents a **specific process** that underpins a **function**.
- **Functions**
  - **Subset** of **ecological processes** and **ecosystem structure**.

Indicators = Function indicators

Functions

Water-Tree Interaction



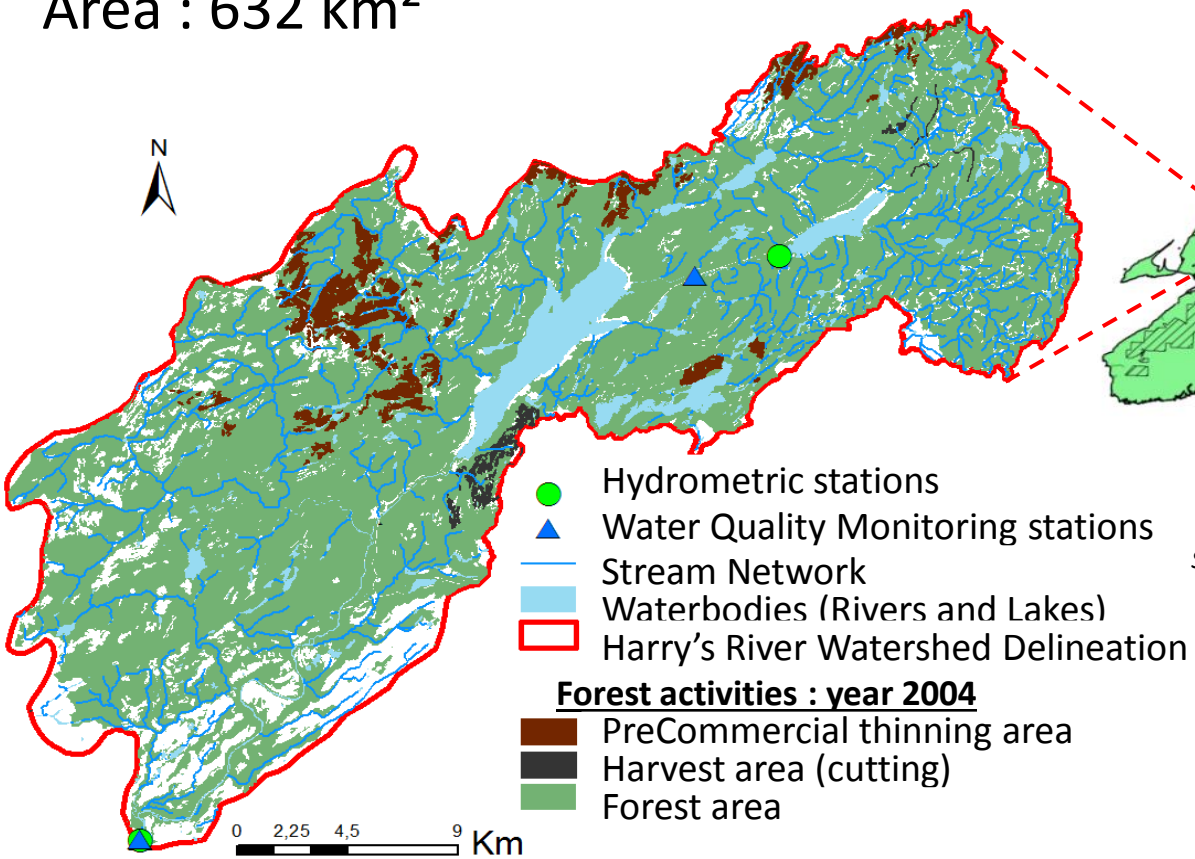
Source: Bonan, 2008

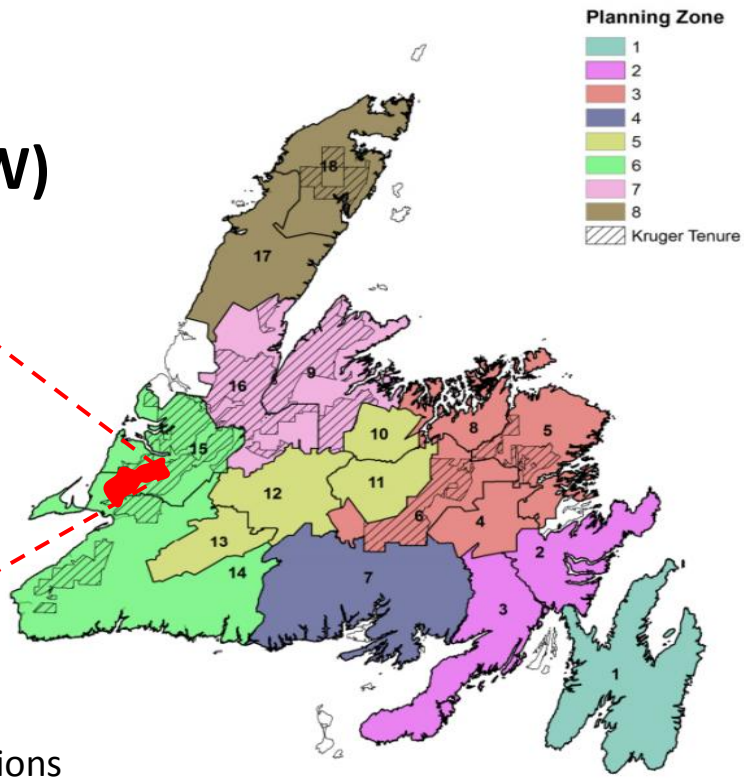
Methodological framework

The case of water quality service

Test area: Harry's River Watershed (HRW)

Area : 632 km²





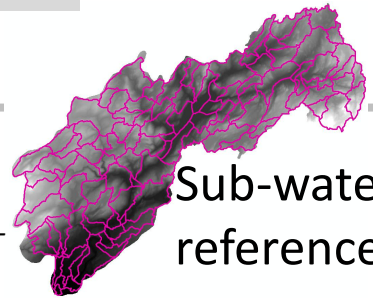
Source : Government Newfoundland and Labrador, 2014

© FSC data, Geogratis data
Author : A. Schmidt 2016

The case of water quality service

Index of Water Quality Potential (I_{WQP})

Spatial data



ArcGIS ® 10.2
Ext. ArcSWAT

Sub-watershed reference units

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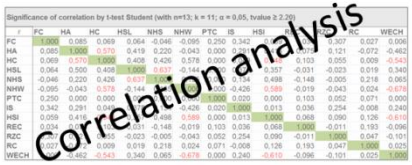
Identify possible Function Indicators (FI)

Literature review

Criteria (five criteria)

Select relevant Functions Indicators (FI)



Correlation analysis

Calculate & Normalize FI values

2 Mapping of water quality service

$$I_{WQP} = \sum_{i=1}^{n} FI_i \text{ x } w_i$$

I_{WQP} : Index of Water Quality Potential
w : Weights
FI : Function indicator

Fix weighting values

3 Evaluate mapping method

Evaluation data

Ground station data:
Forestry Water Quality Index
(Tobin et al., 2007)

- Potassium
- Turbidity
- Phosphores
- Nitrogen
- DOC

△values

I_{WQP} maps

- Potential to produce quality water

Multiple dates

4 Evaluate effects of forest management activities on water quality service from multiple dates

5 Future scenarios of forest management

- Harvest planned
- Silviculture planned

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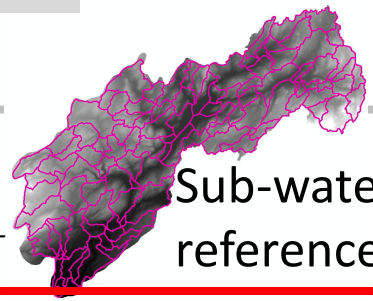

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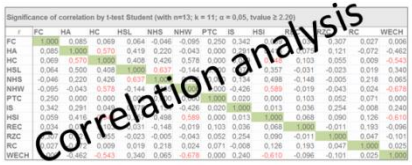

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Spatial data

Raster format data

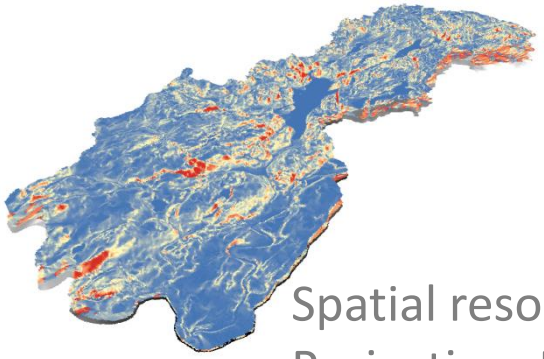
- Elevation
- Aspect
- Slope

Vector format data

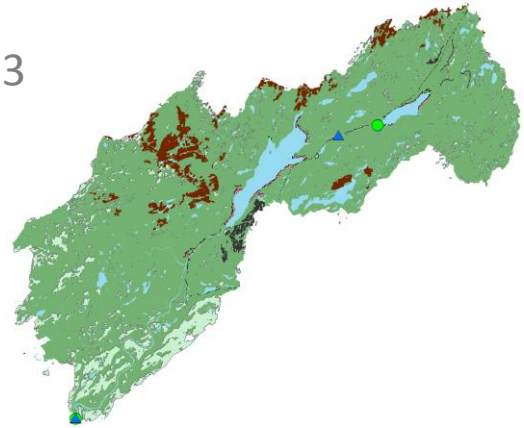
- Watershed delineation
- Hydrology network
- Silvilculture treatment
- Harvest area

Between 1995 and 2013

- Land cover type
  - Roads
  - Forest
  - Wetlands
  - Infrastructure



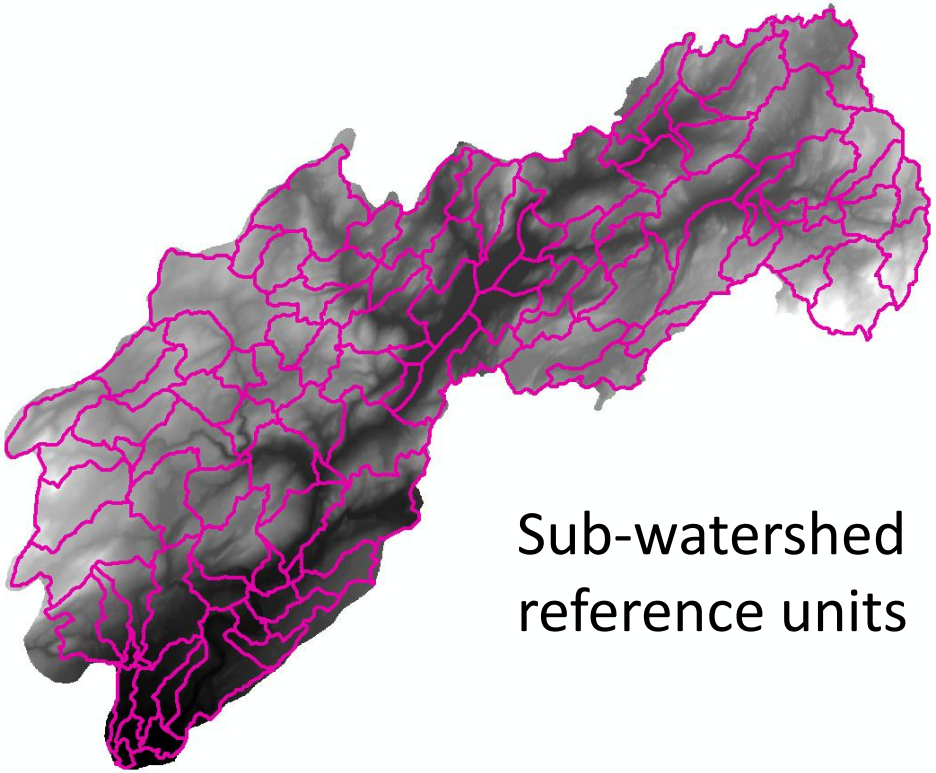
Spatial resolution: 30 m
Projection: NAD83 UTM 21N



The case of water quality service

Index of Water Quality Potential (I_{WQP})

Reference units map



Sub-watershed reference units

The case of water quality service

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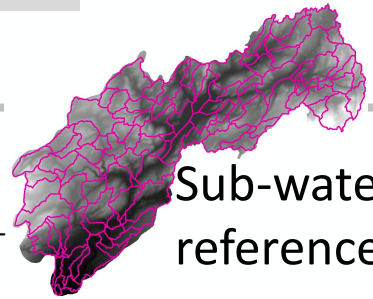

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r	FC	HA	HC	HSL	NHS	NHW	PTC	IS	HSI	REC	RZC	RC	WECH
FC	1,000	0,085	0,069	0,064	-0,046	-0,095	0,250	0,342		0,027	0,027	0,027	0,006
HA	0,085	1,000	0,570	0,419	0,220	-0,043	0,000	0,013	0,013	0,121	0,121	-0,072	-0,462
HC	0,069	0,570	1,000	0,408	0,426	0,578	0,000	0,013	0,013	0,055	0,055	0,009	-0,543
HSL	0,064	0,500	0,408	1,000	0,637	-0,141	0,000	0,000	0,357	-0,031	-0,023	0,019	0,340
NHS	-0,046	0,220	0,426	0,637	1,000	0,000	0,000	0,148	0,488	-0,148	-0,005	0,218	0,065
NHW	-0,095	-0,043	0,578	-0,141	0,000	1,000	-0,426	0,589	-0,019	-0,043	0,024	-0,678
PTC	0,250	0,000	0,000	0,000	0,000	-0,426	1,000	0,020	0,000	0,103	0,052	0,071	0,000
IS	0,342	0,291	0,041	0,000	0,148	0,020	0,020	1,000	0,013	0,036	0,254	-0,008	0,240
HSI	0,059	0,417	0,013	0,357	0,488	0,589	0,000	0,013	1,000	0,068	0,090	0,126	-0,610
REC	0,027	-0,072	0,055	-0,031	-0,148	-0,019	0,103	0,036	0,068	1,000	-0,011	0,193	-0,096
RZC	0,027	0,121	0,055	-0,023	-0,005	-0,043	0,052	0,254	0,090	-0,011	1,000	0,047	-0,101
RC	0,027	0,121	0,009	0,019	0,218	0,024	0,071	-0,008	0,126	0,193	0,047	1,000	0,025
WECH	0,006	-0,462	-0,543	0,340	0,065	-0,678	0,000	0,240	-0,610	-0,096	-0,101	0,025	1,000

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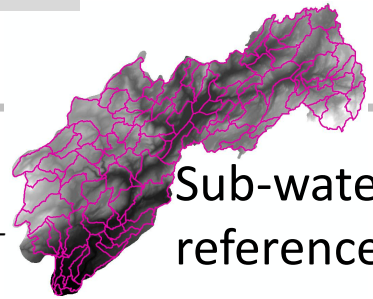

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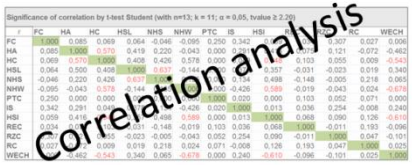

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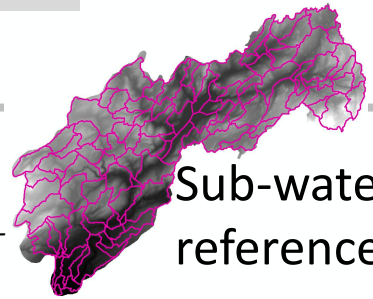

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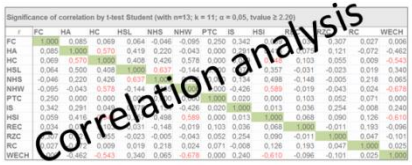

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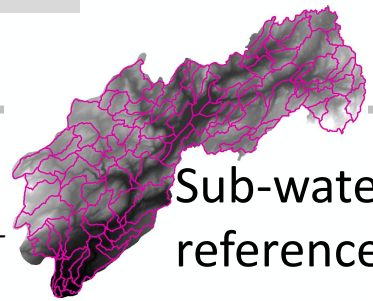

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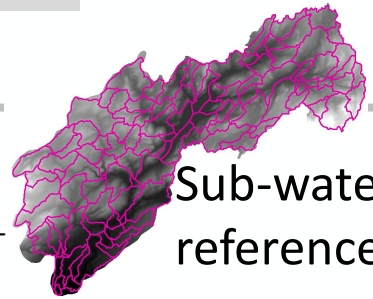

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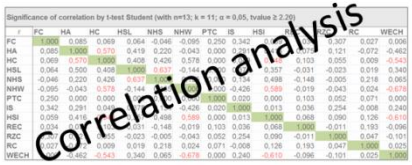

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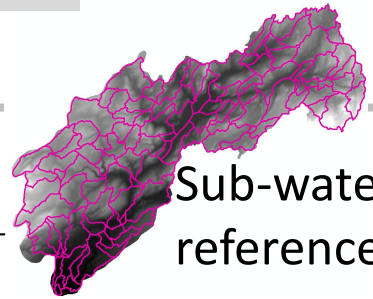
Preliminary results

Spatial data



ArcGIS ® 10.2
Ext. ArcSWAT

Sub-watersh
reference u

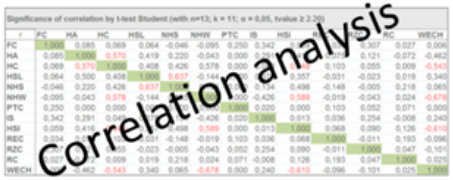
1 Quantification of water quality service

Identify possible Function Indicators (FI)

Literature review

Criteria
(five criteria)

Select relevant Functions Indicators (FI)



2 Mapping of water quality service

Calculate & Normalize FI values

Fix weighting values

$$I_{WQP} = \sum_{i=1}^{n} FI_i \times w_i$$

I_{WQP} : Index of Water Quality Potential
w : Weights
FI : Function indicator

3 Evaluate mapping metho

Evaluation data

Ground station data:
Forestry Water Quality Index
(Tobin et al., 2007)

- Potassium
- Turbidity
- Phosphores
- Nitrogen
- DOC

△values

I_{WQP} ma

- Potential to
quality wate

Multip
dates

4 Evaluate effects of forest management activities from multiple dates

5 Future scenarios of forest management

- Harvest planned
- Silviculture planned

The case of water quality service

Preliminary results: Index of Water Quality Potential (I_{WQP})

I_{WQP} maps for years 2004 and 2000

Indicator		Type
% Forest Cover	**FC**	State
% Harvest Cover	**HC**	Pressure
% Average Slope of Harvest area	**HSL**	Pressure
m Proximity Harvest to Waterbodies	**NHW**	State
% Past Thinning Cover	**PTC**	Pressure
% Impervious Surface	**IS**	Pressure
% Regeneration Cover	**REC**	State
% Riparian Zone Cover (20m)	**RZC**	State
% Forestry Road Cover	**RC**	Pressure

Relevant Function Indicators selected

$$I_{WQP} = \sum_{i=1}^{n} FI_i \text{ x } w_i$$

I_{WQP} = FC + HC + HSL + NHW + PTC + IS + REC + RZC + RC

The case of water quality service

Preliminary results: Index of Water Quality Potential (I_{WQP})

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Relevant Function Indicators selected

$$I_{WQP} = \sum_{i=1}^{n} FI_i \text{ x } w_i$$

I_{WQP} = FC + HC + HSL + NHW + PTC + IS + REC + RZC + RC

Weight equal 1 for each Function Indicator

The case of water quality service

Preliminary results: Index of Water Quality Potential (I_{WQP})

I_{WQP} maps for years 2004 and 2000

Indicator		Type
% Forest Cover	**FC**	State
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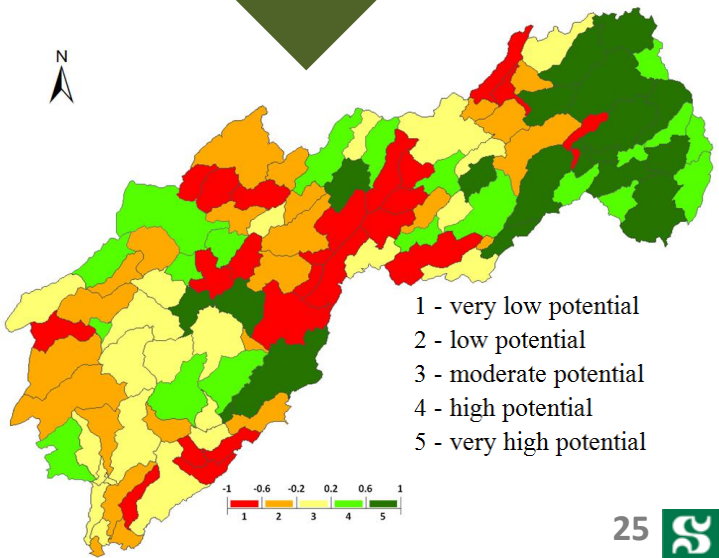
Relevant Function Indicators selected

$$I_{WQP} = \sum_{i=1}^{n} FI_i \text{ x } w_i$$

I_{WQP} = FC + HC + HSL + NHW + PTC + IS + REC + RZC + RC

Weight = 1



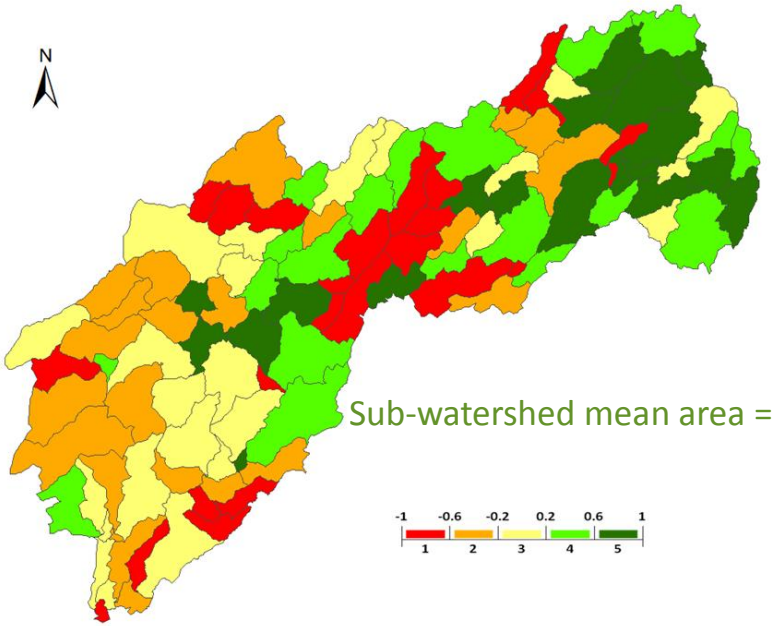
The case of water quality service

Preliminary results : I_{WQP} maps for years 2004 and 2000

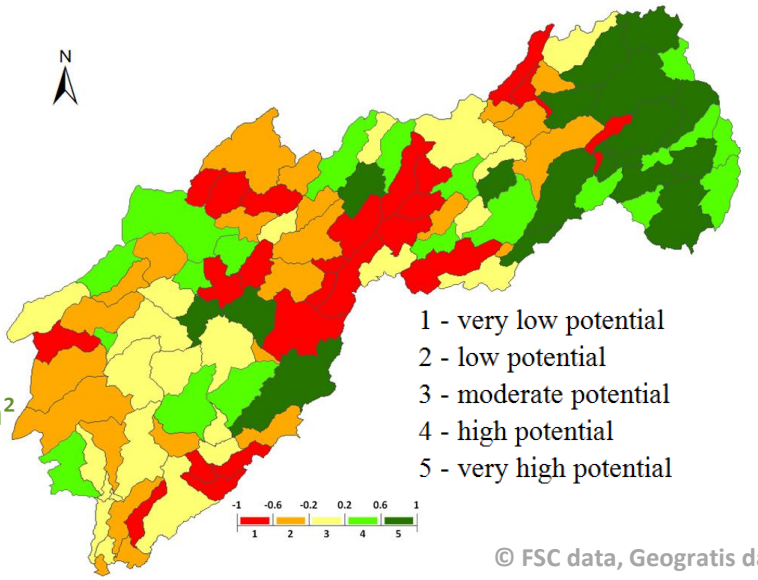
Index of Water Quality Potential (I_{WQP}) map

at sub-watershed

Year 2000



Year 2004



Sub-watershed mean area = 5,47 km²

1 - very low potential
2 - low potential
3 - moderate potential
4 - high potential
5 - very high potential

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Author : A. Schmidt 2016

- Harry's River Watershed
- Classification in 5 categories
- Normalisation of index between -1 and 1
- 2004 and 2000 maps of water quality service

Ongoing work

- Planned improvements
  - Choice of Function Indicators : integrate key variables associated with climate metric, such as the mean degree-days, annual precipitation, mean annual vapor pressure
  - Define more homogeneous spatial reference units
- A significant challenge : Validation process of the mapping method
- Assess impacts of forest activities on Aquatic Ecosystem Services for making recommendations based on a quantified and reproducible analysis

Thank you for your attention

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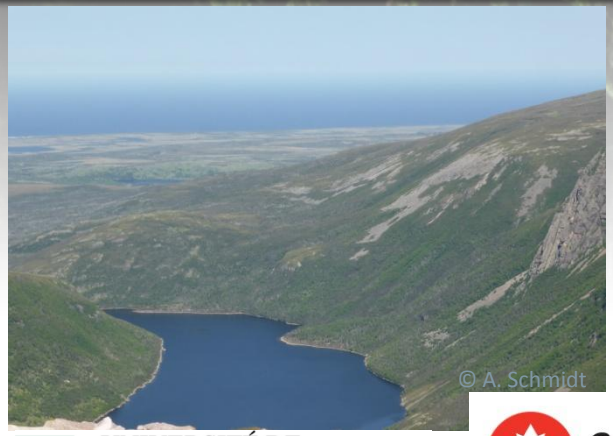

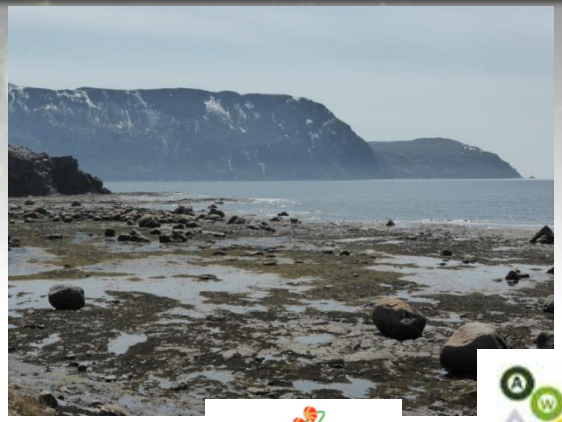

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Newfoundland Labrador

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