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COMPARING SWAT, SWAT+ AND SWAT-WIL MODELS FOR **A HOLISTIC ENVIRONMENTAL FLOW ASSESSMENT** OF TROPICAL HIGHLAND RIVERS

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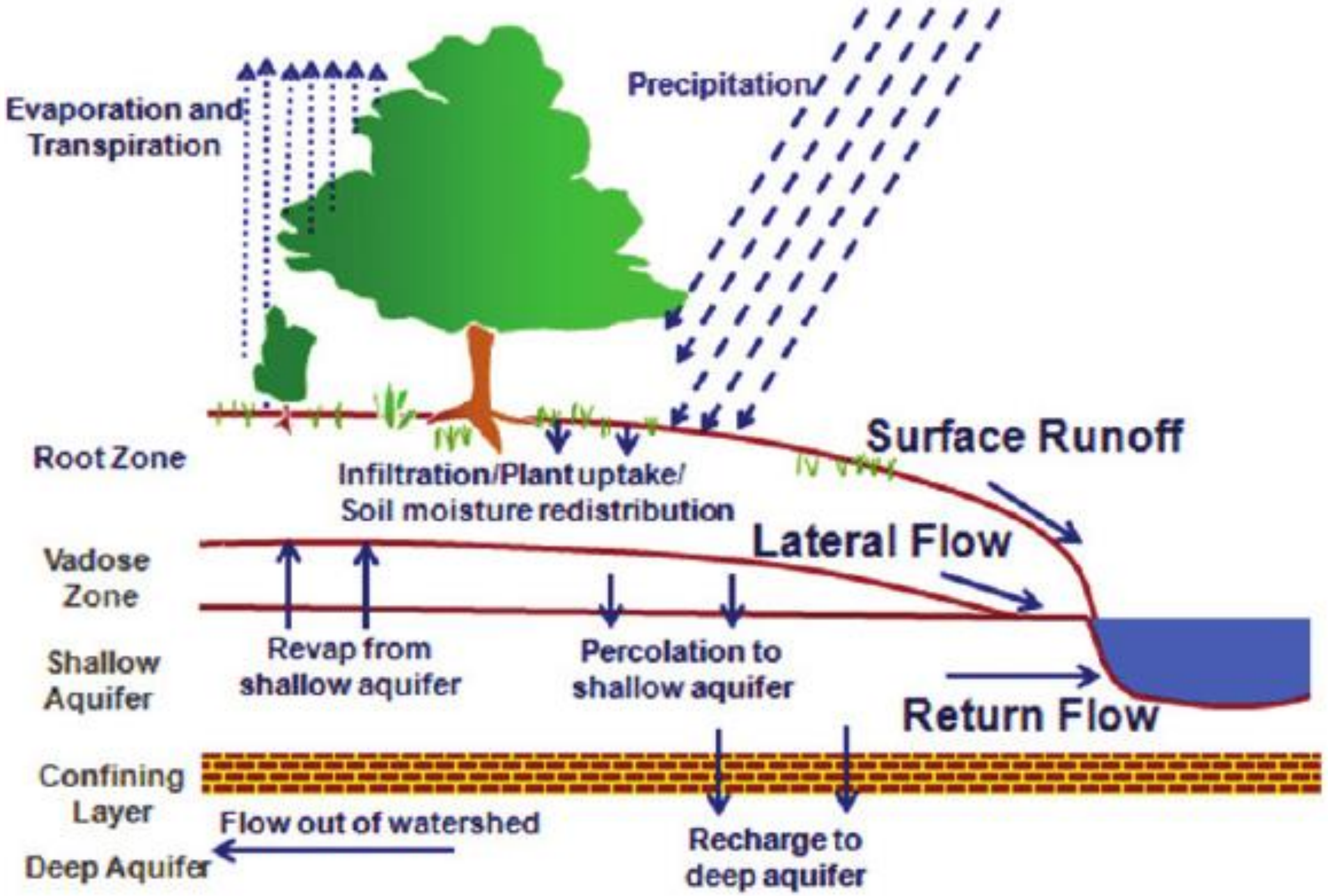
Aarhus, Denmark

Outline

- Background
- Methodology
- Results and discussion
- Conclusion

SWAT



Evaporation and
Transpiration
Precipitation
Root Zone
Surface Runoff
Infiltration/Plant uptake/
Soil moisture redistribution
Lateral Flow
Vadose
Zone
Shallow
Aquifer
Revap from
shallow aquifer
Percolation to
shallow aquifer
Return Flow
Confining
Layer
Flow out of watershed
Deep Aquifer
Recharge to
deep aquifer

Background

- Aquatic ecosystems are degrading in the Lake Tana basin
  - Landscape degradation (Lemma *et al.*, 2019)
  - Climate change (Tigabu *et al.*, 2021, Setegn *et al.*, 2011, Belete, 2014)
  - Water resources development (Singh *et al.*, 2020, Hughes and Farinosi, 2020)

- The preservation of natural hydrological regimes is relevant for maintaining ecosystem services (Reitberger and McCartney, 2011)

- Maintenance of flows in rivers help make water resources uses sustainable (McClain, 2013, Pahl-Wostl *et al.*, 2013)

Background …

- knowledge about environmental flows is essential for conserving rivers (NSW, 2020)
  - Flora, fauna, human being

- Lack of knowledge on relationships between ecological processes and hydrological characteristics (Abebe, 2021)

- Ecological studies to infer relationships with environmental flow are being undertaken internationally (Poff et al., 2017),

  ✓ helpful to do proper planning and management

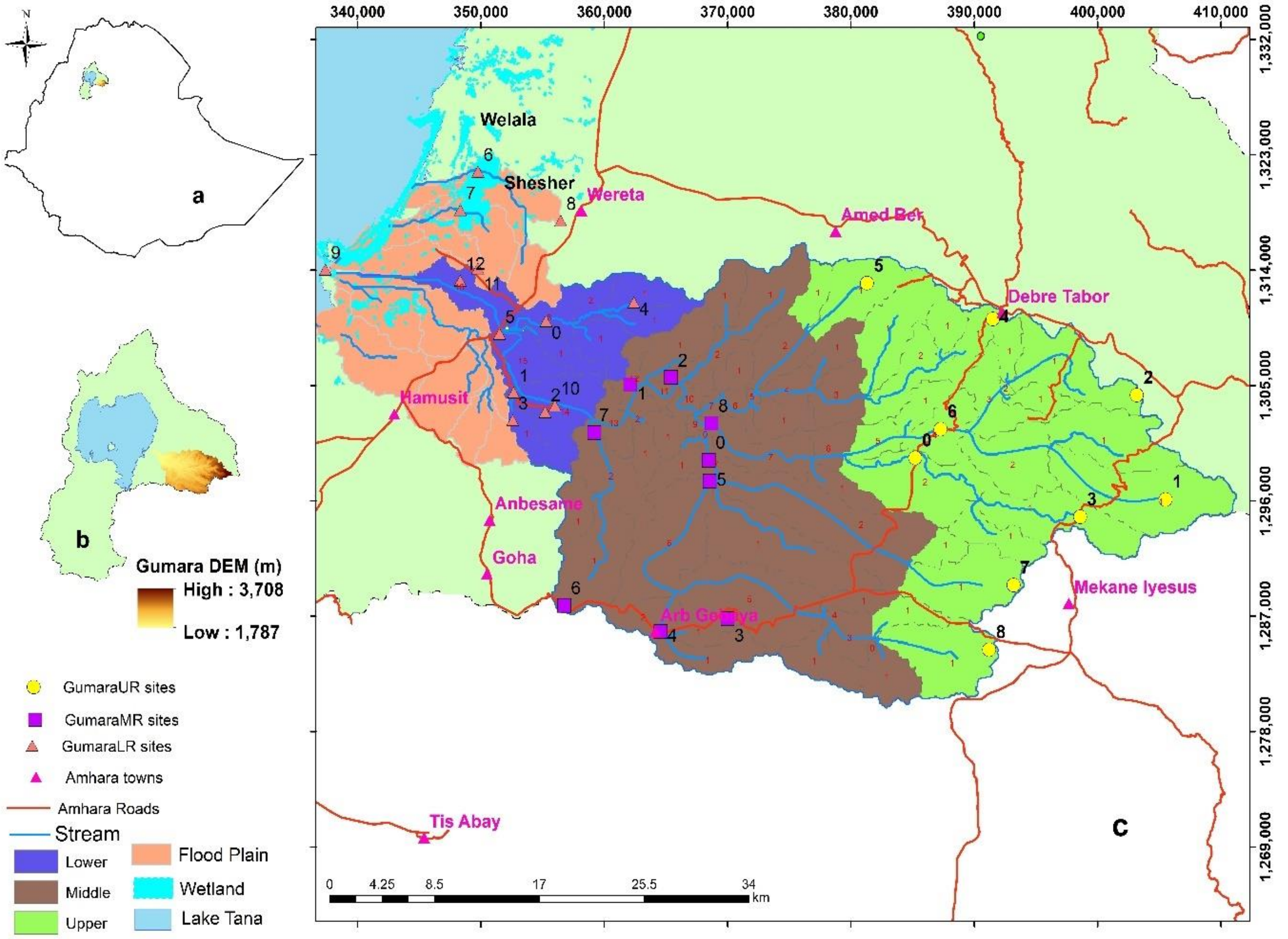
Background …

- In Ethiopia, water is being abstracted impacting the environment (Alemayehu *et al*., 2010, Awulachew *et al*., 2007)
- Environmental flow recommendations in Ethiopia:
    - ABA = 10%–25% MAF
    - Most dam projects = the 95% exceedance probability flow (Q95)
- Lack consideration of the variable and dynamic nature of rivers
    - Timing? Quality? Which ecosystem? livelihoods? = Are not sought
- Lack consideration of the impacts on societal livelihoods dependent on ecosystem services (Abebe *et al*., 2007)

- **Objective:** is to compare the different SWAT models in simulating the important hydrological components for environmental flow assessment in the Gumara River basin
  - Modelling flow of Gumara River using SWAT2012, SWAT+ and SWAT-WIL
  - Comparing model performances, water balance terms closure and locating runoff generation areas
  - Evaluate capturing of environmental flow components

Description of the study area

- Area 1376 km^2
- Major tributary of Lake Tana basin
- Rainfall 1,326 mm
- Welala and Shesher wetlands
- Ecologically important
  - 15 unique Labeobarbus fish
  - 12 globally threatened bird species
  - UNESCO Biosphere reserve areas



Methodology – SWAT modelling

- Data

S.N.	Data type	Spatial resolution	Source
1	River flow, 1981-2018, Q in m^3s^{-1}		MoWIE, Ethiopia
2	Precipitation, 1981-2018	0.25^0	CHIRPS 2.0 Africa (KNMI climate explorer)
3	Temperature Min/Max, 1981-now	0.25^0	ERA5 Africa (KNMI climate explorer)
4	Soil	1:250,000	MoWIE, BCEOM (1998)
5	Land use/cover, 2019	30 m	USGS Landsat images
6	DEM SRTM	30 m	NASA / USGS / JPL-Caltech

- Analysis
  - Modeling flow, Performances, Water balance
  - Mapping runoff areas

- Tools
  - SWAT2012, SWAT-WIL (30 and 60 DPIMP), SWAT+ (with/without LSU), SWAT-Editor
  - ArcGIS, TauDEM, Google earth engine, excel

Results and discussions: **Model performance**

Scenarios	Objective function	SWAT2012	SWAT+LSU	SWAT+	SWATwil60DPIMP	SWATwil30DPIMP
Default	NSE	**0.2**	**0.31**	**0.31**	**0.34**	**0.37**
	R^2	**0.35**	**0.11**	**0.1**	**0.13**	**0.2**
	RSR	**0.89**	**0.94**	**0.95**	**0.93**	**0.89**
	PBias	**58.5**	**68.5**	**69.4**	**67.8**	**61.7**
Calibration	NSE	**0.87**	**-**	**0.82**	**-**	**0.81**
	R^2	**0.93**		**0.86**		**0.83**
	RSR	**0.35**		**0.43**		**0.43**
	PBias	**13.4**		**4.7**		**14.9**
validation	NSE	**0.67**	**-**	**0.66**	**-**	**0.32**
	R^2	**0.89**		**0.77**		**0.82**
	RSR	**0.57**		**0.59**		**0.82**
	PBias	**42.6**		**34.6**		**66.1**

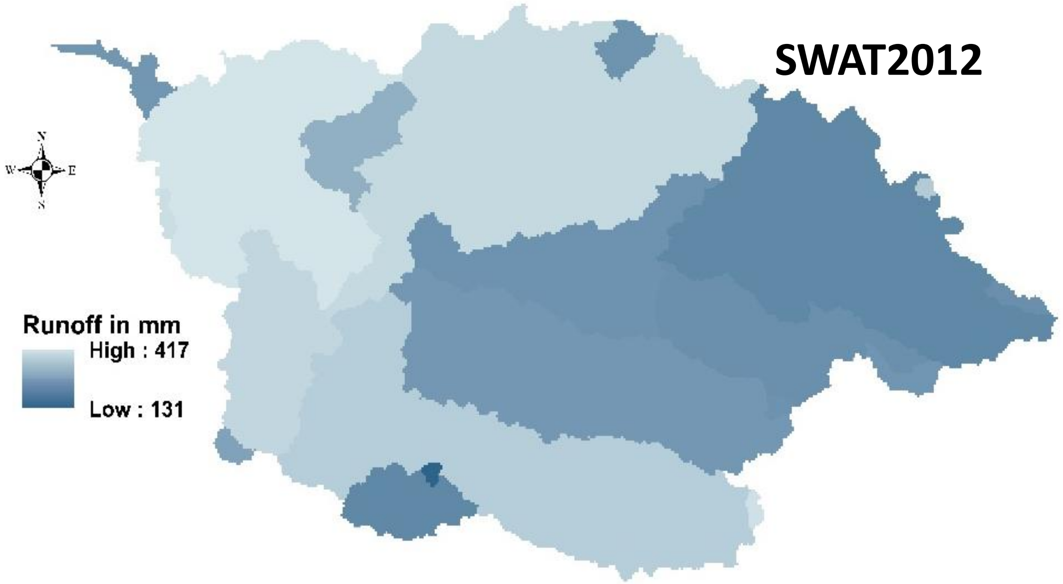
Water balance closures

- Higher closure term for SWAT+ LSU; where run-on was not considered

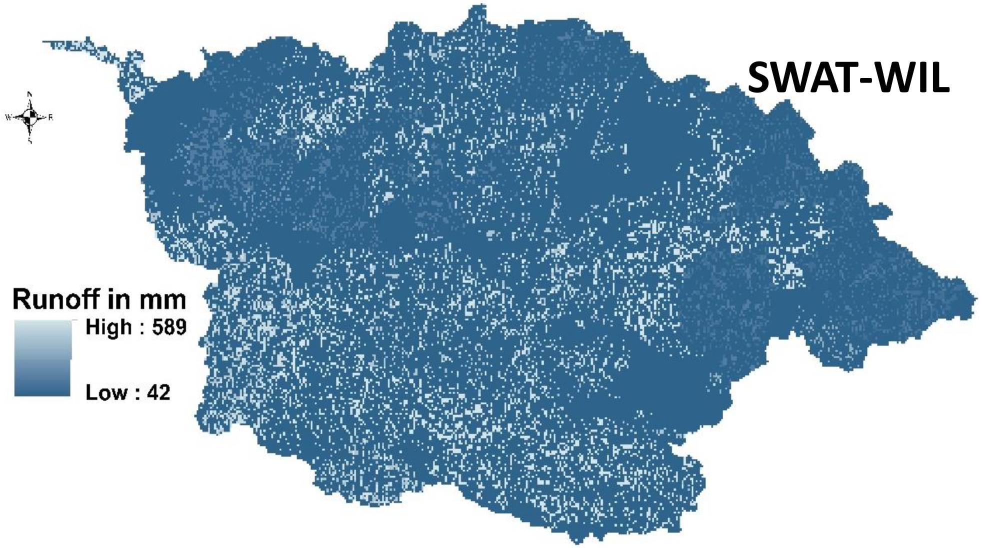
S.N.	Water Balance parameter	SWAT2012	SWAT+LSU	SWAT+	SWATWIL_DEPIMP=60cm	SWATWIL_DEPIMP=30cm
1	P	1333.6	1391.5	1391.3	1345.8	1345.8
2	SurQ	820.0	550.2	485.7	299.17	368.39
3	LatQ	13.7	9.97	10.0	24.39	29.81
4	GwQ	6.5	7.3	7.3	129.57	134.27
5	ET	501.5	890.1	890.2	890.5	812.2
6	Run-on		60.069	0	1343.63	1344.67
Sum (2 to 5)		1341.8	1,457.6	1,393.2		
Balance		-8.2	-66.1	-1.9	**2.17**	**1.13**
Balance with run-on		**-8.2**	**-6.031**	**-1.9**		

Locating Runoff Areas

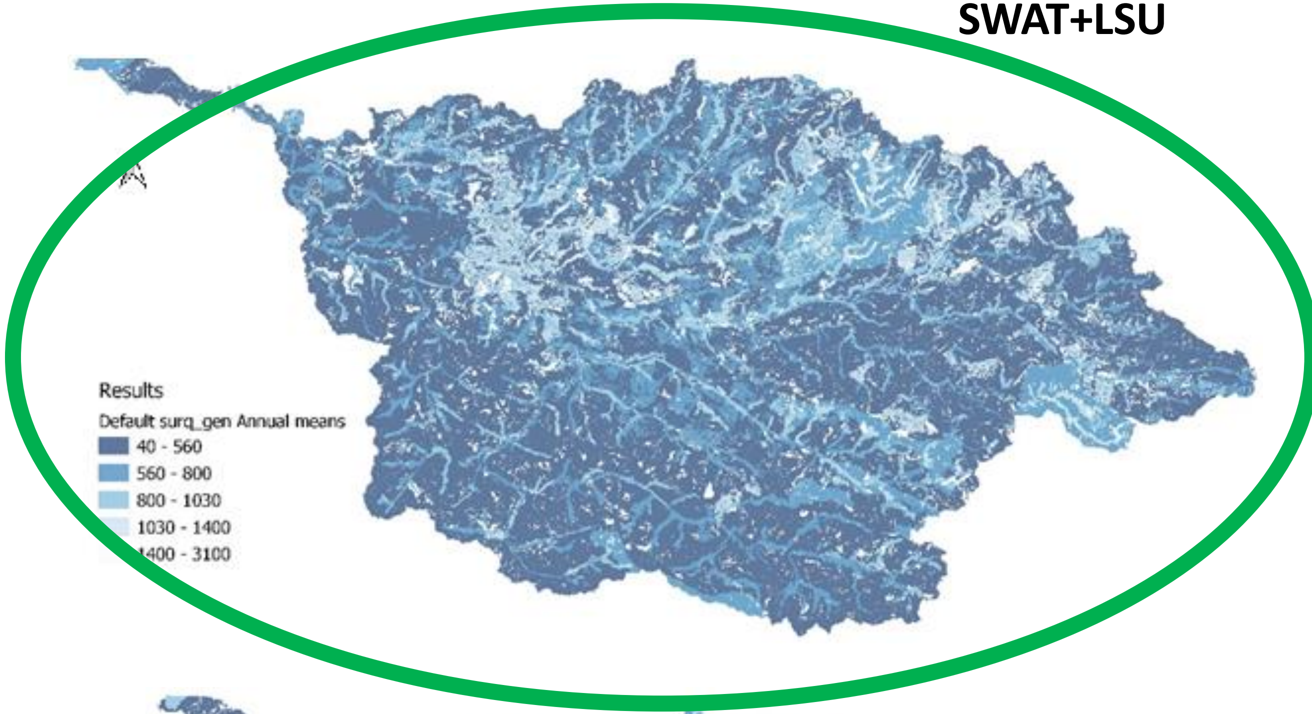
SWAT2012



SWAT-WIL



SWAT+LSU



SWAT+

Capturing Environmental flow components

- **Captured better!** SWAT-WIL for low flow and SWAT+ for high flow

Environmental flow component	Observed flow (Abebe et al., 2020)		SWAT2012	SWAT+ LSU	SWAT+	SWATwil 30	SWATwil 60
	Flow, m^3s^{-1}	percentile	Flow, m^3s^{-1}	Flow, m^3s^{-1}	Flow, m^3s^{-1}	Flow, m^3s^{-1}	Flow, m^3s^{-1}
Extremely low flow	<0.17	<10	0	0	0	<0.73	<0.46
Low flow	0.17-4.76	10 to 28	0	0	0	0.73–1.03	0.46-0.74
High flow pulse	4.76-294.4	28 to 97.5	0-179	0-174	0-174	1.03-17	0.74-158
Small flood	294.4-483.1	97.5 to 99.93	179-476	174-466	174-466	177-425	158-402
Large flood	> 483.1	>99.93	>476	>466	>466	>425	>402

Conclusions

- SWAT-WIL and SWAT+ performed better than SWAT2012 in capturing the low flows and the high flows respectively and located accurately runoff generation areas

- Locating runoff area accurately helps accurately locating the fate of pollutants and planning water quality management

- The water balance terms closed well for SWAT2012, SWAT-WIL and SWAT+ without landscape unit but not SWAT+LSU unless run-on considered

- Looking at the possibilities to integrate SWAT-WIL with SWAT+ for environmental flow assessment study of different catchment characteristics

Thank you for your attention!

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ADSWE

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VUB VRIJE UNIVERSITEIT BRUSSEL

TUDelft

Alliance

Bioversity International

CIAT

IWMI International Water Management Institute