Agro-environmental risks: from the assessment with a spatialised multicriteria modelling on a small territory, to the use of remote sensing on his larger covering watershed

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1- Introduction and objectives

✓Many water systems are degraded with human activities, including intensive agriculture (e.g. nitrates, pesticides)
=> many problems with the pumping stations for drinking water!

✓ European Union adopted the Water Framework Directive 2000/60/EC.

- Aim => To maintain or restore the good ecological status (physico-chemical and biological) of hydrosystems in 2015.

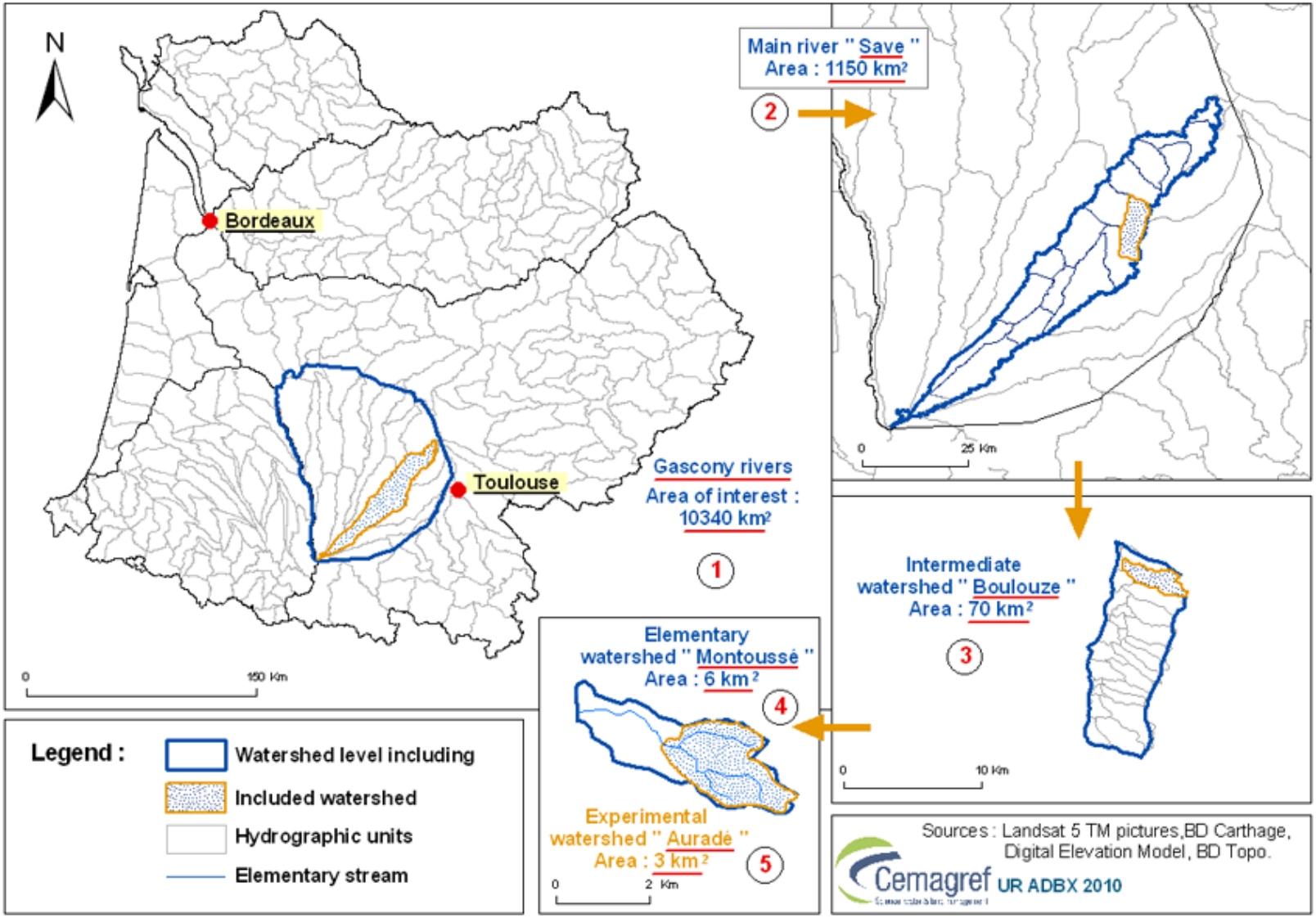
✓In France, the last Law on water and aquatic environments (2006) has renovated the whole of water policy.
=> Now, managers like those in water agencies, must get not only means, but results, in restoring the quality of water!

1- Introduction and objectives

- ✓ They decided to protect first the pumping zones.
- ✓ Farmers receive subsidies of the Commun Agricultural Policy (EU), but with conditions to improve their practices!
  => Reduction negatives impacts of agricultural practices on the environment, especially on water.
- ✓ The apply of public policies needs first an assessment of environmental risks => choice of several methods at different spatial scales.

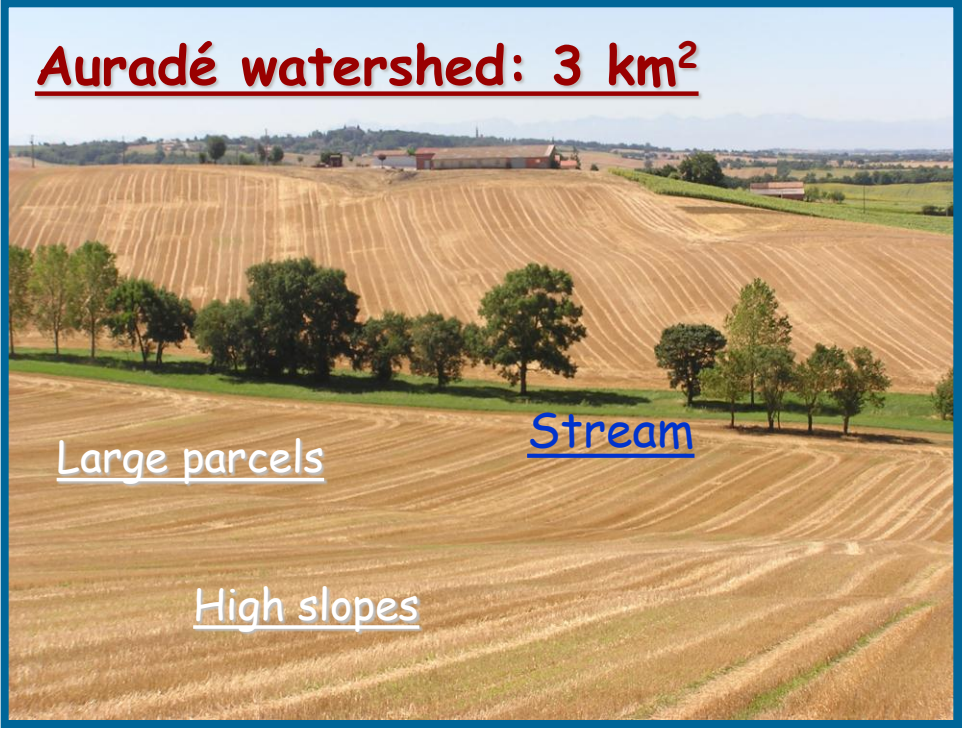
- ✓ We tried to address this issue with 2 methods:
  - ¤ a MCDA method coupled with a GIS in a small watershed of intensive agriculture.
  - ¤ a spatial method coupling remote sensing & GIS in the large watershed including.

2- Location of the study site



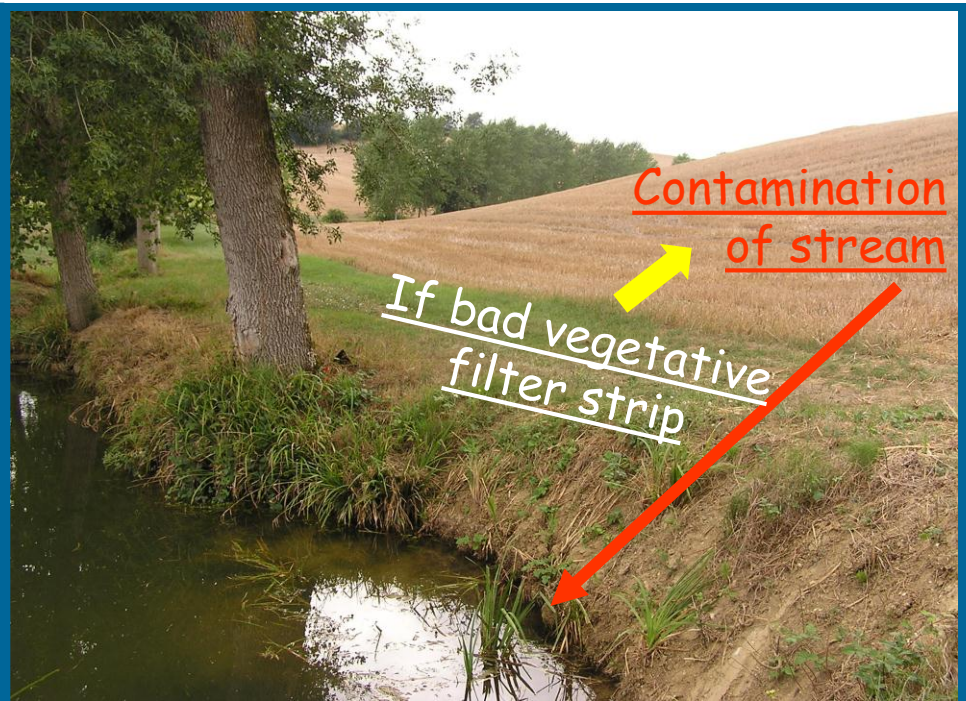
3- General context of the project

- ✓ Local context: atlantic climate & geological substratum essentially impermeable = very favorable for transfers of contaminants into the surface waters.
- ✓ Intensification of the agricultural practices => Degradation of the surface water quality which is collected for human drinking! (crops successions very short, higher inputs like nitrogen, pesticides => to obtain best yields.)
- ✓ Protection of waters against contaminants is the priority!
- ✓ E.g. for the Save watershed, in 2008 => Water agency decided to create a protection area around the pumping zone of the L'Isle Jourdain town (20.000 hab.)
- ✓ The small watershed of Auradé is situated at 5km from it.


Auradé watershed: 3 km²
Large parcels
Stream
High slopes


A Short crop rotation: Wheat / Sunflower


BEPs
Riparian zones


Contamination of stream
If bad vegetative filter strip

Save watershed: 1150 km²

Upstream: extensive area

Grass &

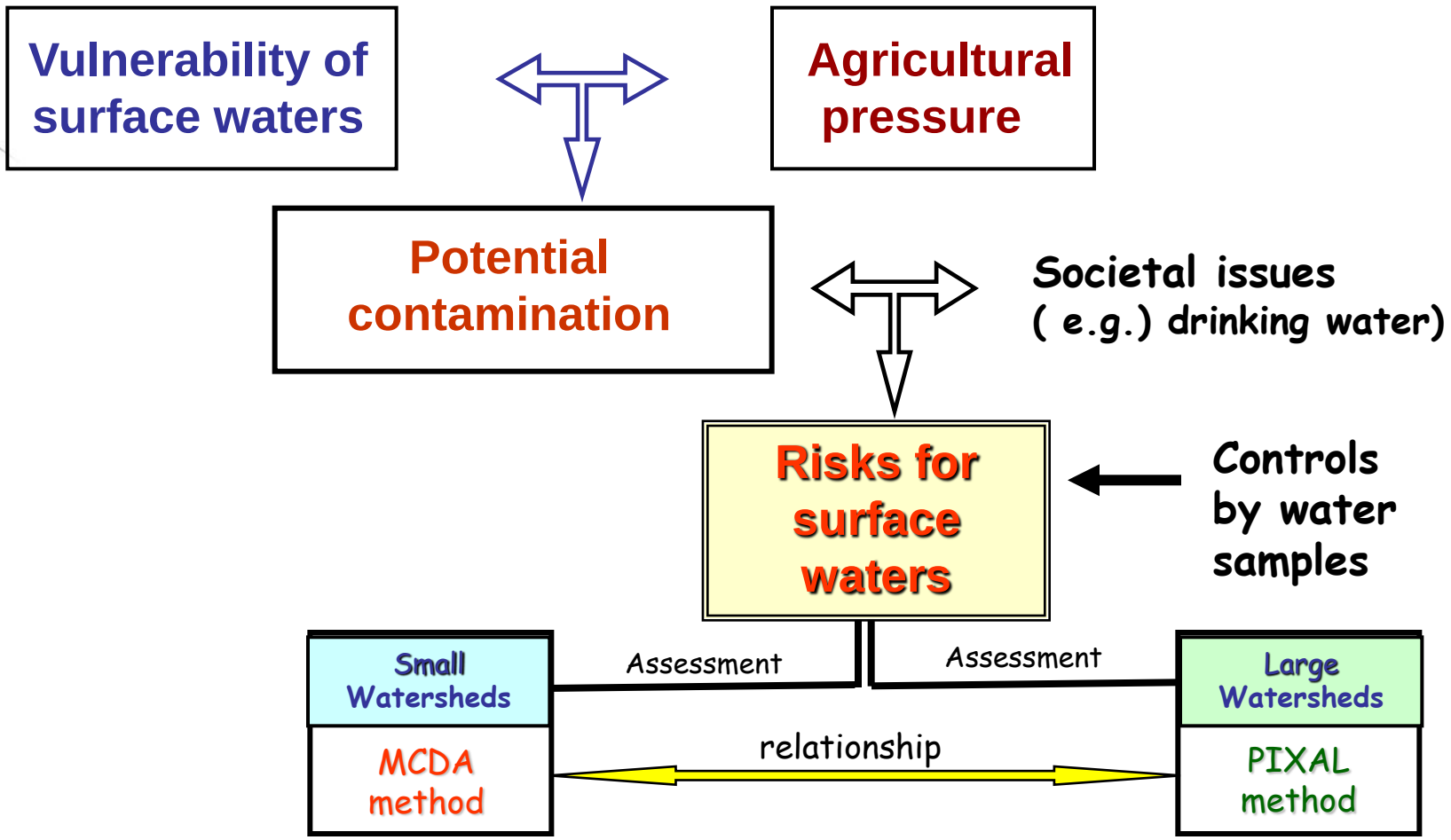
Forests

Central area: forests, grass, crops

downstream: intensive area

4- Global conceptual model

Issue => Assessment of agro-environmental risks at different spatial scaling



4- Two methods: MCDA method & PIXAL method

4.1- MCDA method: terminology

- An action = representation of the element which contributes to the decision => 1 of the 85 agricultural parcels of land into Aurade watershed

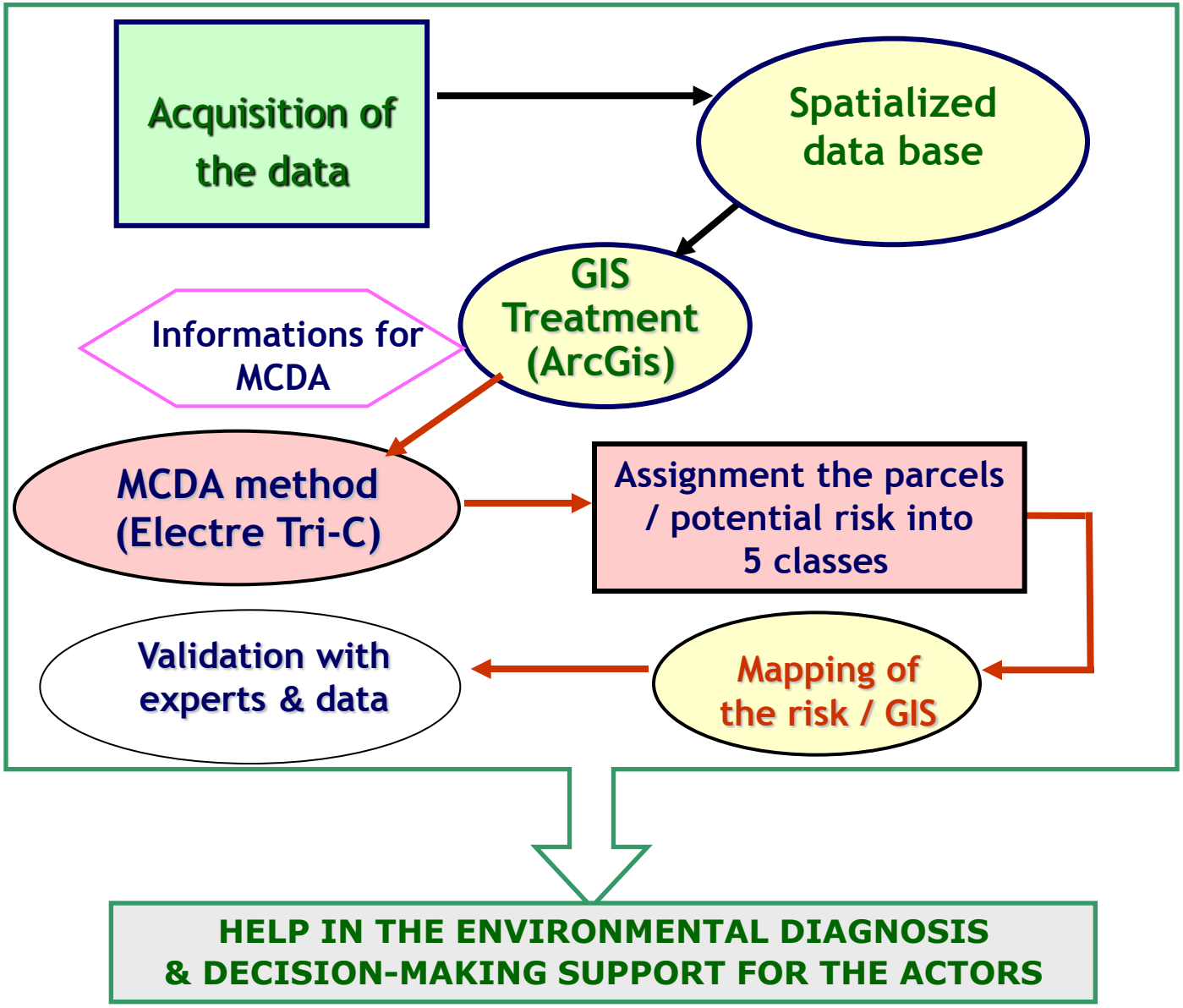
- A criterion = factor of judgment on the basis of which we measure and estimate the performances of the parcels for the risk of surface water contamination.

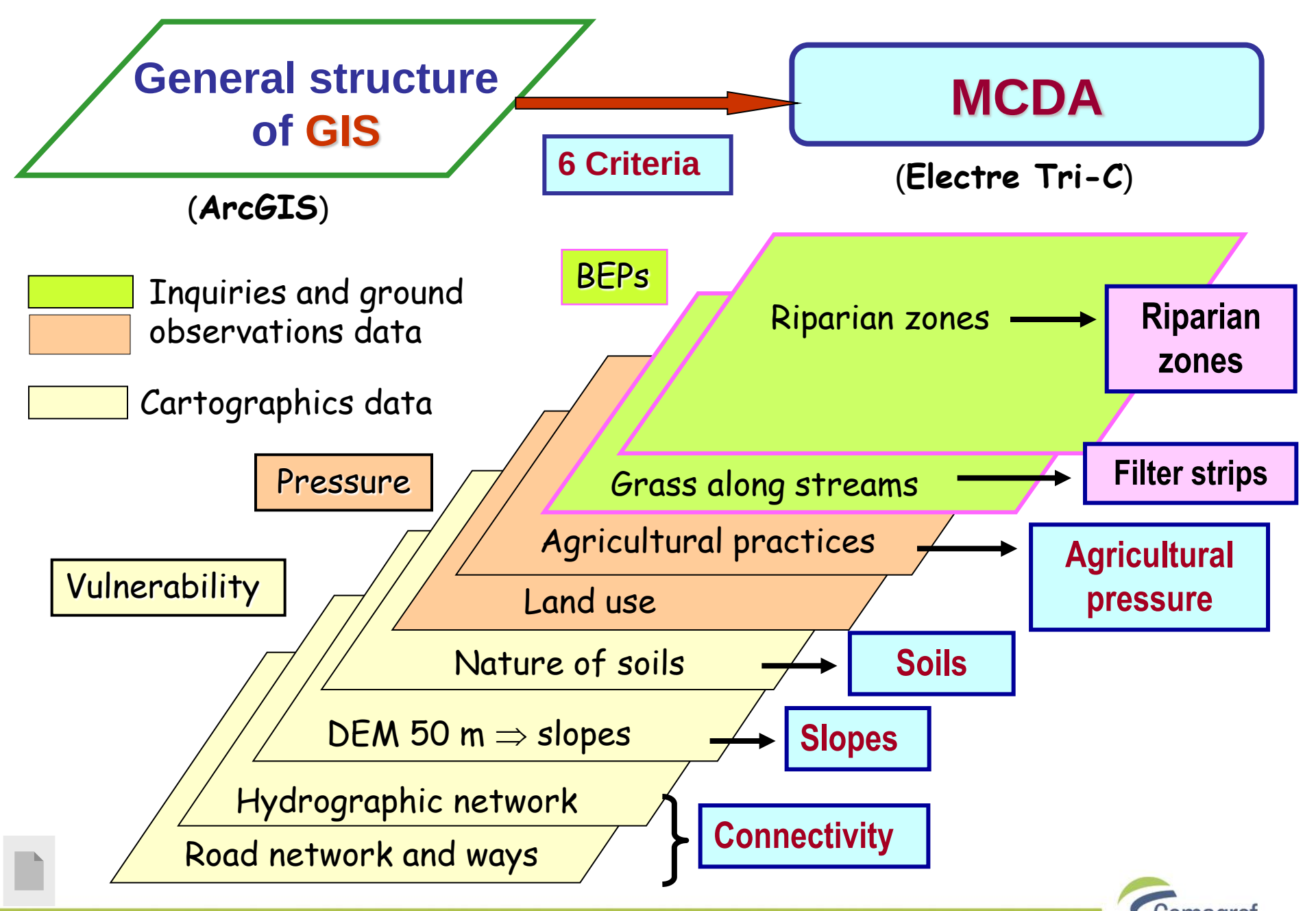
- Multicriteria evaluation = measure of the parcels performances with regard to 6 criteria, using the Electre Tri-C method.

- Assigment procedure of the parcels into 5 categories of risk level:

=> Very high / High / Intermediate / Low / Very low or no risk.

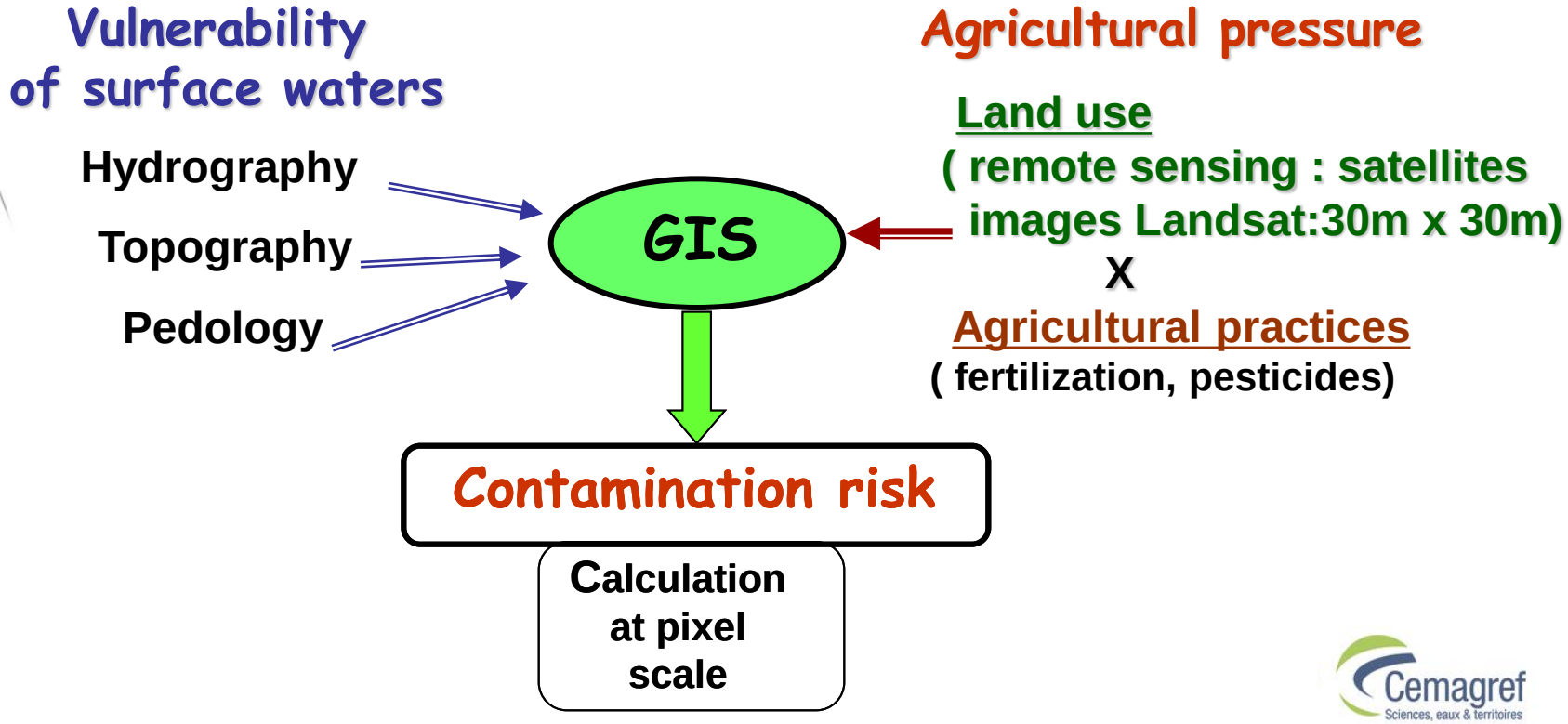
4- Method 1 : MCDA & GIS




General structure of GIS
(ArcGIS)
6 Criteria
MCDA
(Electre Tri-C)
Inquiries and ground observations data
Cartographics data
BEPs
Riparian zones
Riparian zones
Grass along streams
Filter strips
Pressure
Agricultural practices
Agricultural pressure
Vulnerability
Land use
Nature of soils
Soils
DEM 50 m ⇒ slopes
Slopes
Hydrographic network
Road network and ways
Connectivity

Method 2- Pixal (step 1)

- **Choice of a RSO (Reference Spatial Objet)**
  - Homogenus: Adapted to scaling change → The pixel
  - Inducing the best precision



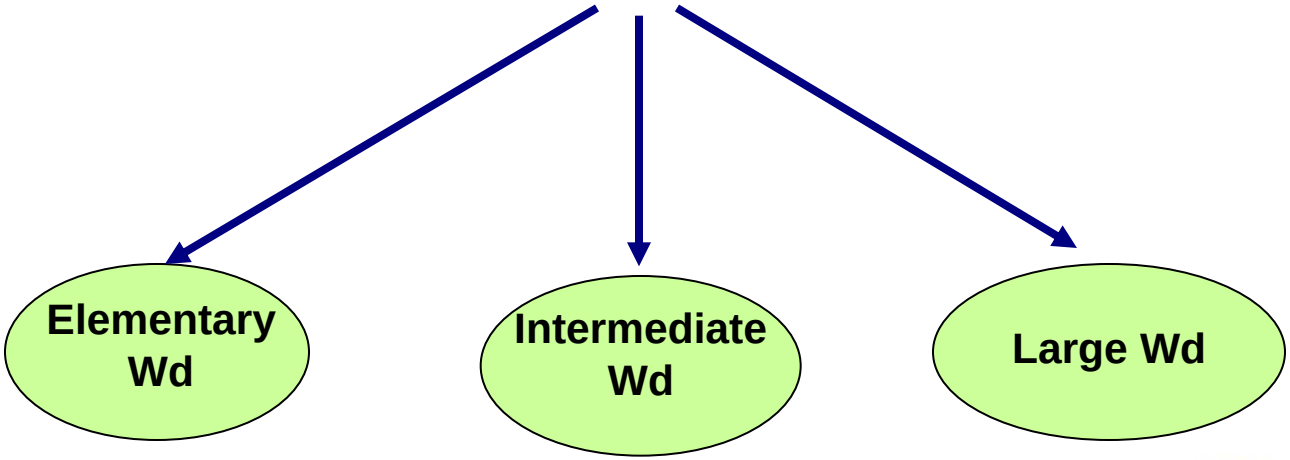
Method 2- Pixal (step 2)

Contamination risk

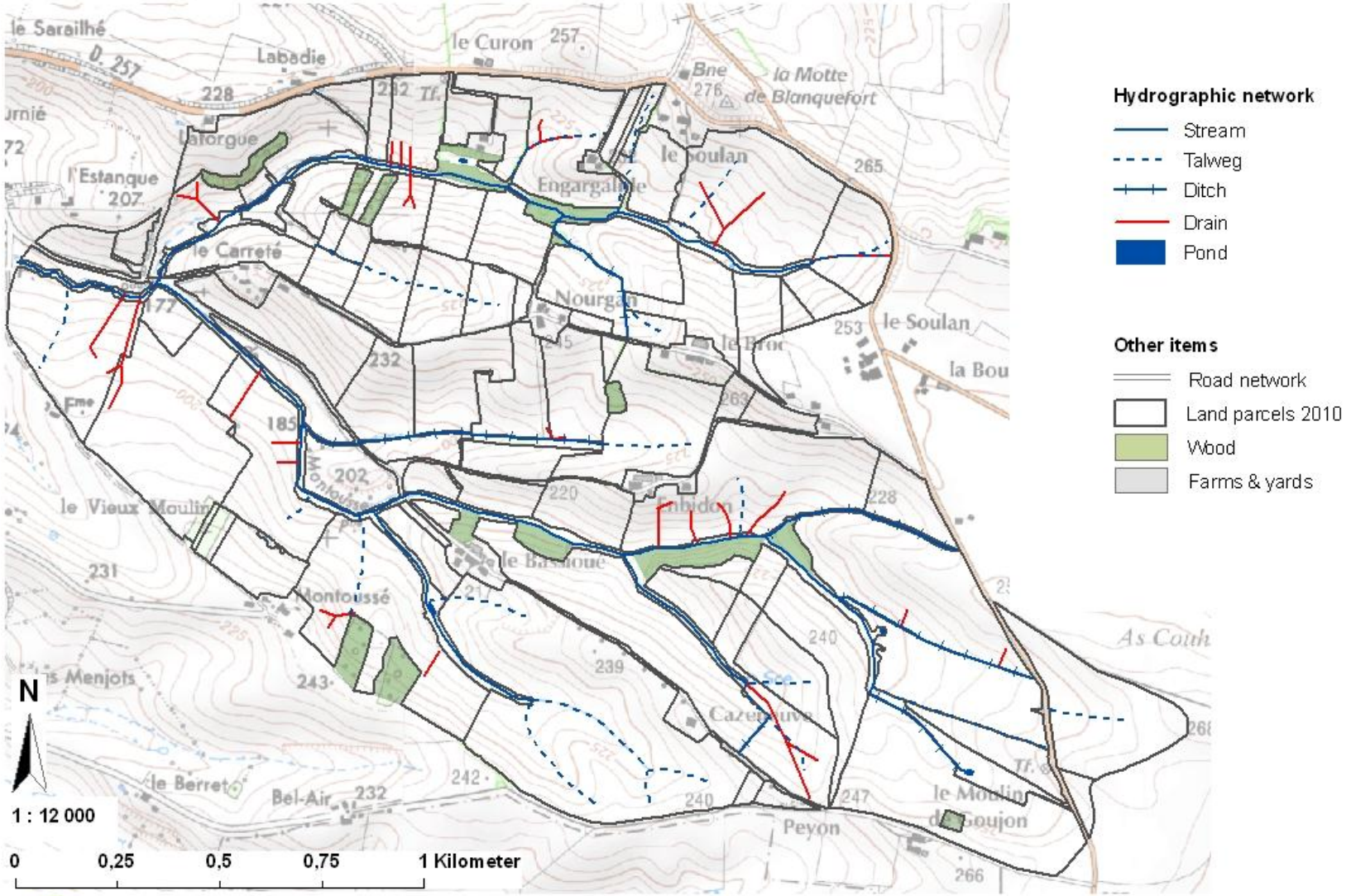
(pixel scale)

Aggregation

$$\frac{\text{of values obtained / watershed}}{\text{Surface of watershed (Wd)}}$$



Auradé-Cr3 Connectivity of parcels to the streams (e.g. Qualitative criterion for MCDA)



Cemagref Bordeaux, ADBX Unit, 2010

Sources : IGN, Auradé farmers association

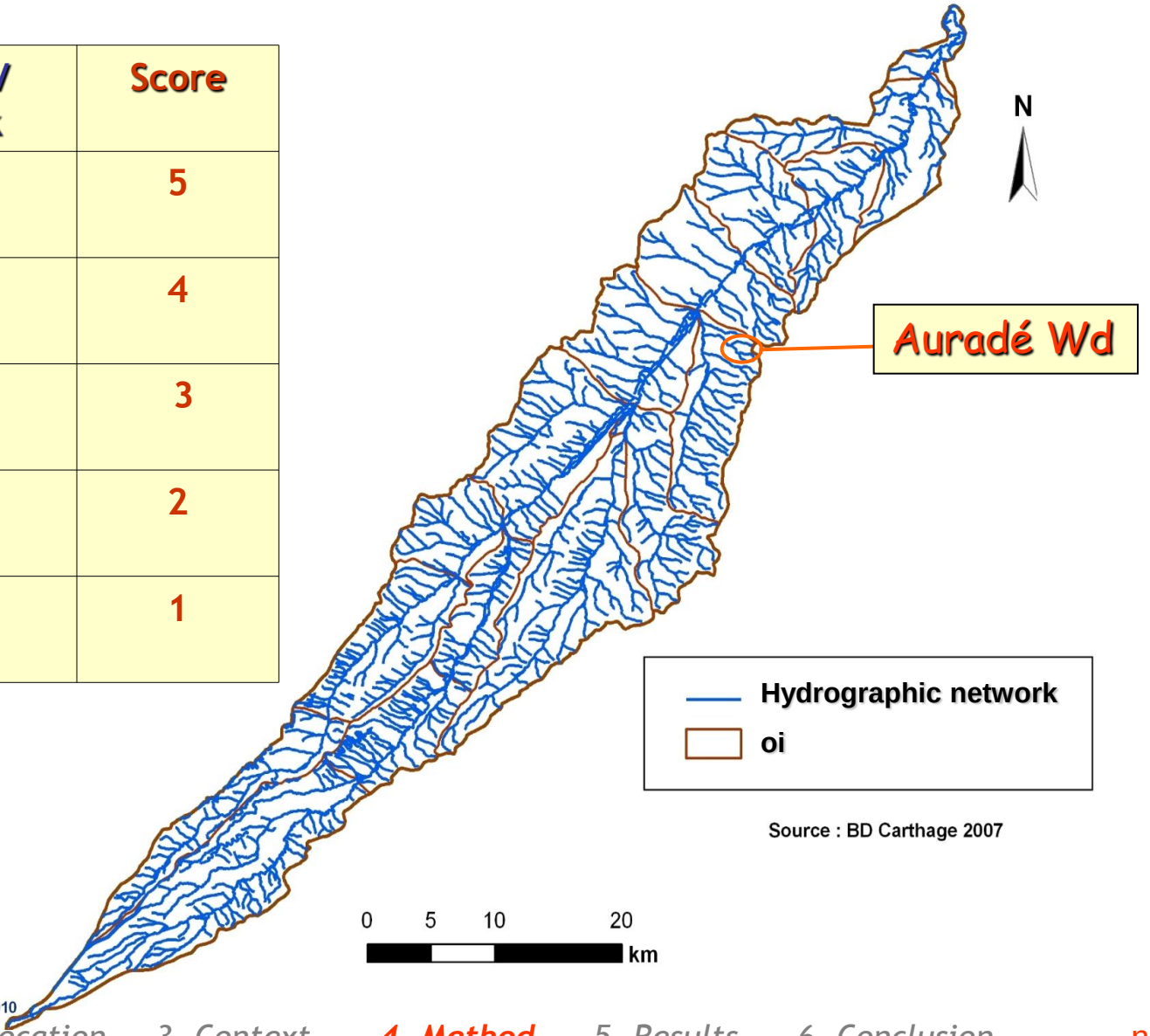
Auradé-Cr3 Connectivity of parcels to the streams (Qualitative criterion of MCDA)

The connectivity facilitates the transfer of contaminants from the parcels to the streams. MCDA can assess quality of connexion!

Connectivity type	Description	Scores MCDA
Very high	Edge of the streams with some drains	9
High	Edge of the streams	8
	Edge of the streams, but partially	6
Intermediate	Talwegs, ditchs	5
Weak	Ways, roads	3
Very weak	No, or very weak connectivity	1

Save: Connectivity of pixels to the streams (=> quantitative scores)

Distance:pixel / hydro-network	Score
< 30 m (1pixel)	5
30 -60 (2 pixels)	4
60 -90 (3 pixels)	3
90-120 (4 pixels)	2
> 120 m (>4 pixels)	1



Cemagref, UR ADBX, 2010

Auradé-MCDA-Cr4-Vegetative filter strips (VFS) : BEPs

- They limit the transfer of contaminants into the steams

Width	Quality	Protection level	Score MCDA
≤ 3 m	Bad Good	Very weak	15 14
]3 ; 5 m [	Bad Good	Weak	12 11
[5 ; 7 m [	Bad Good	Average	9 8
[7 – 9 m [	Bad Good	High	6 5
≥ 9 m	Bad Good	Very high	3 2
No interest	Parcel, far from the stream		0

Bad VFS

Good VFS

Impossible to implement in the PIXAL method !

Auradé-MCDA-Cr5 – Riparian zones : BEPs

- They limit also the transfer of contaminants into the steams

Importance of riparian zones	Description	Score MCDA
[0 -10 [%	No tree	10
[10 -25 [%	Weak protection, just some trees	9
[25 -50 [%	Passable protection	7
[50 -75 [%	Average Protection	5
[75 -100 [%	High protection	3
100 % boisée	Very high protection	2
No interest	Parcel, far from the stream	0

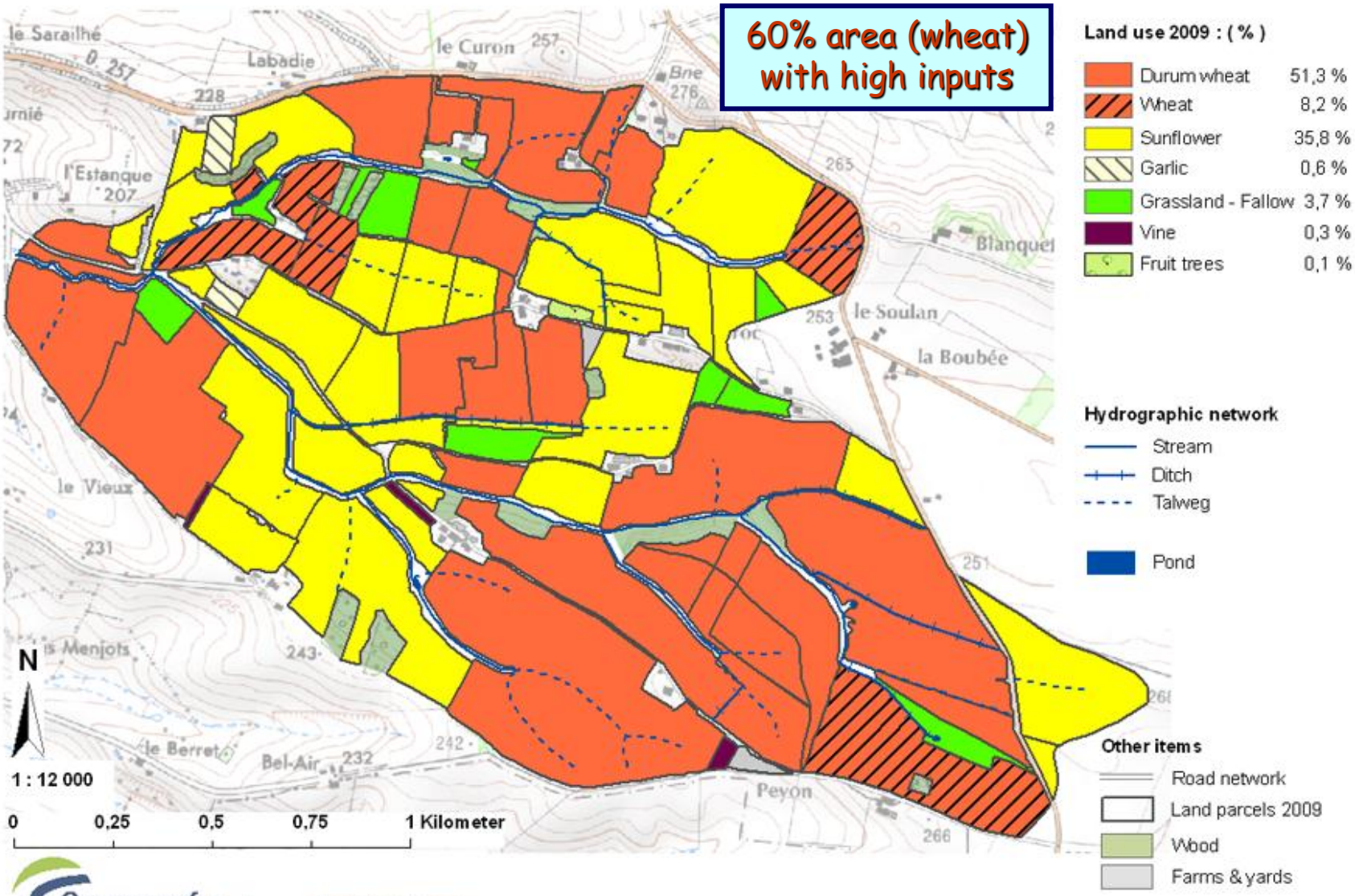
Riparian zone = 100%

Riparian zone < 25 %

Impossible to implement in the PIXAL method !

Auradé-Cr6 – Agriculture pressure in Auradé Wd

- Land use 2009 into the arable parcels



Cemagref Bordeaux, ADBX Unit, 2010

Sources : IGN, Auradé farmers association

Auradé-MCDA-Cr6 – Agriculture pressure : Nitrogen

When nitrogen inputs are high => Transferts risks increase!

=> Risks are less important with inputs divided

Number of Nitrogen inputs	Correction of quantities
1	100% Qtes
2	85% Qtes
3	75% Qtes
4 & more	70% Qtes

Category MCDA	Risk level	Inputs Value (Kg N / ha)
Category 1	Very high	130
Category 2	High	100
Category 3	Intermediate	70
Category 4	Low	40
Category 5	Very low	20

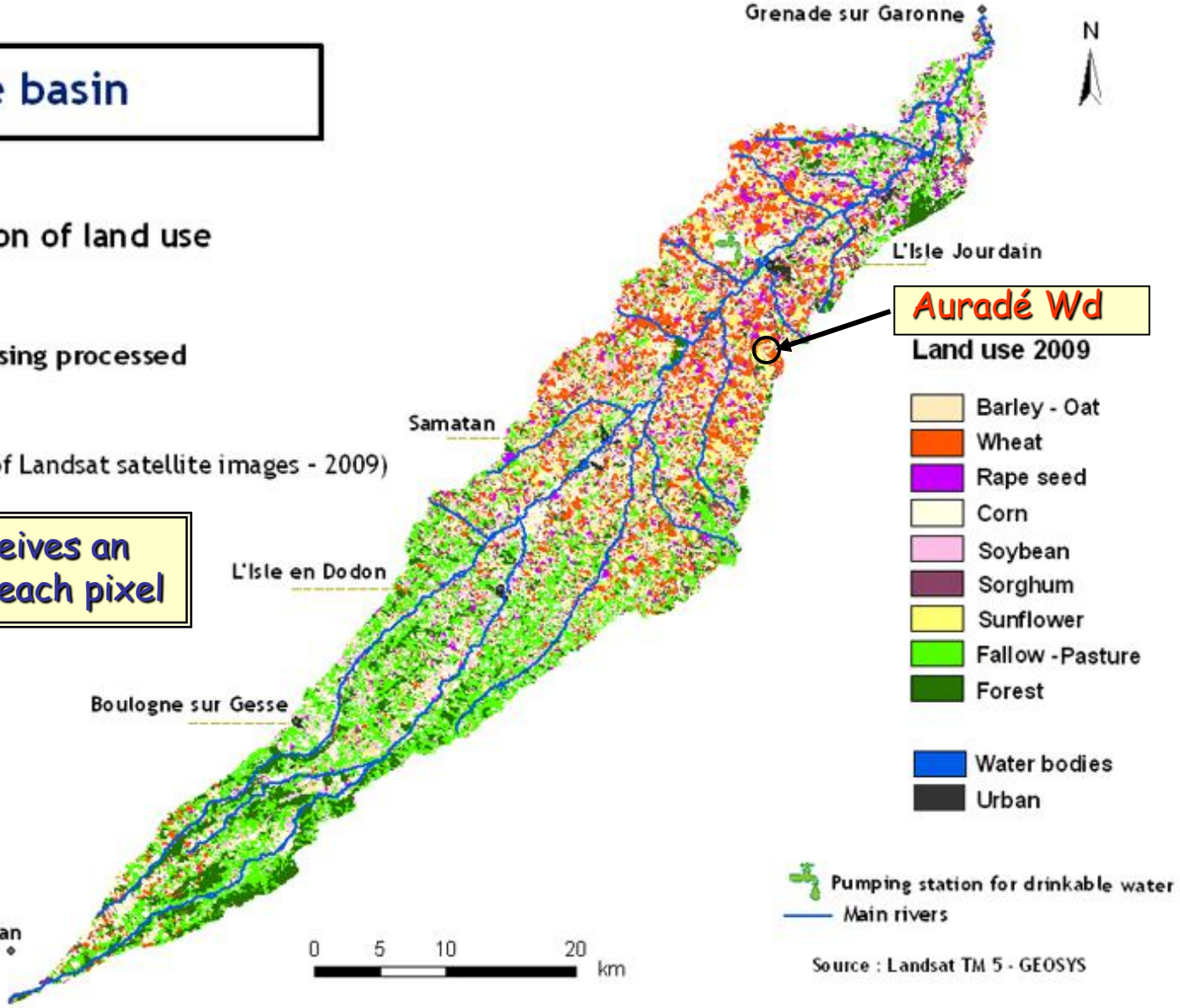
Save basin

Characterization of land use

By remote sensing processed

(supervised classification of Landsat satellite images - 2009)

Each crop receives an input scored on each pixel



Weighting of the 6 criteria in MCDA method

Criteria	Slopes CR1	Soils CR2	Connexion CR3	Filter strips CR4	Riparian zones CR5	Nitrogen pressure CR6
Weights (%)	18	6	23	13	10	30

¤ The weights of the criteria were determined by using the **S.R.F. software (Simos-Roy-Figueira)**, with agronomists experts.

¤ **CR1+CR2+CR3 = Vulnerability** => **47%** of the weights sum

¤ **CR4+CR5 = Environmental practices** => **23%** of the weights sum

¤ **CR6 = Nitrogen pressure** => **30%** of the weights sum

✓After testing by comparing the assignments obtained by expert, we chose the credibility level **λ = 0,70** used in Electre Tri-C method.

Weighting of the PIXAL method

	Vulnerability			BEPs		Pressure
Criteria	Slopes CR1	Soils CR2	Connexion CR3	Vegetable Filter strips CR4	Riparian zones CR5	Nitrogen pressure CR6
Weights (%) of MCDA	18	6	23	13	10	30
Weights (%) of PIXAL method	⇩ 38	⇩ 15	⇩ 47			100
PIXAL method =>	Weight =100			X		Wt =100

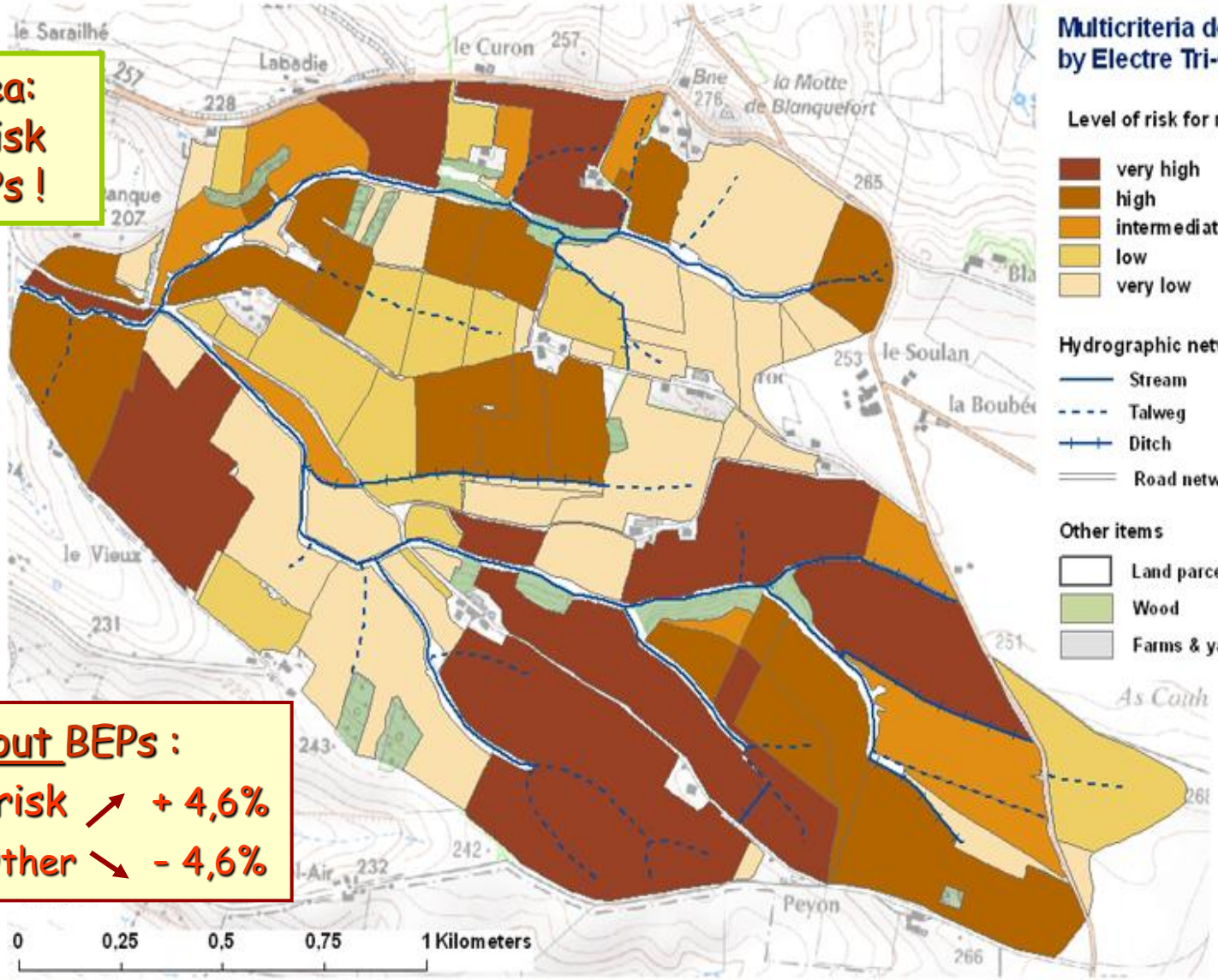
In PIXAL method, weights are applied from those of MCDA, only for vulnerability criteria => Risk = V. x P.

Relations between the methods: MCDA & PIXAL

- MCDA applied in a small territory gives information for scoring indicators used in a large territory:
  - The **slope classes** have been modified to PIXAL.
  - Observation of the **nature of soils** in small watersheds was useful for scoring pedology in Save Wd.
  - **Connectivity** has been appreciated in small Wd. In large Wd, scores only take account of distances. Buffers have been made according local characteristics of connections.
- Scores of inputs applied to Save Wd have been identified on small local Wd.
- Weighting of criteria applied in MCDA have been extrapoled for vulnerability in PIXAL method.

5- Results : Auradé Wd with effects of BEPs

55% area: strong risk with BEPs !



Without BEPs :

Very high risk ↗ + 4,6%

4 Other ↘ - 4,6%

Cemagref Bordeaux, UR ADBX, 2010

Sources : IGN, Auradé farmers association

5- Results : Save - Weighting of vulnerability

Save basin

Nitrogen contamination risk at surface waters

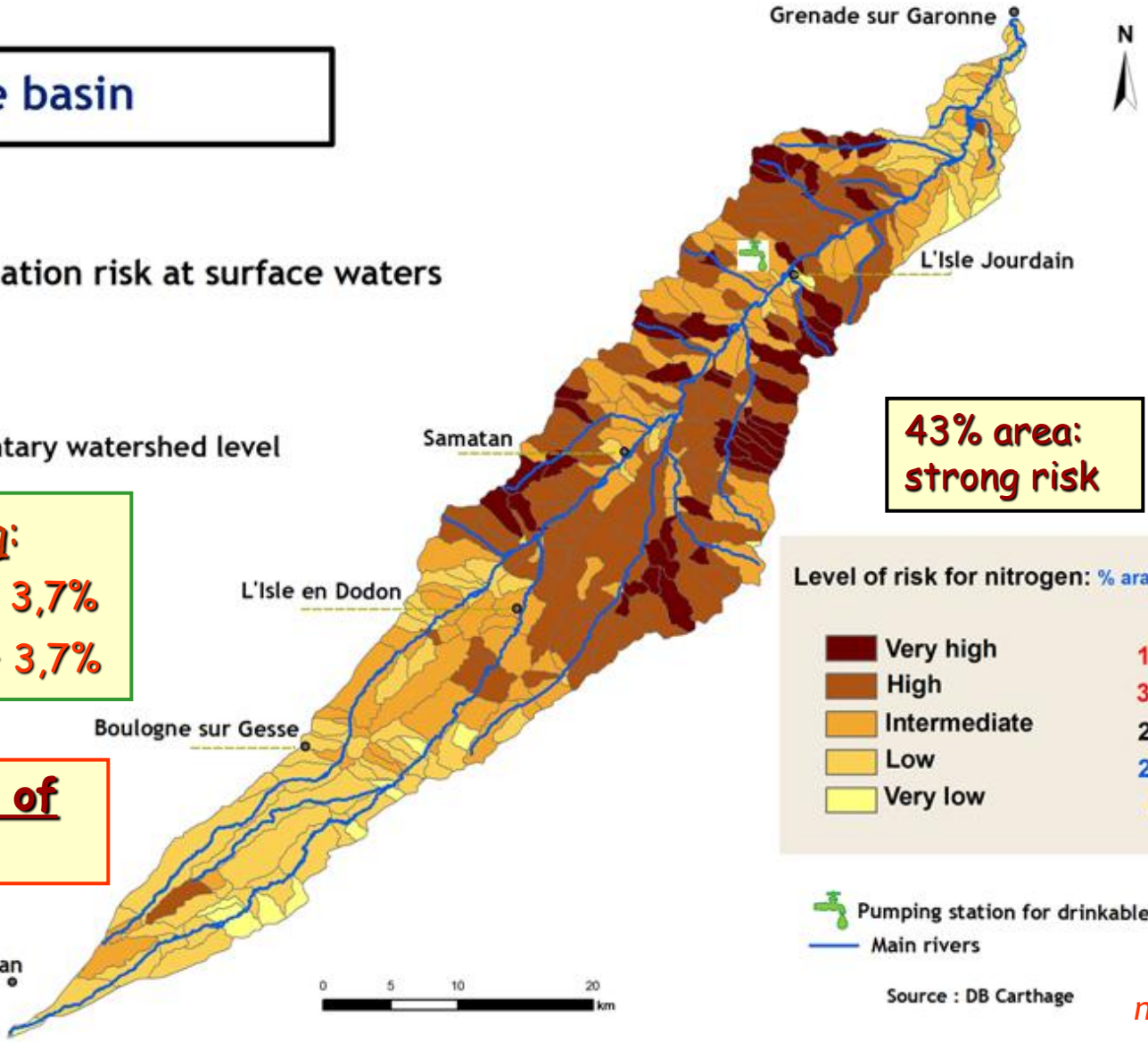
Aggregation at elementary watershed level

With weighting:

Very high risk ↘ - 3,7%

4 Other ↗ + 3,7%

Underestimation of strong risks



43% area: strong risk

Level of risk for nitrogen: % arable area

Very high	11,4 %
High	31,7 %
Intermediate	28,8 %
Low	25.2 %
Very low	2,9 %

Pumping station for drinkable water

Main rivers

Source : DB Carthage

Cemagref ADBX, 2011

6- Conclusion

- ✓The MCDA (Electre Tri-C method) coupled with the GIS allows to assess zoning of agro-environmental risks in small watersheds.
- ✓Taking into account qualitative criteria, the MCDA method is able to show the interest of BEPs for limiting pollutants transfers.
- ✓MCDA contributes to improve scores for other methods (like PIXAL) applied at different spatial scales.
  BUT it cannot be implemented in a large territory like Save Wd !
- ✓Also different methods are useful & necessary: this study shows how they can be complementary.
- ✓Coupling of these methods at different scales => an interesting decision aid for agricultural and environmental managers !

THANK YOU FOR YOUR ATTENTION

Cemagref
Sciences, eaux & territoires