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SWAT modelling approach to assess the impacts of Best Management Practices (BMPs) in a potato crop

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Introduction

The environmental authorities defined Best Management Practices (Conservational Tillage) as solution of

Eutrophication process and degrades water quality caused by **potato** crop




How BMP- Conservational Tillage in a potato crop could influence the soil and nutrients (N and P) losses in runoff at the watershed level?

Objectives

General

To assess the impacts of CT on sediments, nitrogen (N) and phosphorus (P) losses in runoff for potato crop at the watershed level

Specific

To simulate a CT extrapolation scenario for the entire potato crop area in Fuquene watershed

Study Area

- Fuquene Lake watershed
  - Located North of Bogota, Colombia (5°28′00″N, 73°45′00″W)
    - Area of approximately 784 Km^2
    - Elevation range between 2,520 asl and 3,780 asl
    - Annual mean precipitation is 780 mm
  - Mean annual temperature values are between 12 °C and 18 °C
- The agricultural activity is based on monocultures, mostly on potato crop

What has been done before?

- Identifying sources of pollution through isotopes
- Supporting the availability of machinery for tillage
- **Adoption of Conservation Tillage (CT) practices as Best Management Practices**





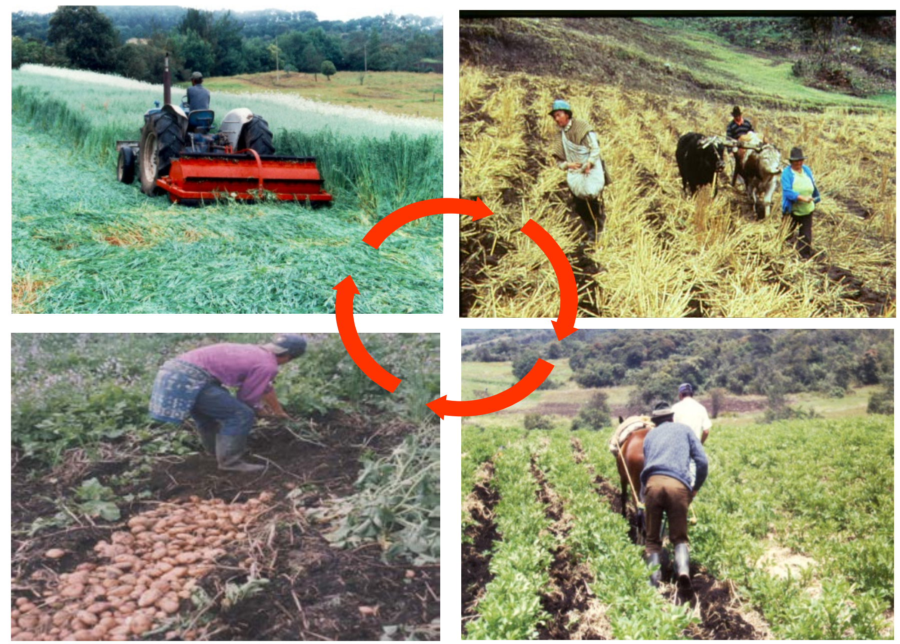

BMPs

Conservational Tillage (CT)

Intensive Tillage(IT) - Baseline

- ✓ **Intensive tillage**
  (Rotovator bedder–Invert the soil)
- ✓ **Without vegetation cover**

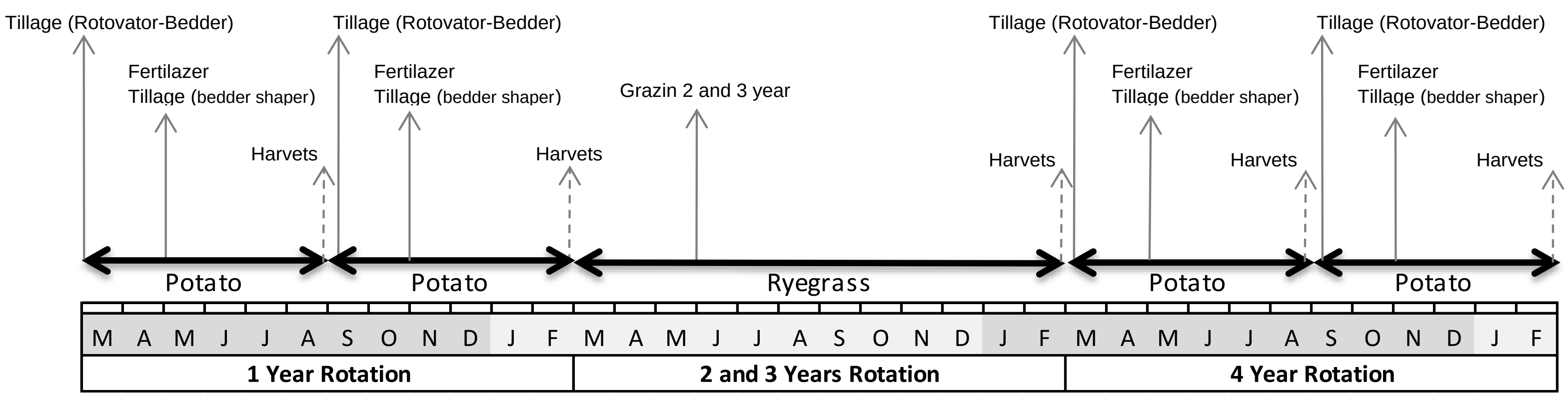
Conservational tillage (CT) - Scenario



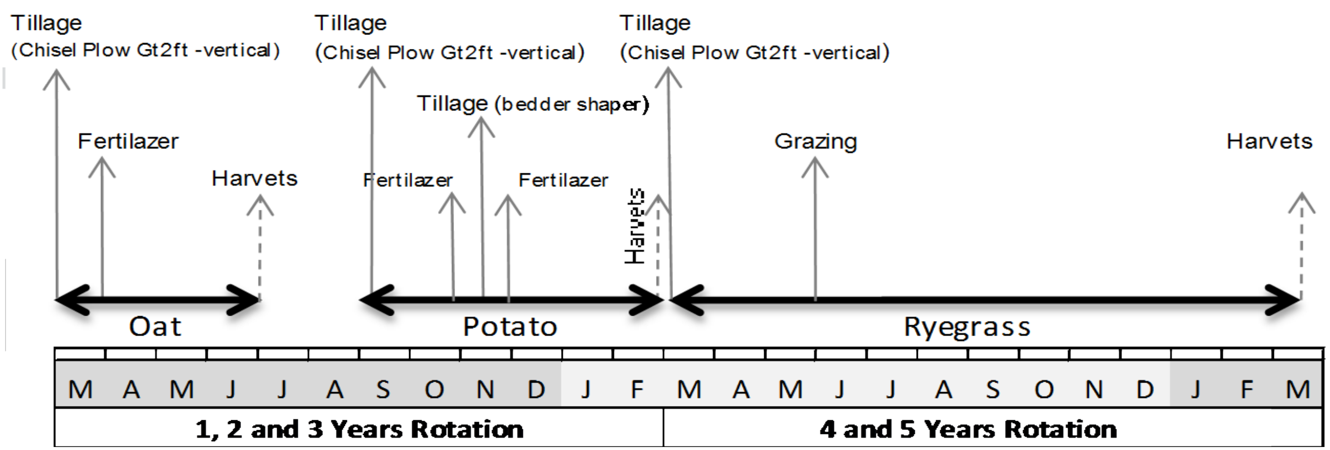
- ✓ **Reduced tillage**
  (chisel plow - vertical)
- ✓ **Rotations with green manures (oat)**
- ✓ **Permanent soil cover (oat residue)**

Input Data

Intensive Tillage(IT) - Baseline



Conservational tillage (CT) - Scenario

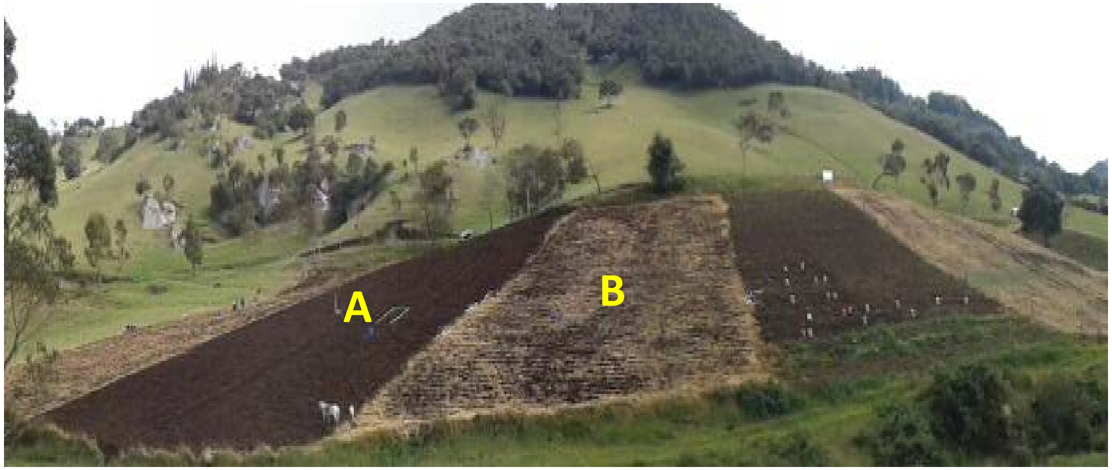


Conservational Tillage (CT)

Measuring impact of conservation tillage for potato crop

Experimental plots were installed in 2011 by CIAT in CT and IT systems

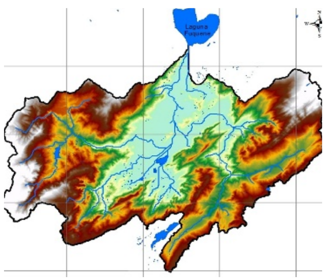
- Soil losses
- N and P in runoff



A) Intensive Tillage (IT)
B) Conservational Tillage (CT)

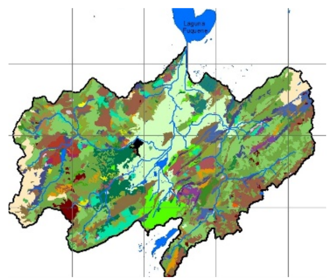
Input Data

Watershed level



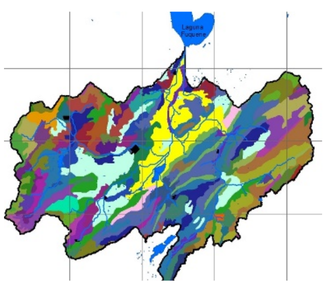
DEM

CAR – 30m



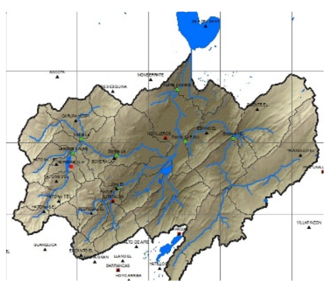
Land Use

IGAC - 1:25.000



Soils

IGAC - 1:100.000

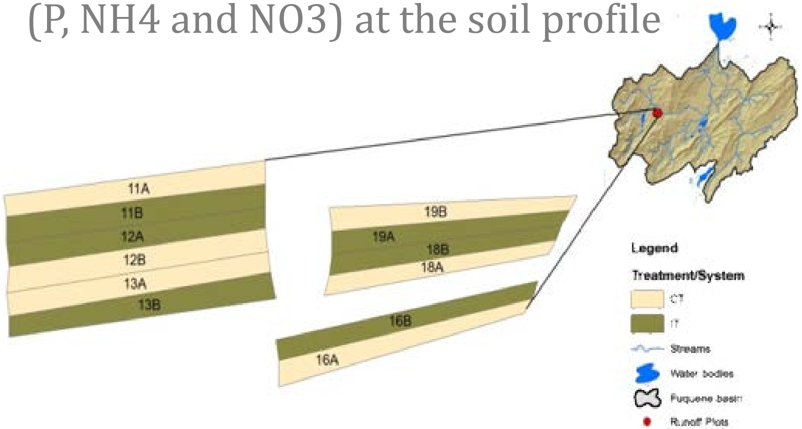


Weather stations

CAR / IDEAM –
St. Number: 21

Experimental field plots

- Soil profile descriptions in each plot
- Lab soil analysis
(Bulk density, Soil available water content , Hydraulic conductivity , % carbon , % sand, % silt, % clay and OM)
- Chemical parameters
(P, NH4 and NO3) at the soil profile



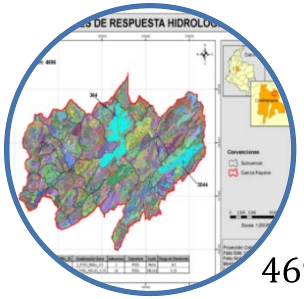
Fuquene Watershed – Plot Location

Modelling process

SWAT set up

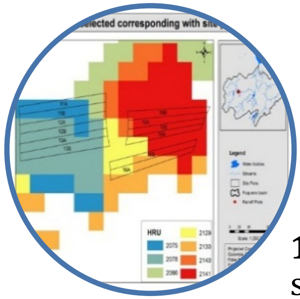
- ArcSWAT Version 2012.10_1.15
  For ArcGIS 10.1 released 6/20/14 revision 627 was used jointly by SWAT 2012
- Daily rainfall, temperature and relative humidity data
- 5 slope ranges
  (0-5%; 5-15%; 15-25%; 25-45%; and >45%)
- Hargreaves method used for potential evapotranspiration (PET)

31 drainage areas (sub-basins) were defined



4696 **HRU** defined

Combinations of sub-basin, land use, soil and slope



170 HRUs were selected because these spatially correspond with the plots installed in the field

SWAT set up

Parameter values related management practices per scenario

Variable Name	Definition	Value				
		IT		CT		
		POTA	PASTURE	POTA	OAT	PASTURE
Planting						
PLANT_ID	Plant/land cover code from crop.dat	POTA	RYEG	POTA	OATS	RYEG
HEAT UNITS	PHU: Total heat units required for plant maturity	800	700	800	400	700
BIO_INIT	Initial dry weight biomass (Kg/ha)	200		200	18	
HI_TARG	Target harvets index					
BIO_TARG	Biomass (dry weight) target (metric tons/ha)					
CN2	Initial SCS runoff curve number (Min 35- Max 98)	62	40	62	53	40
Grazing						
MANURE_ID	Manure code from fert.dat		Beef-Fresh			Urea
GRZ_DAYS	Number of days of grazing		200			200
BIO_EAT	Dry weight plant biomass consumed daily (kg/ha)		30			30
BIO_TRMP	Dry weight of biomass trampled daily ((Kg/ha)/day)		14			14
MANURE_KG	Amount of manure applied -dry weight (kg/ha)		6			6
BIO_MIN	Minimum plant biomass for grazing to occur (kg/ha)		500			500
Tillage						
TILLAGE_ID	Tillage implementation	Bedder shaper	Rotovator-bedder	Chisel Plow Gt2ft -vertical		Bedder shaper
EFFMIX	Mixing efficiency of tillage operation (fraction)	0.55	0.8	0.3		0.55
DEPTIL	Depth of mixing by tillage operation (mm)	150	100	150		150
BIOMIX	Biological mixing efficiency (fraction)	0.2	0.2	0.2	0.2	0.2
Fertilizer						
FERT_ID	Type of fertilizer/manure applied	13-26-06		13-26-06	Urea	
FRT_KG	Amount of fertilizer/manure applied (Kg/ha)	1400 (2 times of 700 each one's)		1000 (2 times of 500 each one'sl)	300	
FRT_SURFACE	Fraction of fertilizer applied to top 10 mm	1		1	1	

Results — Flow calibration and validation

Parameters included in the flow calibration process and their final calibration values

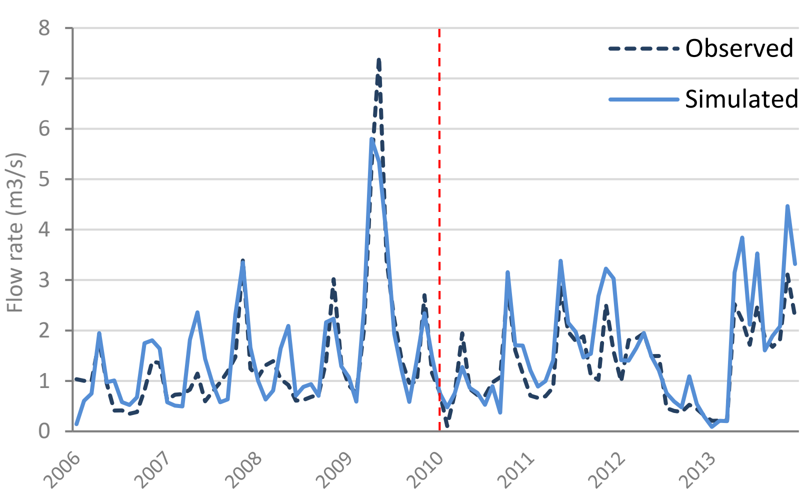
Parameters	Description in SWAT	Range	Model default value	Final value
ALPHA_BF	Baseflow alpha factor [days]	0 - 1	0.048	0.02
GW_DELAY	Groundwater delay [days]	0 - 500	31	25
GW_REVAP	Groundwater "revap" coefficient	0 - 1	0.02	0.02
RCHRG_DP	Deep aquifer percolation fraction	0 - 1	0.05	0.1
REVAPMN	Threshold water depth in the shallow aquifer for "revap" [mm]	0 - 500	1	100
GWQMN	Threshold water depth in the shallow aquifer for flow [mm]	0 - 5000	0	100
SHALLST	Initial depth of water in the shallow aquifer (mm).	0 - 1000	0.5	100
GW_SPYLD	Specific yield of the shallow aquifer (m3/m3).	0 - 0.4	0.003	0.2
GWHT	Initial groundwater height [m]	0 - 25	1	25
CN2	Initial SCS CN II value	35 - 98	Changes conducted for each HRU	
SOL_K	Saturated hydraulic conductivity [mm/hr]	0 - 2000	Changes conducted for each Soil Survey Unit	
SOL_AWC	Available water capacity [mm H20/mm soil]	0 - 1		

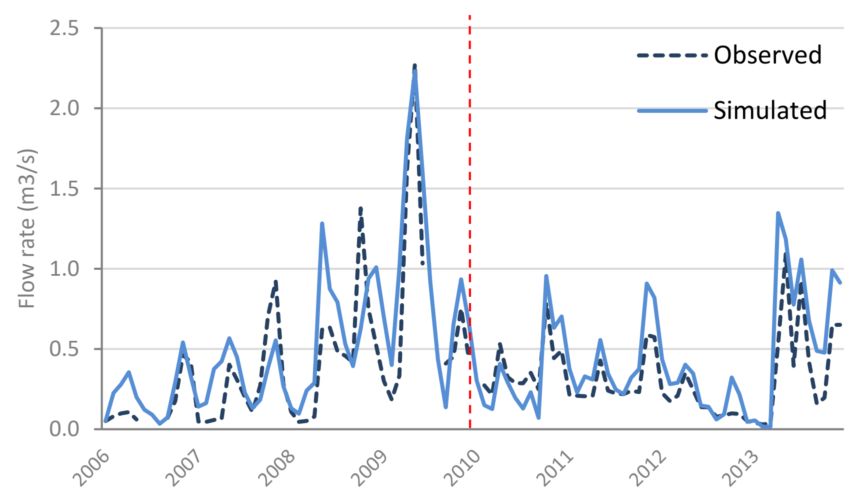
Flow calibration and validation

Catchment station	CALIBRATION (2006-2009)			VALIDATION (2010-2013)		
	Flow rate (m^3/s)		NSE	Flow rate (m^3/s)		NSE
	Sim.	Obs.		Sim.	Obs.	
La Boyera	1.50	1.41	0.78	1.60	1.32	0.45
El Pino	0.52	0.43	0.61	0.42	0.32	0.33
Pte. La Balsa	1.58	1.38	0.50	2.03	1.45	0.45
Pte. Colorado	3.58	3.85	0.68	4.60	3.87	0.61

Nash–Sutcliffe coefficient of efficiency (NSE)

NSE ranges between -∞ and 1.0.
NSE=1 being the optimal value
NSE ≤ 0 unacceptable performance





Simulated and observed flow rate in the La Boyera station and El Pino stations respectively

Sediment and nutrient calibration and validation

Parameters included in the sediment and nutrient calibration and their final values

Parameters	Description in SWAT	Location	Range	Default value	Final value
Sediment					
BIOMIX	Biological mixing efficiency	.mgt	0 - 1	0.2	0.2
CN2	SCS runoff curve number for moisture condition II	.mgt	35 - 98	69	+ 10%
USLE_P	USLE equation support practice practices	.mgt	0 - 1	1	0.5
SLSUBBSN	Average slope length.	.hru	10 - 150	Changes for HRU	- 10%
Crop growth					
T_OPT	Optimal temp for plant growth.	.dat	11 - 38	22	17
T_BASE	Min temp plant growth.	.dat	0 - 18	7	5
HEATUNITS	Total heat units for cover/plant to reach maturity	.mgt	0 - 3500	1800	800*
Nutrients					
PHOSKD	Phosphorus soil partitioning coefficient.	.bsn	100 - 200	175	200
NPERCO	Nitrogen percolation coefficient.	.bsn	0 - 1	0.2	1
RSDCO	Residue decomposition coefficient	.bsn	0.02 - 0.1	0.05	0.1
SOL_LABP	Initial (soluble) P concentration in surface soil layer [mg/kg]	.chm	0 - 100	0	44
SOL_NO3	Initial NO3 concentration in the soil layer [mg/kg]	.chm	0 - 100	0	12
SOL_ORGN	Initial organic N concentration in the soil layer [mg/kg]	.chm	0 - 100	0	10
SOL_ORGP	Initial organic P concentration in surface soil layer [mg/kg]	.chm	0 - 100	0	10
PPERCO_SUB	Phosphorus percolation coefficient.	.chm	10 -17.5	10	17
BIO_TARG	Biomass (dry weight) target (metric tons/ha)	.mgt	4 - 100	0	30
FRT_SURFACE	Fraction of fertilizer applied to top 10mm of soil	.mgt	0 - 1	0	1

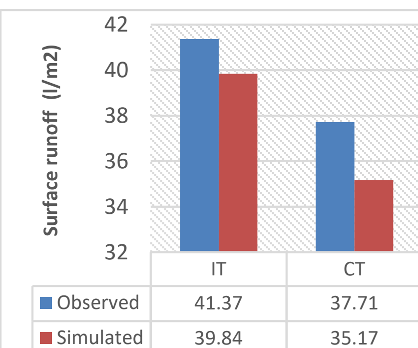
* Value calculated with local weather using PHU_program available at SWAT webpage (http://swat.tamu.edu/software/potential-heat-unit-program/)

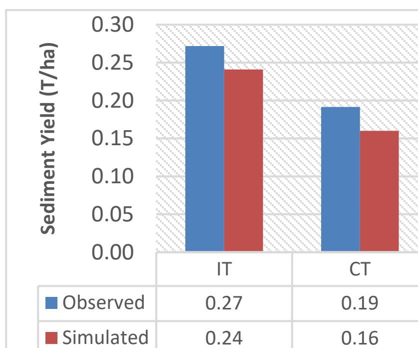
Sediment and nutrient calibration and validation

Sediment and nutrient losses performance

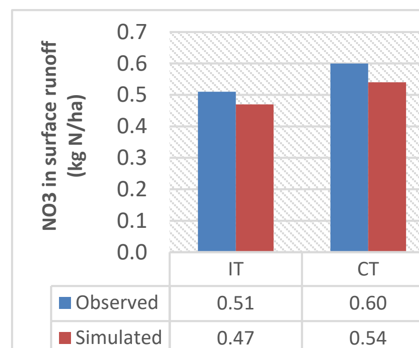
Variable **	IT			CT		
	Observed	Simulated	Ɛ*	Observed	Simulated	Ɛ
Surface runoff (l/m2)	41.37	39.84	-1.53	37.71	35.17	-2.54
NO_3 in surface runoff (kg N/ha)	0.51	0.47	-0.04	0.60	0.54	-0.06
Soluble P (kg P/ha)	0.19	0.27	0.08	0.28	0.33	0.05
Sediment Yield (T/ha)	0.27	0.24	-0.03	0.19	0.16	-0.03

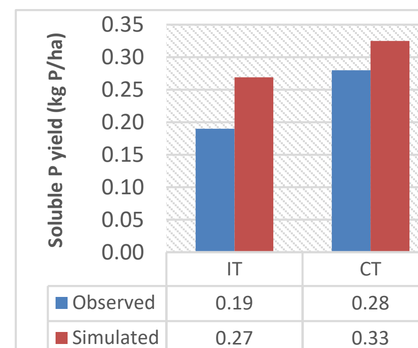
Accumulate total values for calibration period (September 2011 - March 201). * **Ɛ: Relative error.





Surface runoff and Sediment yield decrease – Simulated values were underestimated





Nitrate in surface runoff and Soluble P increase – Soluble P value was overestimated

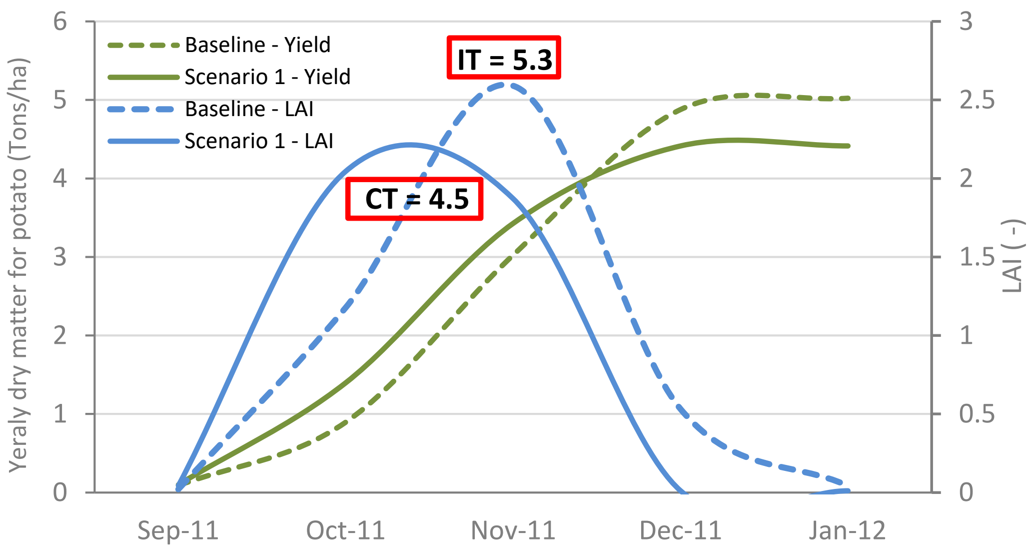
Effect on potato crop yield

Average biomass and yield potatoes measured by CIAT team for IT at the runoff plots

Potato variety	Total Yield (Ton/ha)	Yield (Ton/ha) Dry weight	Humidity Potatoes (%)	Total Biomass (Ton/ha) Dry weight
ICA-UNICA	28.20	6.11	0.22	9.87
BETINA	24.35	5.46	0.22	8.76
Average	**26.28**	**5.79**	**0.22**	**9.32**

- ✓ Good dry matter yield calibration (5.3 ton/ha SWAT model at IT system and 5.8 ton/ha measured)
- ✓ Average dry matter yield from IT is half ton more than CT (4.5 ton/ha)

Average yield potatoes by SWAT model at HRU level



LAI and dry matter development for potato crop at 2141 HRU – Baseline and Scenario 1

Summary results

Effects of the CT system at HRU level according to SWAT simulations

Variable	Scenario 1 (IT)	Scenario 2 (CT)	Reduction (%)
Surface runoff (l/m2)	32.84	24.03	-26.83
Sediment Yield (T/ha)	0.58	0.31	-45.49
Nitrogen Losses (kg/ha)			
Total N Loss	221.15	258.05	16.69
Organic N	0.08	0.12	51.32
Nitrate Surface Runoff	0.39	0.47	19.34
Nitrate Leached	166.65	191.16	14.71
Nitrate Lateral flow	4.00	4.85	21.23
Nitrate Groundwater Yield	50.03	61.46	22.84
Phosphorus Losses (kg/ha)			
Total P Loss	0.24	0.31	27.69
Organic P	0.03	0.02	-25.81
Soluble P Surface Runoff	0.21	0.29	35.55

- ✓ **CT reduce surface runoff by 27%**
- ✓ **CT reduce sediments yield by 45%**
- ✓ **CT reduce Organic P by 26%**
- ✓ **CT increase total N and P (17% and 28% respectively)**

Effect on the CT extrapolation at the basin level

Effect on the CT extrapolation scenario for the entire potato crop in the Fuquene basin

Variable	Scenario 1 (IT)	Scenario 2 (CT)	Reduction (%)	Reduction at HRU level (%)
Surface runoff (mm/yr)	15.91	14.13	-11.19	-26.83
Sediment Yield (T/ha)	1.89	1.40	-25.91	-45.49
Nitrogen Losses (kg/ha)				
Total N Loss	21.33	21.71	1.81	16.69
Organic N	3.36	3.38	0.65	51.32
Nitrate Surface Runoff	0.53	0.62	17.99	19.34
Nitrate Leached	9.22	9.43	2.20	14.71
Nitrate Lateral flow	6.03	6.11	1.46	21.23
Nitrate Groundwater Yield	2.17	2.20	1.15	22.84
Phosphorus Losses (kg/ha)				
Total P Loss	0.77	0.63	-18.22	27.69
Organic P	0.49	0.45	-7.00	-25.81
Soluble P Surface Runoff	0.29	0.18	-37.15	35.55

Summary of results of the main effects of the IT and CT system on N and P total losses at watershed level

Conclusions

- Results suggest that CT at watershed level reduces 26% sediment yield and 11% surface runoff compared with IT, which means an overall reduction of load.

- The main CT effect on nutrient losses in runoff is an increase in the total N and P (2% to 18% respectively) compared to baseline.

- The results at watershed scale showed different patterns than the ones obtained at HRU (calibrated and validated).

- Additional study needs to be carried out in order to make an appropriate extrapolation of CT.

Recommendations

An adjustment to the **amounts of fertilizer** could help decrease nutrients in runoff of CT in potato, considering that green manure made an important nutrients contribution.

Modeling approach can be used to estimate the impacts of CT-BMPs, however, it is necessary to have data for others runoff plots in different type of soils.

Thank you.

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Time for questions

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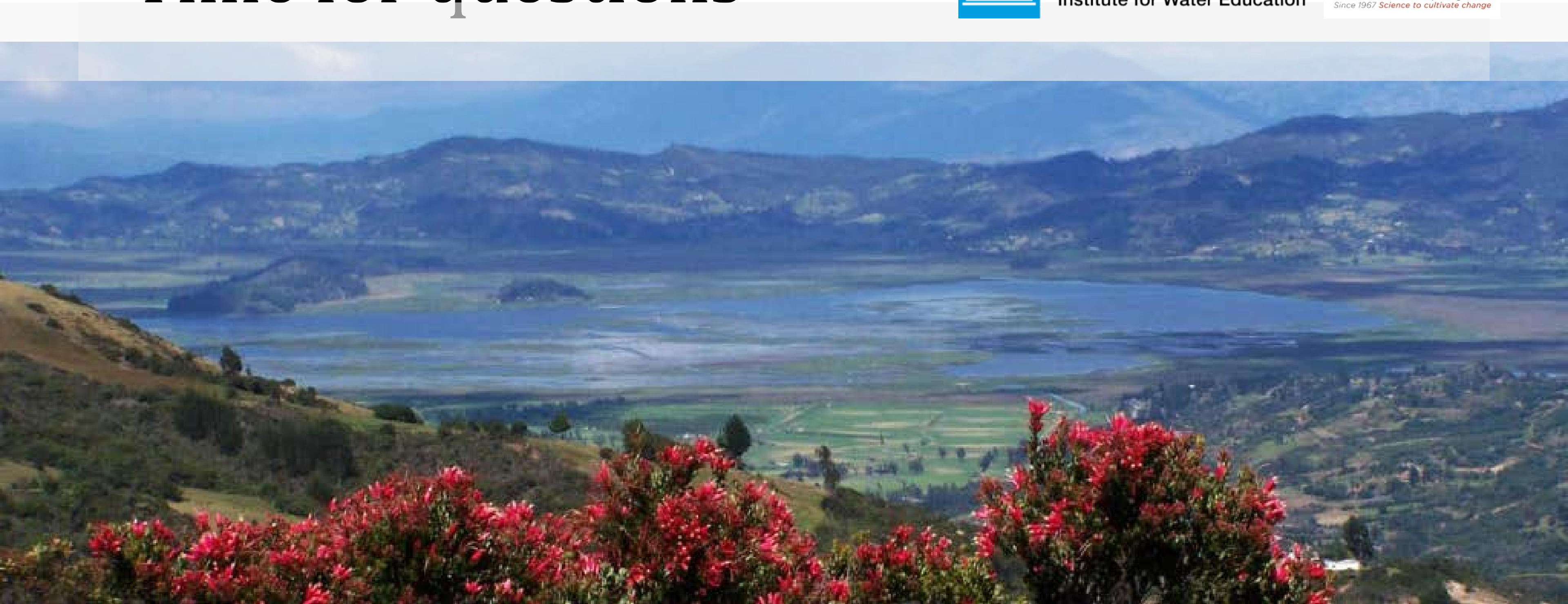
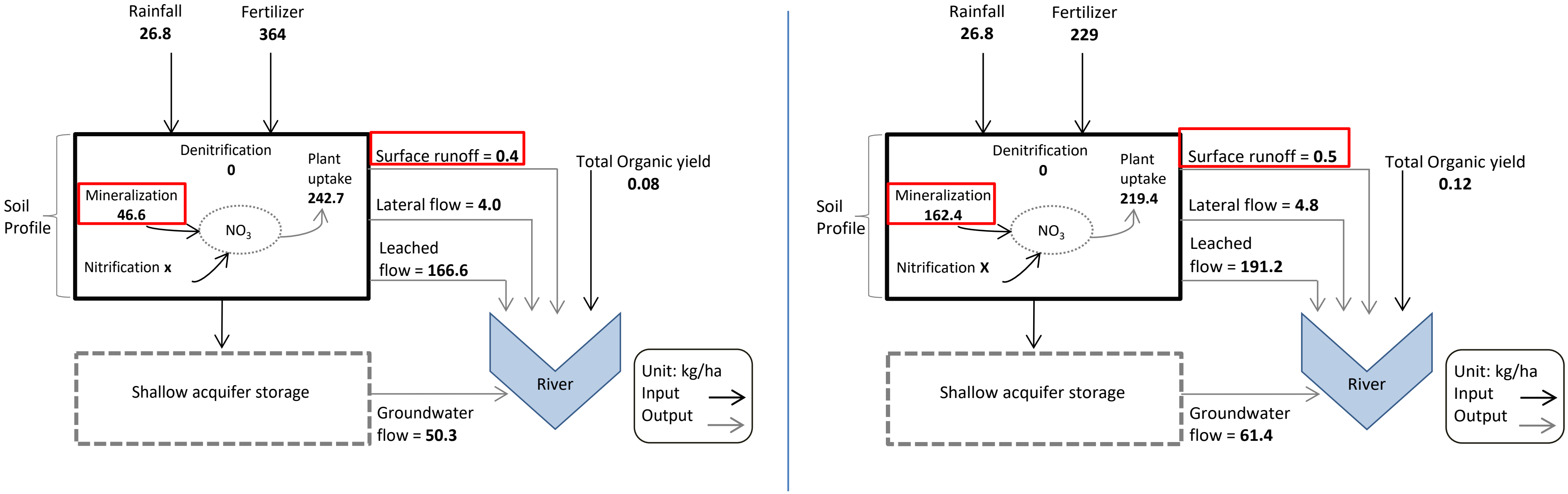


Results

Effect on nutrients (N and P)

Annual nitrogen mass balance at HRU level – Baseline (left) and CT (right)



- ✓ **Available N** at the surface due to **residual green manure increase Nitrate Surface Runoff** by **19%**
- ✓ **Percolation increase** by **29%** → **Soil water content increase** by **3%** → **Mineralization increase** by **240%** (transformation of fresh N organic to mineral N, which allows to be released)