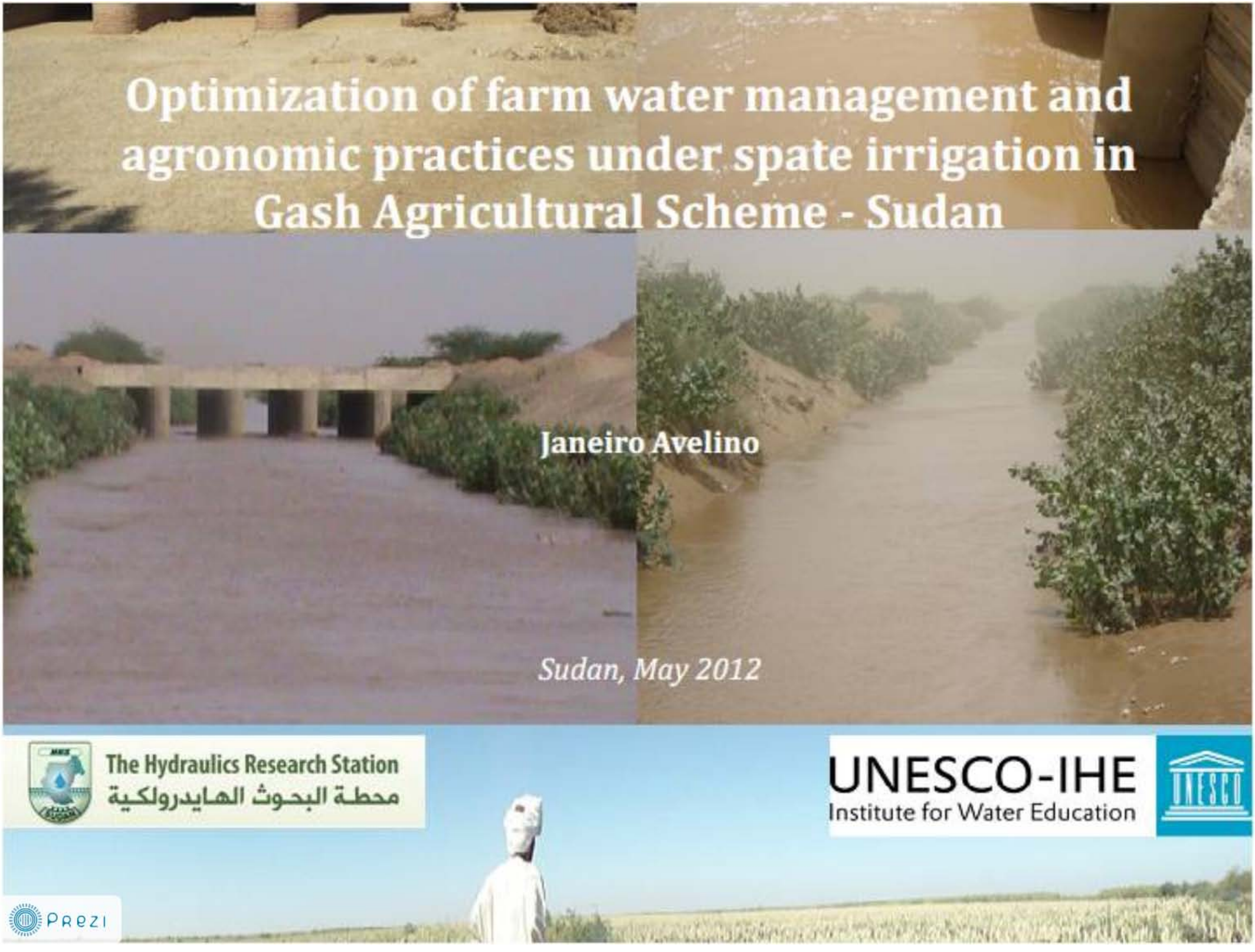
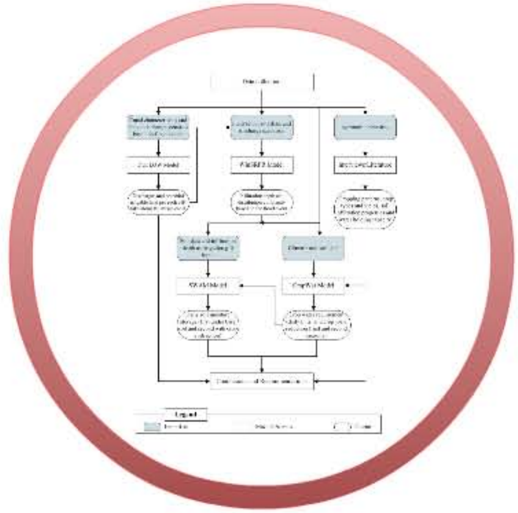
Optimization of farm water management and agronomic practices under spate irrigation in Gash Agricultural Scheme - Sudan

Janeiro Avelino

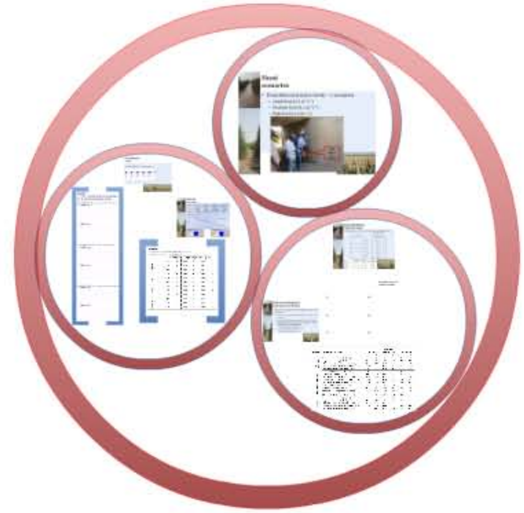
Sudan, May 2012



STUDY AREA DESCRIPTION AND PROBLEM DEFINITION

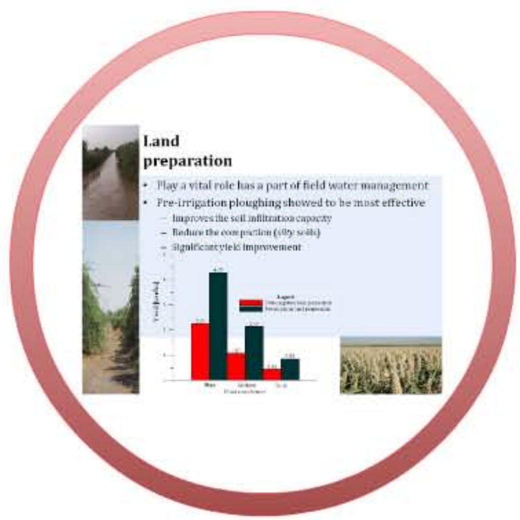


METHODOLOGY



HYDRAULIC PERFORMANCE OF MISGA CANAL AND WATER DISTRIBUTION WITHIN THE MISGA

WATER BALANCE IN UNSATURATED ZONE / SMS AND CROP PRODUCTIVITY MODELLING



SPATE SPECIAL AGRONOMIC PRACTICES

CONCLUSIONS AND RECOMMENDATIONS

STUDY AREA DESCRIPTION AND PROBLEM DEFINITION

Country background

- Sudan - 3rd largest country in Africa located in eastern Africa

- Agriculture basis of Sudanese economy
  - 39% contribution on GDP
  - 80% contribution on country exports
  - Employs 62% of the labour
  - 80% total population livelihood relying on agriculture

Prezi

Study area description

- Gash Agricultural Scheme (GAS)
  - Kassala State
  - Established 1930's
  - Command area of 100,000 ha
  - 7 main canals – 6 blocks

- Case study
  - Fota canal – Kasir Rabakasa *misga* and *misga* canal

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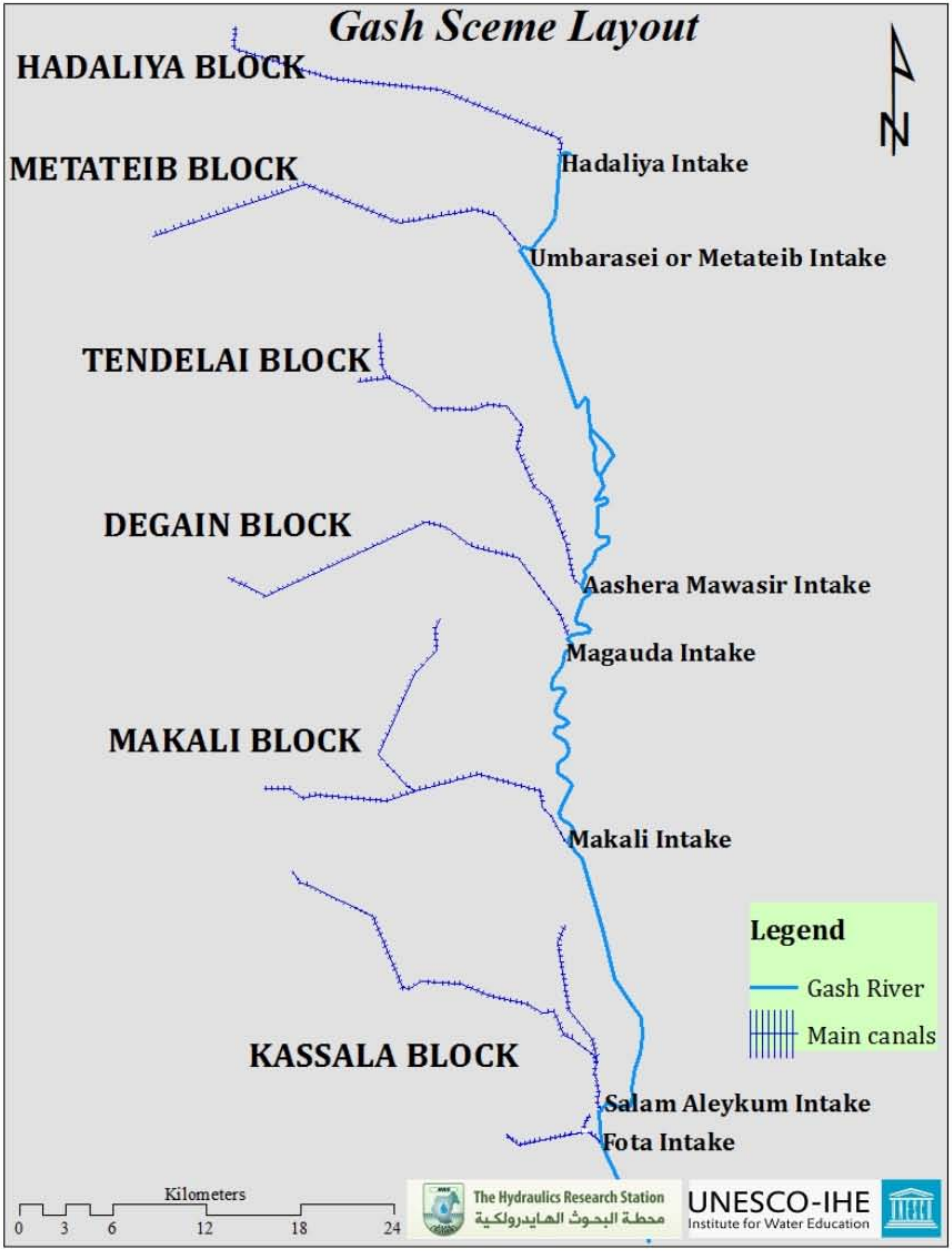

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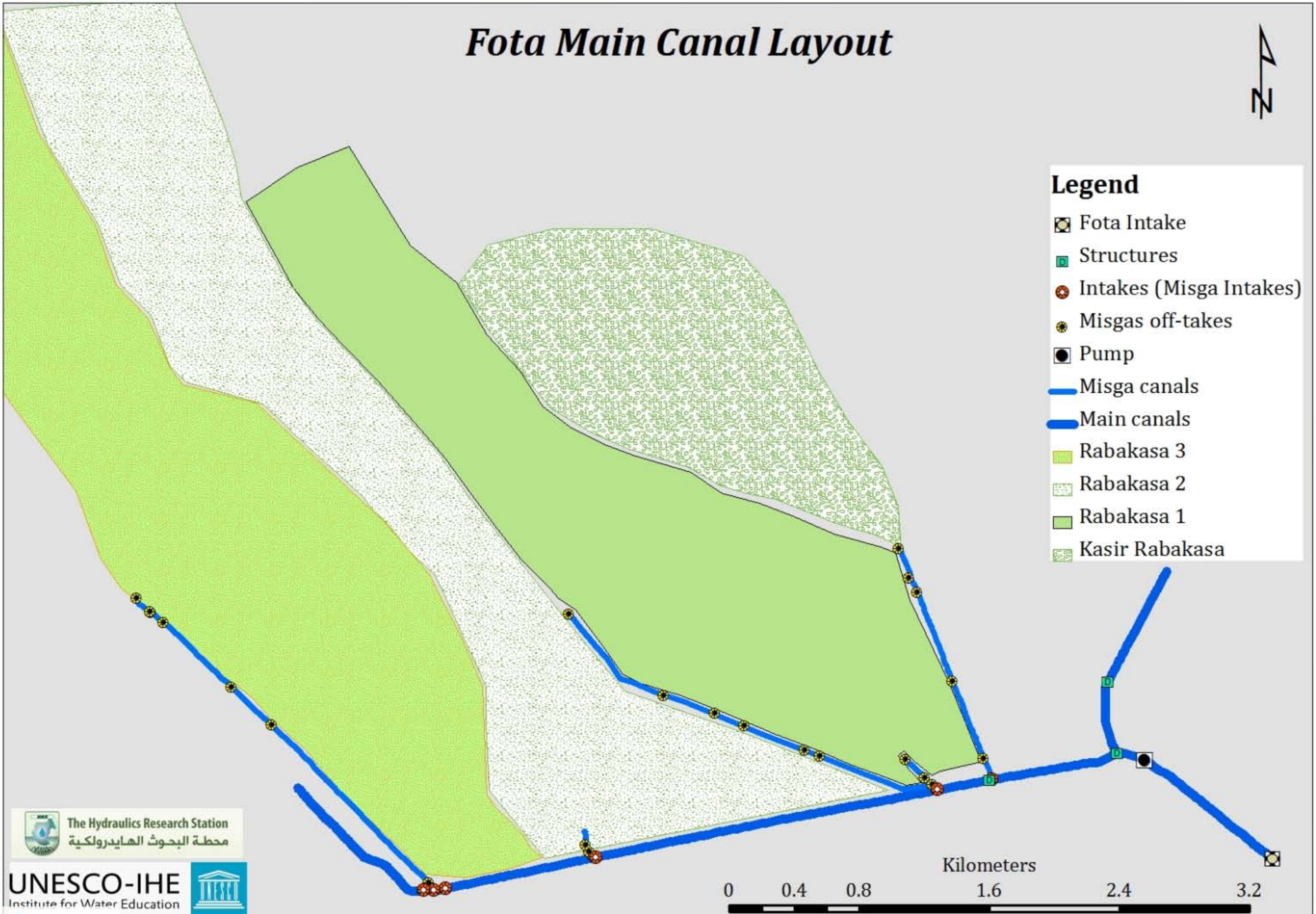

Fota Main Canal Layout
N
Legend
Fota Intake
Structures
Intakes (Misga Intakes)
Misgas off-takes
Pump
Misga canals
Main canals
Rabakasa 3
Rabakasa 2
Rabakasa 1
Kasir Rabakasa
Kilometers
0
0.4
0.8
1.6
2.4
3.2
The Hydraulics Research Station
محطة البحوث الهايدرولكية
UNESCO-IHE
Institute for Water Education

Problem definition

- 1970's GAS scheme performance went into serious decline
  - Drought spells and security problems
  - 20% of total refugees settled in Kassala State
  - Cultivated area declined by 50%

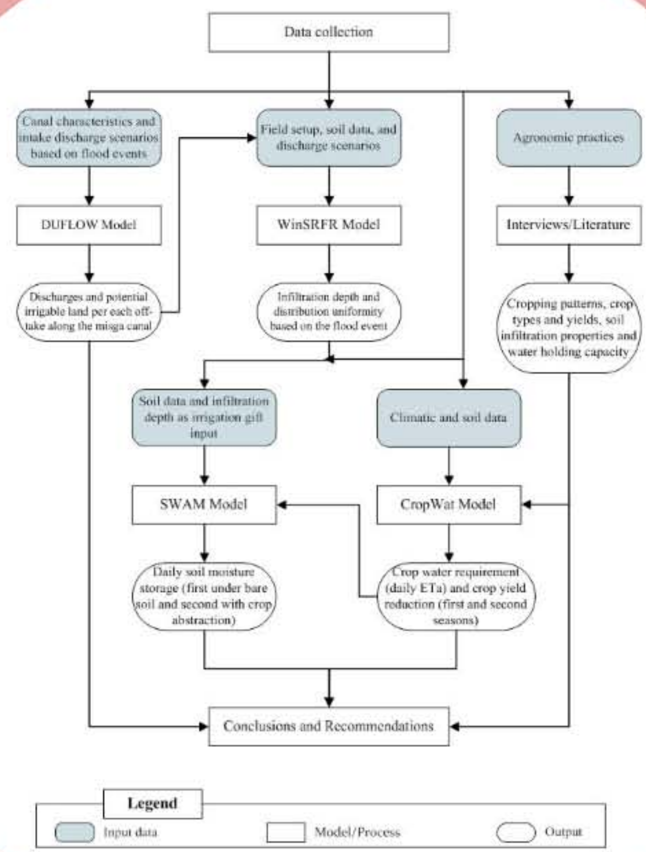
- On-farm water management in GAS not well adopted
  - Irrigation scheduling/water application practices
  - Field setup
  - Agronomic practices
    - Land preparation
    - Crop type selection
    - Cropping pattern

Research questions

- What types of field water management systems that are appropriate for GAS?
- What are the impacts of different agronomic practices and field water management systems on agricultural productivity?

Objectives

- Quantitatively evaluate the existing and alternatives on-farm water management practices, including water distribution at tertiary canal and field levels, and soil moisture storage capacities at the field; with regard to:
  - Availability of water at different off-takes and sections of the field;
  - Implication to crop yield with the existing and alternative cropping patterns.
- Identify agronomic practices including land preparation and cropping pattern that can improve the soil infiltration and water holding capacity.
- Recommend locally effective and practically feasible on-farm water management and for the GAS.



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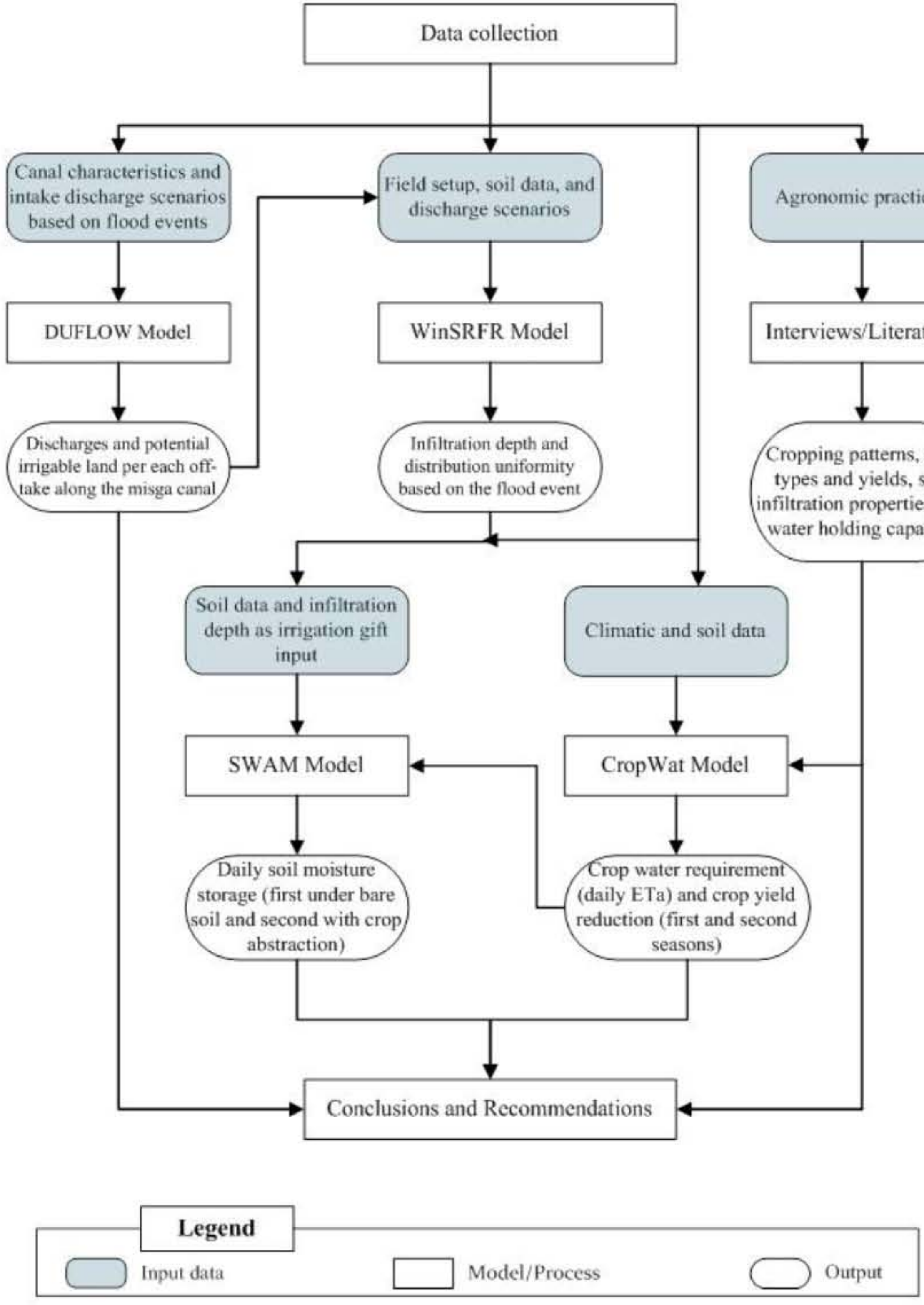
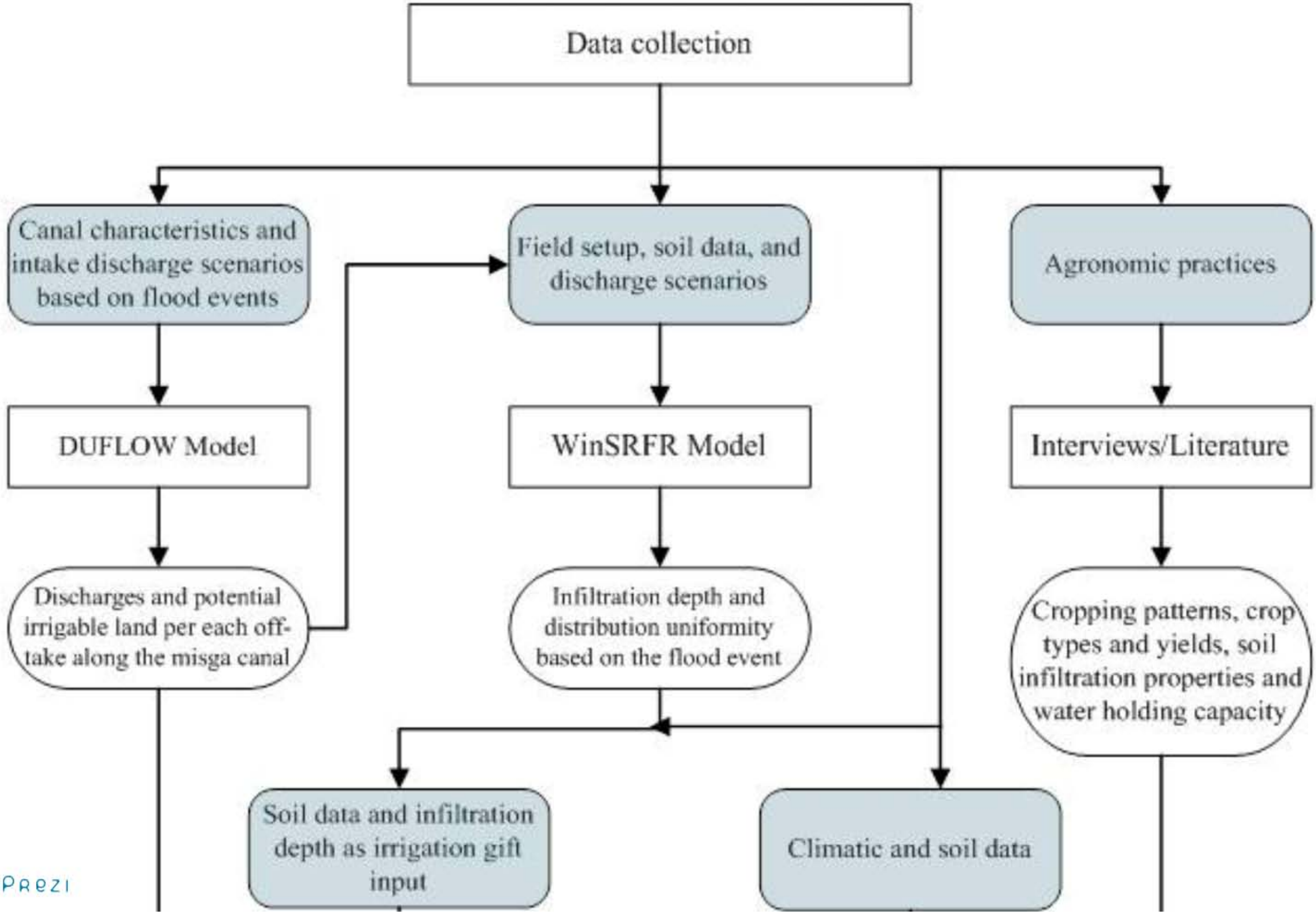


Data collection
Canal characteristics and intake discharge scenarios based on flood events
Field setup, soil data, and discharge scenarios
Agronomic practices
DUFLOW Model
WinSRFR Model
Interviews/Literature
Discharges and potential irrigable land per each off-take along the misga canal
Infiltration depth and distribution uniformity based on the flood event
Cropping patterns, crop types and yields, soil infiltration properties and water holding capacity
Soil data and infiltration depth as irrigation gift input
Climatic and soil data
SWAM Model
CropWat Model
Daily soil moisture storage (first under bare soil and second with crop abstraction)
Crop water requirement (daily ETa) and crop yield reduction (first and second seasons)
Conclusions and Recommendations
Legend
Input data
Model/Process
Output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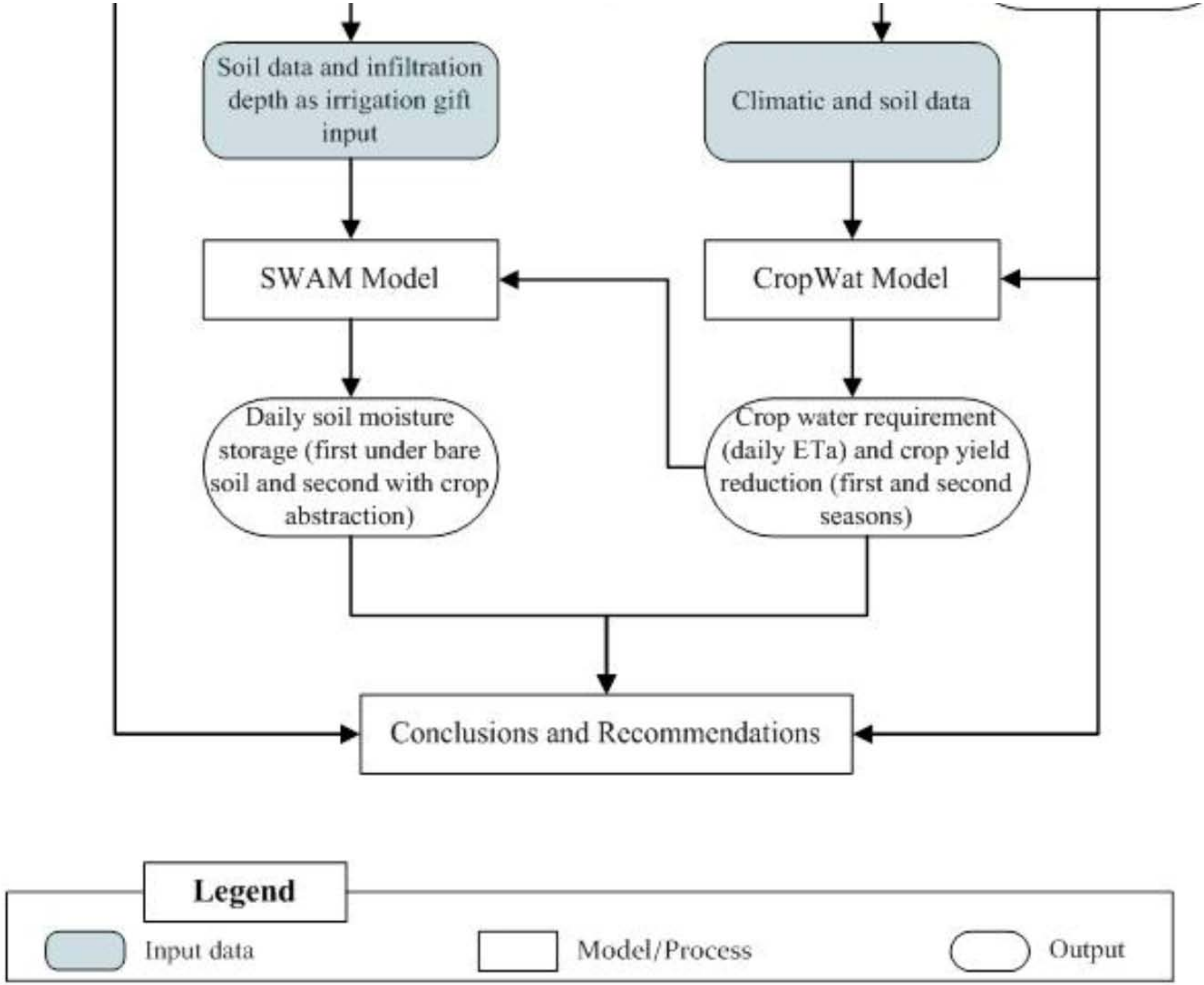

Soil data and infiltration depth as irrigation gift input
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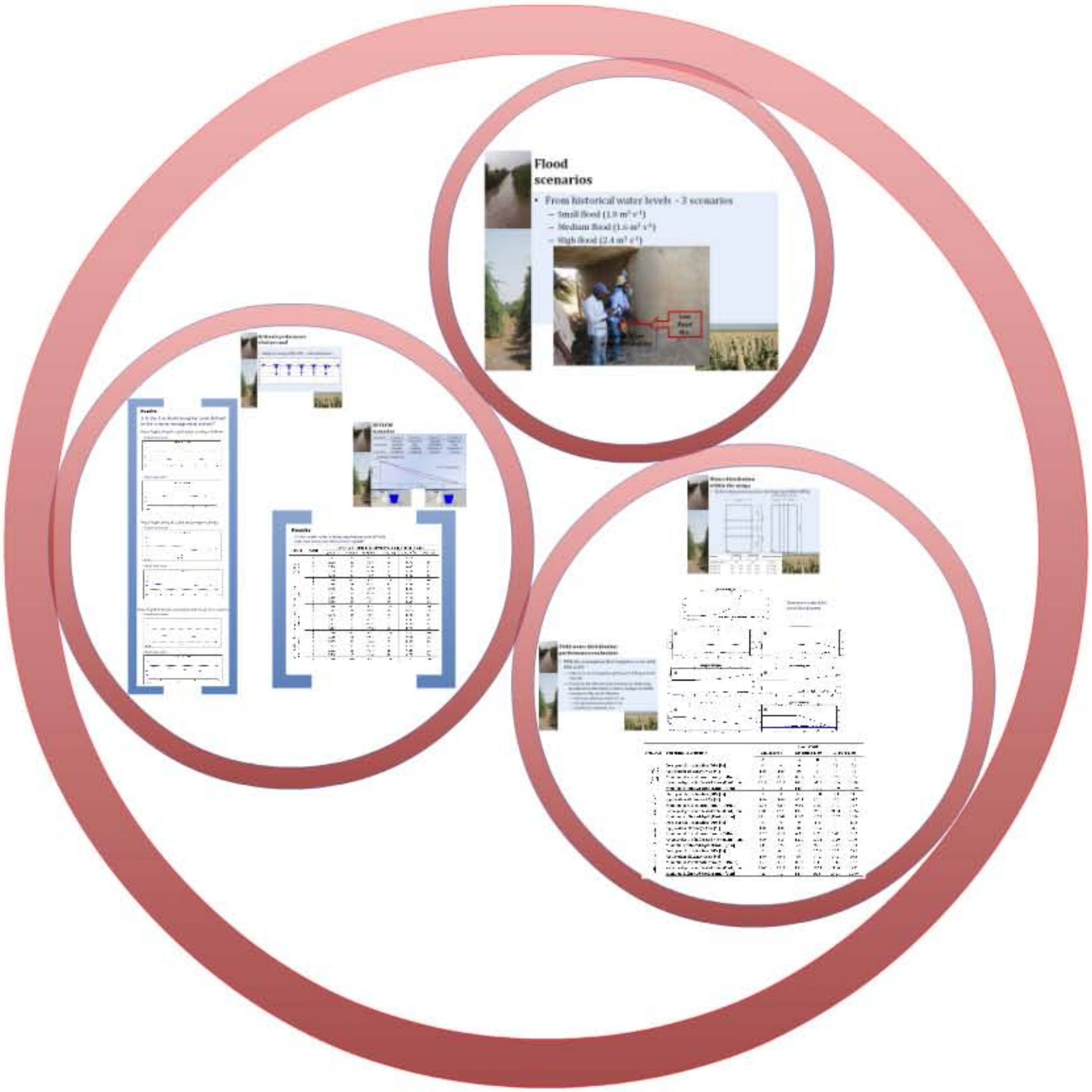
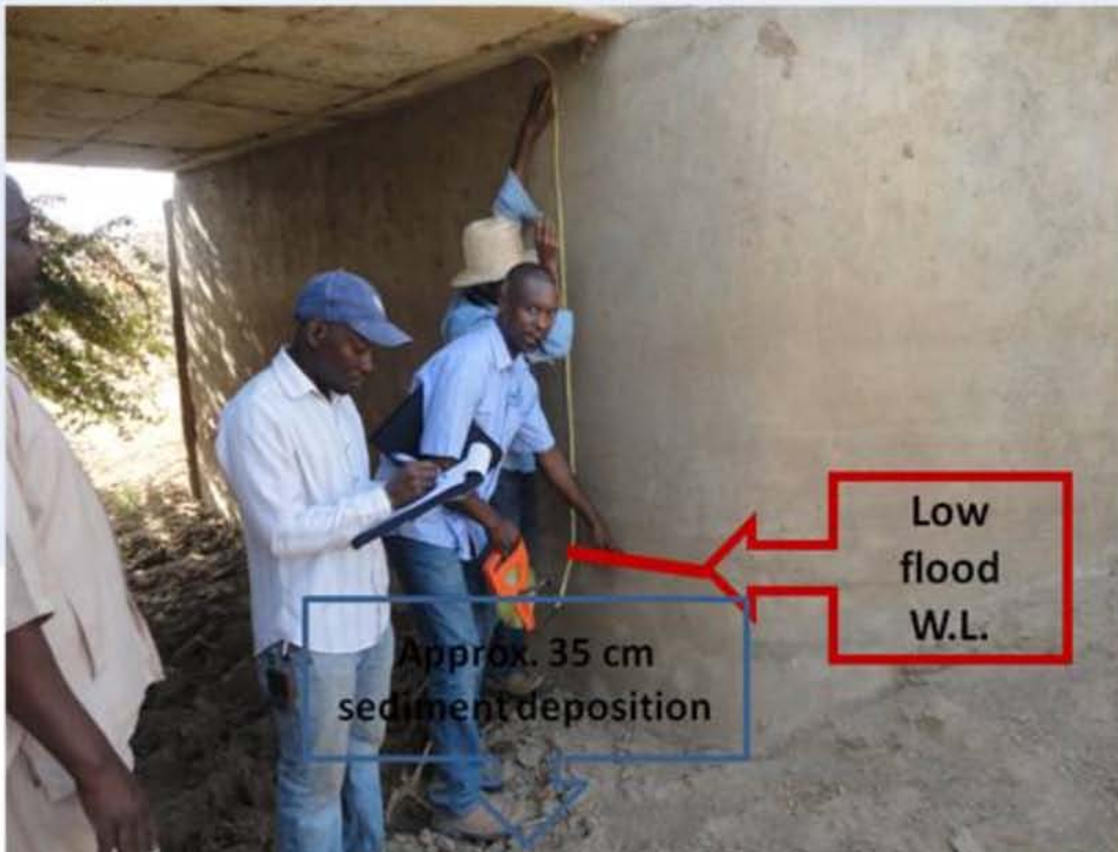


HYDRAULIC PERFORMANCE OF MISGA CANAL AND WATER DISTRIBUTION WITHIN THE MISGA

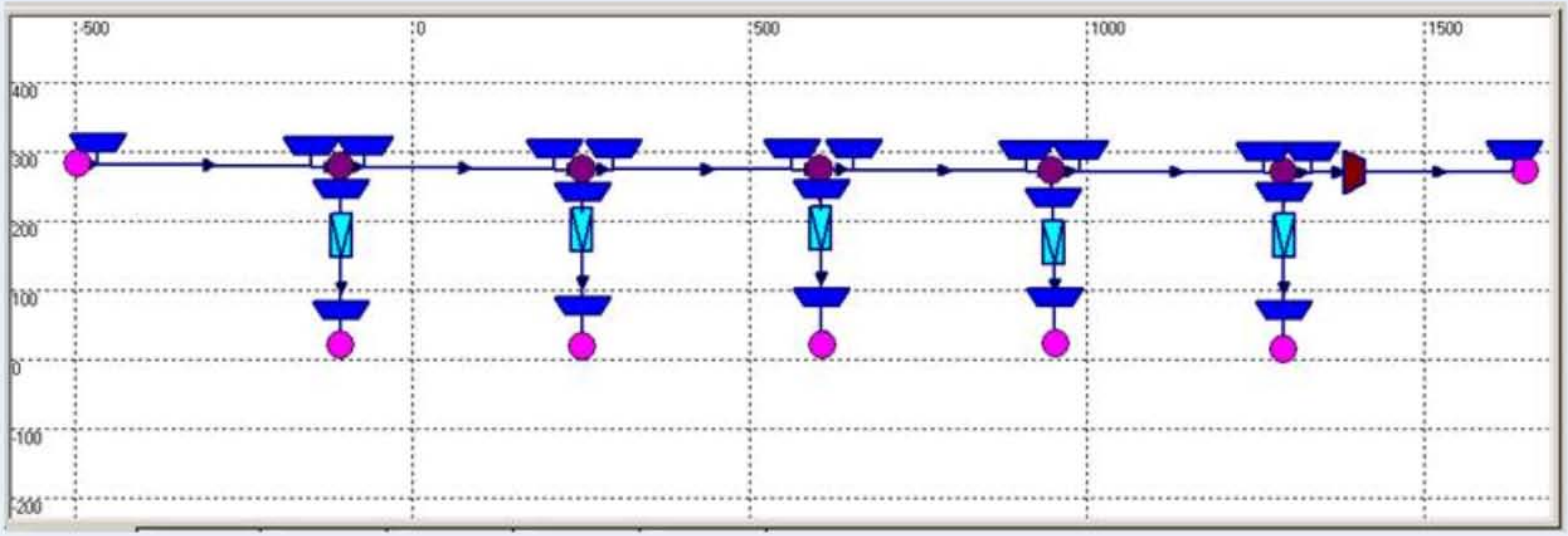
Flood scenarios

- From historical water levels - 3 scenarios
  - Small flood (1.0 $m^3 s^{-1}$)
  - Medium flood (1.6 $m^3 s^{-1}$)
  - High flood (2.4 $m^3 s^{-1}$)



Hydraulic performance of *misga* canal

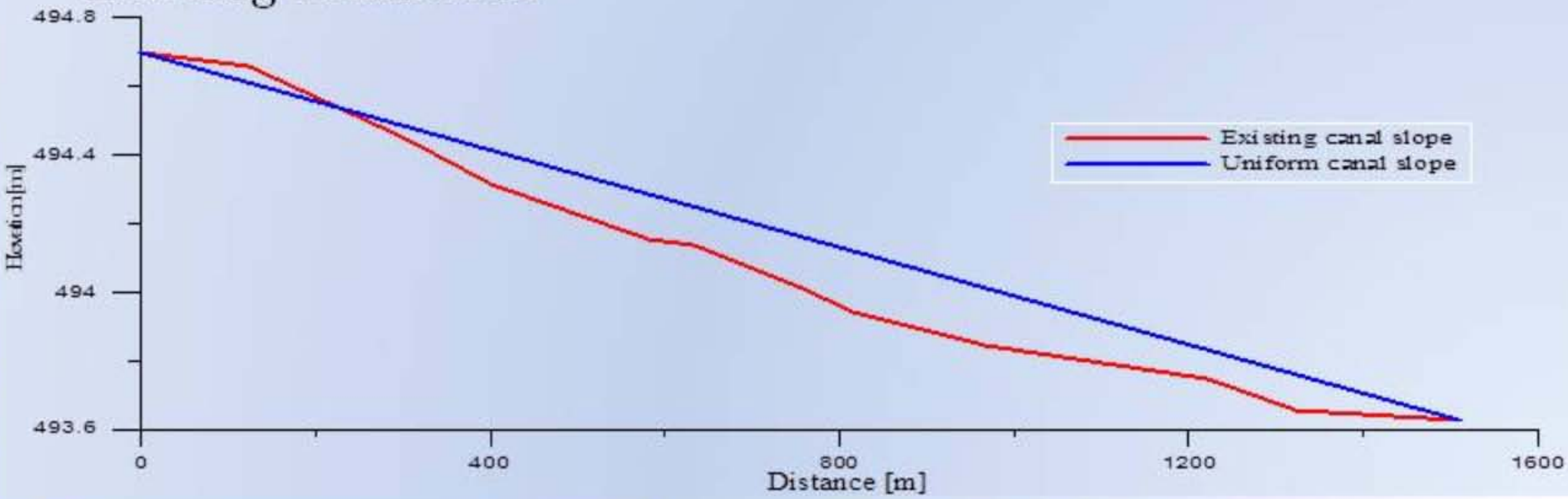
- Analysed using DUFLOW - schematization

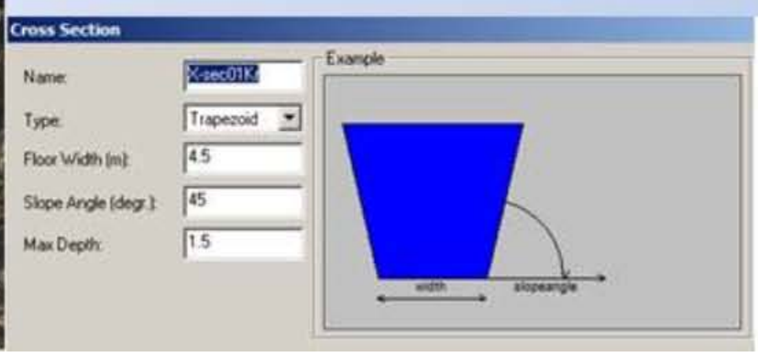


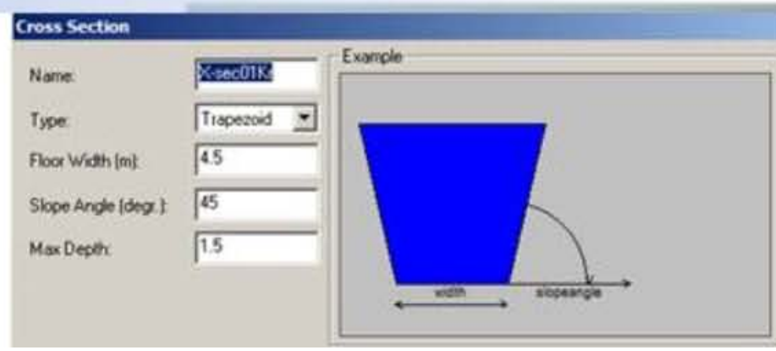
DUFLOW scenarios

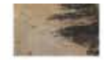
Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Canal slope	Existing conditions	Improved slope	Existing conditions	Improved slope
X-sections	Existing conditions	Existing conditions	Narrowed X-sections	Narrowed X-sections

- Existing conditions







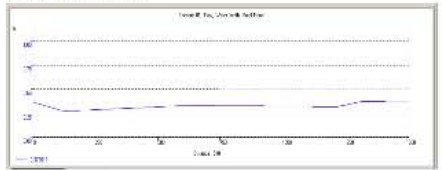


Results

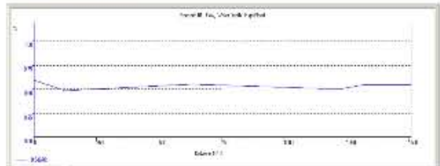
1. Is the 1 m depth along the canal defined by the scheme management realistic?

Water Depth along the canal under existing conditions

- Small Flood event

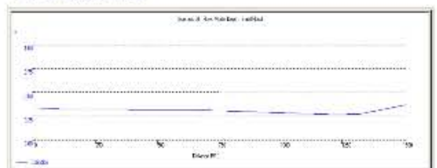


- High Flood event

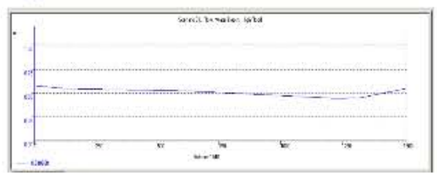


Water Depth along the canal under improved slope

- Small Flood event

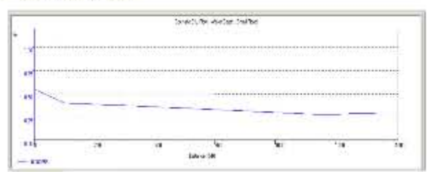


- High Flood event

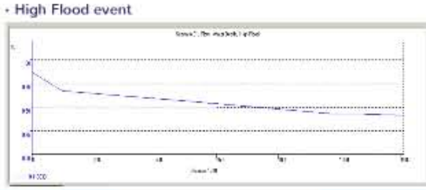


Water Depth along the canal under narrowed cross-sections

- Small Flood event



- High Flood event



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Results

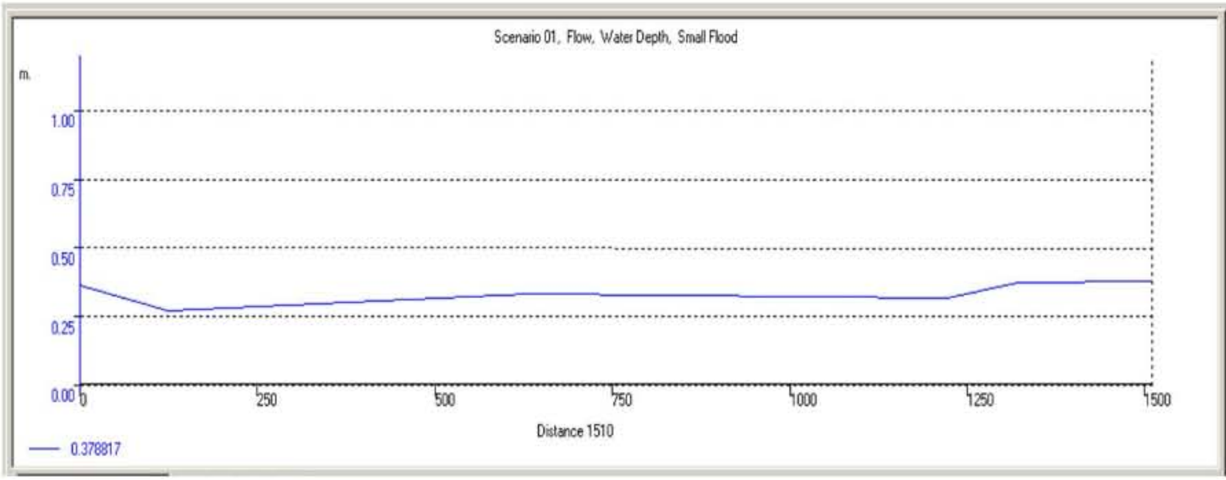
2. How much water is being supplied per each off-t and what is the area that can be irrigated?

Scenario	Outlet	Simulated discharge and Potent		
		Q_1=1m³/s	Area [ha]	Q_2=1.6m³/s
Existing conditions	1	0.171	24	0.318
	2	0.231	32	0.376
	3	0.184	26	0.294
	4	0.206	30	0.306
	5	0.212	30	0.309
	∑	**1.00**	**142**	**1.60**
Improved canal slope	1	0.184	26	0.365
	2	0.262	37	0.397
	3	0.173	24	0.269
	4	0.160	23	0.248
	5	0.221	32	0.321
	∑	**1.00**	**142**	**1.60**
Narrowed cross-sections	1	0.361	51	0.594
	2	0.242	34	0.394
	3	0.139	20	0.227
	4	0.131	19	0.197
	5	0.127	18	0.188
	∑	**1.00**	**142**	**1.60**
Combination of two alternatives	1	0.389	55	0.645
	2	0.259	36	0.403
	3	0.143	20	0.220
	4	0.091	13	0.147
	5	0.118	16	0.185
	∑	**1.00**	**140**	**1.60**

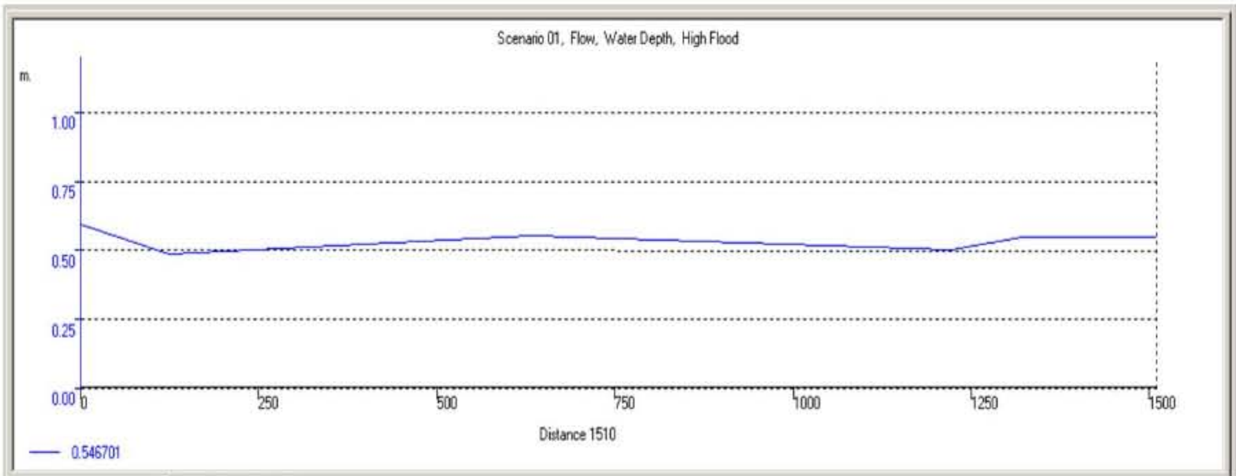
1. Is the 1 m depth along the canal defined by the scheme management realistic?

Water Depth along the canal under existing conditions

- Small Flood event

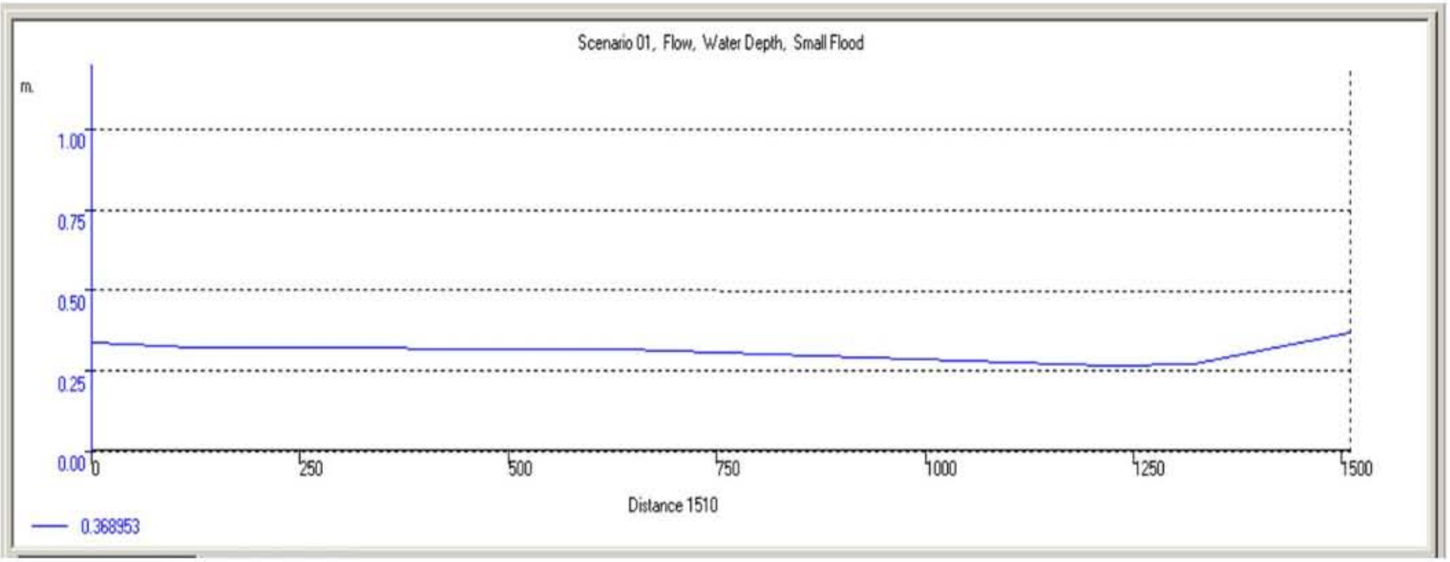


- High Flood event



Water Depth along the canal under improved slope

- **Small Flood event**



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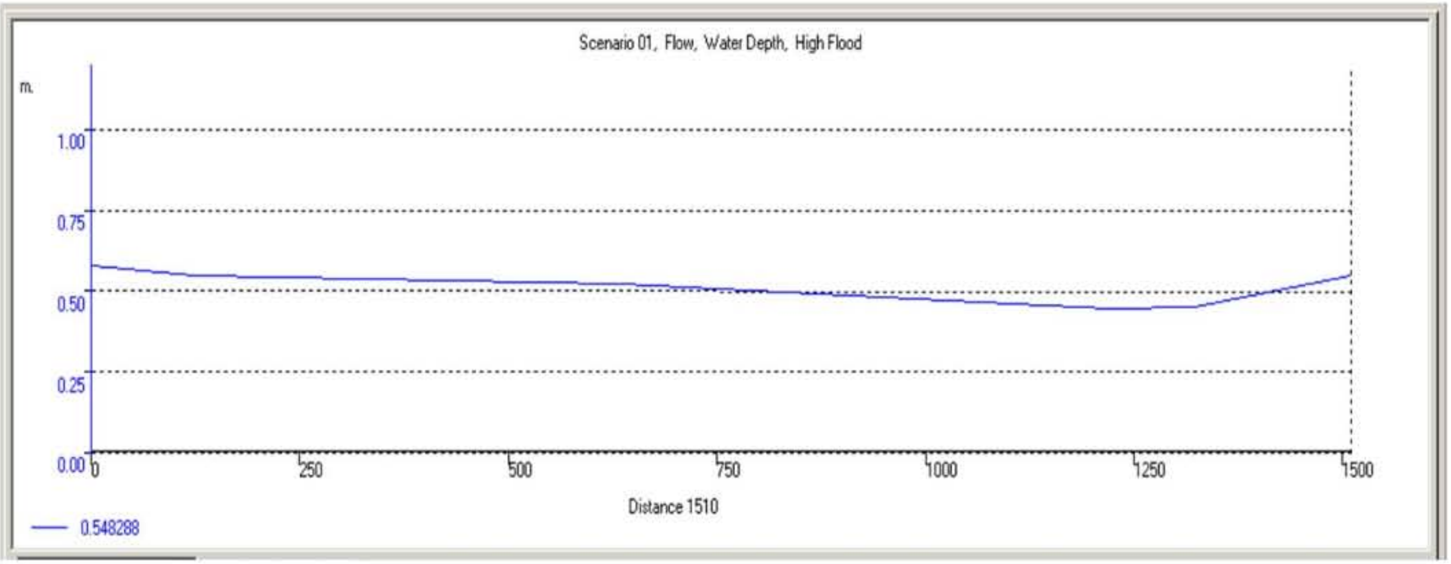
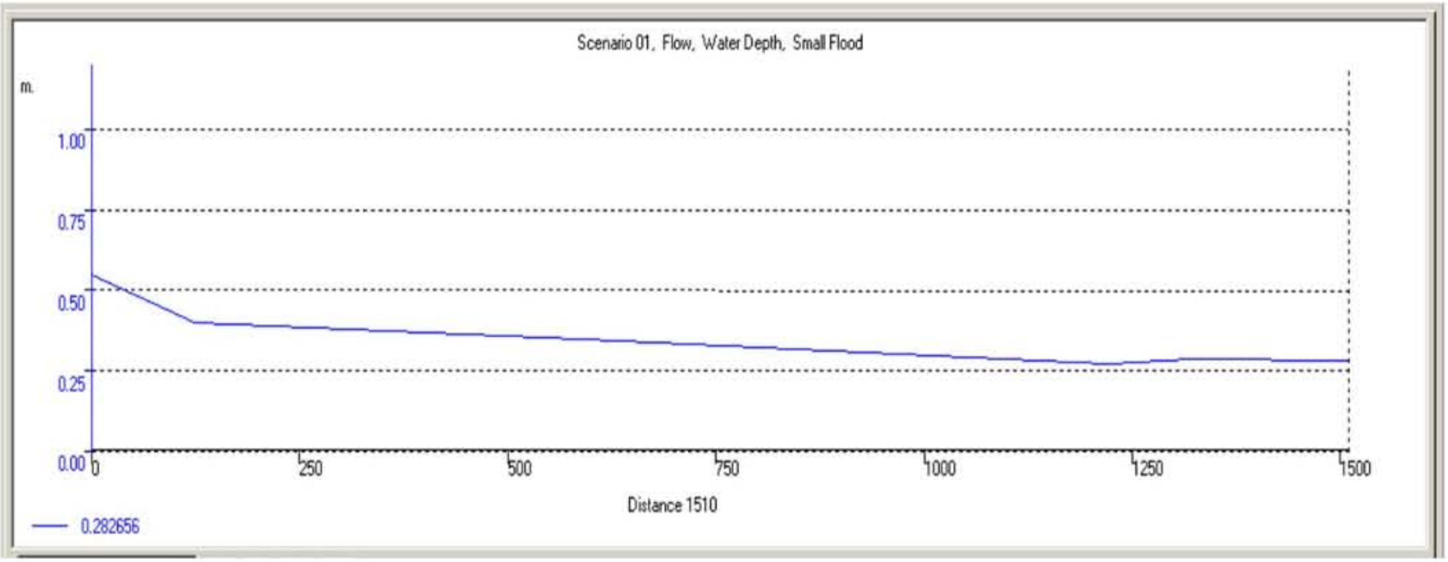


Water Depth along the canal under narrowed cross-sections

- **Small Flood event**



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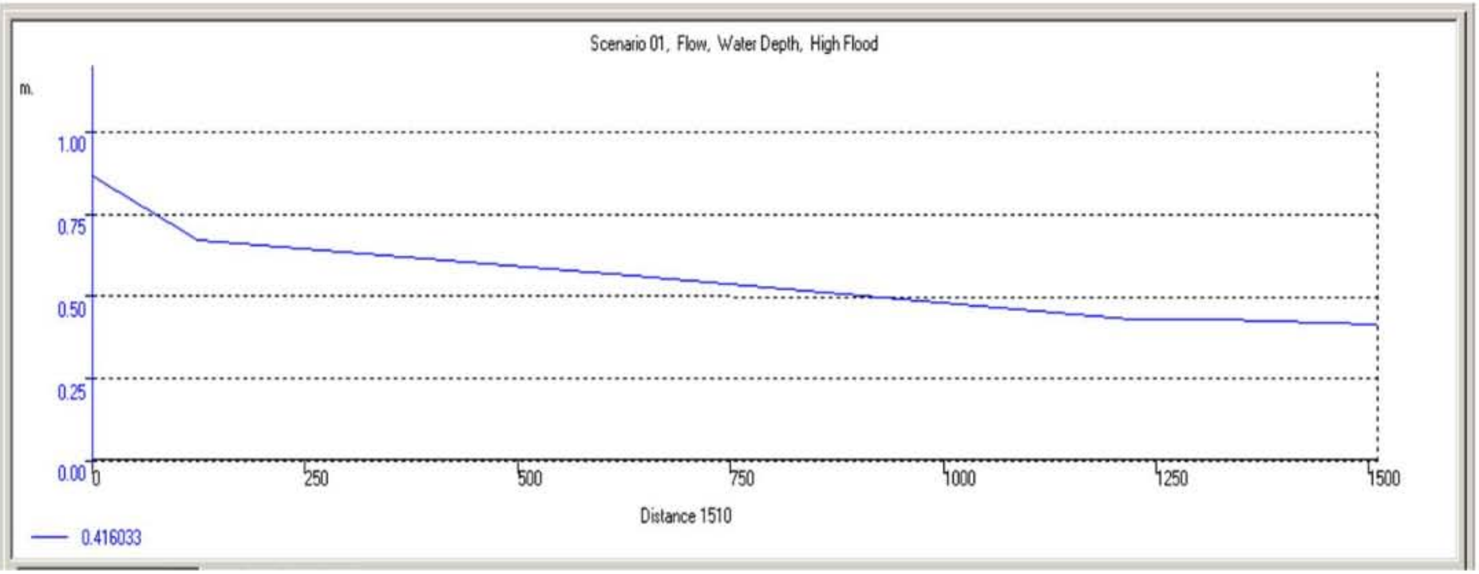


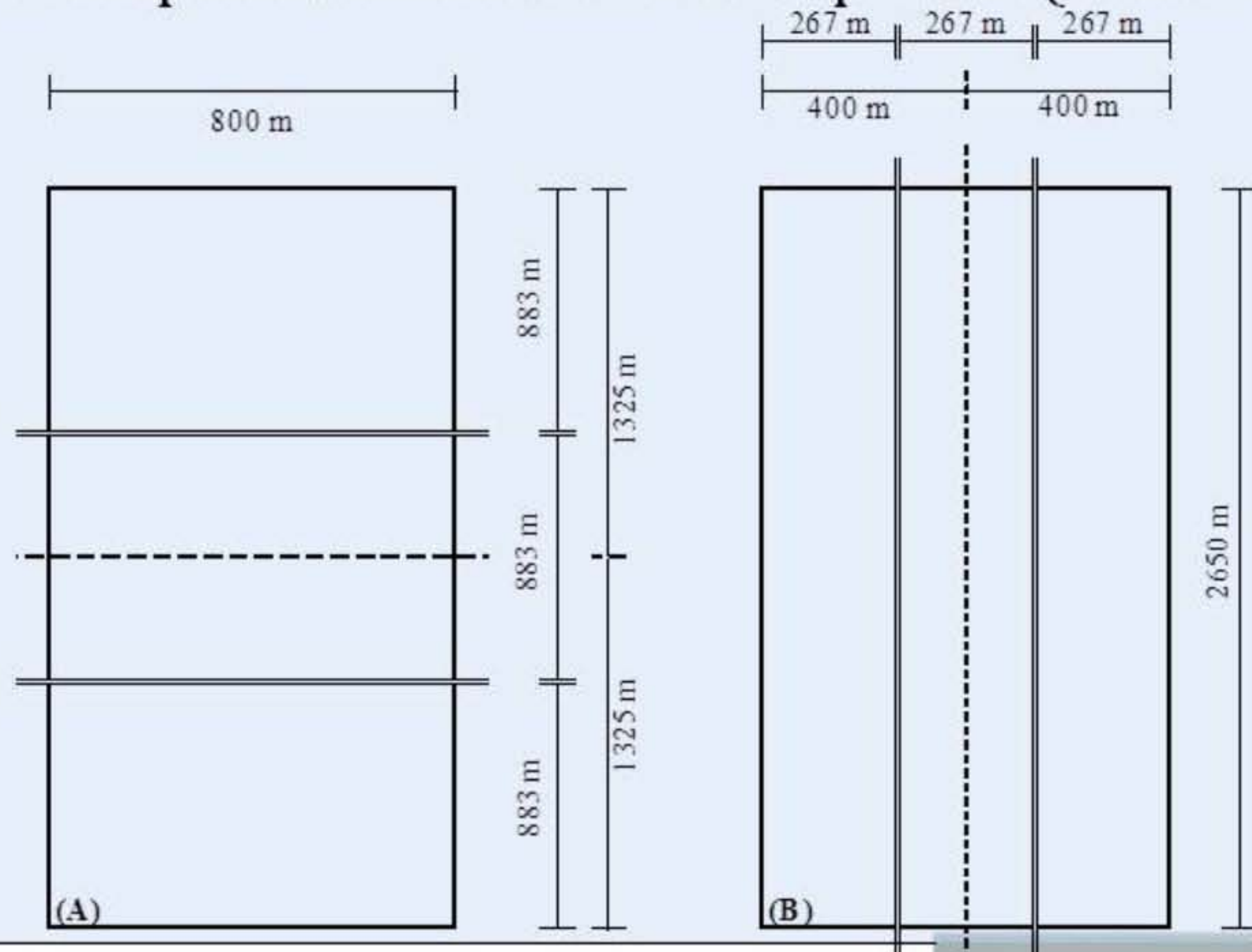
Results

2. How much water is being supplied per each off-take and what is the area that can be irrigated?

Scenario	Outlet	Simulated discharge and Potential irrigable land per flood event					
		$Q_1=1m^3/s$	Area [ha]	$Q_2=1.6m^3/s$	Area [ha]	$Q_3=2.4m^3/s$	Area [ha]
Existing conditions	1	0.171	24	0.318	46	0.514	73
	2	0.231	32	0.376	53	0.570	80
	3	0.184	26	0.294	41	0.440	62
	4	0.206	30	0.306	43	0.438	61
	5	0.212	30	0.309	42	0.439	60
	∑	**1.00**	**142**	**1.60**	**224**	**2.40**	**335**
Improved canal slope	1	0.184	26	0.365	52	0.594	84
	2	0.262	37	0.397	56	0.585	82
	3	0.173	24	0.269	38	0.401	57
	4	0.160	23	0.248	35	0.368	51
	5	0.221	32	0.321	45	0.452	63
	∑	**1.00**	**142**	**1.60**	**226**	**2.40**	**337**
Narrowed cross-sections	1	0.361	51	0.594	84	0.912	129
	2	0.242	34	0.394	55	0.591	83
	3	0.139	20	0.227	32	0.339	48
	4	0.131	19	0.197	27	0.287	41
	5	0.127	18	0.188	26	0.271	40
	∑	**1.00**	**142**	**1.60**	**224**	**2.40**	**341**
Combination of two alternatives	1	0.389	55	0.645	91	0.983	139
	2	0.259	36	0.403	57	0.598	84
	3	0.143	20	0.220	31	0.323	45
	4	0.091	13	0.147	19	0.225	32
	5	0.118	16	0.185	26	0.271	38
	∑	**1.00**	**140**	**1.60**	**224**	**2.40**	**338**

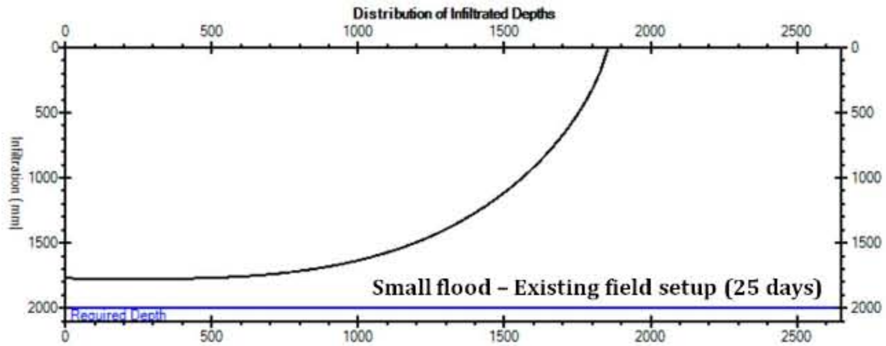
Water distribution within the misga

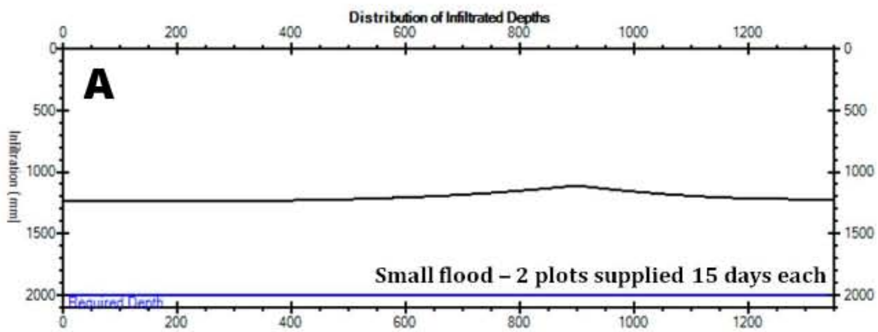
- Field setup and scenarios development (WinSRFR)

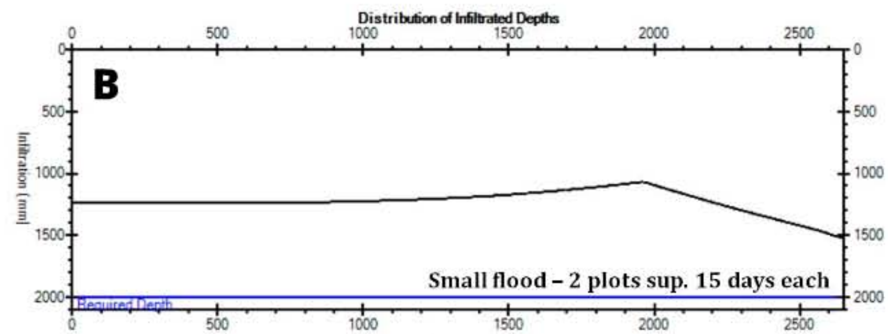


Scenario	Width [m] A	Width [m] B	Length [m] A	Length [m] B	Application duration
Existing conditions	800		2650		25 days
Alternative 1	800	400	1350	2650	2 x 15 days
Alternative 2	800	400	1350	2650	2 x 10 days
Alternative 3	800	267	900	2650	3 x 10 days

Scenarios output for small flood event







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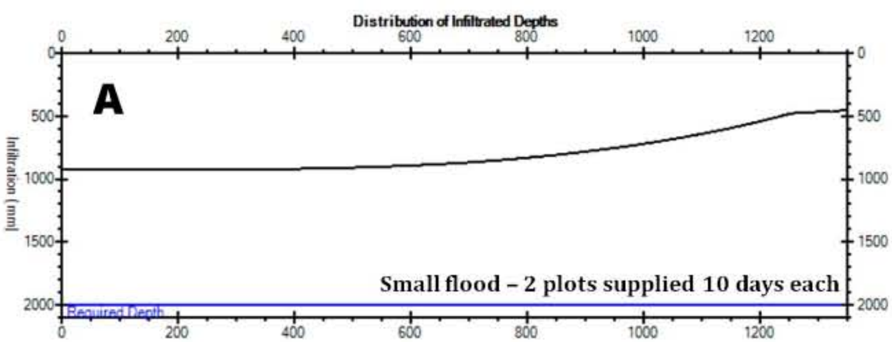
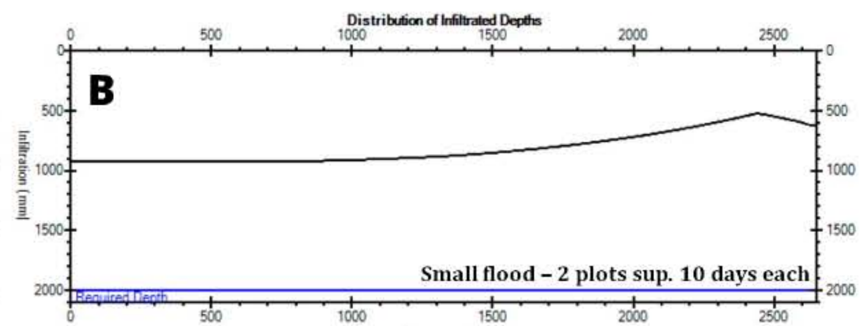
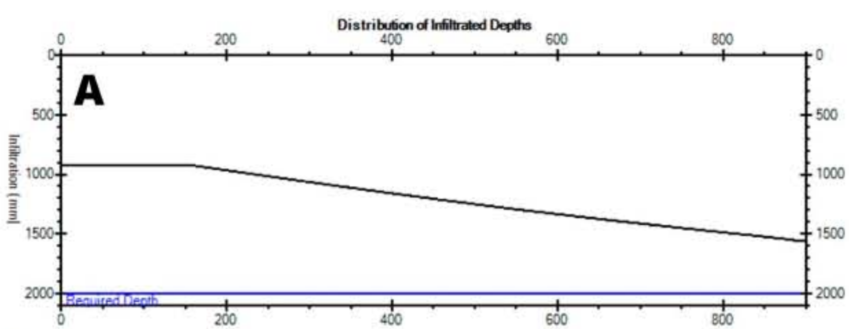
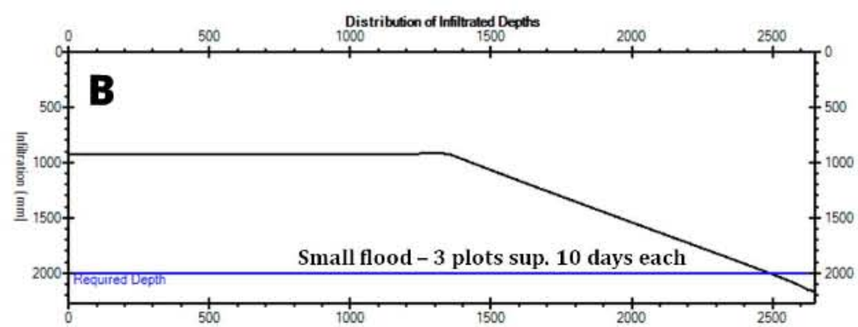
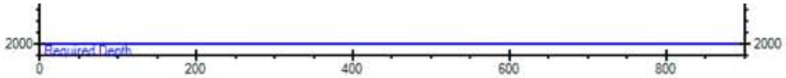
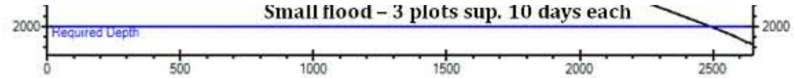












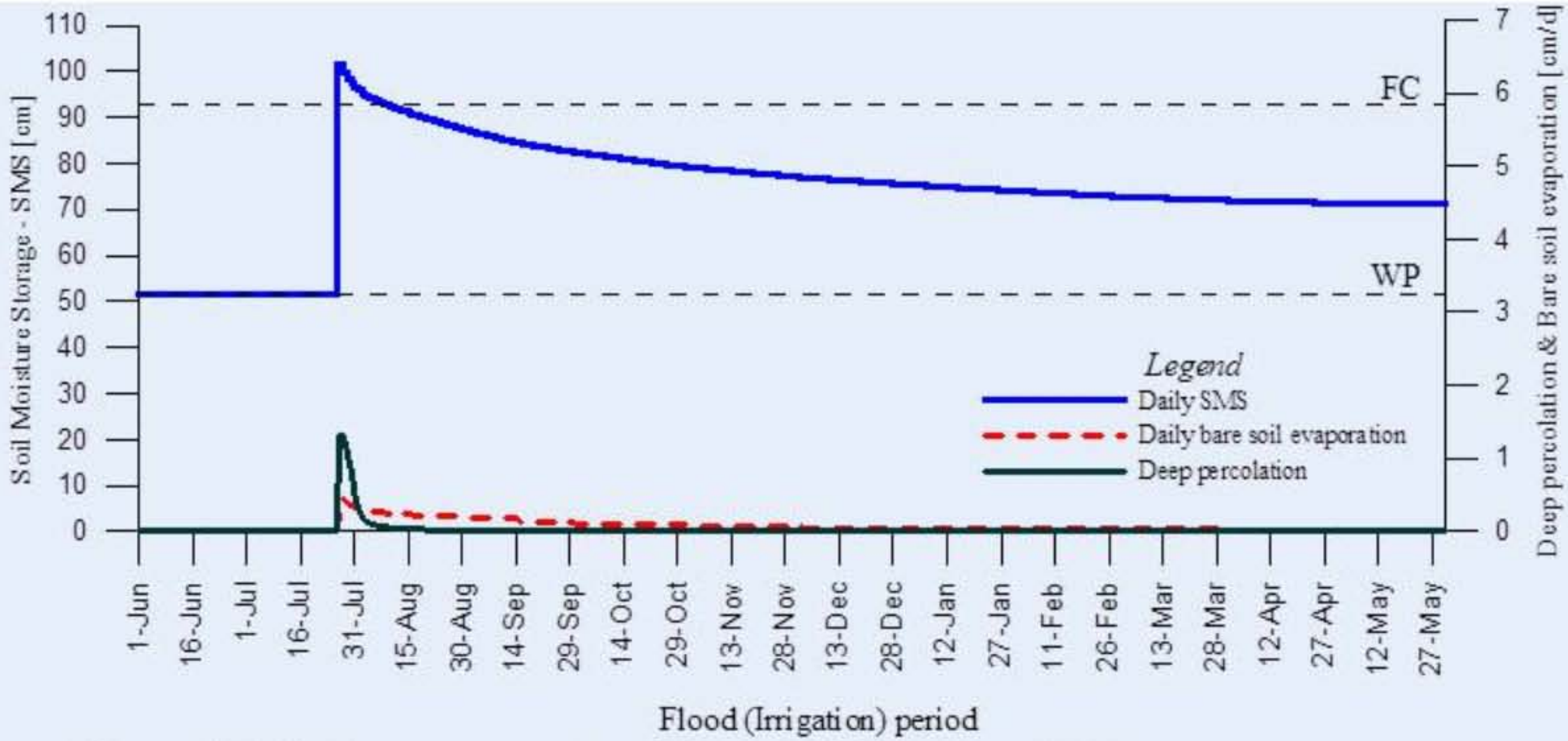
Scenarios	Performance indicators	Flood events					
		Small Flood		Medium Flood		Large Flood	
		A	**B**	**A**	**B**	**A**	**B**
Existing conditions	Deep percolation fraction (**DP**) [%]	0	0	0	0	22	22
	Application efficiency (**AE**) [%]	100	100	100	100	78	78
	Minimum distribution uniformity (**DUmin**)	0.00	0.00	0.85	0.85	0.72	0.72
	Average depth of infiltrated water (**Dinf**) [mm]	1029	1029	1646	1646	2469	2469
	Minimum infiltrated depth (**Dmin**) [mm]	0	0	1400	1400	1779	1779
Alternative 1	Deep percolation fraction (**DP**) [%]	0	0	6.6	13.8	30.8	33.3
	Application efficiency (**AE**) [%]	100	100	93.4	86.2	69.2	66.7
	Minimum distribution uniformity (**DUmin**)	0.93	0.87	0.66	0.63	0.77	0.55
	Average depth of infiltrated water (**Dinf**) [mm]	1200	1223	1920	1956	2880	2934
	Minimum infiltrated depth (**Dmin**) [mm]	1114	1068	1263	1233	2207	1609
Alternative 2	Deep percolation fraction (**DP**) [%]	0	0	0	1.6	7	15.8
	Application efficiency (**AE**) [%]	100	100	100	98.4	93	84.2
	Minimum distribution uniformity (**DUmin**)	0.56	0.64	0.72	0.71	0.65	0.47
	Average depth of infiltrated water (**Dinf**) [mm]	800	815	1280	1304	1920	1956
	Minimum infiltrated depth (**Dmin**) [mm]	445	524	923	923	1247	923
Alternative 3	Deep percolation fraction (**DP**) [%]	0	0.4	4	15.8	30.7	33.2
	Application efficiency (**AE**) [%]	100	99.6	96	84.2	69.3	66.8
	Minimum distribution uniformity (**DUmin**)	0.77	0.75	0.77	0.47	0.84	0.55
	Average depth of infiltrated water (**Dinf**) [mm]	1200	1221	1920	1954	2880	2931
	Minimum infiltrated depth (**Dmin**) [mm]	923	917	1474	923	2428	1600

Field water distribution performance evaluation

- With the assumption that irrigation occur with SMS at WP
  - Only 41.2 cm of irrigation gift need to fill up to field capacity
  - Practical and effective intervention on field setup modification *Alternative 2* under changes in width scenarios is the most effective
    - Minimum infiltration depth 52.4 cm
    - Average infiltration depth 81.5 cm
    - Distribution Uniformity 64%

WATER BALANCE IN UNSATURATED ZONE / SMS AND CROP PRODUCTIVITY MODELLING

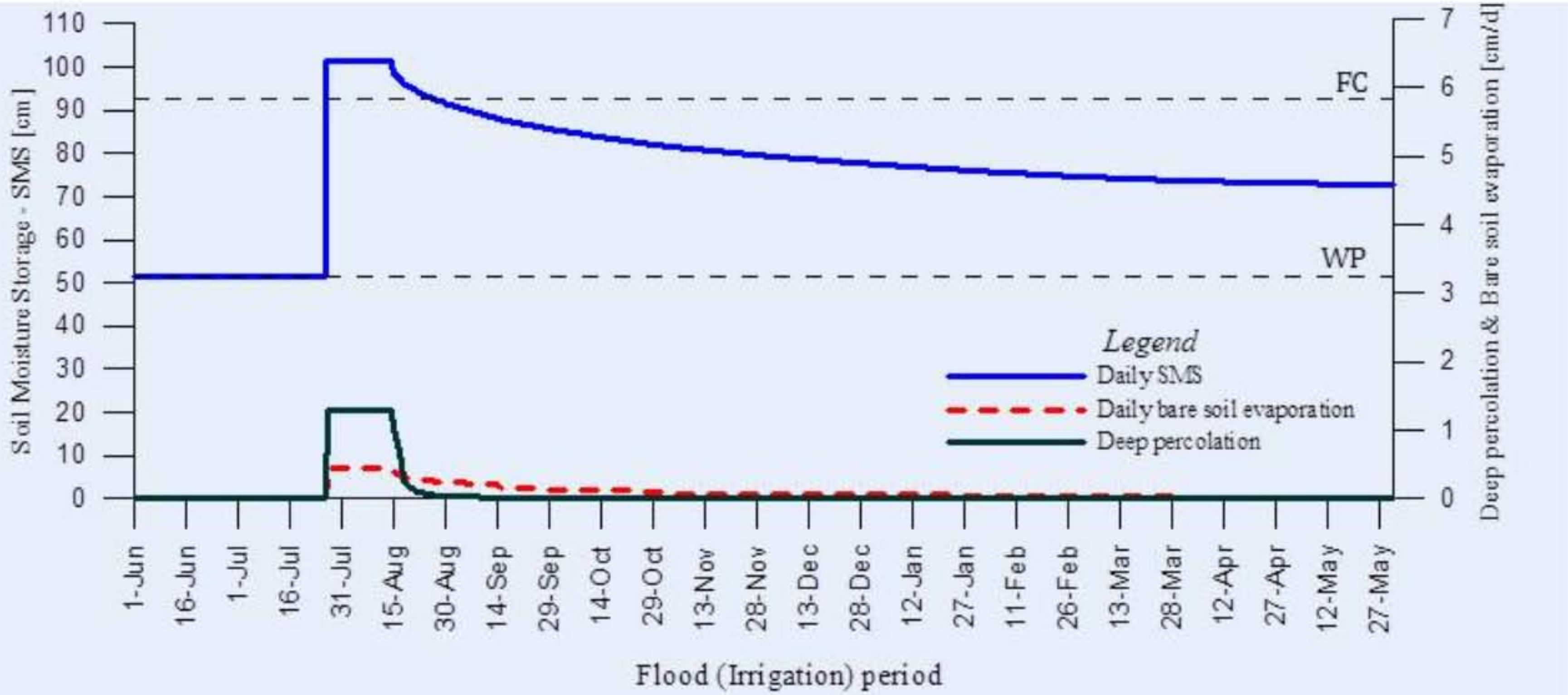
Soil Moisture Storage for the minimum infiltration depth



- After 310 days under bare soil conditions
  - Remaining SMS 71.2 cm (soil moisture retained)
  - Total evaporation losses 25 cm and Deep percolation losses 7.3 cm

Prezi

Soil Moisture Storage for the average infiltration depth



- After 310 days under bare soil conditions
  - Remaining SMS 72.8 cm (soil moisture retained)
  - Evaporation losses 31 cm and Deep percolation losses 29 cm

Crop productivity analysis

- CropWat program
  - Climatic data from CLIMWAT database (Kassala station)
  - Soil characteristics defined for *silty clay* from mechanical Lab. analysis
  - Cropping pattern

Cropping patterns

- Existing

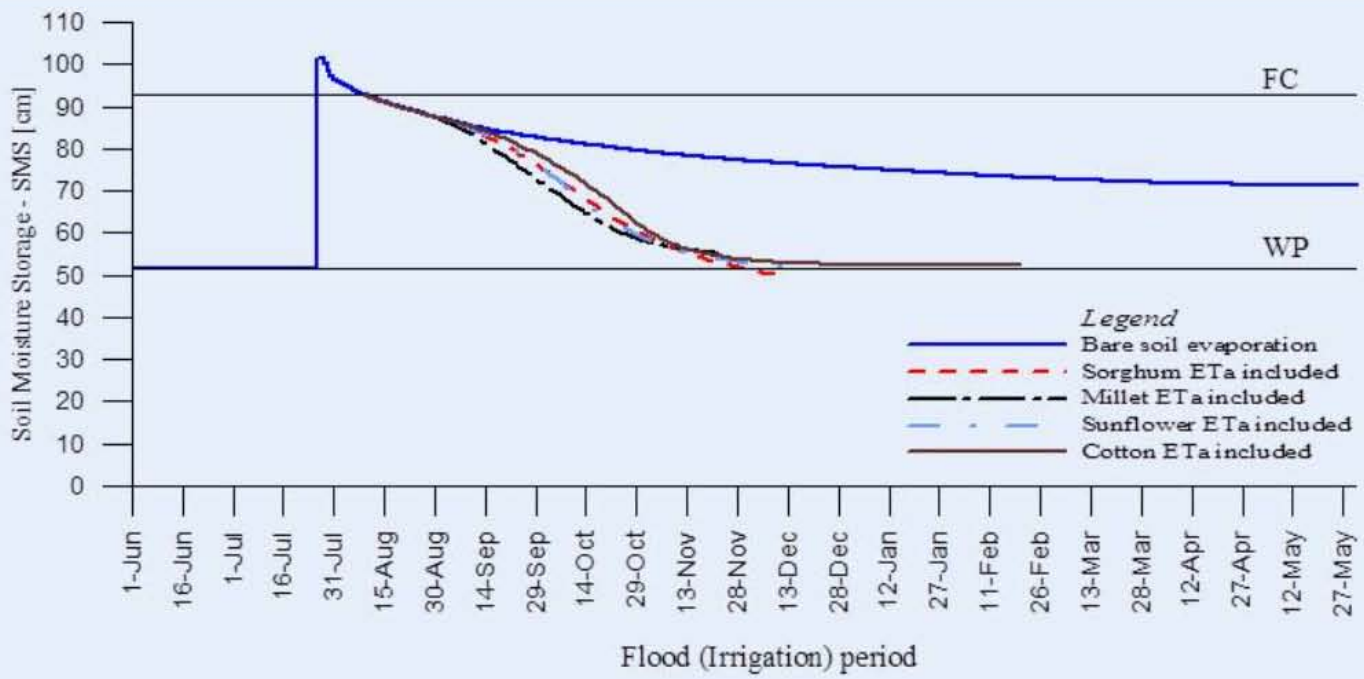
Month	Jul	Aug			Sep			Oct			Nov			Dec			Jan			Feb			Mar			Apr	
Decade	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late	Late		Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late	Late
Pattern	Sorghum 1														Sorghum 2												
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late	Late		Init	Deve	Deve	Mid	Mid	Late	Late	Late					
Pattern	Sorghum														Watermelon												

- Farmers wishes

Month	Aug		Sep			Oct			Nov			Dec			Jan			Feb			Mar			Apr			
Decade	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late	Late		Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late	Late
Pattern	Sorghum 1														Sorghum 2												
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late	Late		Init	Deve	Deve	Mid	Mid	Late	Late	Late					
Pattern	Sorghum 1														Watermelon												
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late	Late		Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late	
Pattern	Sorghum 1														Millet 2												
Dev. Stage	Init	Init	Init	Deve	Deve	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Mid	Mid	Late	Late	Late	Late		Init	Deve	Deve	Mid	Mid	Late	Late	Late
Pattern	Cotton																			Watermelon							
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late		Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late	Late	
Pattern	Sunflower													Sorghum 2													
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late		Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late		
Pattern	Sunflower													Millet 2													
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late		Init	Deve	Deve	Mid	Mid	Late	Late	Late						
Pattern	Sunflower													Watermelon													
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late		Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late	Late	
Pattern	Millet													Sorghum 2													
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late		Init	Deve	Deve	Mid	Mid	Late	Late	Late						
Pattern	Millet													Watermelon													
Dev. Stage	Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late		Init	Init	Deve	Deve	Deve	Mid	Mid	Mid	Mid	Late	Late	Late		
Pattern	Millet													Millet 2													

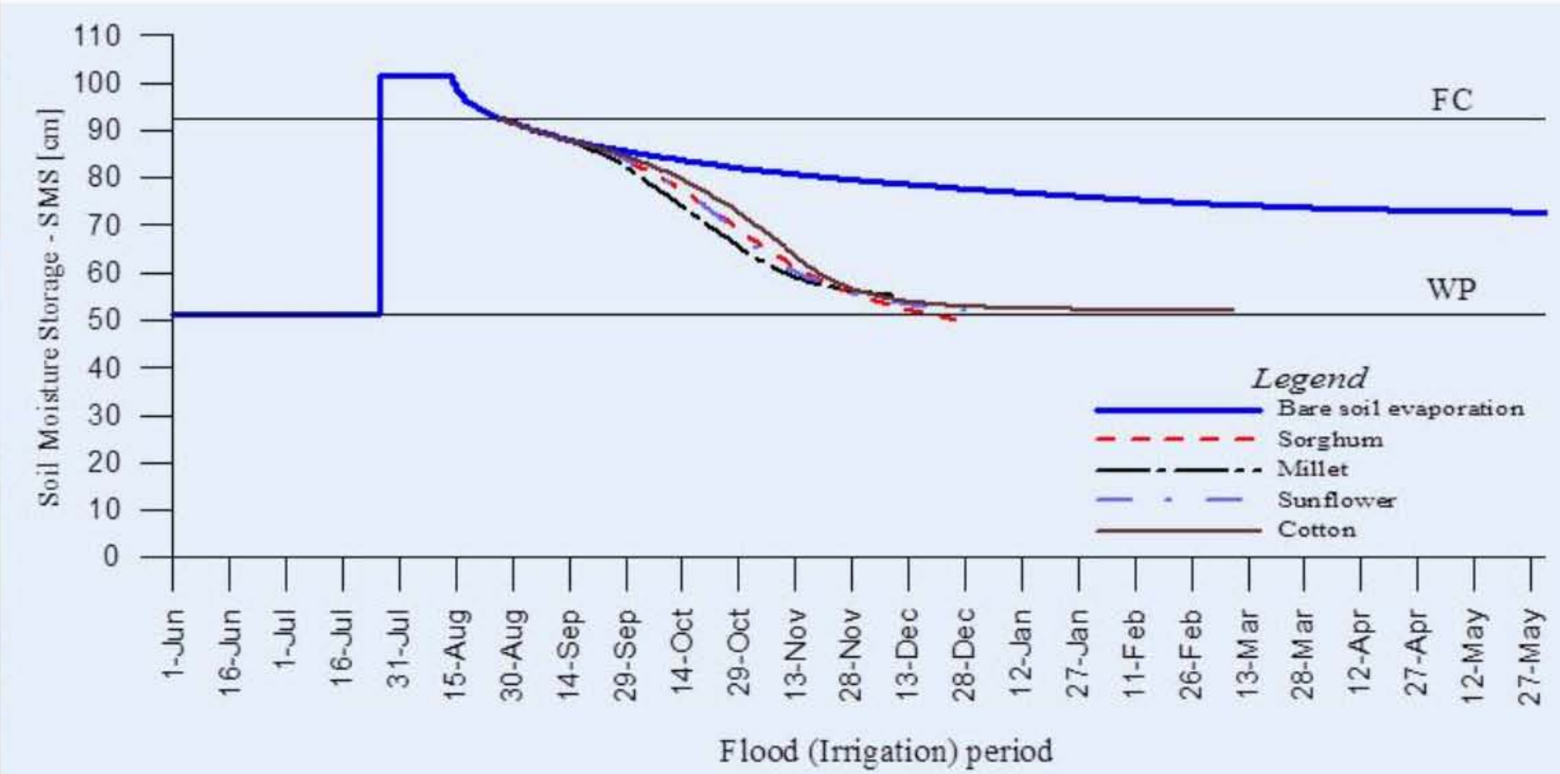
First grown crops yield response

Crop productivity analysis for the minimum infiltration depth



- Yield reduction can be expected for Cotton
- No yield reduction for other crops

Crop productivity analysis for the average infiltration depth



- No yield reduction expected for all crops

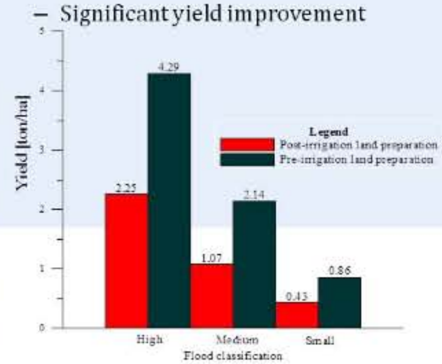
Second grown crops yield response

Second cropping season

- Sorghum yield reduction 60%
  - Extreme conditions 90%
- Millet yield reduction 65%
- Water melon yield reduction 50%

Land preparation

- Play a vital role has a part of field water management
- Pre-irrigation ploughing showed to be most effective
  - Improves the soil infiltration capacity
  - Reduce the compaction (*silty* soils)
  - Significant yield improvement



SPATE SPECIAL AGRONOMIC PRACTICES

Land preparation

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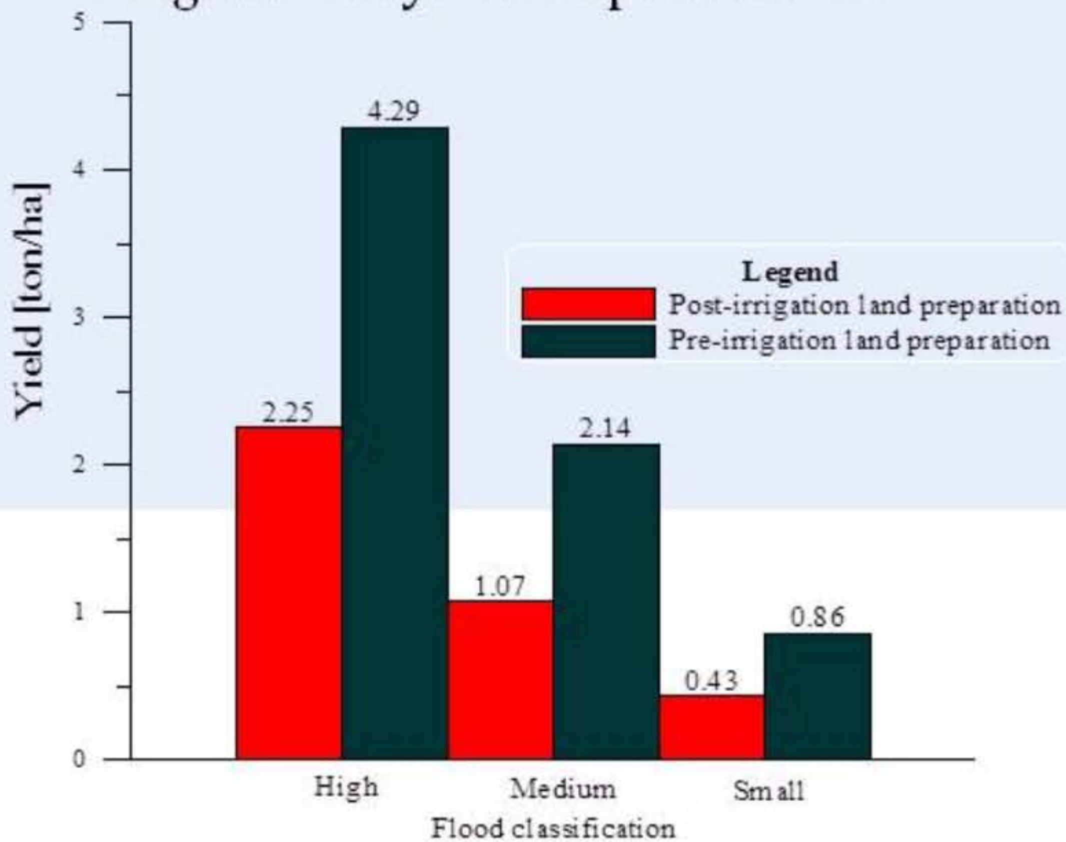

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- Misga Rabakasa 1 can at most irrigate 340 ha from the Kasir Rabakasa canal for high flood event and the 210 ha has to be supplied from the Rabakasa 1 canal - for medium and small floods, 225 and 140 ha respectively can be expected.

- 1 m water depth after the Kasir Rabakasa misga canal off-take cannot be attained. Under the best scenario (narrowing the cross-sections), a maximum of 0.9 m of water depth was obtained.

Conclusions

Cont…

- For an improved field water distribution, the misga should be divided into two plots horizontally (400 x 2650 m) instead of the existing field setup. Under the existing conditions, approximately 80 ha for the small flood event are left un-irrigated.

- 410 mm of infiltration water was available for the crops at the planting date, considering the *silty clay* soil type.

Conclusions

Cont…

- Existing cropping pattern
  - No yield reduction can be expected for the first sorghum planting season and for the water melon and second sorghum season, a yield reduction of 50 and 60% can be expected.

- Farmers wishes cropping pattern
  - No yield reduction on the first planting season for sorghum, millet, and sunflower, some yield reduction for cotton can be expected and for the second season crops sorghum, millet and water melon, yield reductions can be expected in magnitude of 60, 65 and 50% respectively.

Conclusions

Cont…

- Agronomic practices in order to improve the infiltration capacity and soil water holding capacity include:
  - Pre-irrigation land preparation (ploughing) that will provide a good infiltration capacity
  - Mulching and inter-cropping that will enhance the soil's water-holding capacity

Recommendations

- The Kasir Rabakasa misga canal has to be re-narrowed from 4.5 to 2.5 m for the first 2 reaches and from 2 to 1.5 m for the remaining reaches - the canal bank's stability has to be taken into account, thus its economic feasibility as well.

- The field setup should be kept as regular as possible, and the misga canal has to be elongated for the additional intake point under the two plots suggested for the Kassir Rabakasa misga.

Follow-up studies

- Identify type of field structures (design, operation and maintenance) and their suitability for the GAS environment.
- Field-based analysis of the impact of pre-irrigation ploughing on soil moisture storage and crop yields.
- Quantitative assessment of different mulching practices with regard to soil moisture storage.
- Economic evaluation of the different proposed on-farm water management practices.


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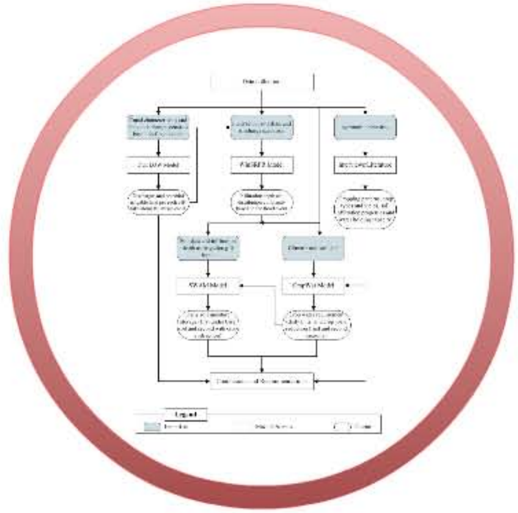
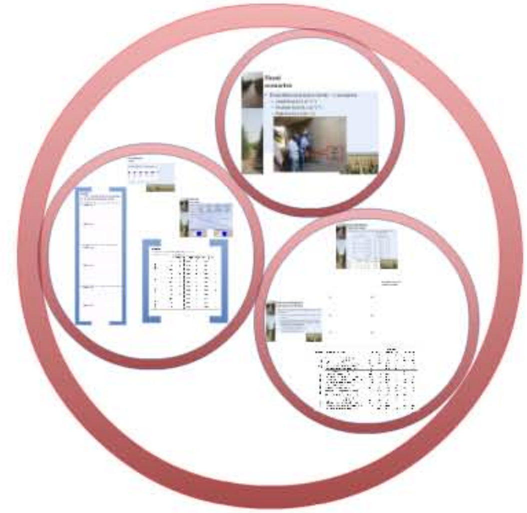
Thank you!

STUDY AREA DESCRIPTION AND PROBLEM DEFINITION

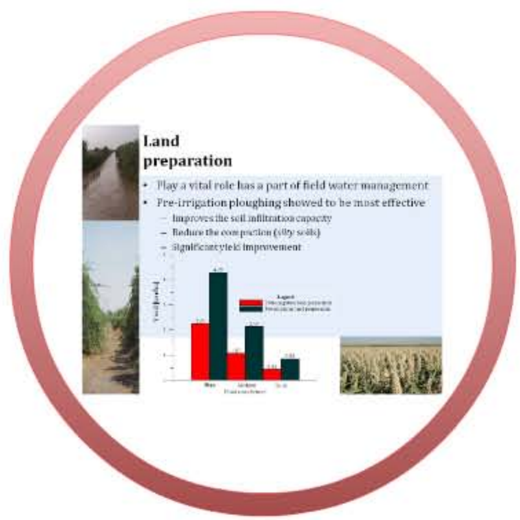


METHODOLOGY



HYDRAULIC PERFORMANCE OF MISGA CANAL AND WATER DISTRIBUTION WITHIN THE MISGA

WATER BALANCE IN UNSATURATED ZONE / SMS AND CROP PRODUCTIVITY MODELLING



SPATE SPECIAL AGRONOMIC PRACTICES

CONCLUSIONS AND RECOMMENDATIONS