SWAT Global Impacts

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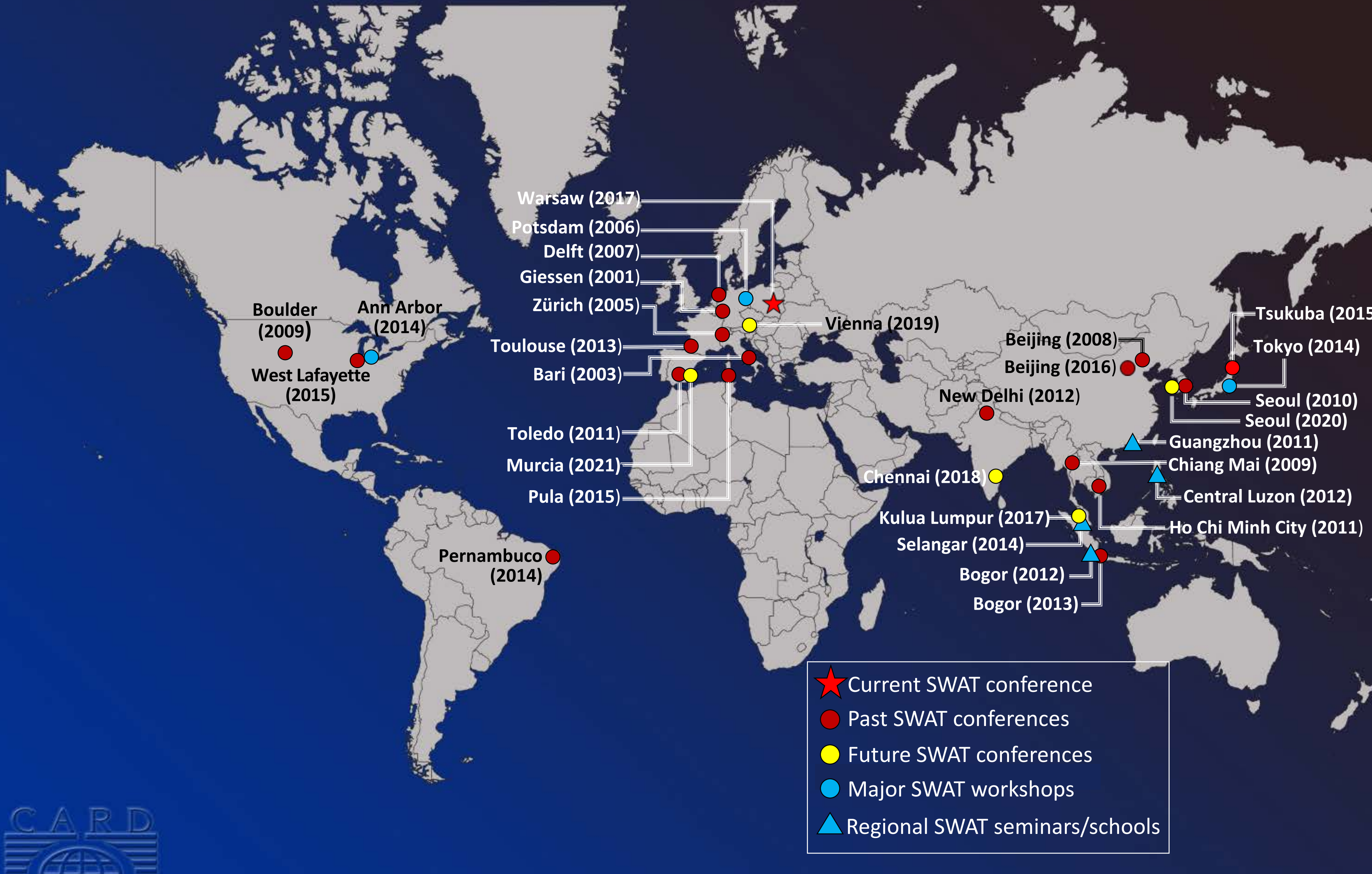
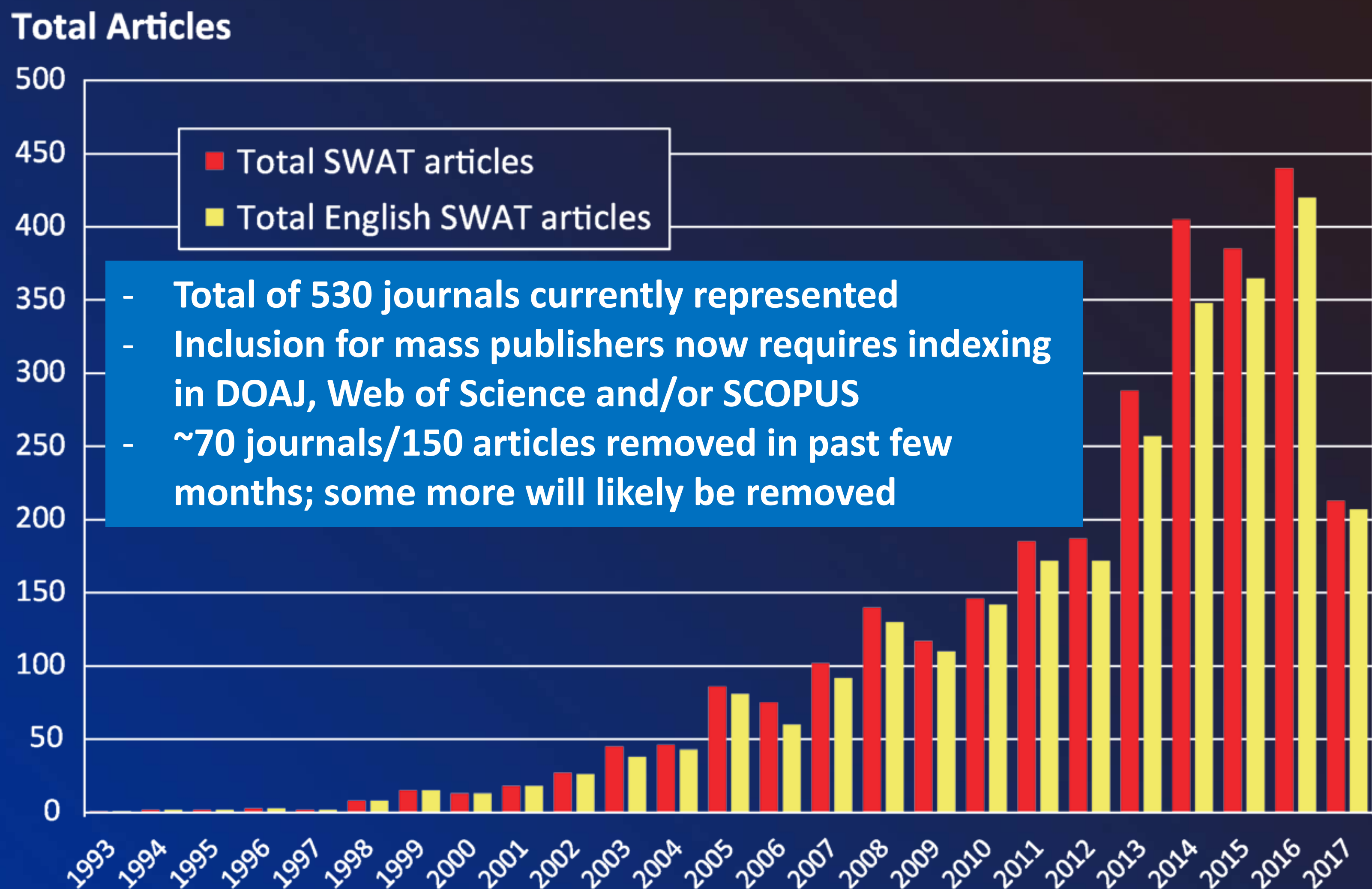
Locations/Years of Past, Present & Future SWAT Events



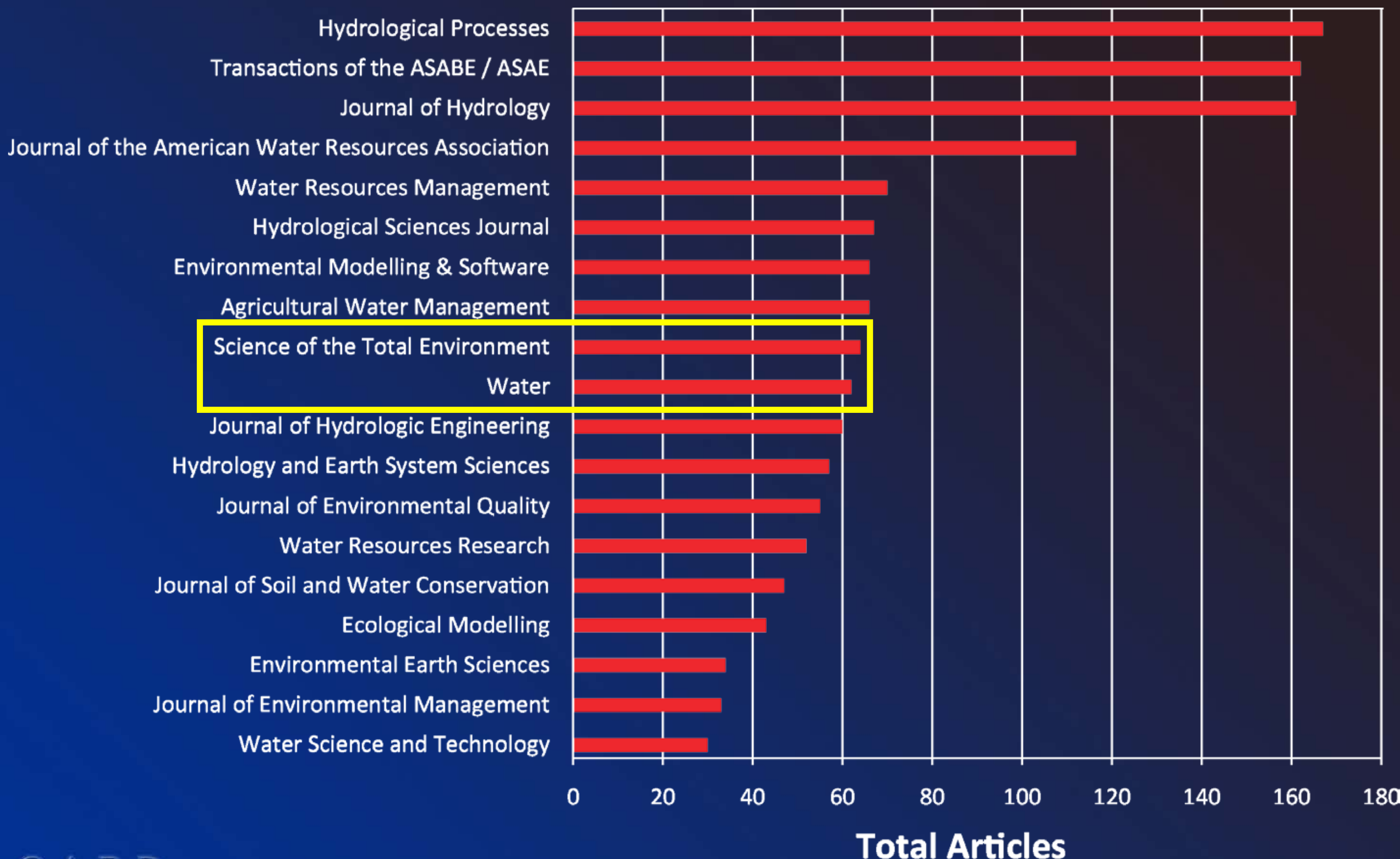
Trends in SWAT-related articles in SWAT Literature Database (June_2017)



- Total of 530 journals currently represented
- Inclusion for mass publishers now requires indexing in DOAJ, Web of Science and/or SCOPUS
- ~70 journals/150 articles removed in past few months; some more will likely be removed

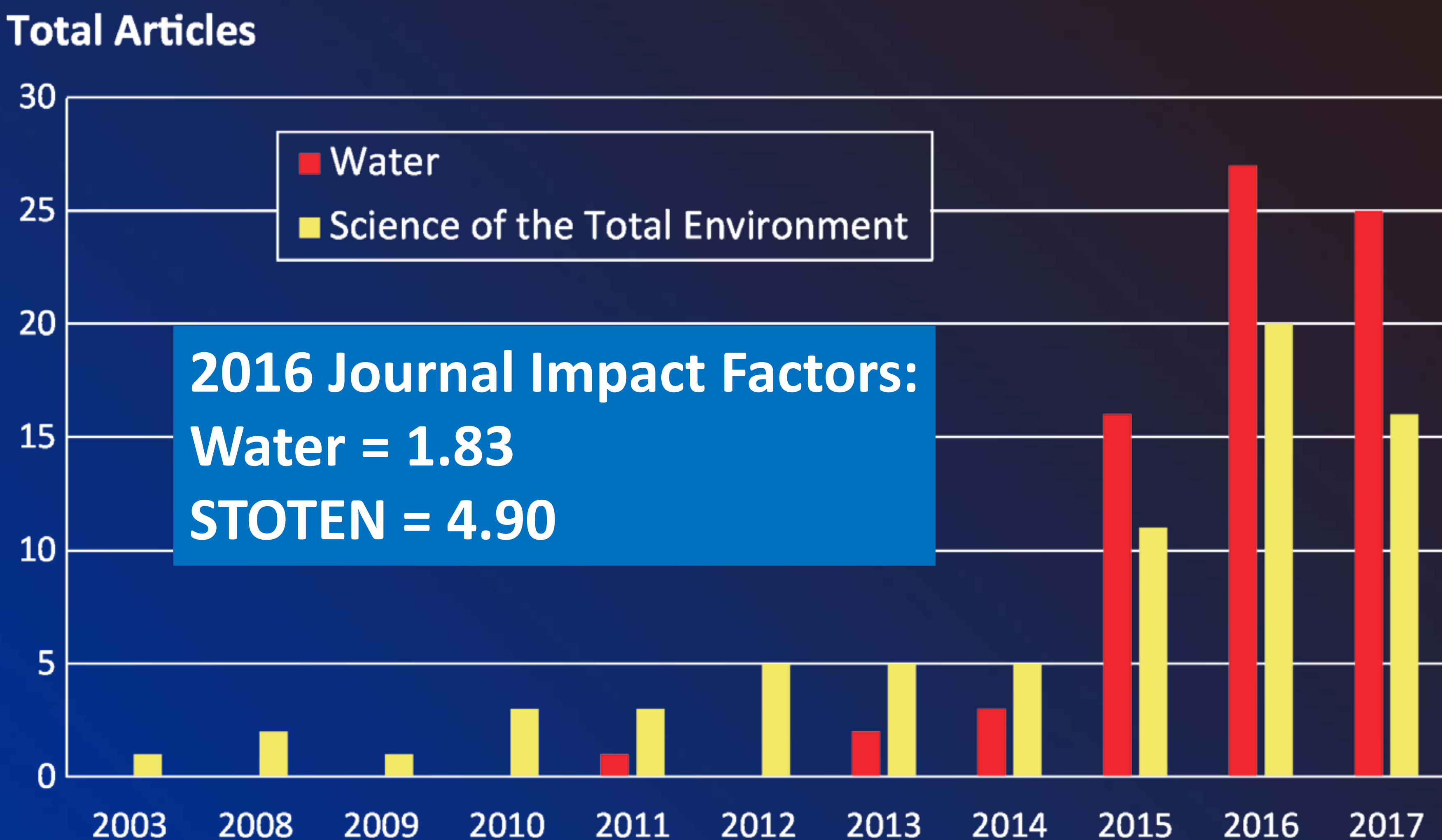
Source: https://www.card.iastate.edu/swat_articles/; data shown here includes both SWAT and modified SWAT applications as well as review articles

Top 20 Journals in SWAT Literature Database



Source: https://www.card.iastate.edu/swat_articles/; data shown here includes both SWAT and modified SWAT applications as well as review articles

SWAT Article Trends in Water & STOTEN



2016 Journal Impact Factors:
Water = 1.83
STOTEN = 4.90

Source: https://www.card.iastate.edu/swat_articles/; data shown here includes both SWAT and modified SWAT applications as well as review articles

SWAT Special Issues/Sections (http://swat.tamu.edu/publications/special-issues/)

Conference or other event	Publication Year	Journal
2001 Giessen	2005	Hydrological Processes
2006 Potsdam	2008	Hydrological Sciences Journal
2009 Boulder	2010	Transactions of the ASABE
2009 Chiang Mai	2009-2011	International Agricultural Engineering Journal
2010 Seoul	2011	Transactions of the ASABE
2011 Toledo	2014	Journal of Environmental Quality
2012 New Delhi	2015	Regional Environmental Change
2013 & 2014 conferences	2015	Hydrological Sciences Journal
2013 to 2015 conferences	2015	International Journal of Agricultural & Biological Engineering (IJABE)

SWAT Special Issues/Sections/Series (http://swat.tamu.edu/publications/special-issues/)

Conference or other event	Publication Year	Journal
2015 Purdue & Sardinia	2017	Journal of the American Water Resources Association (series)
2015 Purdue & Sardinia	2016 & 2017	Agricultural Water Management (two parts)
2015 Purdue & Sardinia	2017	Sustainability of Water Quality and Ecology
2016 Beijing	2016 & 2017	Water
2016 Beijing	2018?	Hydrology & Earth System Sciences
2015 & 2016 conferences	2017?	Environmental Modelling & Software
2017 Warsaw	2018?	Ecohydrology & Hydrobiology; Ecological Engineering; Water
2017 Malaysia	2018?	Malaysian Journal of Soil Science?; Water?

Web of Science All-Time Top-Cited JAWRA Papers (July 22, 2016)

Authors (paper rank)	Year	Title	Model	Citations All Databases	Citations Core Collection
Arnold et al. (1)*	1998	Large area hydrologic modeling and assessment - part 1: Model development	SWAT	2,407	2,210
Santhi et al. (2)	2001	Validation of the SWAT model on a large river basin with point and nonpoint sources	SWAT	537	483
Arnold et al. (6)	1999	Automated methods for estimating baseflow and ground water recharge from streamflow records	-	396	361
White & Chaubey (11)	2005	Sensitivity analysis, calibration, and validations for a multisite and multivariable SWAT model	SWAT	203	194

*Total Google Scholar citations = 4,763; total Scopus citations = 2,771

Web of Science All-Time Top Cited Trans. ASAE/ASABE Papers (July 22, 2016)

Authors (paper rank)	Year	Title	Model	Citations	
				All Databases	Core Collection
Moriasi et al. (1)*	2007	Model evaluation guidelines for systematic quantification of accuracy in watershed simulations	**SWAT**	2,144	2,051
Gassman et al. (2)	2007	The Soil and Water Assessment Tool: Historical development, applications, and future research directions	**SWAT**	948	892
Williams et al. (6)	1984	A modeling approach to determining the relationship between soil erosion and soil productivity	**EPIC**	593	542
Williams et al. (9)	1989	The EPIC crop growth-model	**EPIC**	442	408

***Total Google Scholar citations = 2,738; total Scopus citations = 2,355**

Heistermann et al. 2014 Bibliometric Analysis

Analyzed ~1.9 million references cited in over 170,000 articles categorized in 80 Journals in the Thomson Reuters Journal Citation Reports Water Resources Category for 1965 to 2012

"… the dominance of one topic is particularly remarkable: the use of watershed models and the related aspects of model calibration, evaluation, and uncertainty (ranks 7, 9, 10, 11, 16, 17, 19, 21, 25)."

11	Moriasi et al. 2007. Trans. ASABE
16	Gassman et al. 2007. Trans. ASABE
21	Arnold et al. 1998. J. Amer. Water Resources Assoc.

Source: Heistermann et al. 2014. Increasing life expectancy of water resources literature. Water Resources Research. 50: 5019–5028. Doi:10.1002/2014WR015674.

Nexus Tools Platform: Popularity index P_r for 352 Models

SWAT P_r = 39.2 (no other hydrologic model P_r was close)

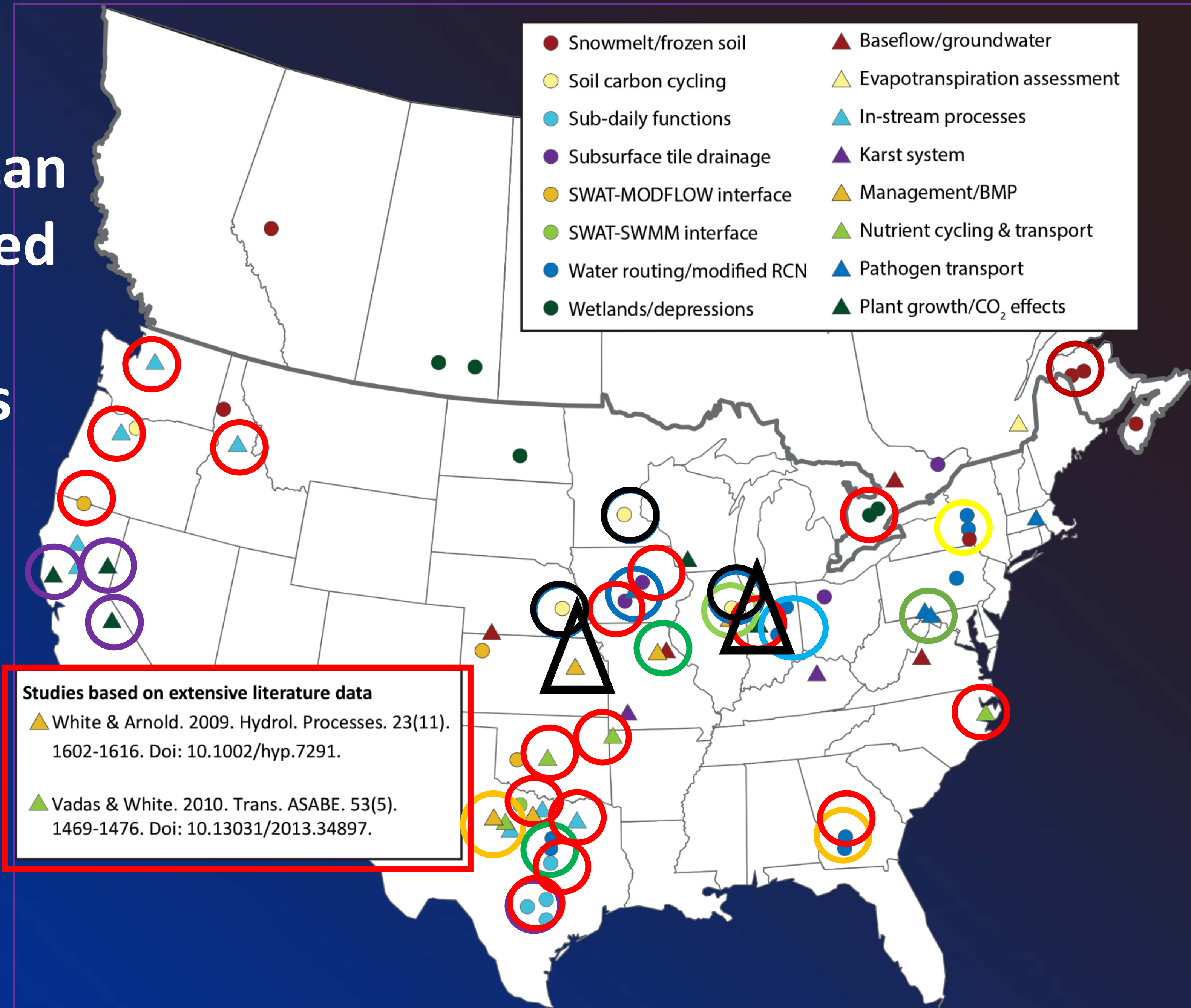
Source: Mannschatz et al. 2016. Nexus Tools Platform: Web-based comparison of modelling tools for analysis of water-soil-waste nexus. Environ. Model. & Software. 76: 137–153.

Other Bibliometric Studies that Highlight the Impact of SWAT

Topic	Analysis type	Citation
Total citations	Web of Science & Google searches	Refsgarrd et al. 2010. Hydrology Research 41(5): 355-377.
Non point source modeling	Key terms (title, abstract,	Zhuang et al. 2014. Journal of Soil and Water Conservation. 69(4): 121A-126A.
Soil monitoring	Keywords	Wang et al. 2015. Acta Agriculturae Scandinavica, Section B — Soil & Plant Science.
GIS applications	Cluster analysis	Wei et al. 2015. The Professional Geographer.
River water quality	Keywords & cluster analysis	Wang et al. 2016. Scientometrics.
BMP research	Keywords	Zhuang et al. 2016. Journal of Soil and Water Conservation. 71(4): 98A-104A.

Citation data available in: https://www.card.iastate.edu/swat_articles/

North American Modified SWAT Models



SWAT model improvements to simulate bioenergy crops production

Presented by: Cibin Raj

Co-authors:

Dr. Indrajeet Chaubey, Elizabeth Trybula, Dr. Jeff Volenec

Dr. Sylvie Brouder, Dr. Jeff Arnold

Miscanthus, switchgrass and crop residue as biofeedstock

Switchgrass (~10 Mg/ha) *Miscanthus (~25 Mg/ha)*

Miscanthus

Crop Growth Algorithm Improvement

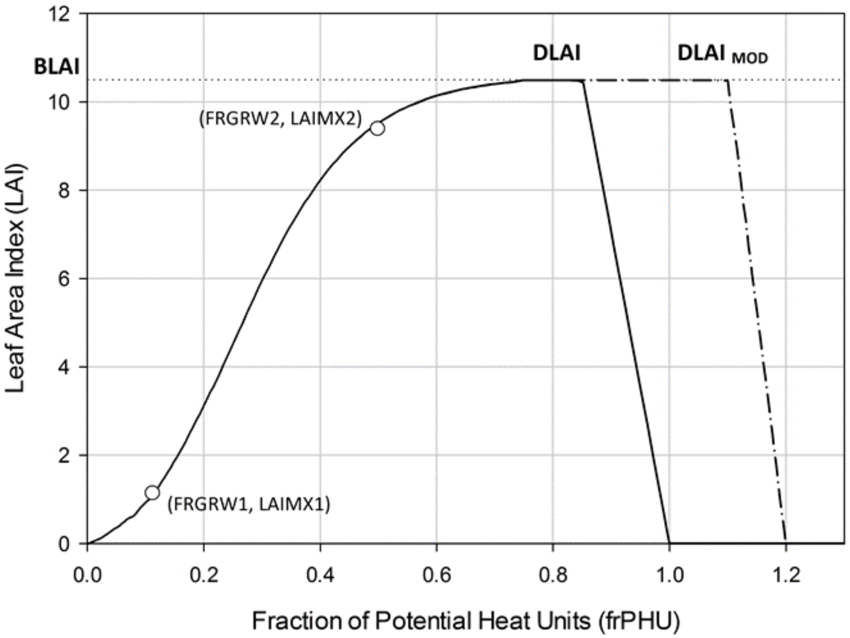
- Plant nutrient uptake in stress periods
- Harvest operation representation – Harvest Index (HI) adjustments with water and nutrient stress
- Dormancy period representation and dead root allocation in harvest operation
- LAI after the crop maturity – senescence representation

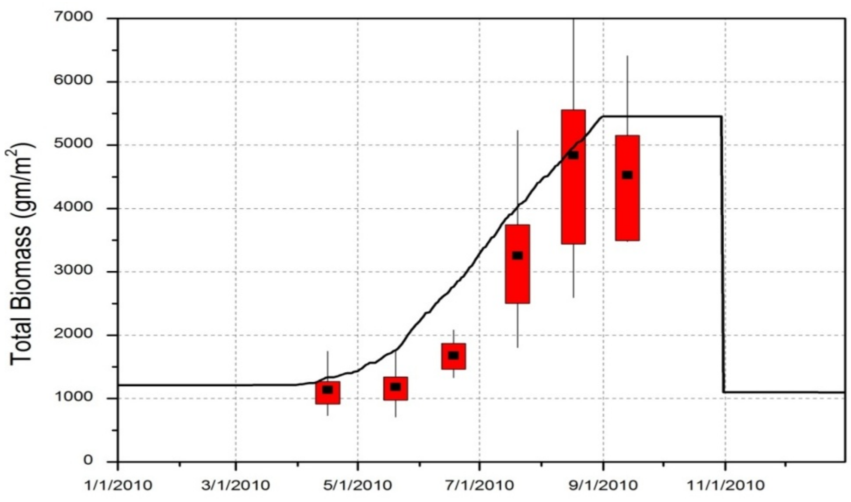
Modification of LAI curve

- No biomass accumulation after September1

plant was still green and physiologically active

- Senescence start at October1
  - PHU=1.1 : DLAI =1.1
- Senescence End : PHU 1.2





All switchgrass are not the same

	Miscanthus		Shawnee Switchgrass		Alamo Switchgrass
Parameter	**Suggested**	**Range**	**Suggested**	**Range**	**Database value**
T_OPT	25	-	25	-	25
T_BASE	8	7-10	10	8-12	12
PHU	1830	2100-1600	1400	1600-1200	
BIO_E	41 (39*)		17 (12*)	10-13	47
HVSTI	1	-	1	-	0.9
HEFF	0.7	0.65-0.75	0.75	0.7-0.75	
BLAI	11	10-13	8	-	6
DLAI	1.1	-	1		0.7
EXT_COEFF	0.55	0.45-0.65	0.5	0.4-0.55	0.33
LAIMX1	0.1	-	0.1	-	0.2
LAIMX2	0.85	-	0.85	-	0.95
FRGRW1	0.1	-	0.1	-	0.1
FRGRW2	0.45	-	0.4	-	0.2
PLTNFR(1)	0.0100	0.0097-0.0104	0.0073	0.0066-0.0081	0.035
PLTNFR(2)	0.0065	0.0062-0.0070	0.0068	0.0067-0.0072	0.015
PLTNFR(3)	0.0057	0.0053-0.0060	0.0053	0.0051-0.0055	0.0038
CNYLD	0.0035	0.0034-0.0035	0.0054	0.0053-0.0058	0.0160
PLTPFR(1)	0.0016	0.0016-0.0017	0.0011	0.0010-0.0012	0.0014
PLTPFR(2)	0.0012	0.0010-0.0014	0.0014	0.0013-0.0016	0.001
PLTPFR(3)	0.0009	0.0007-0.0011	0.0012	0.0011-0.0012	0.0007
CPYLD	0.0003	0.0003-0.0004	0.0010	0.0010-0.0011	0.0022
CHTMX	3.5	-	2	-	2.5
RDMX	3	2-4	3	2-4	2.2
WSYF	1	-	1	-	0.9
ALAI_MIN	0	-	0	-	0
USLE_C	Existing Alamo Value		Existing Alamo Value		0.003
VPDFR	Existing Alamo Value		Existing Alamo Value		4
GSI	Existing Alamo Value		Existing Alamo Value		0.005

Estimated/ Literature

From Measured WQFS Data

From SWAT Database

International SWAT-Asia Conference IV

@Tsukuba, Ibaraki, Japan

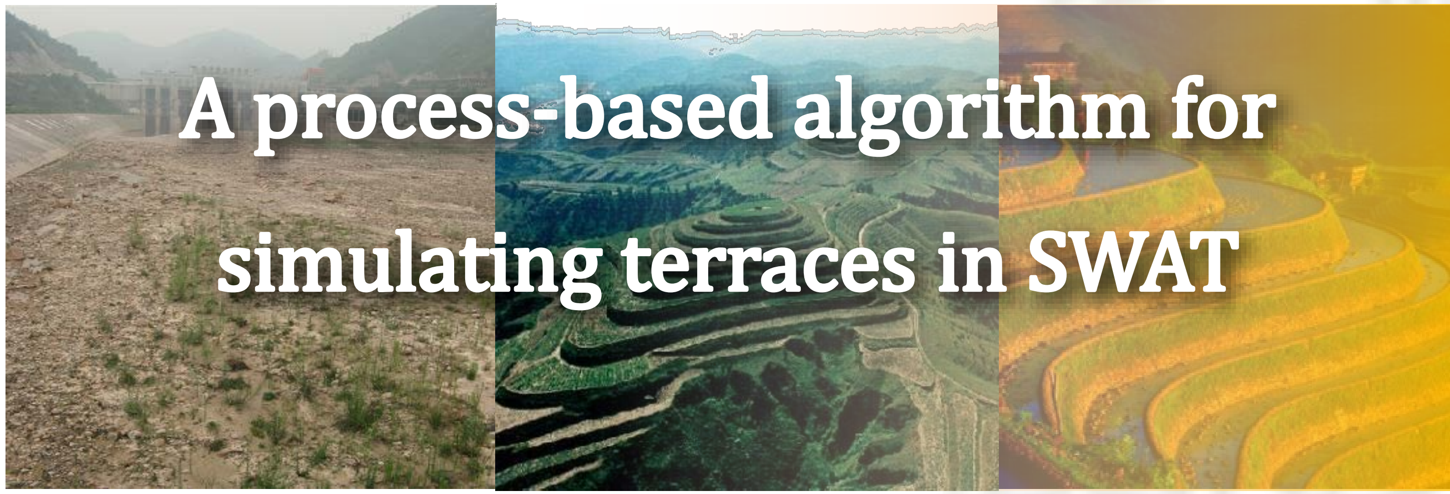
Model Development

Watershed modelling

Terrace evaluation

Future research

A process-based algorithm for simulating terraces in SWAT



Hui Shao (Shawn) PhD

Dept. of Geography

University of Guelph

OCT 2015

Part 2

Terrace model

2.1 Concept design

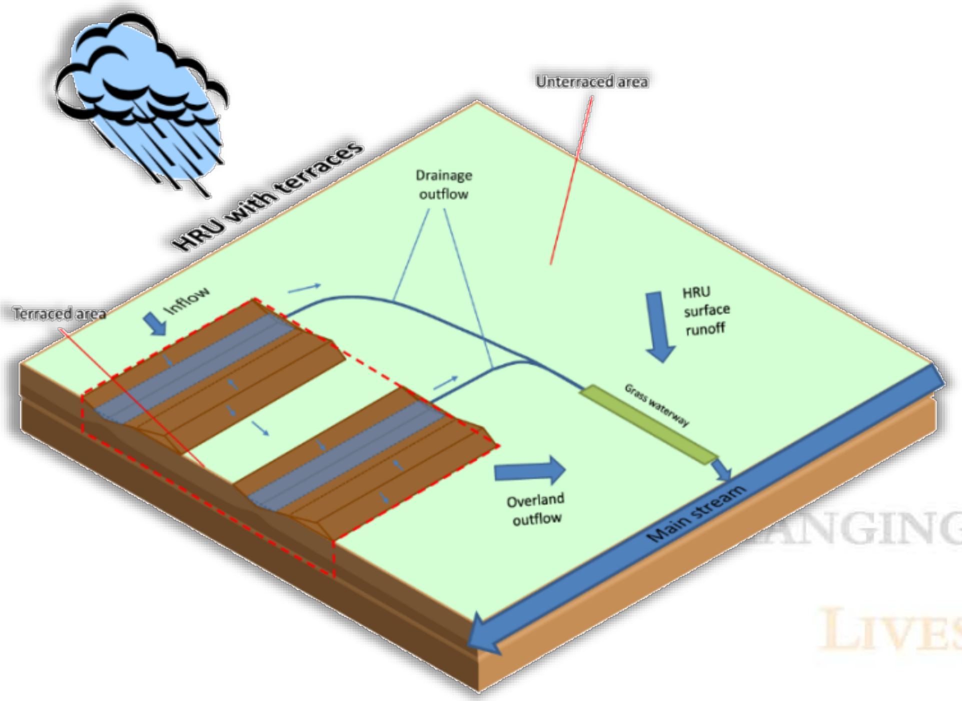
Process-based terrace simulation

Traditional terrace modelling method (Parameter representation)

Parameter	Represent effects
CN2	Adjust rainfall infiltration in terrace
USLE-P	Reduce sediment losses
SLSUBBSN	Distance between terraces

Waidler, D. et al. 2011. Conservation Practice Modeling Guide for SWAT and APEX. TR-399. College Station, Texas A&M University System.

Process-based terrace algorithm in HRU



H. Shao, C. Baffaut, J. E. Gao et al. 2013. Development and Application of Algorithms for Simulating Terraces within SWAT. Transaction of ASABE, 56(5): 1715-1730.

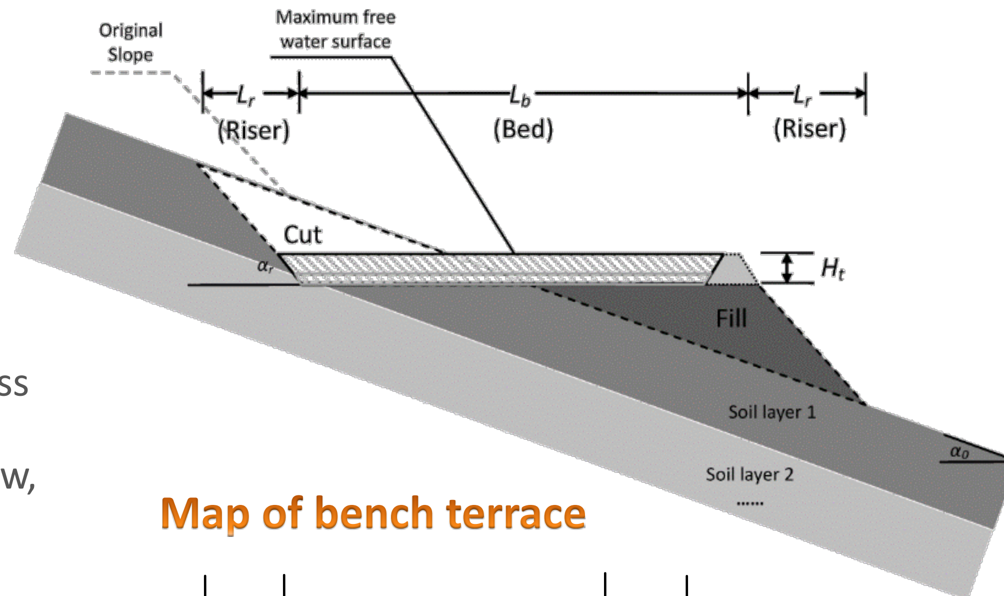
Part 2

Terrace model

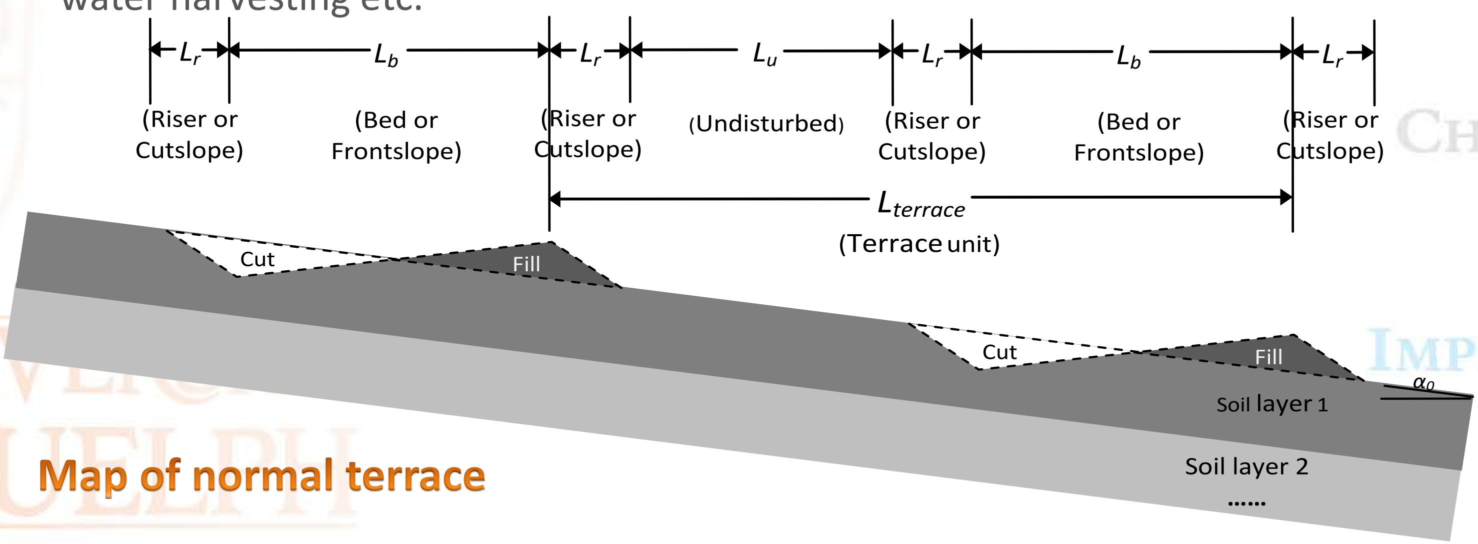
2.2 Terrace algorithm

01 Terrace types and segments

- ✓ Runoff: SCS curve number
- ✓ Erosion: MUSLE method
- ✓ Nutrients: nitrogen & phosphorous
- ✓ Plant growth: optimal growth & stress
- ✓ More: plant management, lateral flow, water harvesting etc.



Map of bench terrace



Map of normal terrace

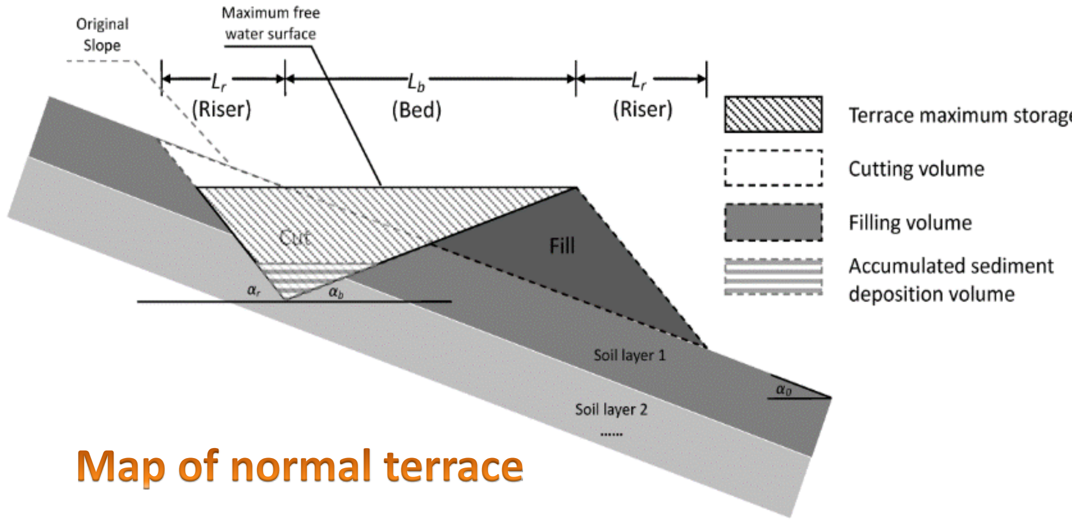
Part 2

Terrace model

2.2 Terrace algorithm

03 Terrace storage effects

- ✓ Sub-daily simulation
- ✓ Sediment and nutrient settlement
- ✓ Extra infiltration
- ✓ Extra evaporation
- ✓ Inside terrace channel erosion
- ✓ Terrace output



Map of normal terrace

Moriasi et al. (2007; 2015) Suggested Streamflow NSE Criteria

(NSE: Nash-Sutcliffe modeling efficiency)

Performance Rating	NSE Criteria (2007 Annual or Monthly)	NSE Criteria (2015 Annual, Monthly or Daily)
Very good	0.75<NSE≤1.00	0.80<NSE≤1.00
Good	0.65<NSE≤0.75	0.70<NSE≤0.80
Satisfactory	0.50<NSE≤0.65	0.50<NSE≤0.70
Unsatisfactory	NSE≤0.50	NSE≤0.50

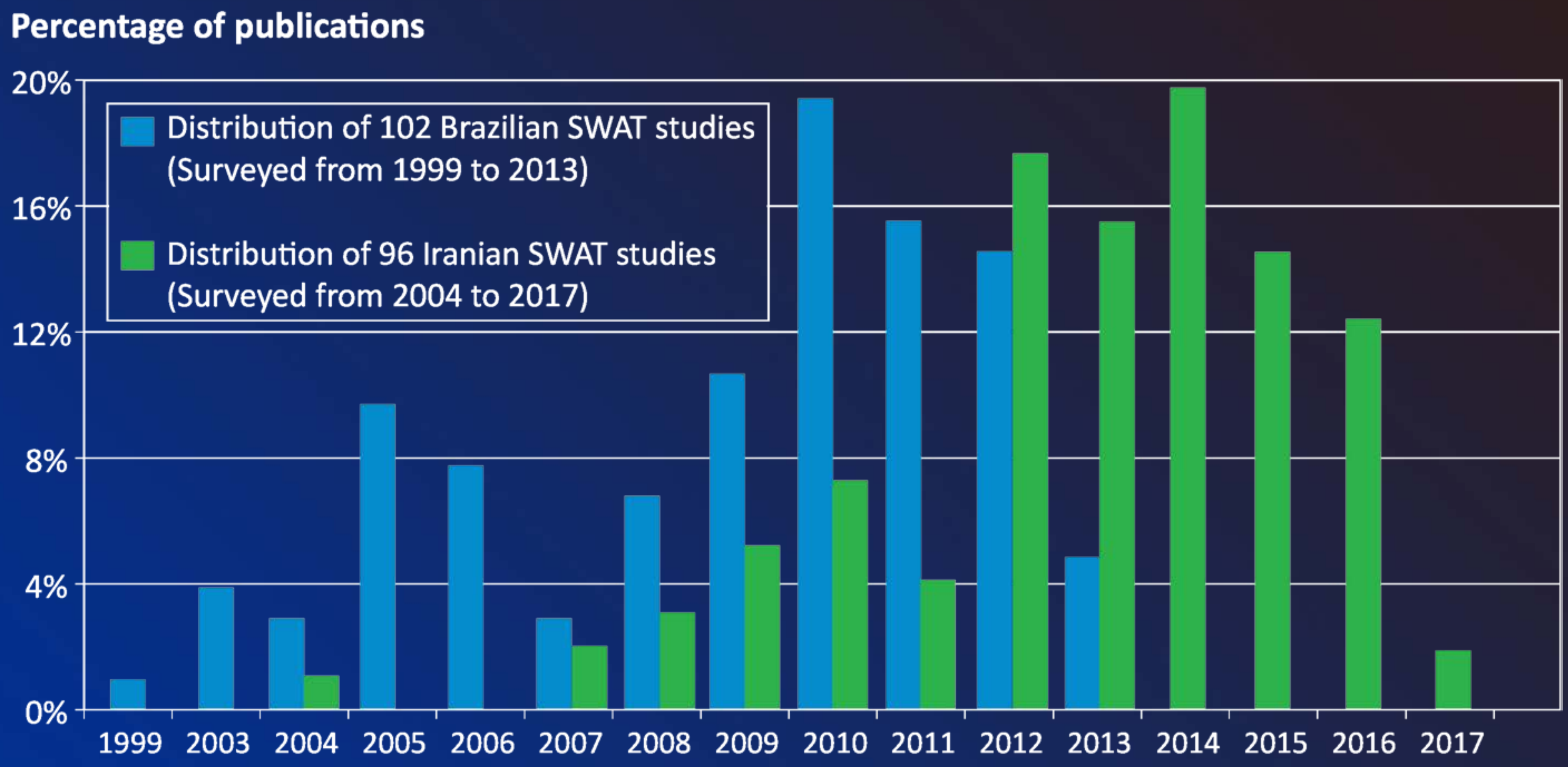
Sources: Moriasi et al. 2007. Transactions of the ASABE. 50(3): 885-900. Doi: 10.13031/2013.23153. & Moriasi et al. 2015. Transactions of the ASABE. 58(6): 1763-1785. Doi: 10.13031/trans.58.10715.

Frequency of SWAT Daily Streamflow Statistical Results (combined from five review studies*)

Frequency	Calibration		Validation	
	R^2	NSE	R^2	NSE
Total models	83	168	78	143
0.9 – 1.0	9	7	3	1
0.8 – 0.89	11	12	7	9
0.7 – 0.79	19	39	18	15
0.6 – 0.69	23	35	17	38
0.5 – 0.59	10	34	14	23
0.4 – 0.49	6	14	10	17
0.3 – 0.39	0	7	4	12
0.0 – 0.29	5	12	5	10
< 0.0	0	9	0	18

*(1) Gassman et al. 2007. Trans. ASABE 50(4): 1211-1250 (2) Douglas-Mankin et al. 2010. Trans. ASABE 53(5): 1423-1431 (3) Tuppad et al. 2011. Trans. ASABE (4) Gassman et al. 2014. JEQ 43(1): 1-8 (5) Akhaven & Mehrabi, personal communication (statistics compiled for Iranian SWAT studies)

Distribution of Surveyed SWAT Studies in Brazil & Iran



Bressiani et al. 2015. IJABE 8(3) Doi: 10.3965/j.ijabe.20150803.1765; Akhaven & Mehrabi, personal communication (statistics compiled for Iranian SWAT studies)

NSE Statistical Results for Brazilian & Iranian SWAT Studies Reporting Calibration Results (based on Moriasi et al. 2007)

Performance Rating	NSE Criteria	Monthly NSE Country (studies)		Daily NSE Country (studies)	
		Brazil (31)	Iran (66)	Brazil (26)	Iran (20)
Very good	0.75<NSE≤ 1.00	61%	40%	25%	21%
Good	0.65<NSE≤ 0.75	29%	40%	18%	32%
Satisfactory	0.50<NSE≤ 0.65	3%	36%	25%	26%
Unsatisfactory	NSE≤0.50	6%	10%	25%	19%

Bressiani et al. 2015. IJABE 8(3): 9-35. Doi: 10.3965/j.ijabe.20150803.1765; Akhaven & Mehrabi, personal communication (statistics compiled for Iranain SWAT studies)

A Few More thoughts on NSE, etc. Criteria

- Keep in mind Moriasi et al. (2007;2015) present **SUGGESTED** criteria

- We can be too strict; e.g., monthly sediment NSE of 0.47 by Beeson et al. (2014)* "unsatisfactory"

- Stronger need to focus on water balance processes, etc. being accurate (more reliance on "soft data")

- Need for more review of "bad SWAT stuff"?!**

*Beeson et al. 2014. JEQ. 43(1): 26-36. Doi: 10.2134/jeq2012.0148.
**van Griensven et al. Hydrol & Earth Syst Sci. 16: 3371-3381. Doi: 10.5194/hess-16-3371-2012.

Increasing Recognition for Checking Model Outputs with "Soft Data"

- Arnold et al. 2015. Hydrological processes and model representation: Impact of soft data on calibration. Transactions of the ASABE. 58(6): 1637-1660. Doi: 10.13031/trans.58.10710.

- Consider known water balance, vegetation biomass & other processes, literature data, expert opinion, etc. in evaluating model output

- SWAT CHECK: can identify possible input problems
  - http://swat.tamu.edu/software/swat-check/

Some Concluding Thoughts

- SWAT has proven to be a useful model worldwide
  - Dominant ecohydrological model in existing literature

- Global testing results indicate that SWAT can accurately replicate streamflow, etc. for many different kinds of conditions.
  - but good statistics can mask problems
  - code and/or input modifications can be needed to achieve desired results

- Incorporation of routines in modified models desirable and development of new algorithms needed, e.g., rice paddy module