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Technical-economic analysis of Best Management Practices for appropriate control of sediment yield

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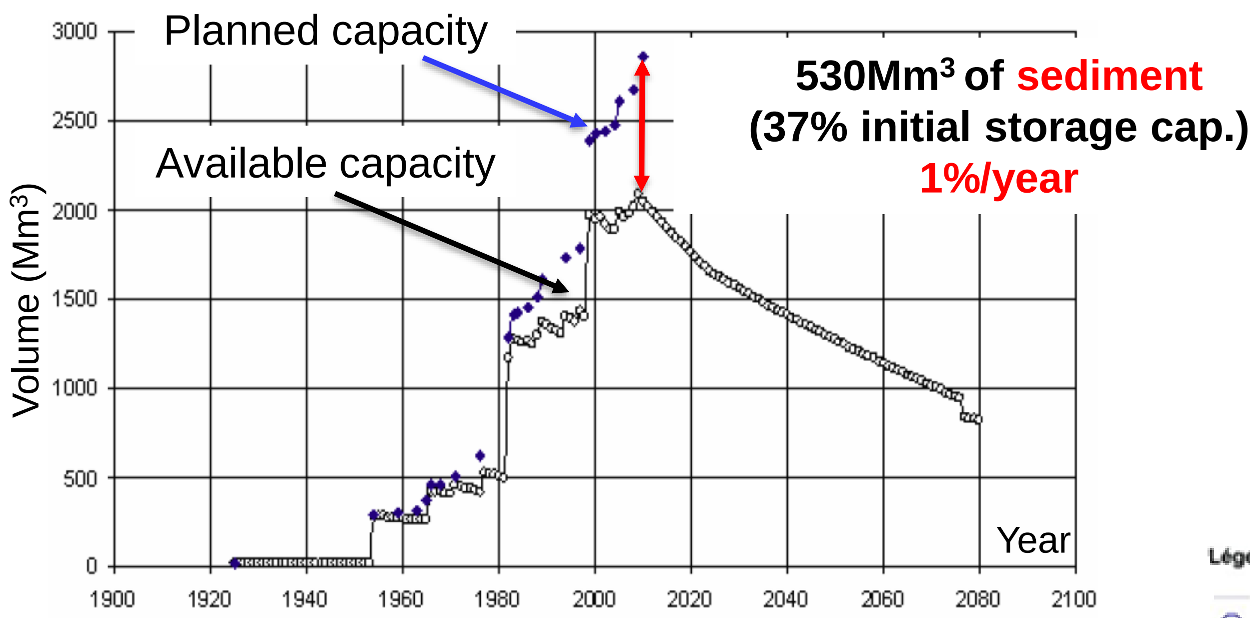
Content

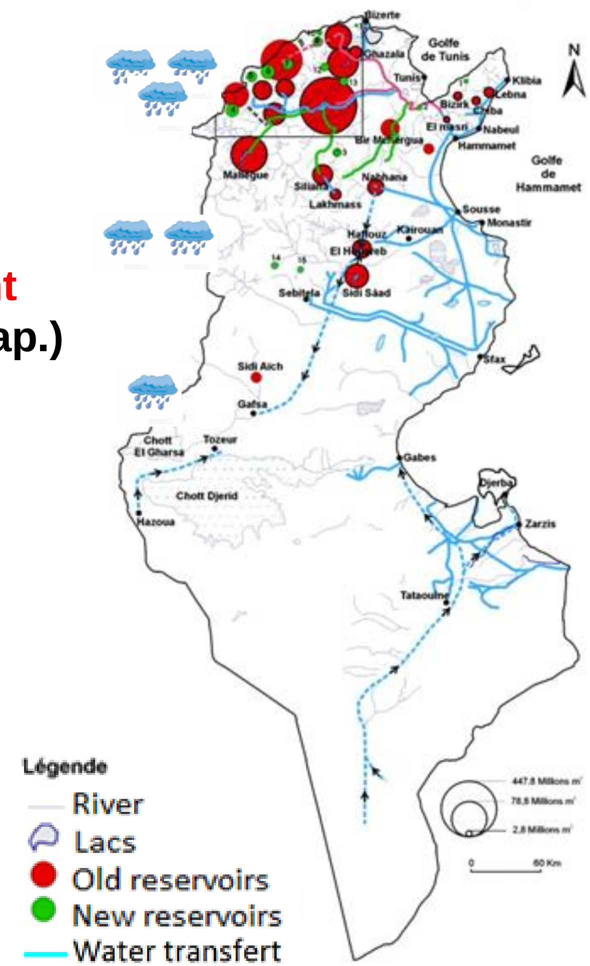
- **Introduction**
- **Conceptual framework of the research**
- **Research objectives**
- **Study site**
- **Research methods**
- **Results**
- **Conclusion and outlook**

Dams are constructed for various reasons:

- Water supply for irrigation and drinking
- Flood control
- Store water for use during drought season



Evolution of planned and available storage capacities of reservoirs in Tunisia

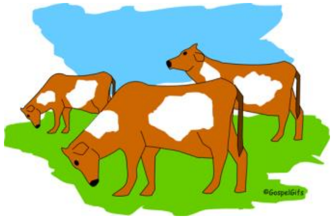


Reservoirs in Tunisia

INTRODUCTION

Soil erosion : one of the main hazards affecting the agricultural productivity and the sustainable use of surface water resources.

CAUSES



Overgrazing

Deforestation

Agrochemicals

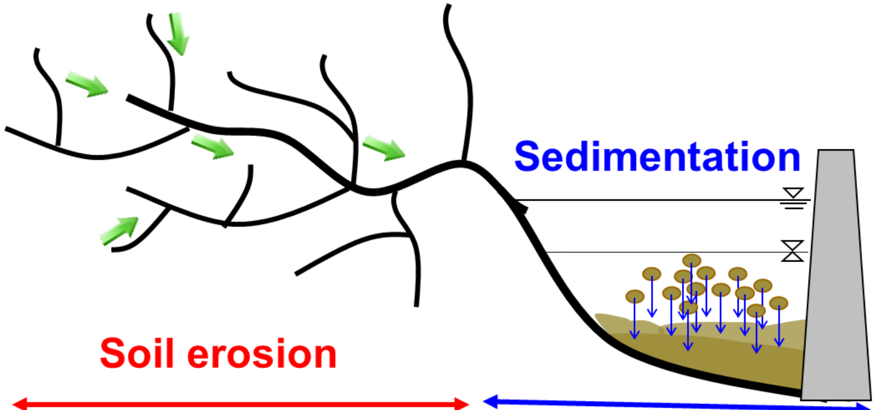
IMPACTS

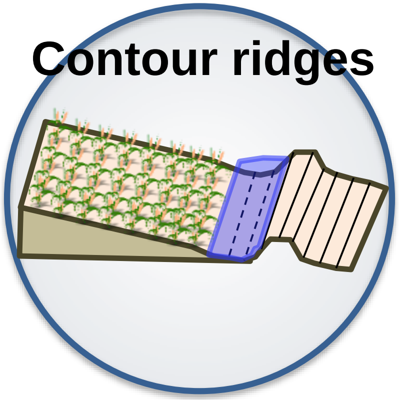
AGRICULTURAL : reduction of soil fertility and crop productivity,

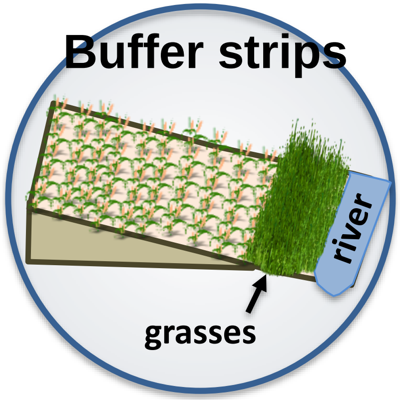
ENVIRONMENTAL : Increase of flooding risk

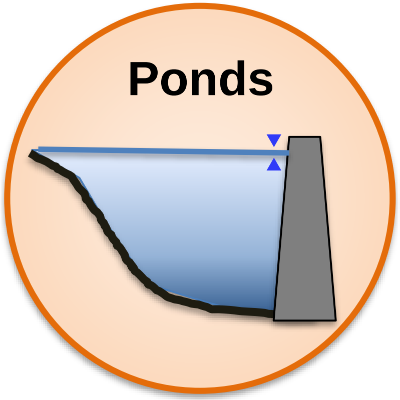
SOCIO-ECONOMIC : Food scarcity and poverty

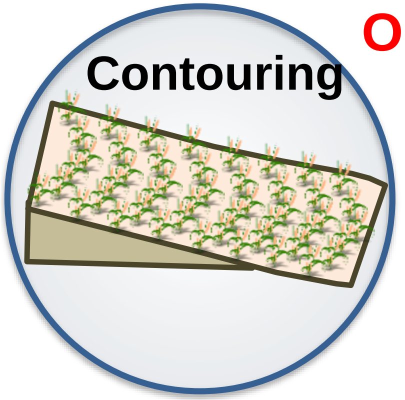
SUSTAINABILITY OF WATER RESSOURCES :
Sedimentation in water reservoirs
➔ Loss of reservoir storage capacity





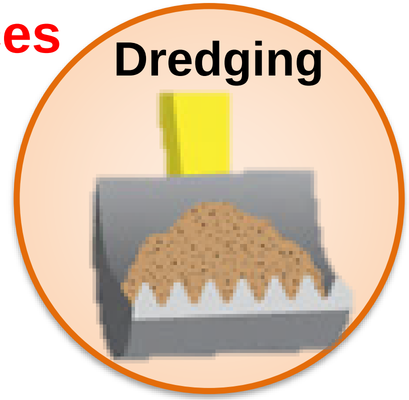


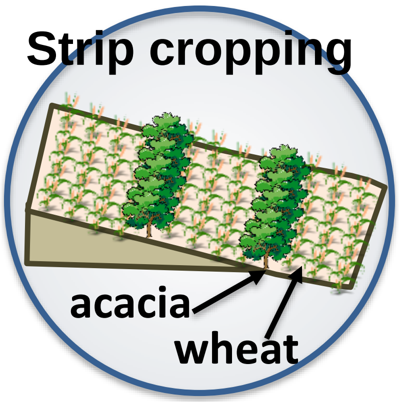


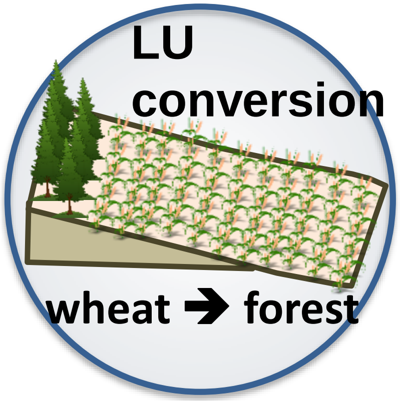


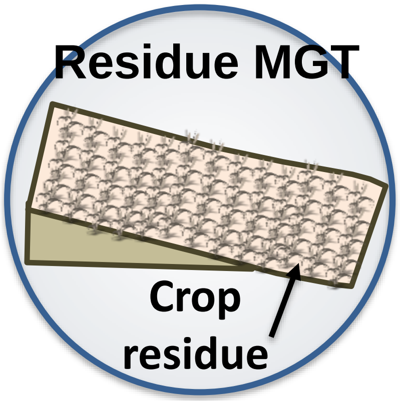
Objectives of sediment management practices

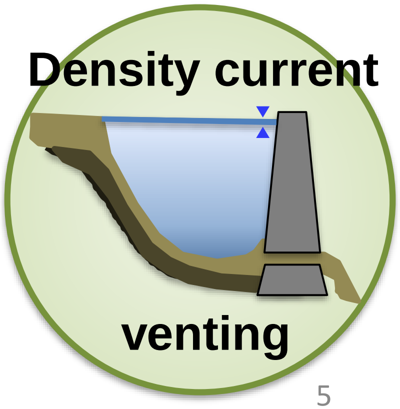
- Reduce sediment yield from watershed
- Minimize sediment deposition
- Recover the lost capacity



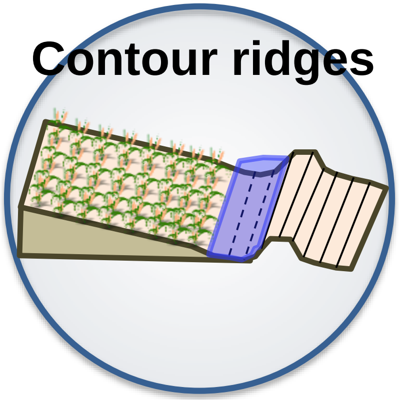


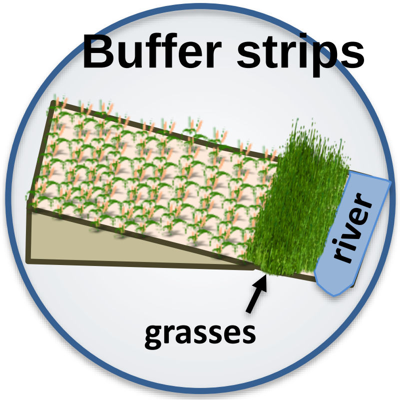


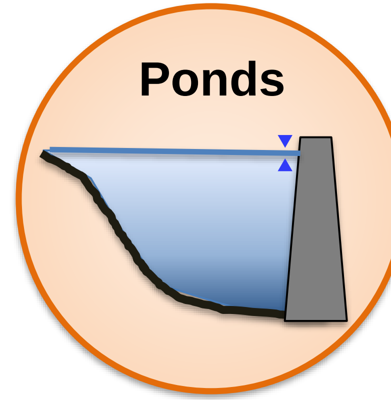


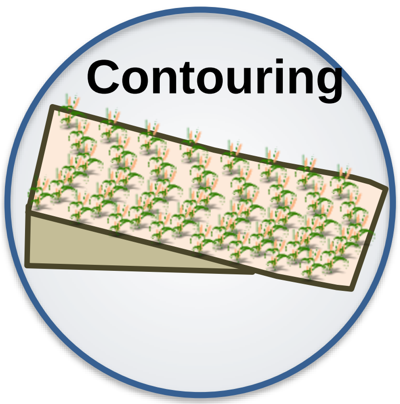


INTRODUCTION



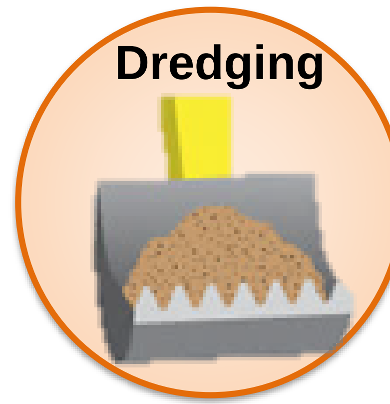


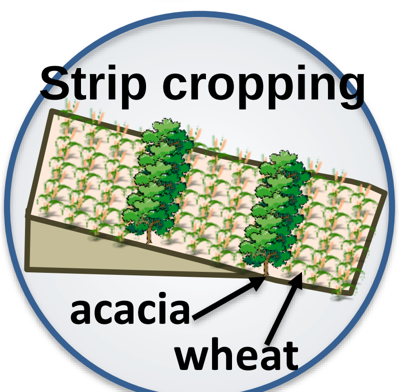


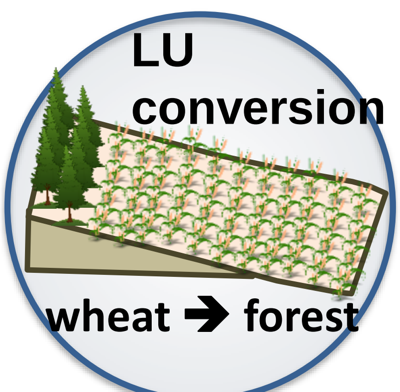


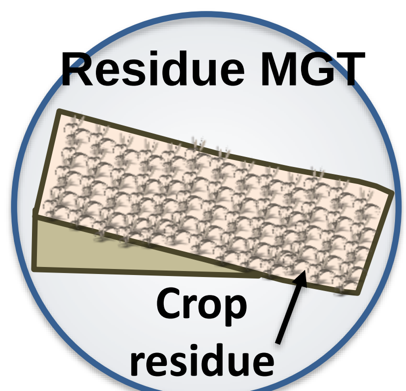
Research Questions

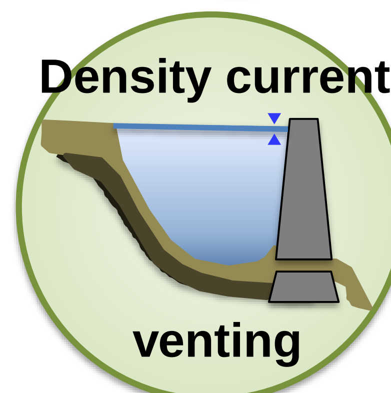
- Where BMPs should be implemented ?
- Which practice is more cost-effective ?
- Are BMPs scenarios more cost effective than dredging?



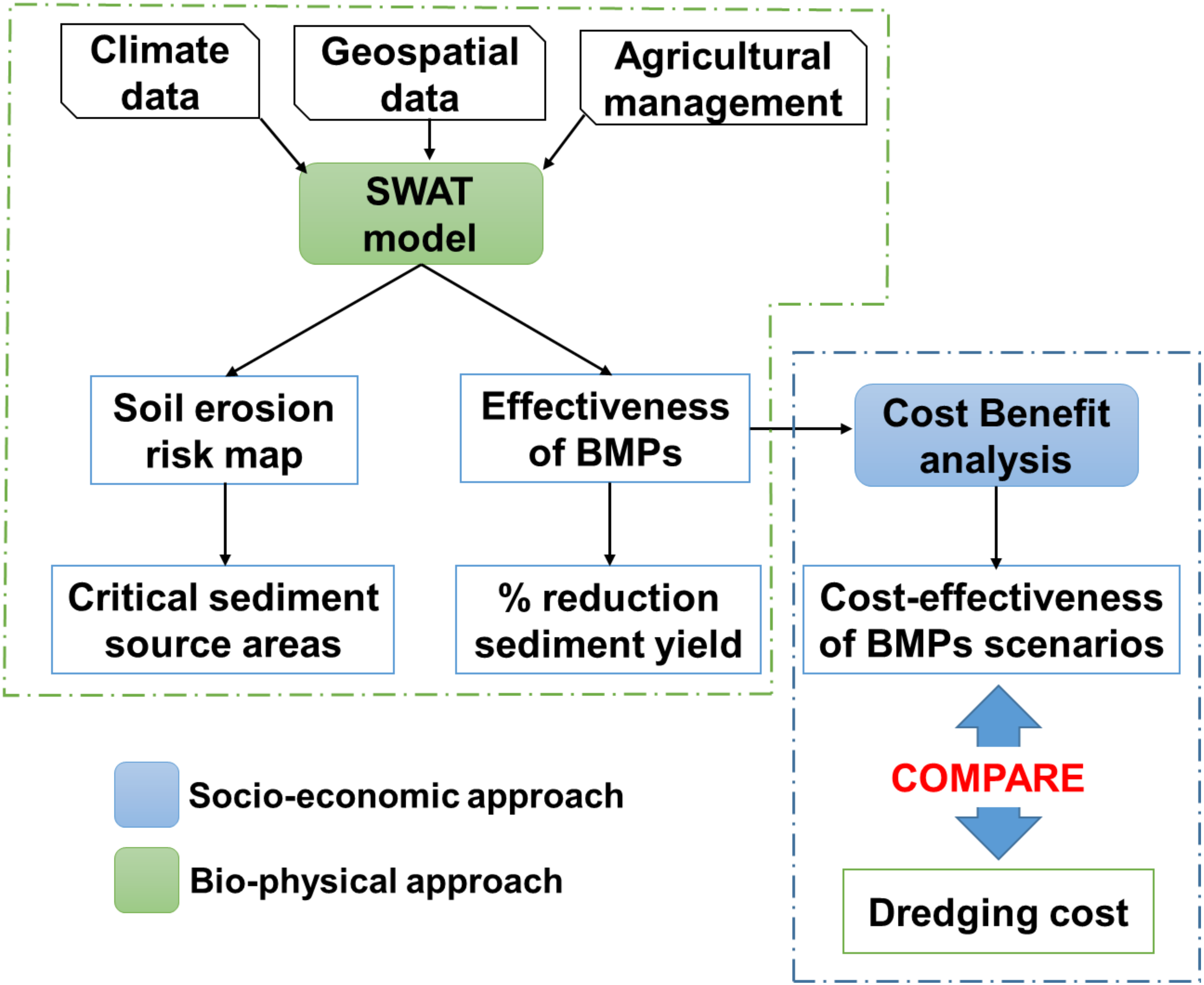




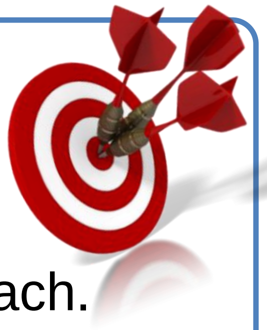




CONCEPTUEL FRAMEWORK OF THE RESEARCH



OBJECTIVES

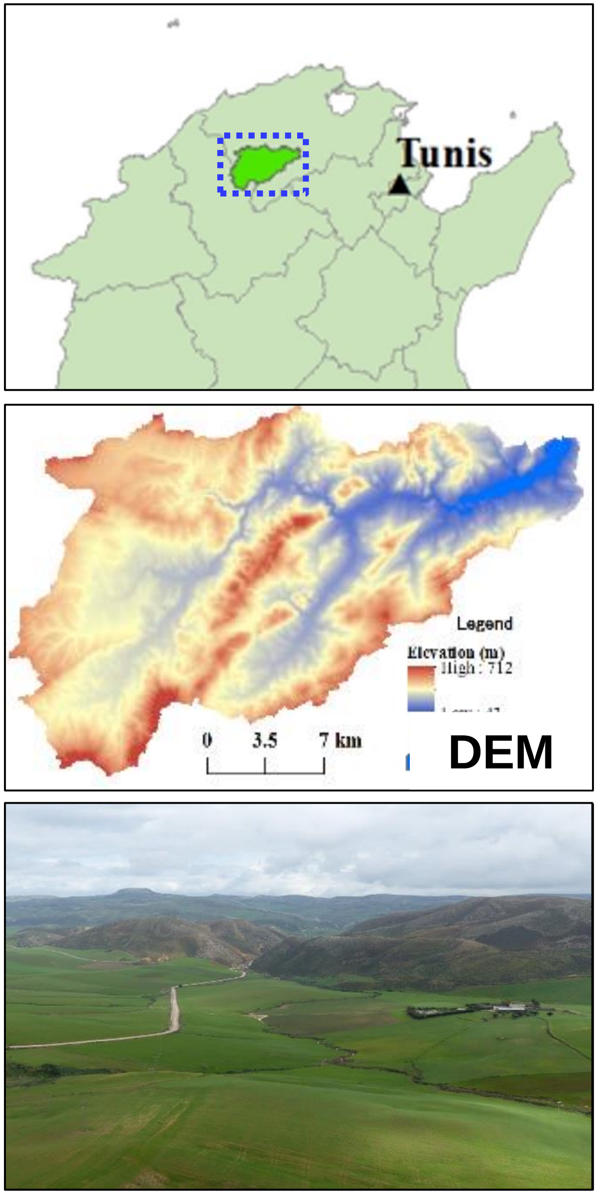


Research Objectives

- Assessing the **effectiveness** of different BMPs scenarios using an integrated **Environmental and Socio-Economic** approach.
- Selecting the **most appropriate scenario** to be applied for **sustainable** agriculture and water resources.

Appropriate strategy for water and soil conservation → **Sustainable use of water resources**

STUDY SITE



Location of Joumine watershed

JOUMINE river basin

Area
418 00 ha

Major land cover
agricultural land
65%

Major soil type
Calcic Vertisol

River discharge
116 Mm³/year

Precipitation
750 mm/year

Temperature
Average = 18 °C

JOUMINE reservoir

Area
660 ha

Construction
1983

Initial storage capacity
120.5 Mm³

Volume needed for flood control
95.1 Mm³

Sedimentation rate
0.513 Mm³/year
capacity lost ≈ 15%

Irrigation / Drinking
80 Mm³/year

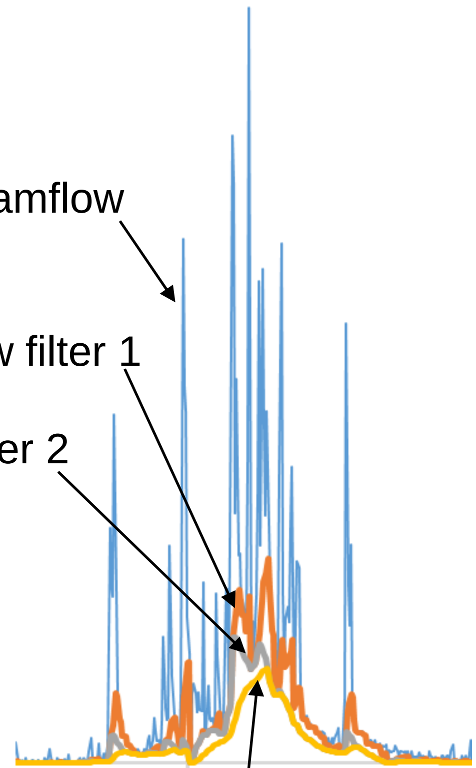
CALIBRATION OF DISCHARGE AND SEDIMENT

Running the model: Period: 1988-2012 (3 years as warmup period)

Calibration of discharge and sediment

Observed discharge
@ Outlet of the basin

Baseflow Filter program

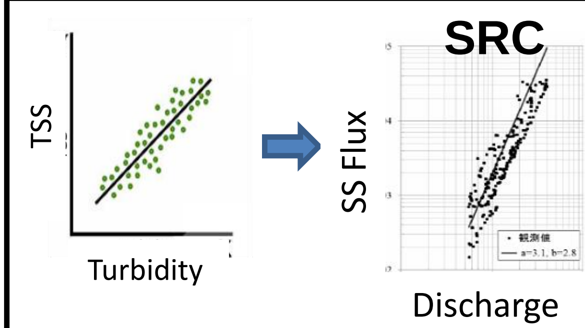


Water yield = **198.58**mm/year
50% < Surf. runoff < **70%**
30% < Base flow < **50%**
Alpha_BF factor = **0.1673**

+

R2 > **80%** NSE > **80%**

Observed Sediment
@ Outlet of the basin



Bathymetry survey

S.rate = **0.513** Mm^3/year

+

R2 > **50%** NSE > **50%**

BMPs MODELING IN SWAT MODEL

Simulation of BMPs effectiveness : according to conservation practices guide

Individual BMPs	Parameters	Specific Module
Contour ridges (CR)	POT_FR, POT_VOLX, CONT_CN-P	.HRU
Buffer strips (BS)	VFSRATIO and VFSCON FILTERW	.OPS and .MGT1
No till with R.Mgt (0.5 t/ha) (NoTill/RM)	CN2 ; USLE_P ; OV_N	.MGT1 and .HRU
Strip cropping (SC)	STRIP_CN, STRIP_C and STRIP_P	.OPS
Land use conversion (LUC)	USLE_C, Plant ID	.LUP

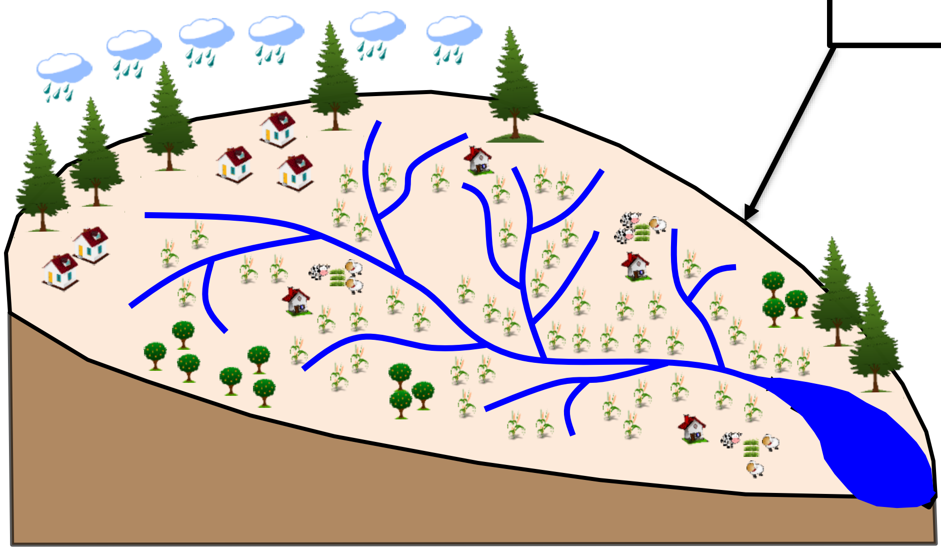
Targeted area	Combined BMPs				
	1	2	3	4	5
CSA 5%<slope<10%	NoTill/RM	SC	NoTill/RM	NoTill/RM	SC
CSA 10%<slope<20%	CR	CR		CR	CR
CSA slope > 20%	-	-		-	-
Slope > 20%	LUC	LUC	-	LUC	LUC
Along the main channel	-	-	20m BS	5m BS	5m BS

Assessing the effectiveness of BMPs:

Comparing the average sediment yield at the outlet of the basin before and after introducing the BMP

Watershed-scale: ***average*** *sediment yield in the whole basin: Avg*

$$Eff = \frac{SY_{Avg(without\ BMP)} - SY_{Avg(with\ BMP)}}{SY_{Avg(without\ BMP)}}$$



COST BENEFIT ANALYSIS OF BMPs SCENARIOS

Compare the **cost** and **benefit** of the project (BMPs) during the expected lifetime of the project (20 years).

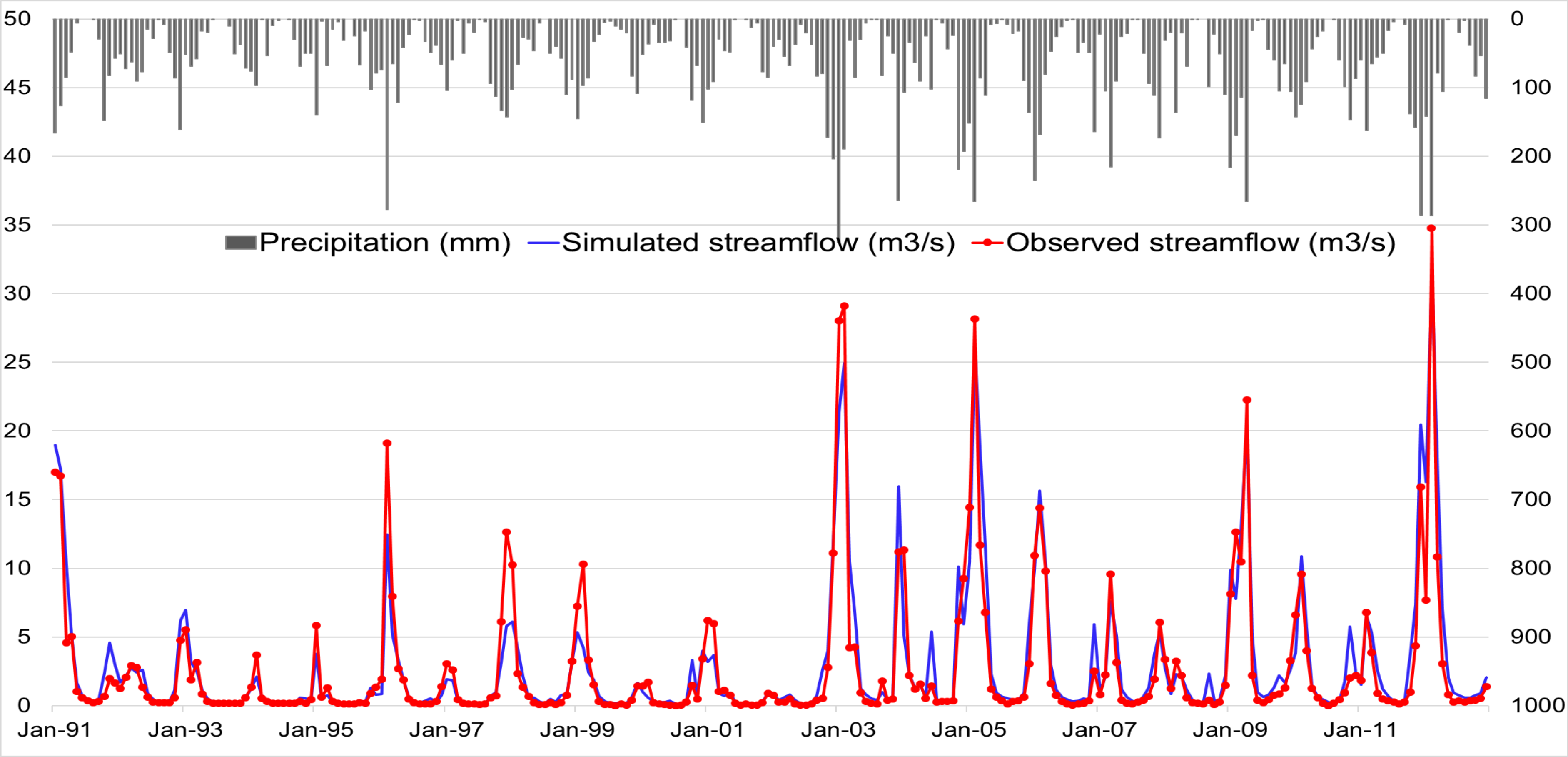
COSTS	BENEFITS
• Construction costs • Maintenance costs. • Opportunity costs : Expected gain from the lands lost for implementing BMPs	• Increase in productivity • Decrease the sedimentation ➔ More water for use. • Decrease the nutrients loss ➔ Opportunity cost

Calculate the different economic index to **judge** the project:

- **NPV:** Net present value : Total net benefits at the end of the project
- **B/C:** Benefit Cost ratio : Benefits / Costs

SIMULATION OF DISCHARGE

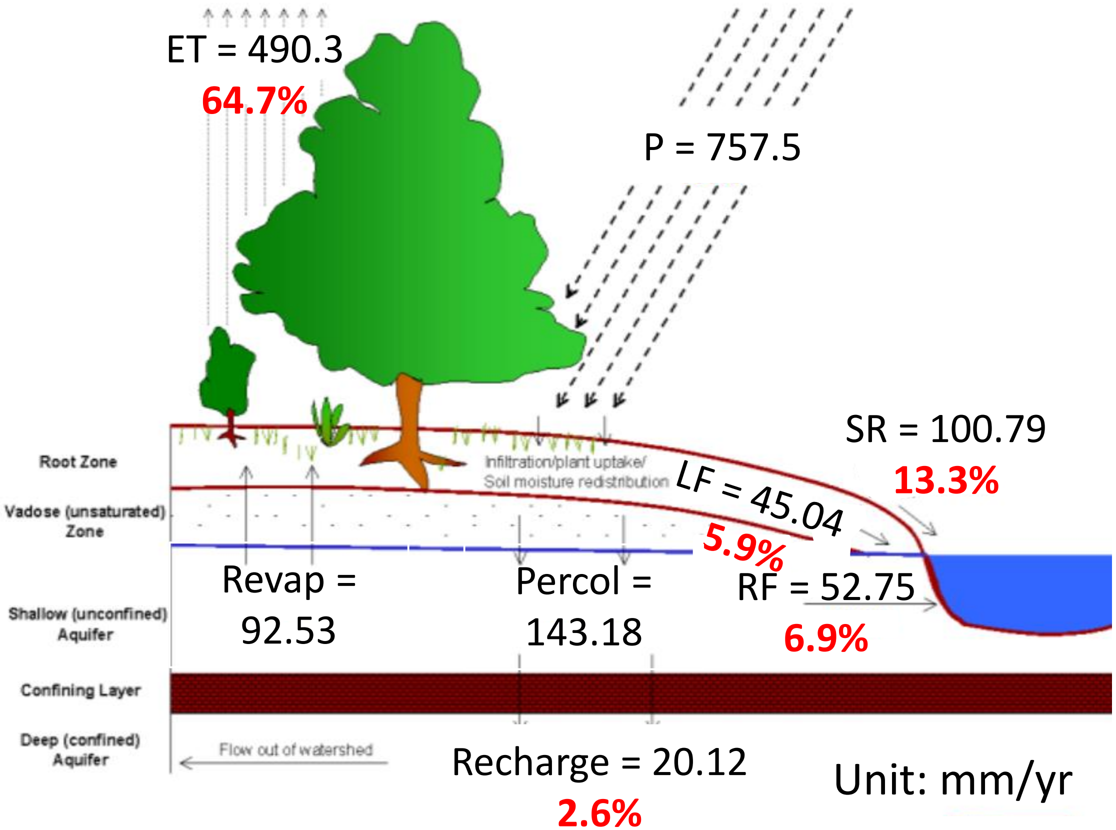
Comparison between observed and simulated discharge



Step	Period	R^2	NSE
Calibration	1991-2003	88%	87%
Validation	2004-2012	88%	86%

SIMULATION OF DISCHARGE

Water balance in Joumine river basin

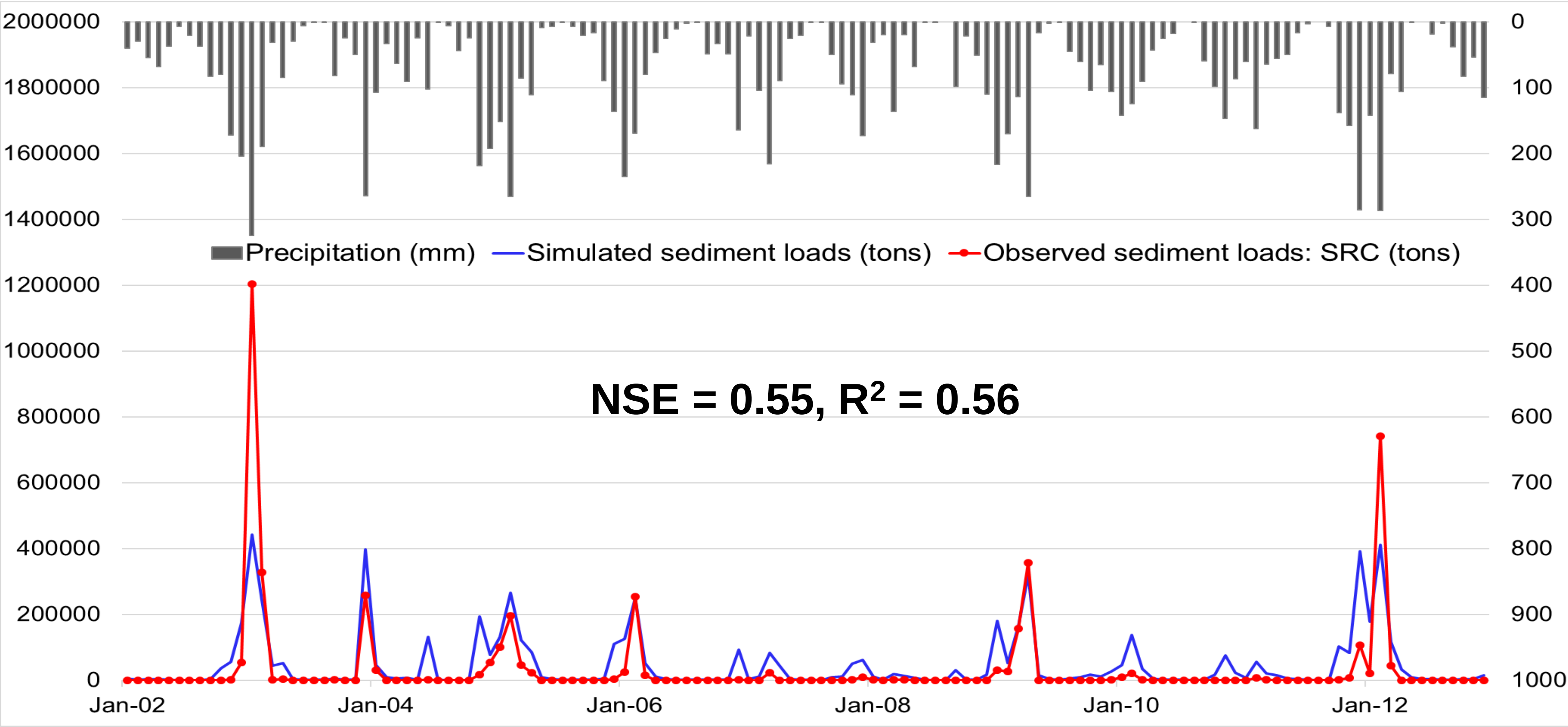


ET = Evapotranspiration
P= Precipitation
SR = Surface runoff
LF = Lateral flow
RF = Return flow
BF = Base flow = LF+RF

Component	SWAT simulation	Calculated by BF filter
Water yield mm/yr	198.58	198.78
SR mm/yr	100.79	Between 99.39 & 139.1
BF mm/yr	97.79	Between 59.63 & 99.39

SEDIMENT YIELD ASSESSMENT

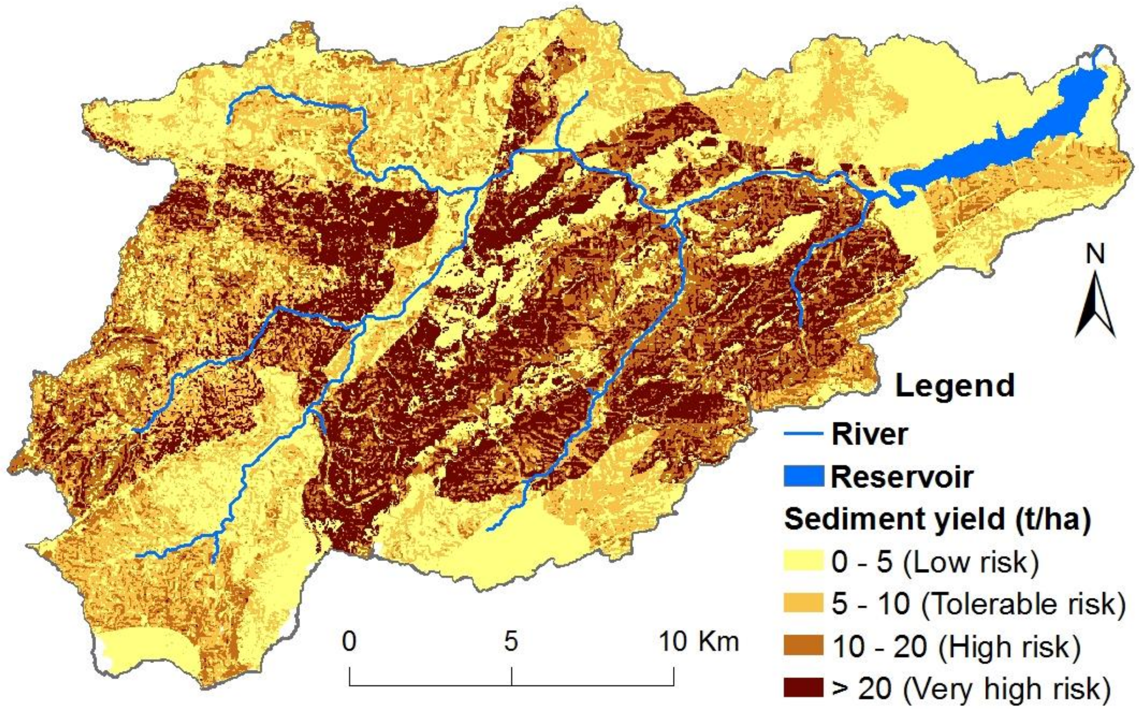
Simulated and observed sediment at the outlet of Joumine river after calibration



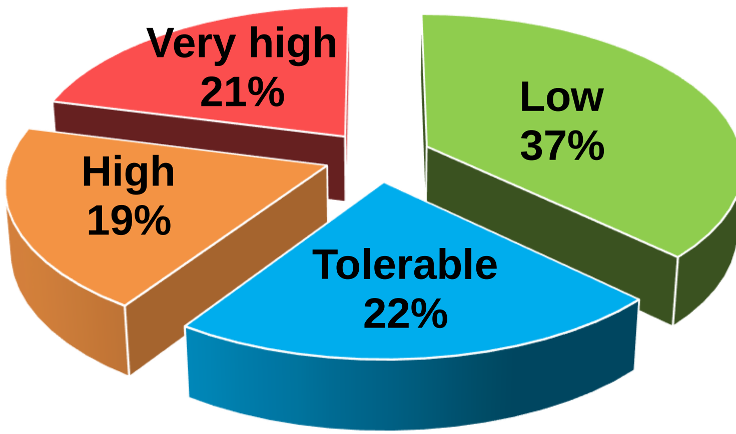
- **Overestimation:** during **low** rainfall events
- **Underestimation:** during **intense** rainfall events
- Sediment loads : Bathymetry vs SWAT model = **+3%**

SEDIMENT YIELD ASSESSMENT

Spatial distribution of sediment yield in Joumine river basin



Upland sediment yield
11.53 t/ha/yr



Percentage of soil erosion risk

Area with high to very high erosion risk

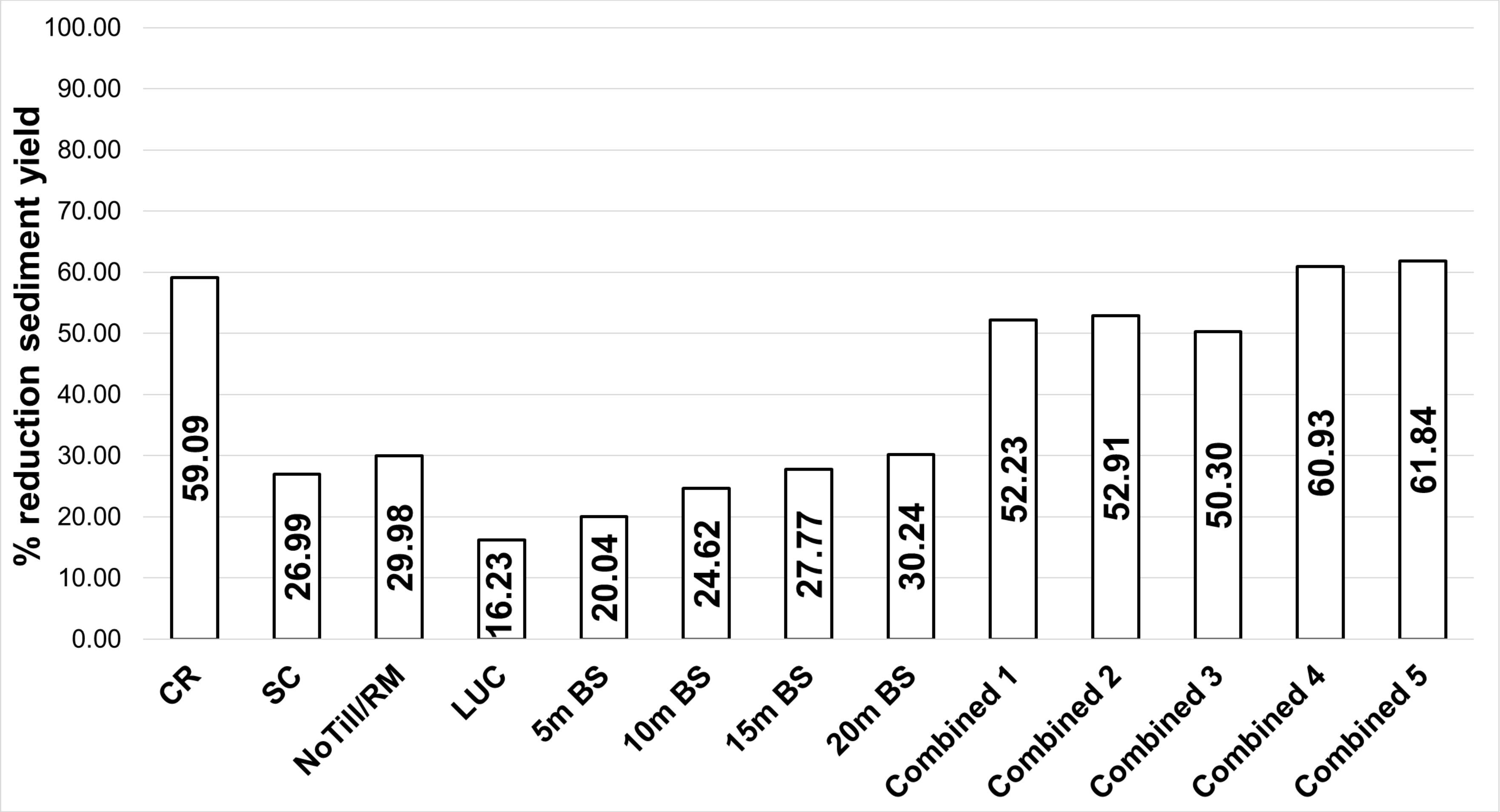
Land use	Area % basin	% Sediment Y
Cropland	**34.266**	**70.8**
Others	6.331	10.08
Total	40.59	80.88

BMPs should be introduced in the **critical sediment source areas** CSAs.

➔ **34.26%** of the basin area

BMPs EFFECTIVENESS

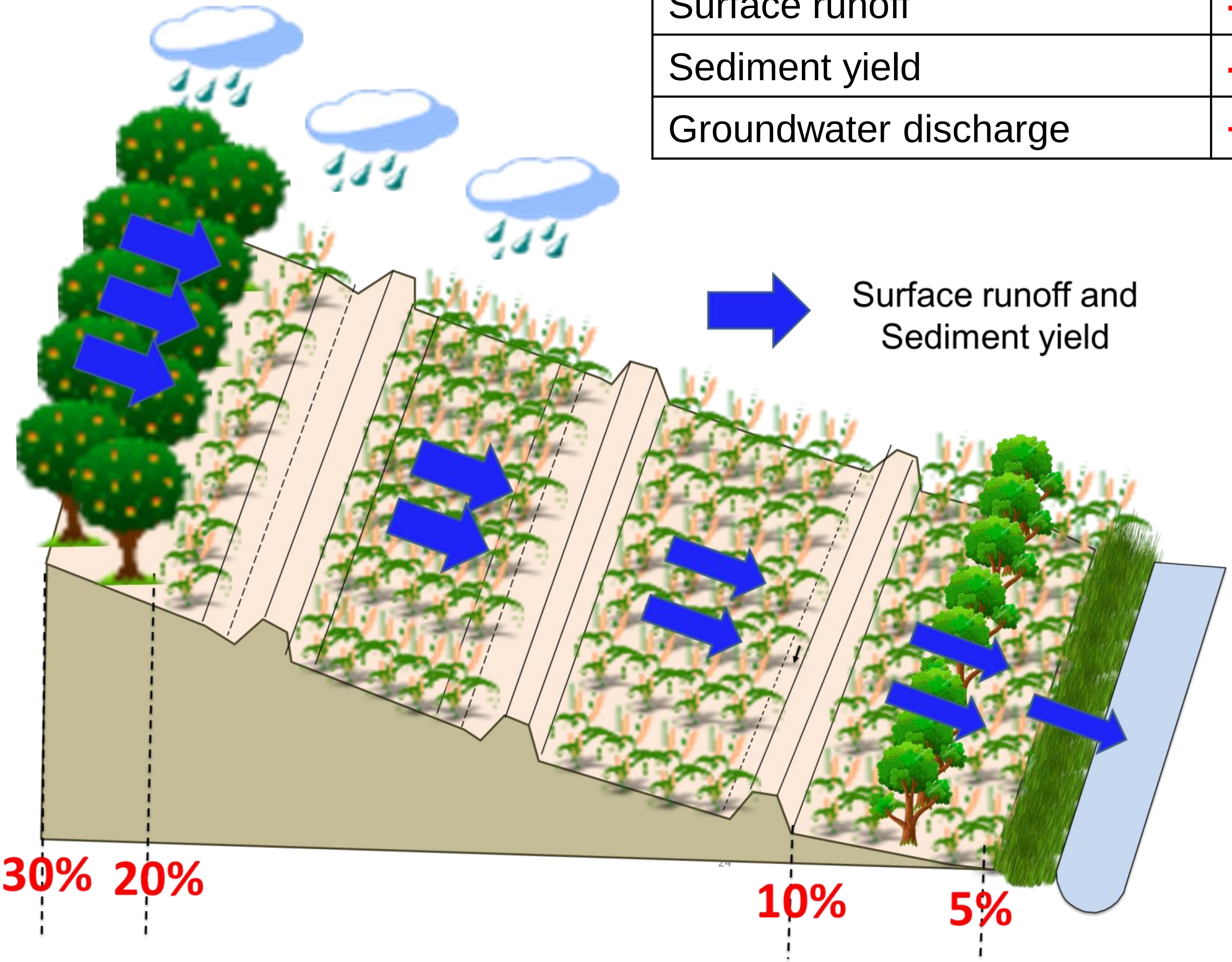
Effectiveness of BMPs scenarios to reduce sediment yield at Joumine river basin



- The most effective individual BMP is contour ridges.
- Combined BMPs scenarios were more effective to reduce sediment than individual BMPs

BMPs MODELING IN SWAT NODEL

Component	% change
Surface runoff	- 40%
Sediment yield	- 61.83%
Groundwater discharge	+ 32 %



COST-BENEFIT ANALYSIS OF BMPS SCENARIOS

BMP cost at farm-scale

BMP	Slope	Effectiveness (%)	Act cost (TND/ha/year)			
			Construction	Maintenance	Opportunity	Total
LUC	20% - 30%	71.1	70.00	16.00	0.00	86.00
CR	20% - 30%	73.38	40.01	13.72	106.52	**160.26**
	10% – 20%	80.99	39.92	13.04	69.97	122.94
	5% - 10%	87.92	35.76	12.28	43.36	91.41
NoTill/RM	5% – 30%	42.46	12.50	0.00	17.02	**29.52**
5 m BS	0% - 5%	59.00	3.50	2.66	12.74	18.90
20 m BS	0% – 5%	89.00	14.00	10.66	50.96	75.63
SC	5% - 10%	54.4	6.59	3.74	23.35	33.68

COST-BENEFIT ANALYSIS OF BMPS SCENARIOS

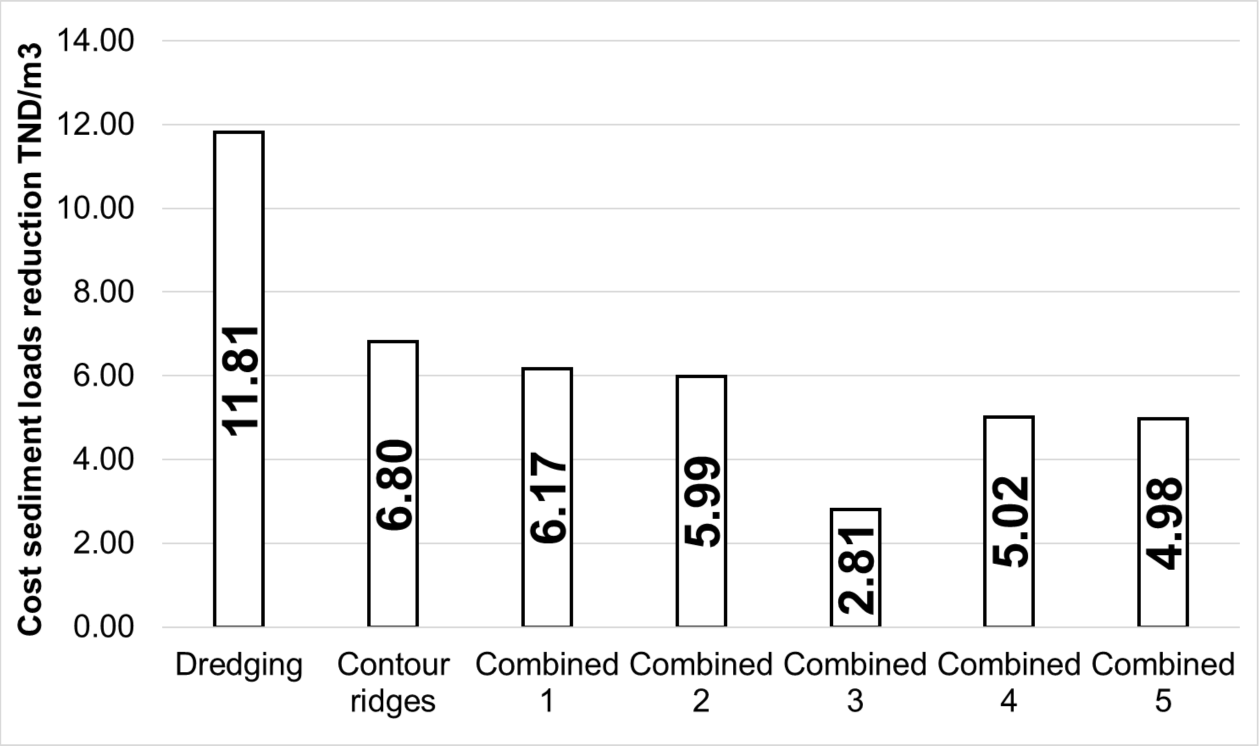
Economic indicators for the different BMPs scenarios

Economic Indicators	**Contour ridges**	**Combined 1**	**Combined 2**	**Combined 3**	**Combined 4**	**Combined 5**
Sediment yield reduction (%)	59.09	52.23	52.91	50.3	60.93	61.84
Cost act millions TND/year	1.72	1.25	1.26	0.54	1.28	1.30
Benefit act millions TND/year	2.07	1.91	2.09	0.70	1.92	2.09
NPV (millions TND)	7.07	13.3	16.50	3.16	12.61	15.81
B/C ratio	1.21	1.53	1.65	1.29	1.49	**1.61**

- The cost of **contour ridges** scenario is the **highest**
- The cost of **combined 2** scenario (NoTill / residue management + 20-m BS) is the **lowest**. However B/C is only 1.29 and it was not acceptable by local farmers because of increasing the crop production cost.
- Combined scenario 5 is the most appropriate in term of cost effectiveness, water quality benefits and sediment yield reduction

COST-BENEFIT ANALYSIS OF BMPS SCENARIOS

Cost of sediment removal (TND/m³)



BMPs scenarios were **more cost effective** to **reduce** sediment loads in the downstream river (Joumine river)

➔ Implementing BMPs scenarios ➔ **Delay** the dredging operations

CONCLUSION & OUTLOOK

SWAT model showed that :

- Contour ridges is the **most effective** individual BMPs
- **34%** of the watershed were identified as **CSA** and need implementing BMPs
- Structural practices (contour ridges) were found **more effective** than agronomic practices (no till, residue management).
- Combined BMPs are **more effective** to reduce sediment than individual BMPs

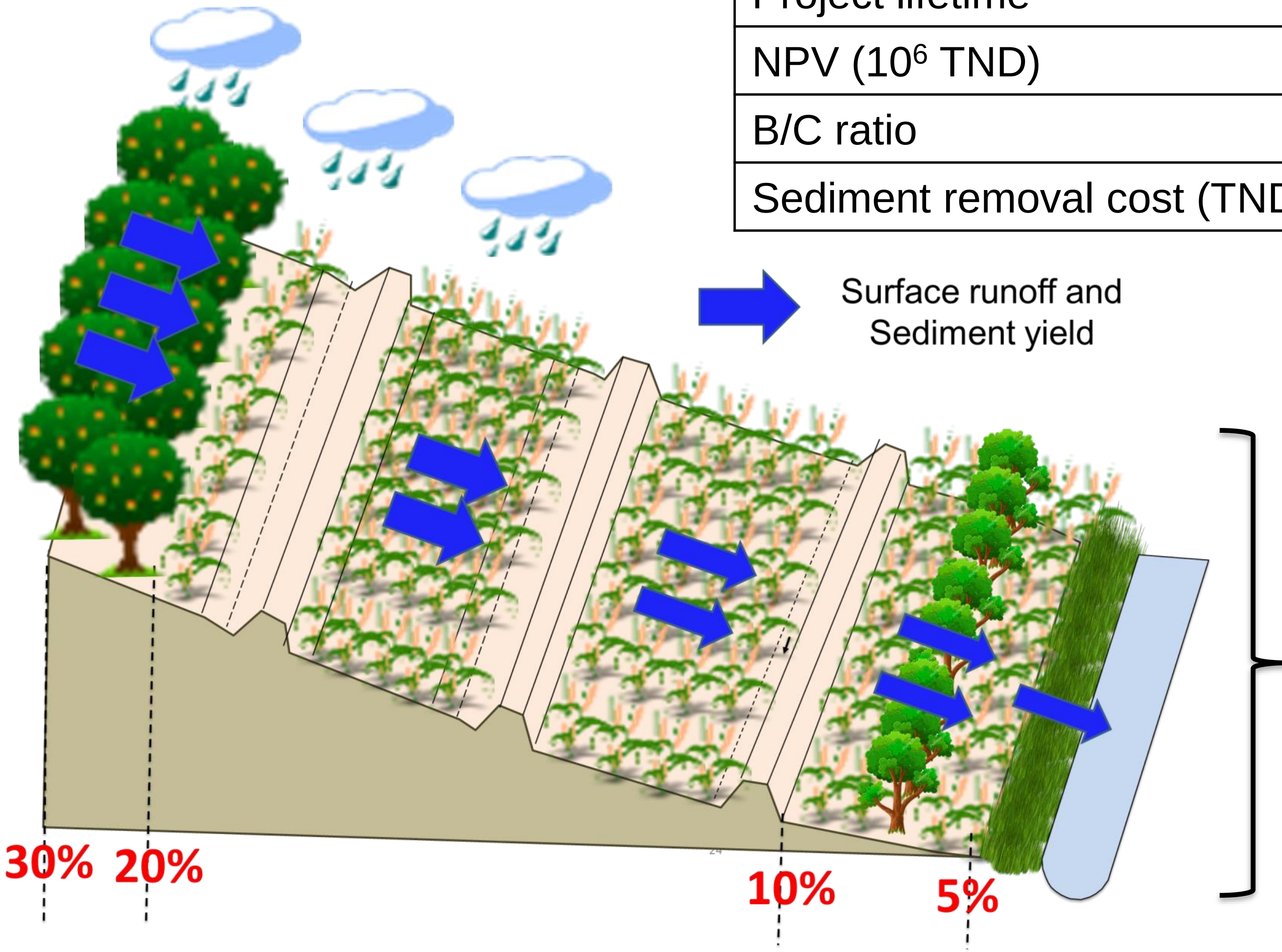
- Combined scenarios were found to be **more cost-effective** than contour ridges scenario
- Combining CR, SC and LUC BMPs depending on field slope with 5-m BS seems to be the most cost-effective scenario.
- BMPs scenario are **more** cost-effective to reduce sediment than dredging

Result of this study should be treated carefully because of the different assumptions considered during the modeling and economic assessments.

➡ In-field experiments would be required to validate the simulated results.

CONCLUSION & OUTLOOK

Sediment yield reduction	**61.83%**
Project lifetime	**20 years**
NPV (10^6 TND)	**18.69**
B/C ratio	**1.61**
Sediment removal cost (TND/m^3)	**4.98**



Appropriate control of sediment yield

Sustainable use of the surface water resources

Thank you for listening!