Simulation Trends and Other Insights Regarding the Worldwide Use of the SWAT Model

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Presentation Overview

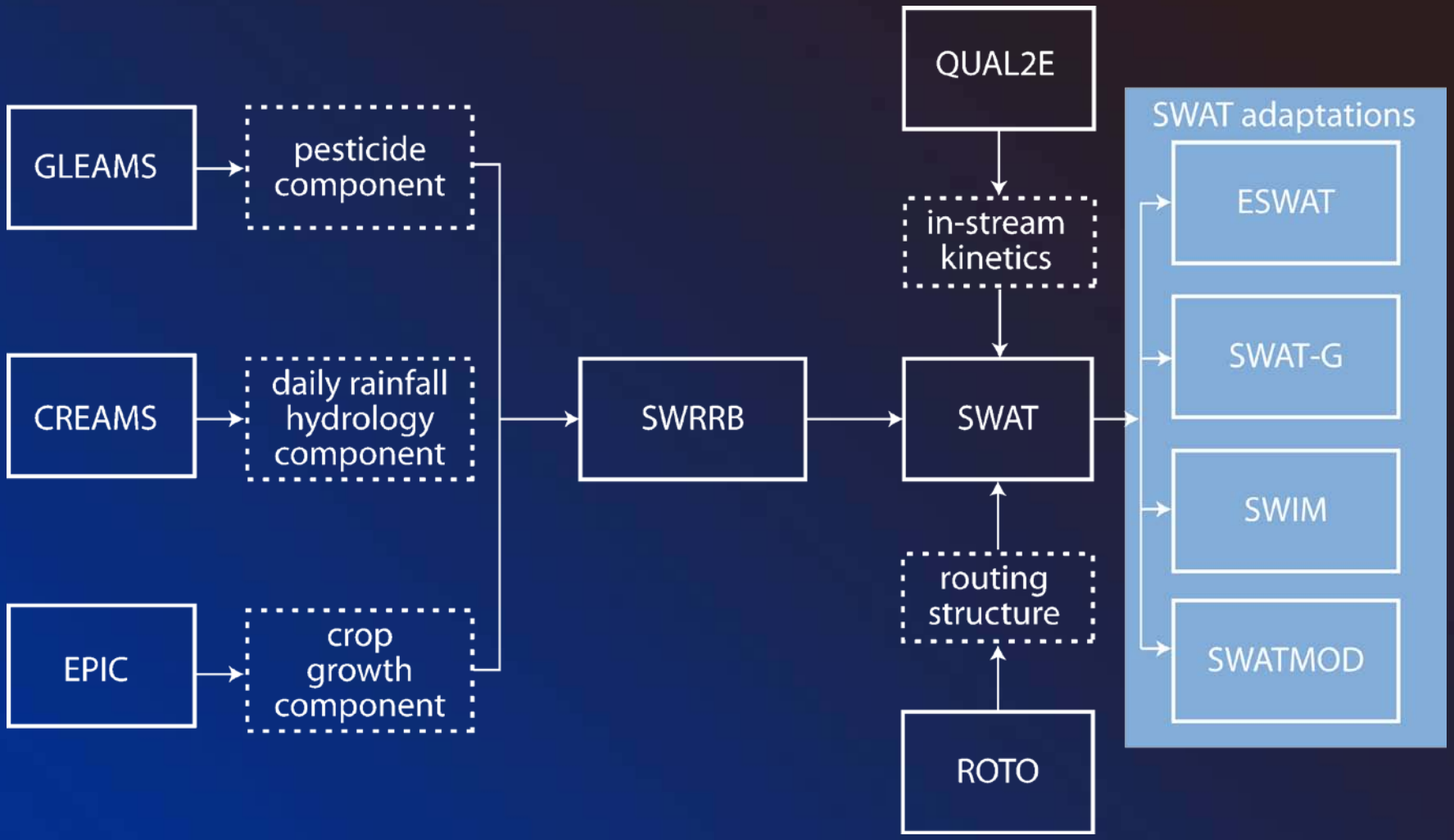
1) Brief historical overview

2) Technological and networking trends driving increased adoption of model

3) Application trends: methodology and specific regions

4) Some thoughts about the future

Schematic of SWAT Historical Development



Williams et al. 2008. History of model development at Temple, Texas. Hydrololgical Sciences Journal 53(5): 948-960.

Technological and Networking Factors

- SWAT website
- Open software and comprehensive documentation
- GIS interfaces and other interfaces and software
- Workshop and conferences
  - -wide range of modeling methods/results
  - -extensive networking opportunities

http://swatmodel.tamu.edu/

SWAT Literature

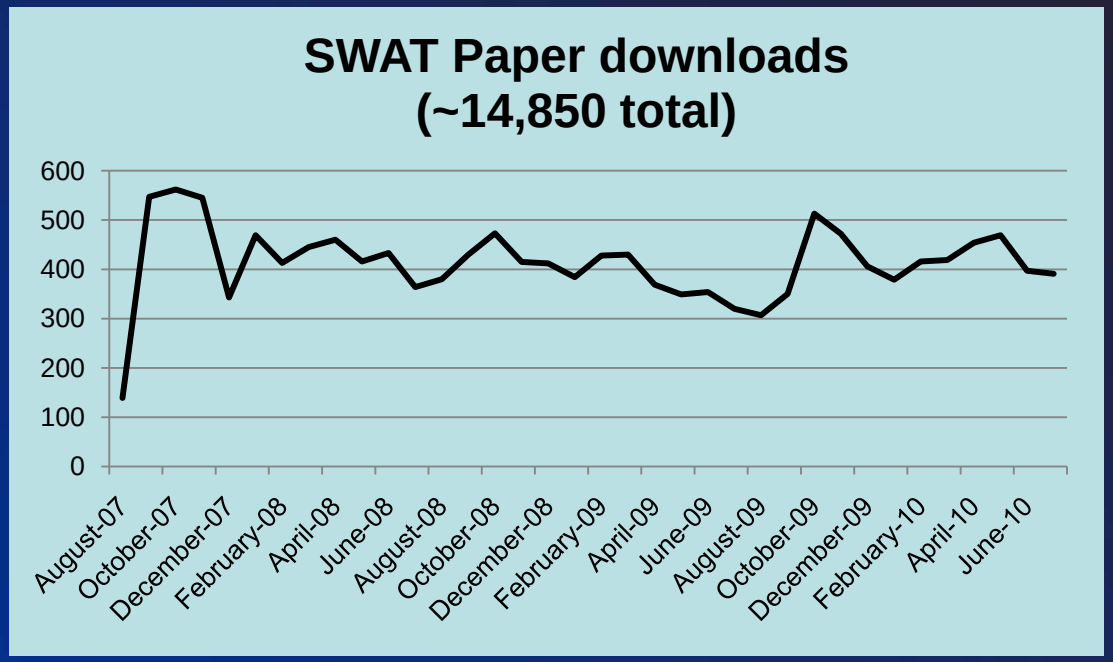
- Arnold, Srinivasan, Muttiah, and Williams. 1998. Large area hydrologic modeling and assessment part I: model development. *JAWRA* 34(1): 73-89.
  - Cited 536 times in ISI Web of Knowledge (#1 all-time in JAWRA)

- Arnold & Fohrer. 2005. SWAT2000: current capabilities and research opportunities in applied watershed modeling. *Hydrol. Process*. 19(3): 563-572.
  - Cited 133 times in ISI (#11 all-time in Hyrol. Process.)

- Arnold, J.G., Allen, P.M. and G. Bernhardt. 1993. A comprehensive surface-groundwater flow model. *J. Hydrol*. 142(1-4): 47-69.
  - Cited 198 times in ISI (#19 all-time in J. Hydrol.)

SWAT Literature

- Gassman et al. 2007. Trans. ASABE 50(4): 1211-1250
  - reviewed ~250 SWAT-related articles
  - cited 98 times in ISI (#1 in Trans. ASABE; since 2006)
  - accessible at SWAT website



SWAT Literature

- Now over 600 peer-reviewed SWAT-related articles

- SWAT literature database:
  https://www.card.iastate.edu/swat_articles/
  - accessible at SWAT website
  - Citation info/abstracts for peer-reviewed journal articles

- Total of 672 articles in database
  - Not all directly about SWAT applications
  - 158 different journals currently represented
  - Trans. ASAE/ASABE (74); JAWRA (63); Hdrol. Process. (60); J. Hydrol. (45); Ecol. Model./JSWC (23); WRR (20)

SWAT Conferences/Workshops

- International SWAT conferences (Europe & elsewhere)
  - 2001: *Hydrological Processes* vol. 19(3), 2005
  - 2003, 2005, & 2007: proceedings/abstracts on-line
  - 2008 Beijing: proceedings forthcoming
  - 2009 S.E. Asia: *IAEJ* vol. 18(1-2 / 3-4); more in 2010
  - 2009 Boulder, CO, USA: proceedings on-line; special issue forthcoming in Trans. ASABE (Sept./Oct.?)
  - 2010 S. Korea (and others in S. Korea)
  - 2011 Ho Chi Minh City, Vietnam (January)
  - 2011 Toledo, Spain
  - 2012 Dehli, India

SWAT Conferences/Workshops

- Ongoing developments/enhancements
  - multiple initiatives - driven by open source code
  - Oct. 2006 Berlin Developers Workshop
    - *Hydrological Sciences J.* vol. 53(5), 2008
  - other developer workshops being held

- Dozens of SWAT training workshops and other user group meetings
  - often announced at SWAT website
  - largest workshop ever held was at this conference?

SWAT GIS Interfaces

Interface	Platform	Comments
SWAT/GRASS	GRASS	Original interface
AVSWAT	ArcVIEW 3.x	AVSWAT-X includes SSURGO Soils and other enhancements
BASINS	ArcVIEW 3.x	USEPA software package with multiple models
ArcSWAT	ArcGIS 9.x	Many enhancements versus AVSWAT
ArcAPEX	ArcGIS 9.x	Supports applications of APEX imbedded within SWAT simulations
SWAPP	ArcVIEW 3.x	Another APEX-SWAT interface
AGWA	ArcVIEW 3.x / ArcGIS 9.x	Different versions exist for different platforms
MWSWAT	MapWindow	Public domain software; may be of particular interest to SWAT users in developing countries
CRP-DSS	ArcIMS / ArcGIS	For Conservation Reserve Program analyses

Application Trends

- Traditional applications ongoing

  -climate change, pollutant loss, BMP scenarios

- Emerging/innovative applications
  - runoff Curve Number (RCN) method enhancements
  - impoundment/wetland/irrigation applications
  - best management practice (BMP) methodology development and applications
  - plant parameter development / crop yield estimation
  - green/blue water analyses

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Application Trends

- Regional application trends

  -Initial major uses of SWAT were in U.S. and Europe; continues to be widely used

- Some key emerging regions

  -Asia in general; especially China, S. Korea, India, Iran
  -Number of applications also reported for Africa
  -Some applications in S. America and Latin America
  -No peer-reviewed studies reported for Russia

Other Modified SWAT Models

Modified Model	Application description (enhancements)
$SWAT_{BF}$	Processes within forested watersheds in the Canadian Boreal Plain
SWAT-DEG	Time rate of channel degradation in watersheds
SWAT-K	Multiple modified modules for Korean conditions including interfaces with MODFLOW and SWIM models
SWAT-VSA	Re-conceptualized approach that simulates hydrologic balance in a manner consistent with variable source area hydrology
SWAT-WH	Effects of water harvesting systems in southeast Tunisia
SWAT-N	Modified nitrogen cycling routine based on approach used in the DNDC model
SWAT-M	Improved tile drainage routine; incorporated in standard version

SWAT-VSA Approach

- Easton et al. 2008. Re-conceptualizing the Soil and Water Assessment Tool (SWAT) model to predict runoff from variable source areas. *J. Hydrol.* 348(3-4): 279-291.

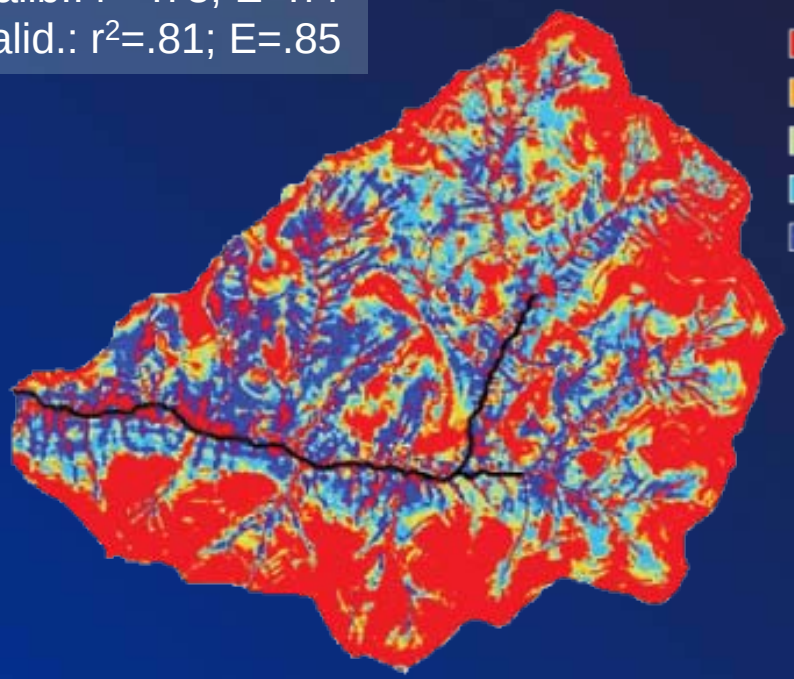
- Sub-watershed in the Cannonsville basin in upstate New York

  -Dominated by Variable Source Area (VSA) hydrology

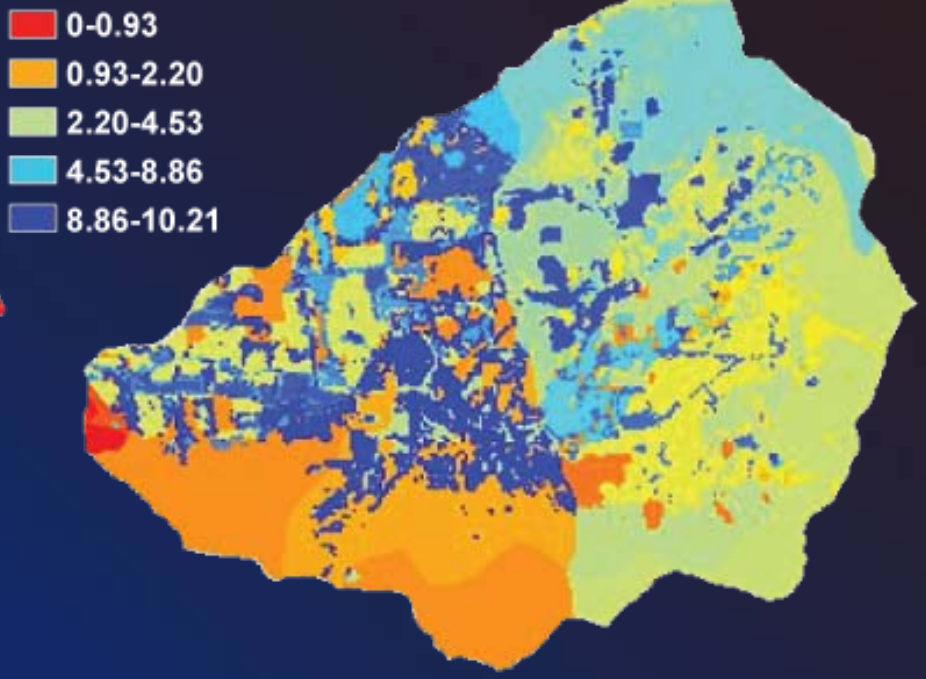
- Modified how the CN and available water content were defined (instead of model modification)

SWAT-VSA RCN Approach

Calib.: r^2=.78; E=.77
Valid.: r^2=.81; E=.85



SWAT-VSA Runoff (mm)

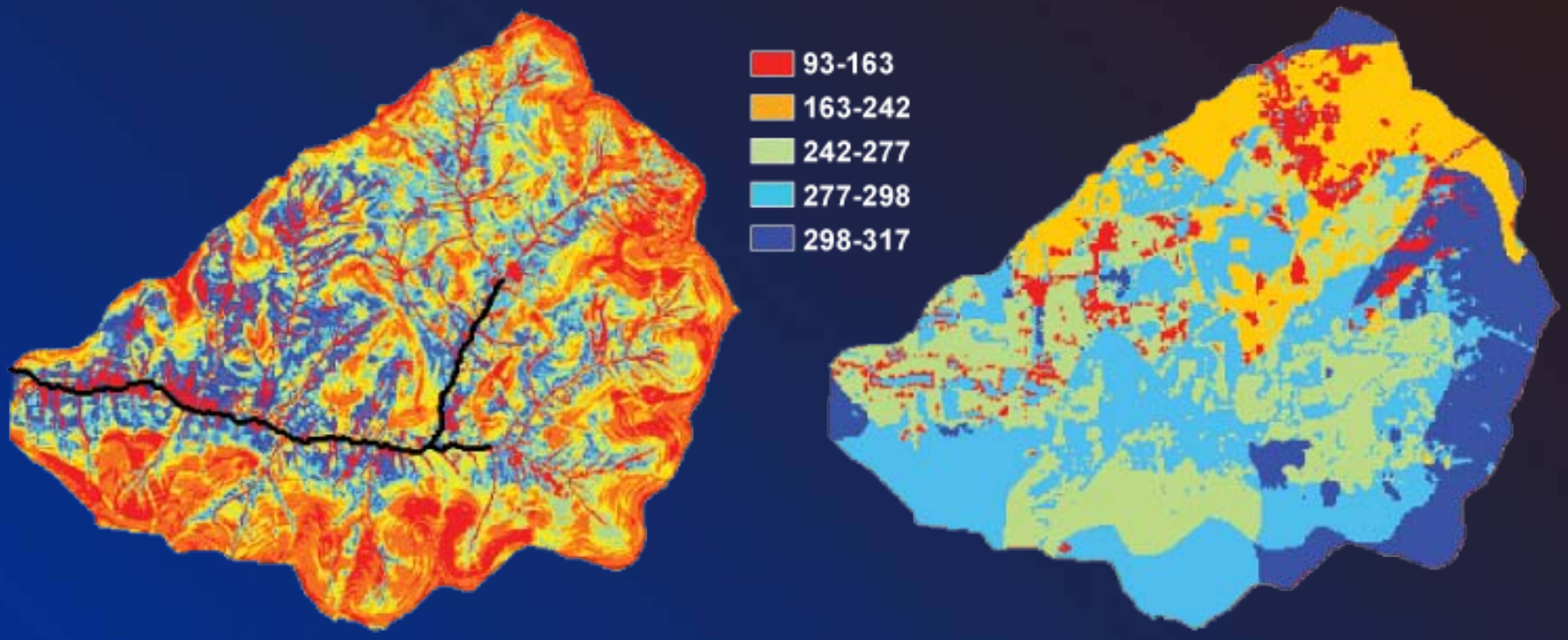


Calib.: r^2=.78; E=.79
Valid.: r^2=.80; E=.84

SWAT Runoff (mm)

Easton et al. 2008. Re-conceptualizing the soil and water assessment tool (SWAT) model to predict runoff from variable source areas Journal of Hydrology 348(3-4): 279– 291.

SWAT-VSA RCN Approach

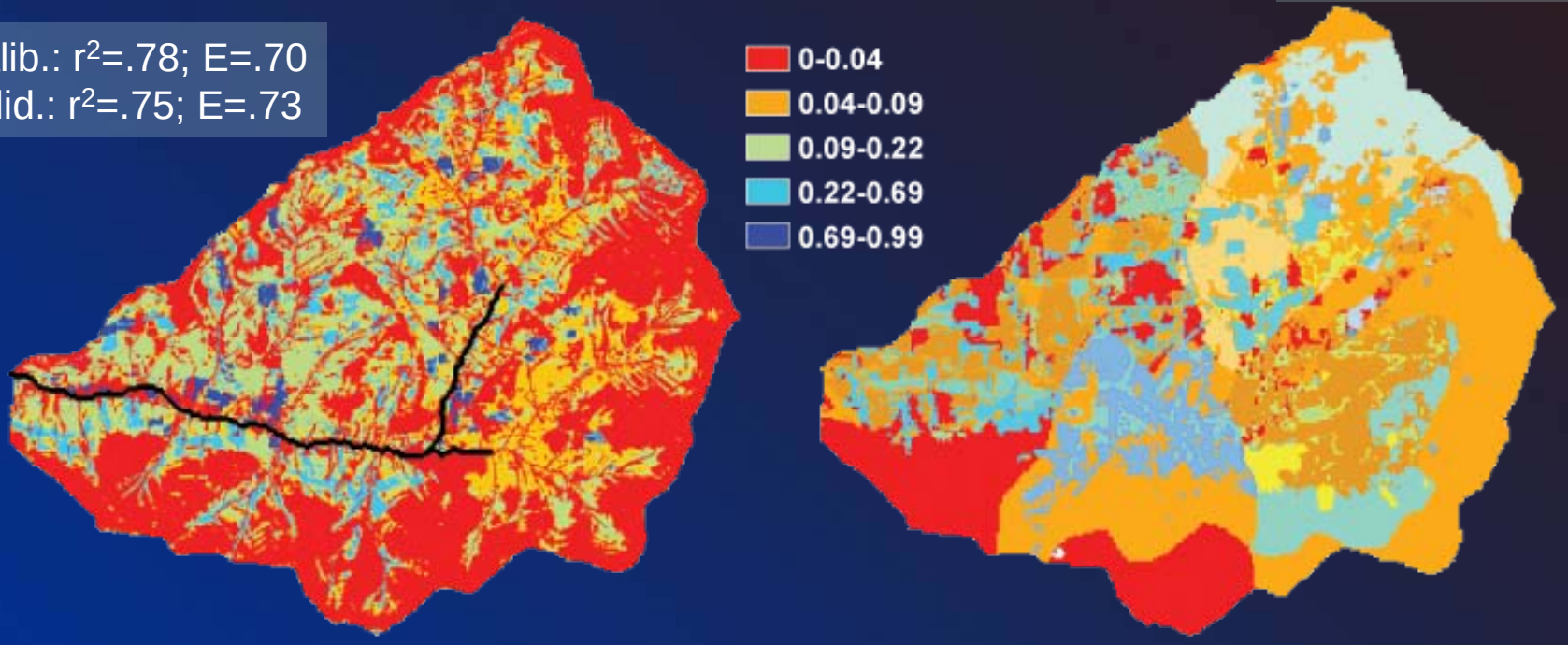


Easton et al. 2008. Re-conceptualizing the soil and water assessment tool (SWAT) model to predict runoff from variable source areas Journal of Hydrology 348(3-4): 279– 291.

SWAT-VSA RCN Approach

Calib.: r^2=.78; E=.70
Valid.: r^2=.75; E=.73

Calib.: r^2=.59; E=.39
Valid.: r^2=.66; E=.54



SWAT-VSA Dissolved P (kg ha^{-1})

SWAT Dissolved P (kg ha^{-1})

Easton et al. 2008. Re-conceptualizing the soil and water assessment tool (SWAT) model to predict runoff from variable source areas Journal of Hydrology 348(3-4): 279– 291.

TWA RCN Approach

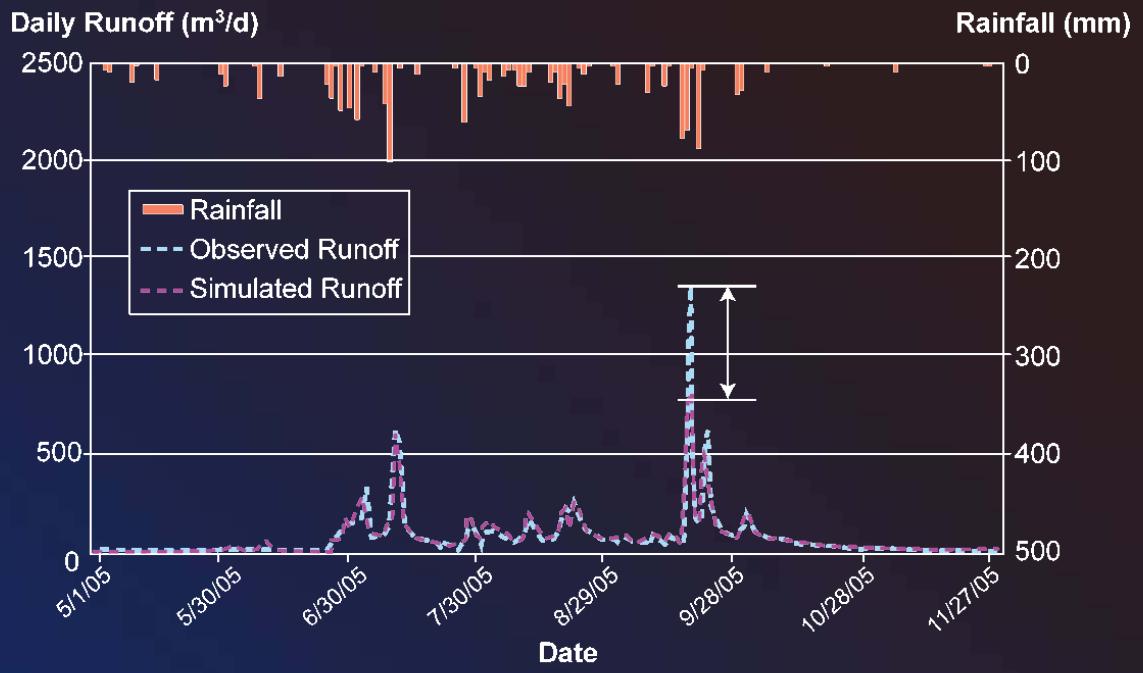
- Kim & Lee. 2008. Temporally weighted average curve number method for daily runoff simulation. *Hydrol. Process*. 22(25): 4936-4948.

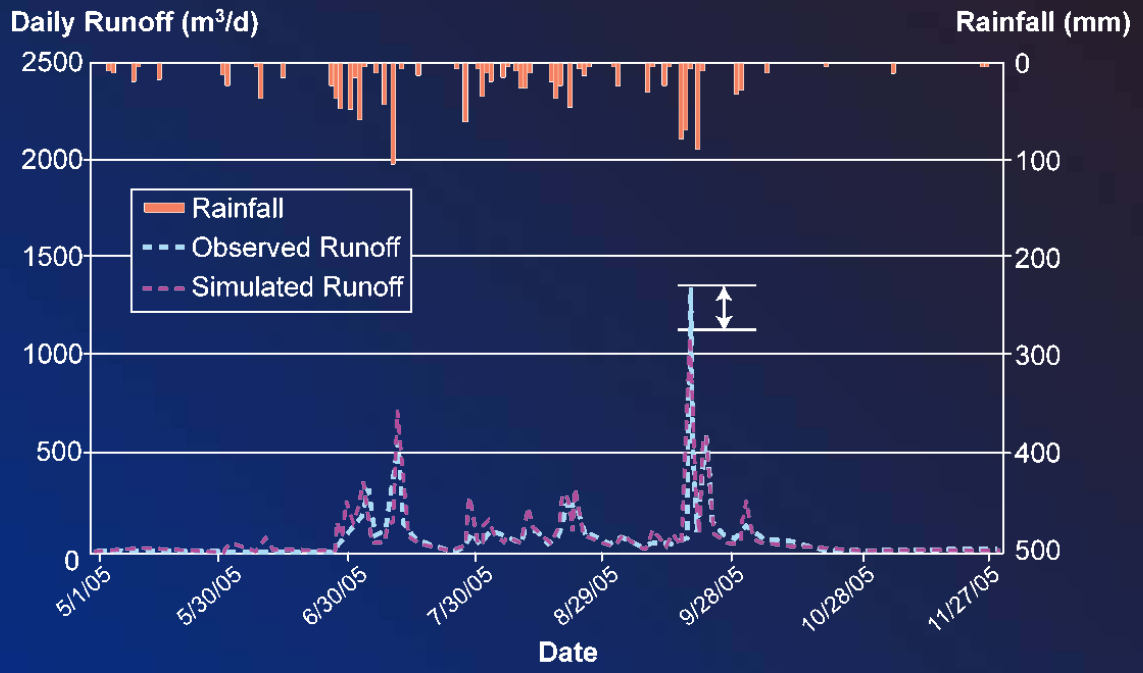
- Temporally weighted average curve number (TWA-CN)

  - f(effect of rainfall during a given day & antecedent soil moisture condition)

- Improved prediction of daily runoff during the high flow periods (peak runoff events)

SWAT-K RCN Method Enhancements





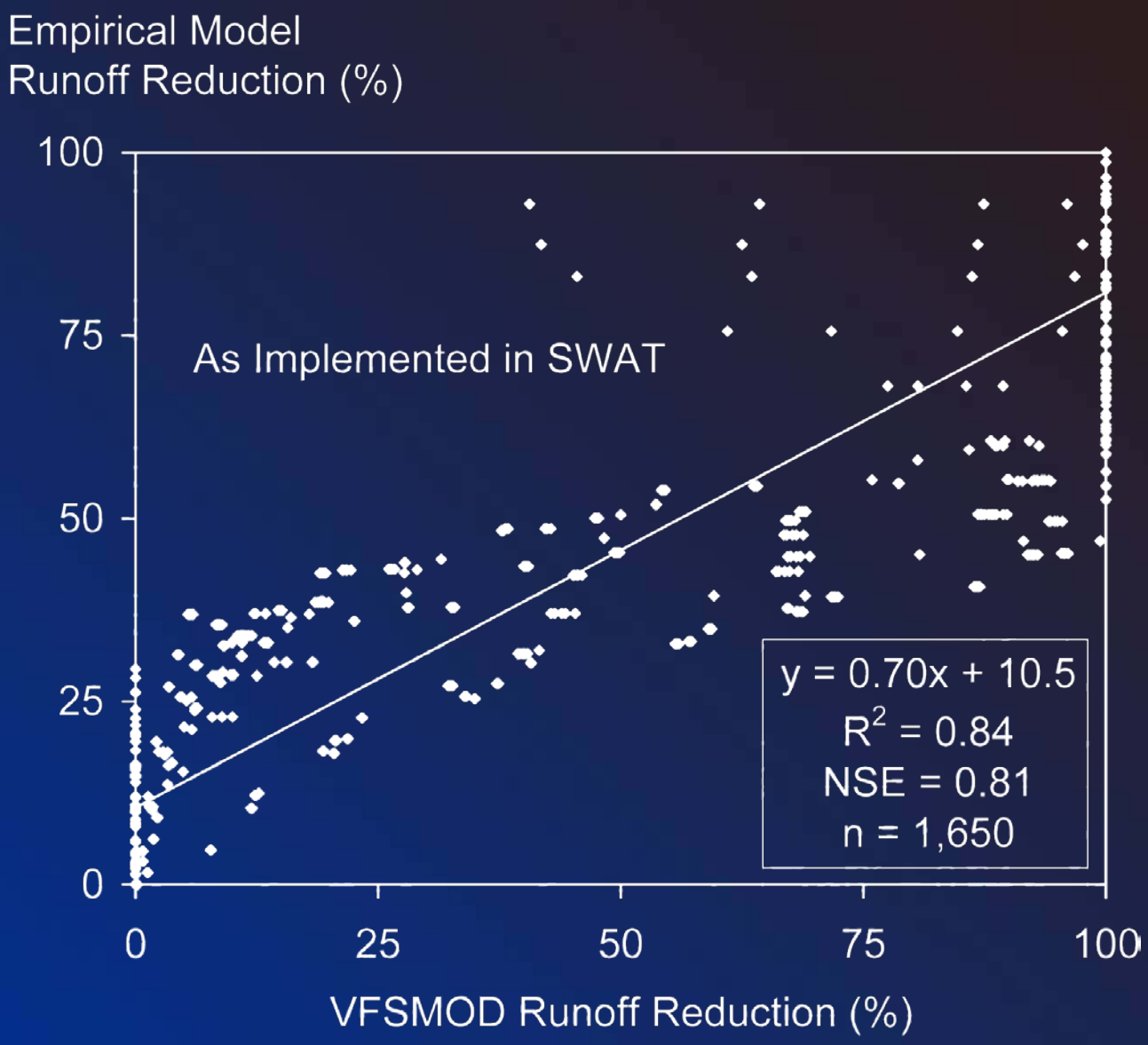
Kim and Lee. 2008. Hydrological Processes. 22(25): 4936-4948.

BMP Improvement: Filter Strips

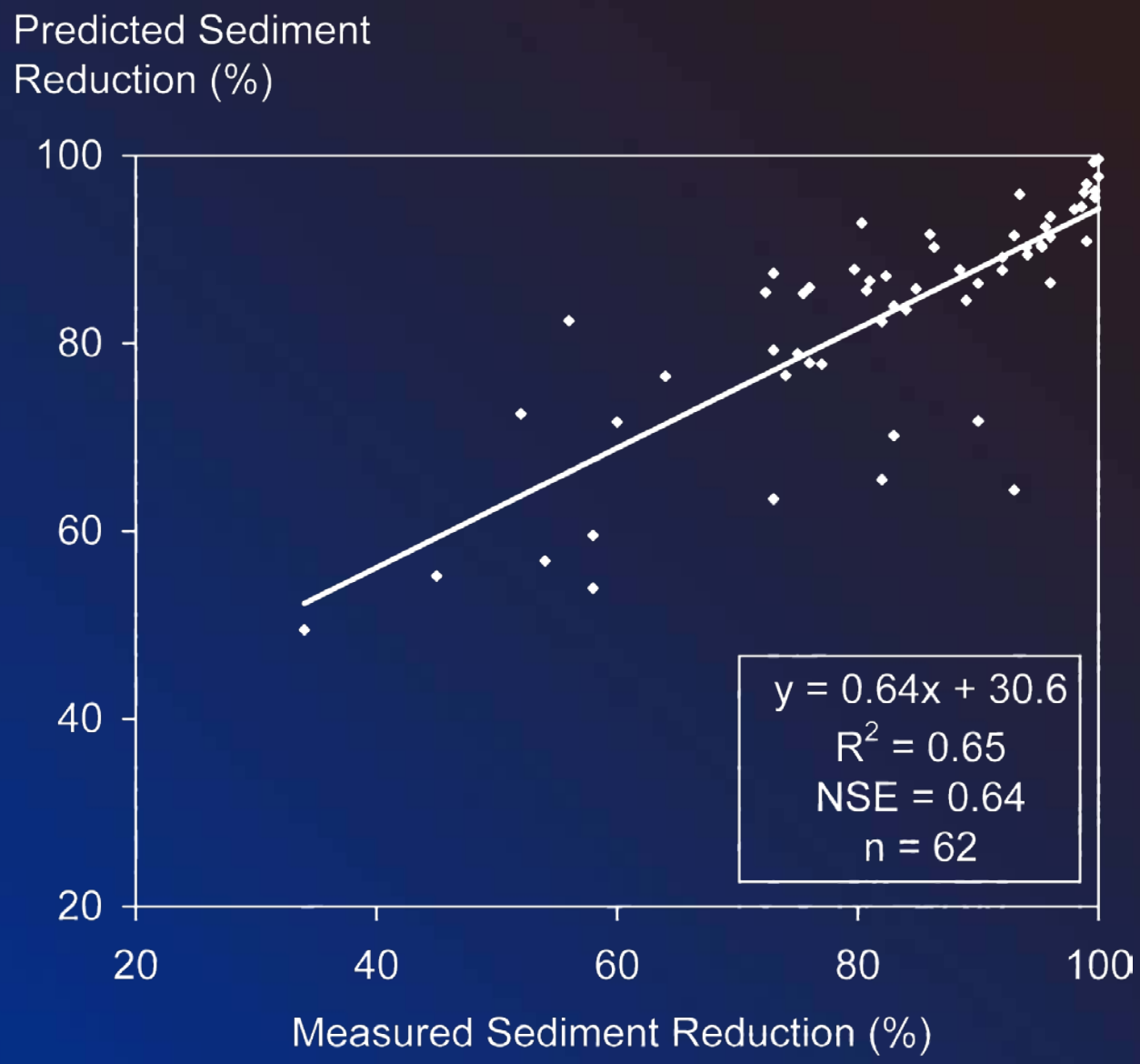
- Original SWAT approach: FILTERW – relatively weak empirical relationship

- White & Arnold. 2009. Development of a simplistic vegetative filter strip model for sediment and nutrient retention at the field scale. *Hydrological Processes* 23(11): 1602-1616.

- More realistic method based on concept of drainage area to VFS area ratio
  - Developed function for SWAT based on empirical data and VFSMOD simulations



White & Arnold. 2009. *Hydrological Processes* 23(11): 1602-1616.



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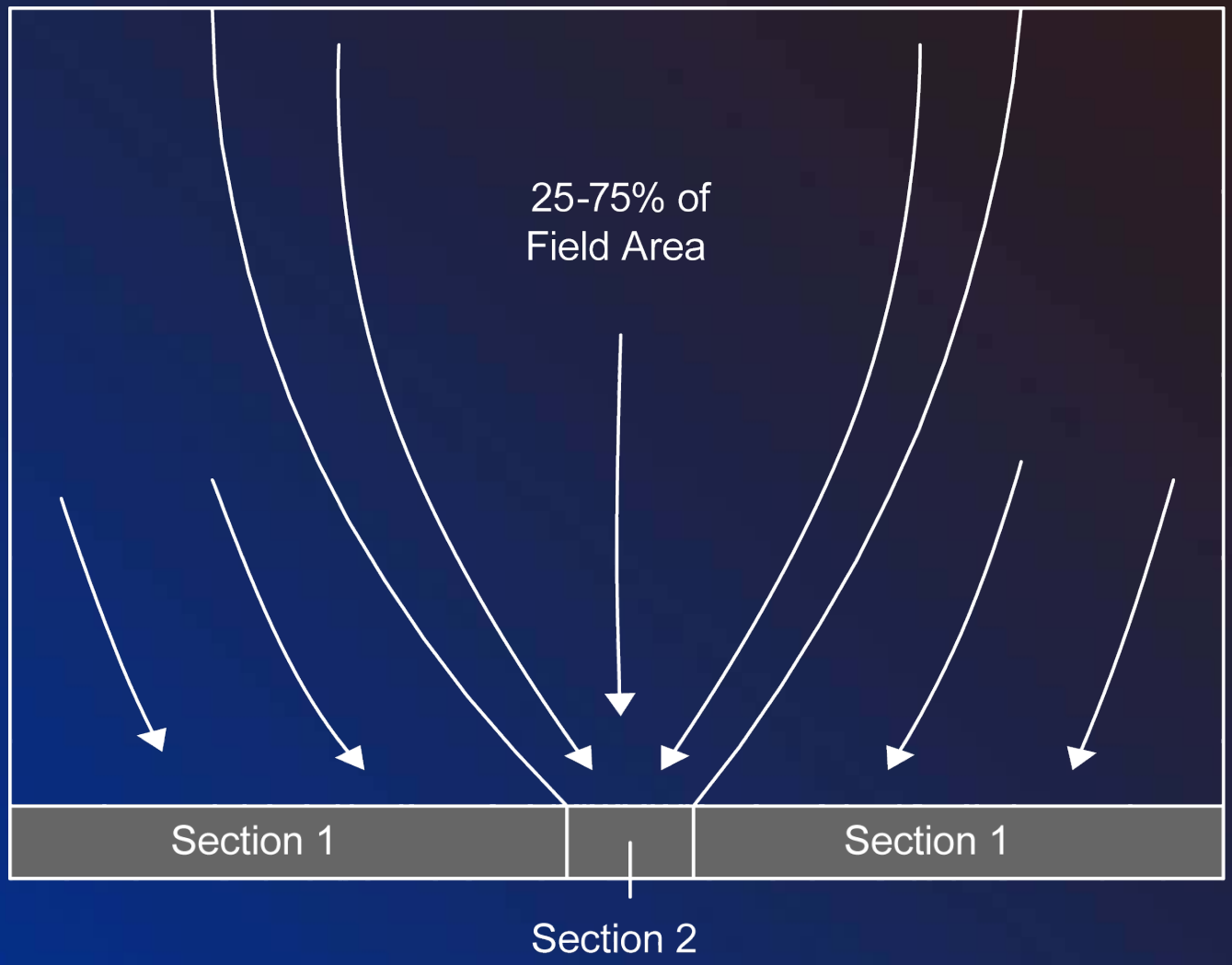

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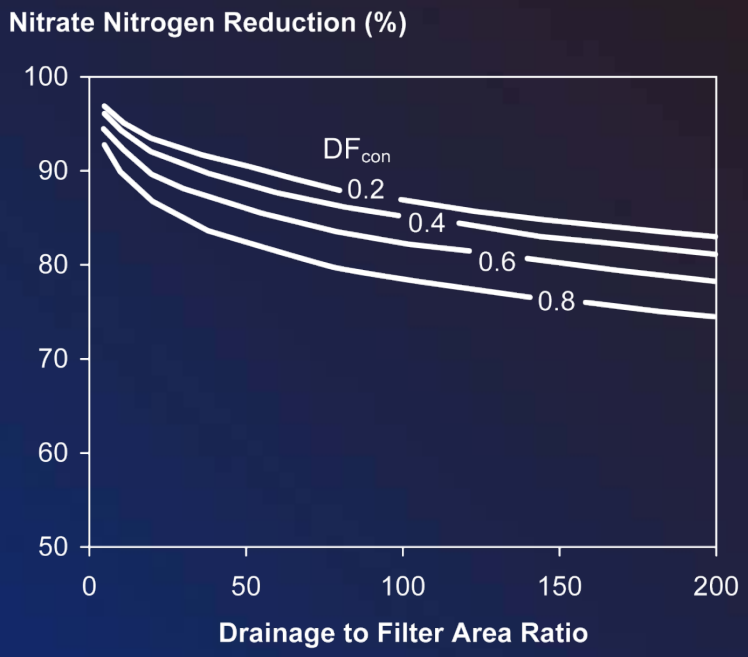
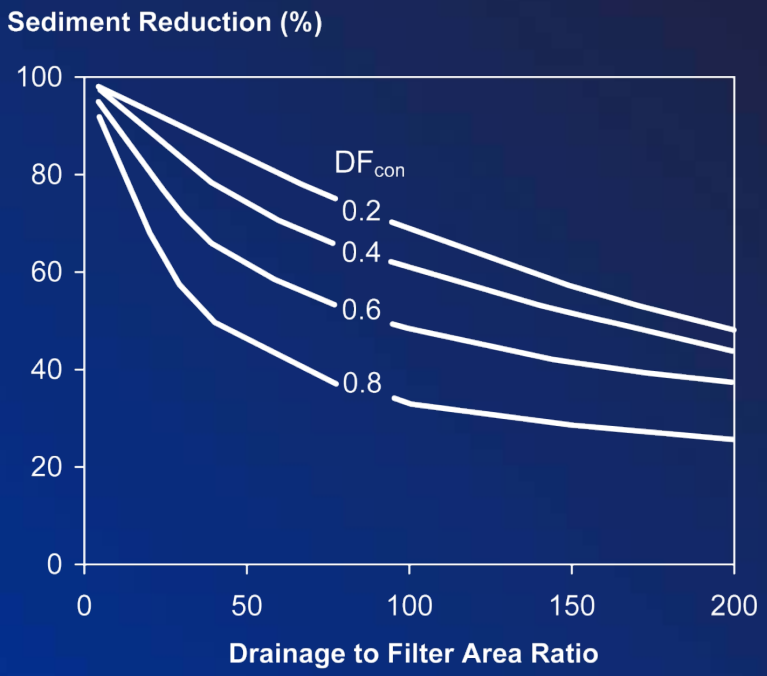




White & Arnold. 2009. Hydrological Processes 23(11): 1602-1616.

Pasture P Management (PPM) Plus Tool

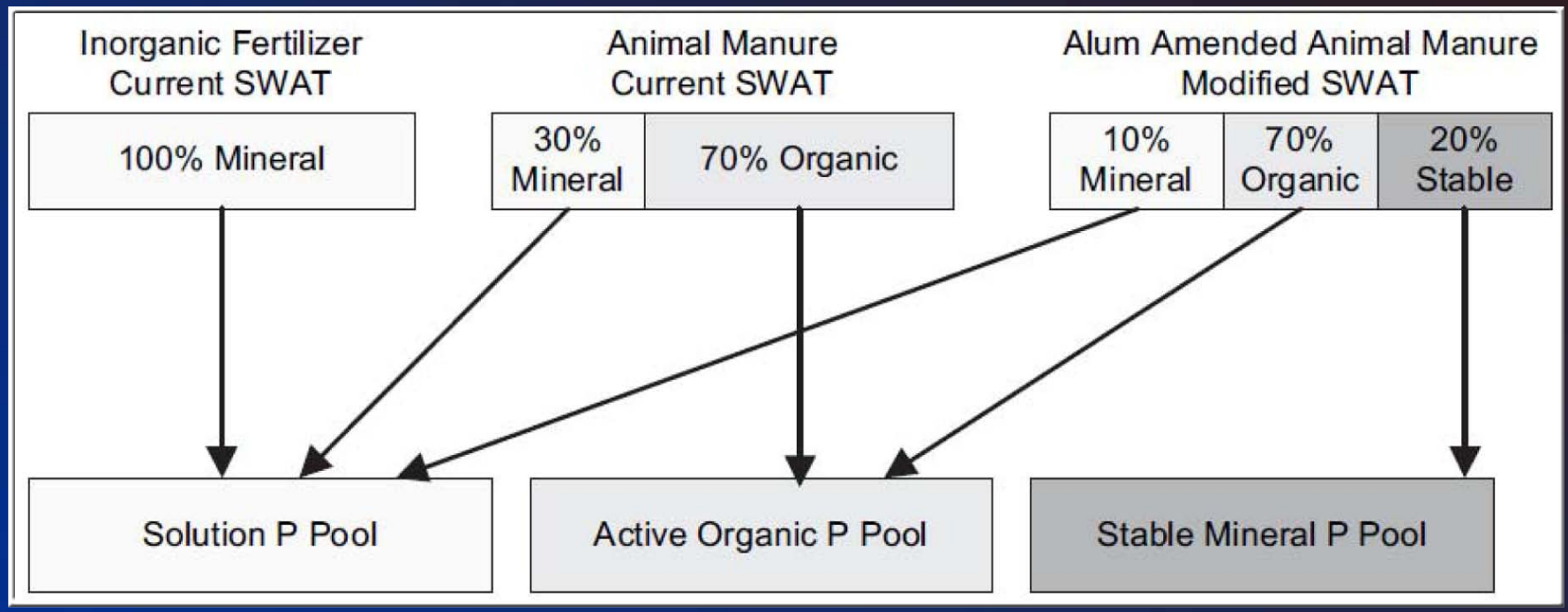
- White et al. 2010. A quantitative phosphorus loss assessment tool for agricultural fields. *Environ. Model. Software* 25: 1121-1129.

- PPM Plus: user-friendly P and sediment loss prediction tool based on SWAT

  - provides a user interface (SWAT is hidden)

- SWAT P algorithms were modifies and improved representation of conservation practices were added

Modified Soil P Cycling Routine



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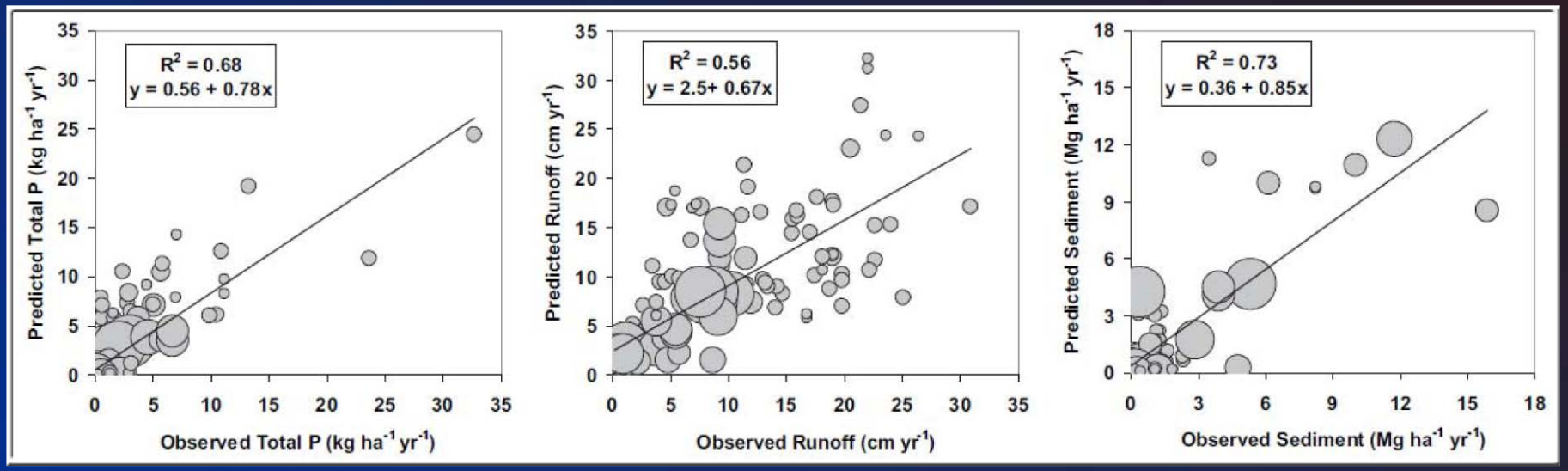
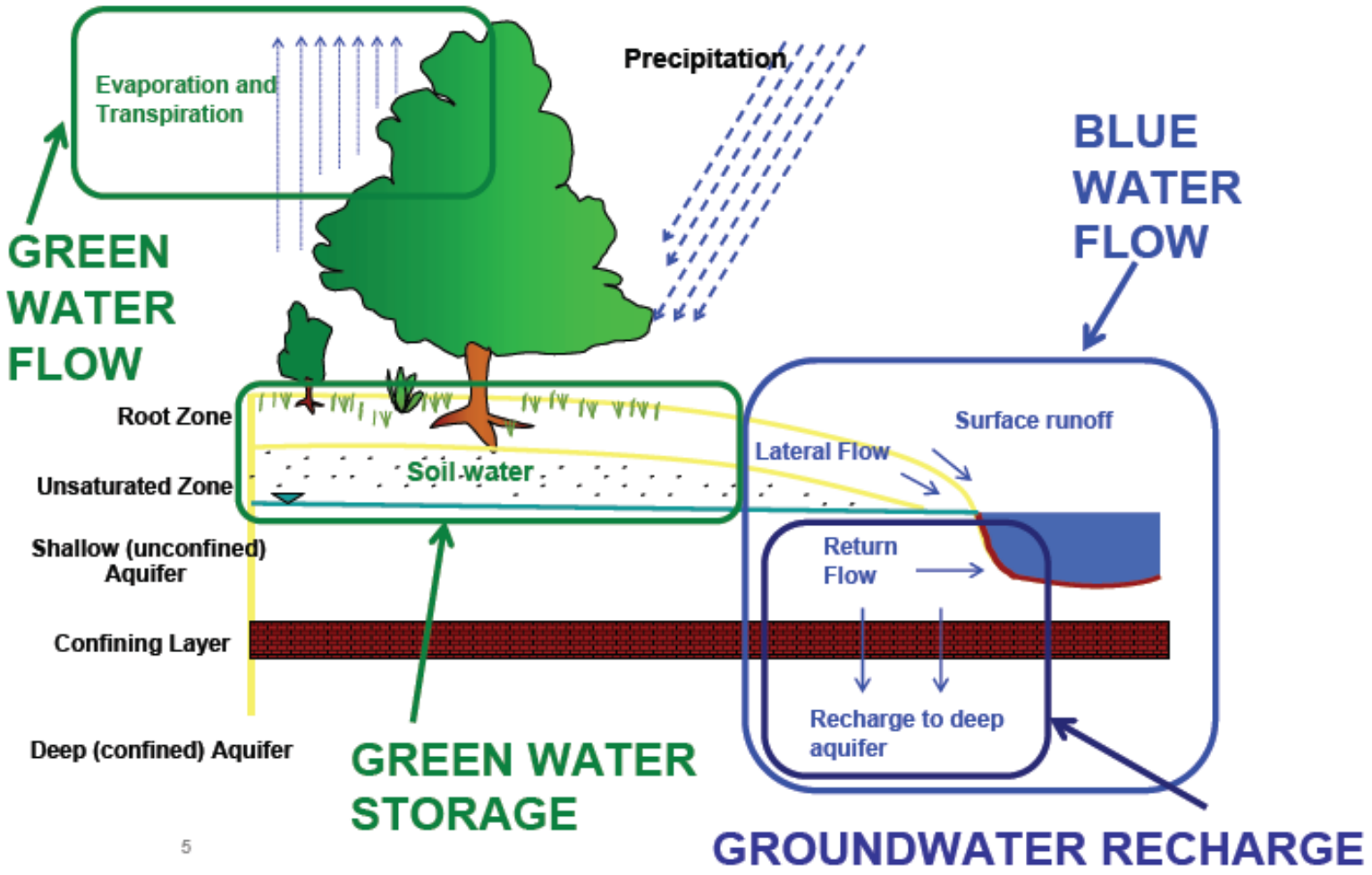
Modified Soil P Cycling Routine



White et al. 2010. A quantitative phosphorus loss assessment tool for agricultural fields. *Environmental Modelling & Software* 25(10): 1121-1129.

Blue and green water

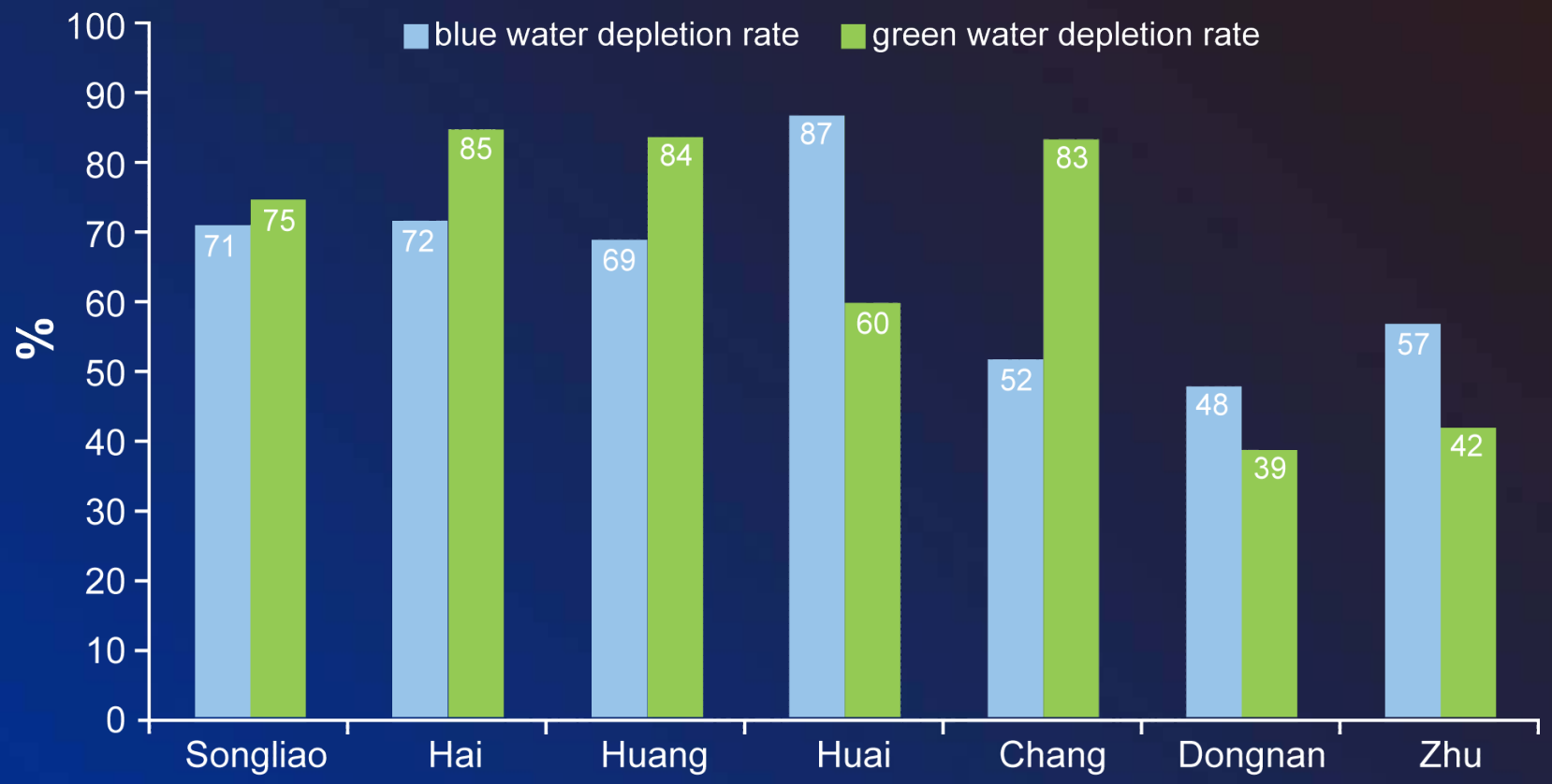


Karim Abbaspour & others; EAWAG, Dubendorf, Switzerland

China Blue/Green Water Study

Huang & Li. 2010. Assessing grain crop water productivity of China using a hydro-model-coupled-statistics approach. Part II: … *Agricultural Water Management* 97(9): 1259-1268.

China Blue/Green Water Study



Huang & Li. 2010. Assessing grain crop water productivity of China using a hydro-model-coupled-statistics approach. Part II: … *Agricultural Water Management* 97(9): 1259-1268.

Overview of SWAT

- USDA-ARS Grassland Soil & Water Research Lab., Temple, TX
- Watershed/river basin scale: water quantity & quality
- Model is well documented; internet accessible
  - http://www.brc.tamus.edu/swat/
  - first versions released in early 1990s
  - swat2009 is now available (with documentation)
- Represents 30+ years of USDA-ARS experience

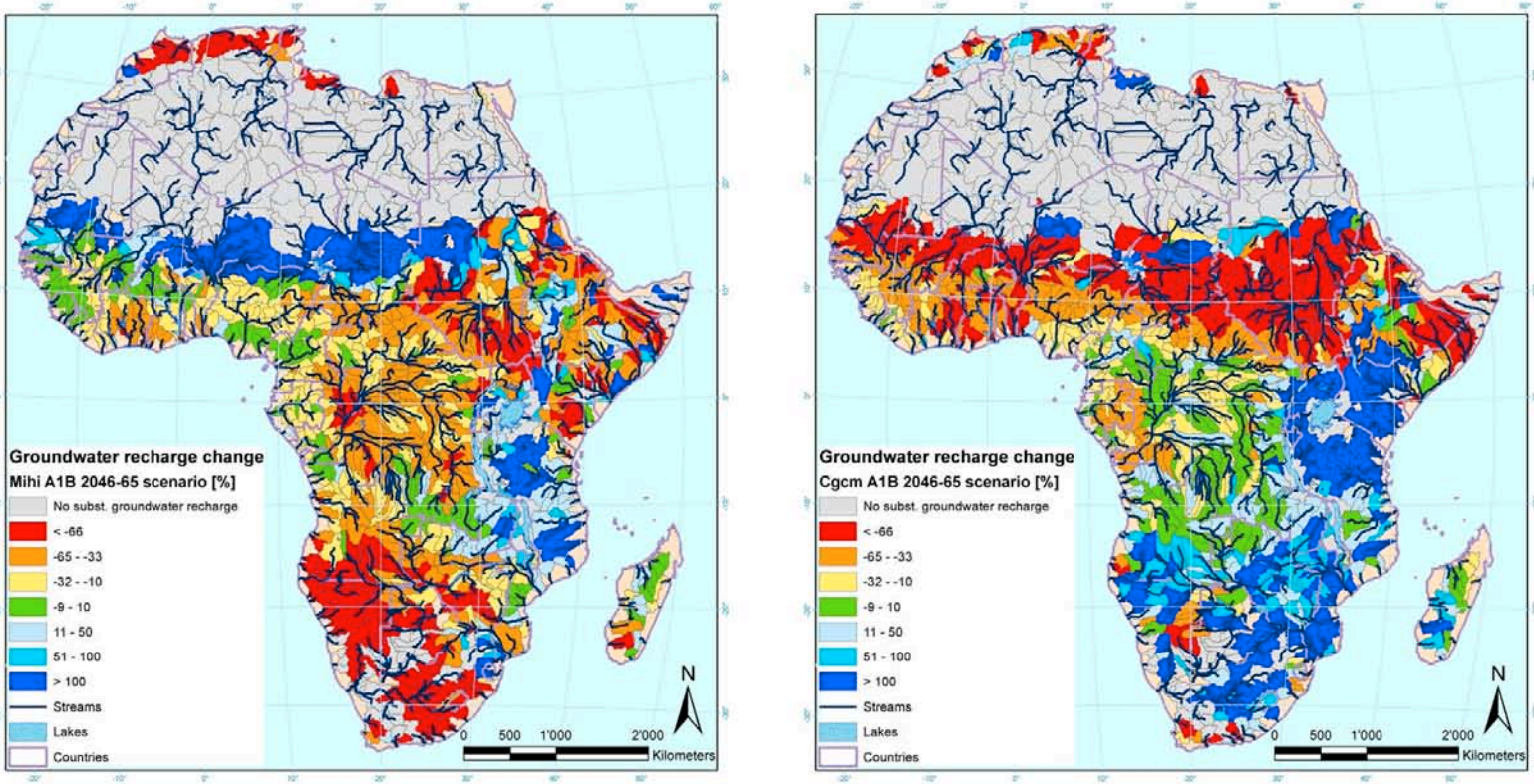
Conclusions

- Worldwide use of SWAT continues to rapidly expand, especially in Asia
- Modified SWAT versions will continue to emerge for many applications
- Many other applications will demand new software tools and model interfaces

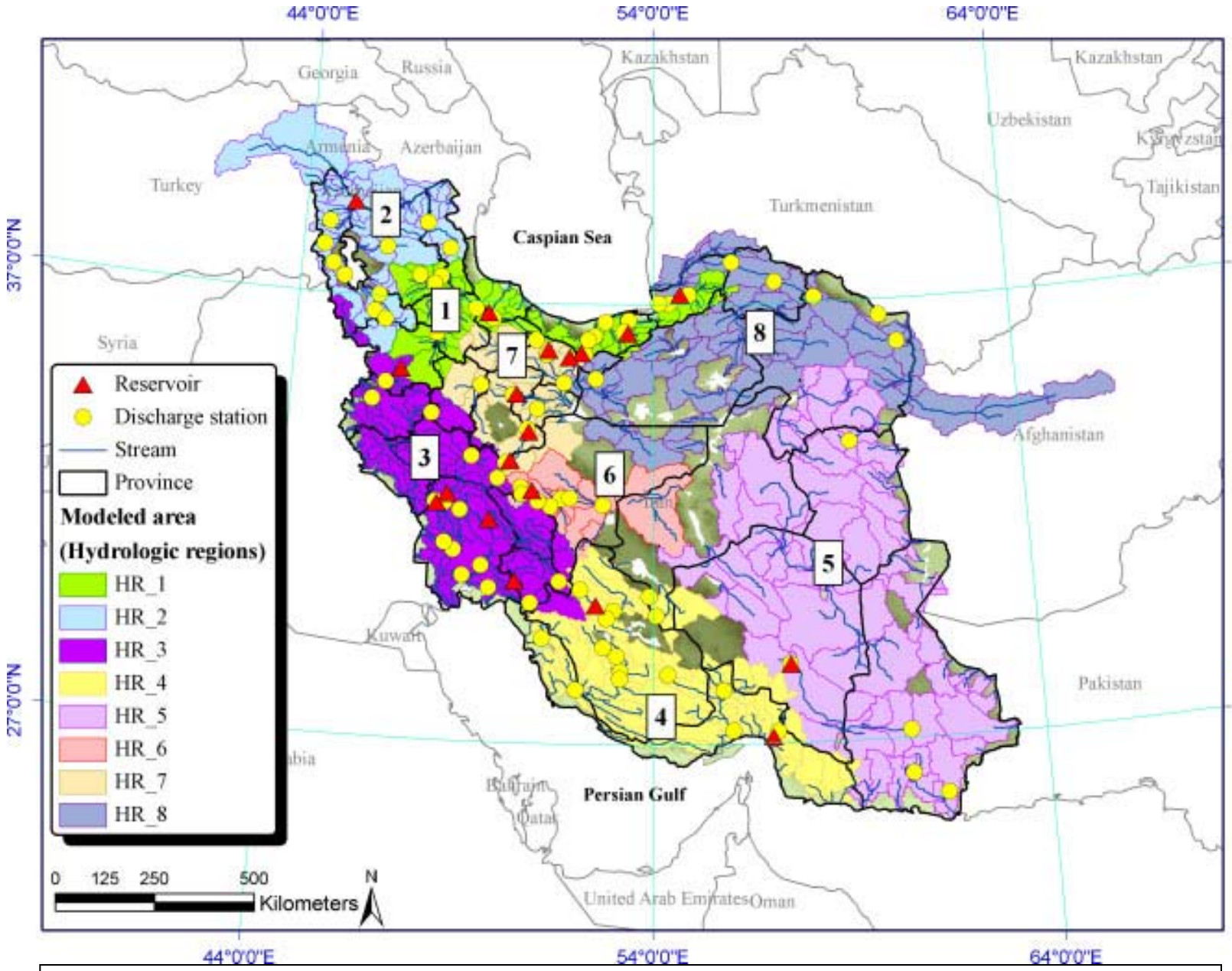
Changes in groundwater recharge

A1B emission scenario

MIROC3.2(hires) 2046-2065 **CGCM3.1(T63)**



Schuol et al. 2008. Modeling blue and green water availability in Africa. *Water Resources Research.* 10.1029/2007WR006609.



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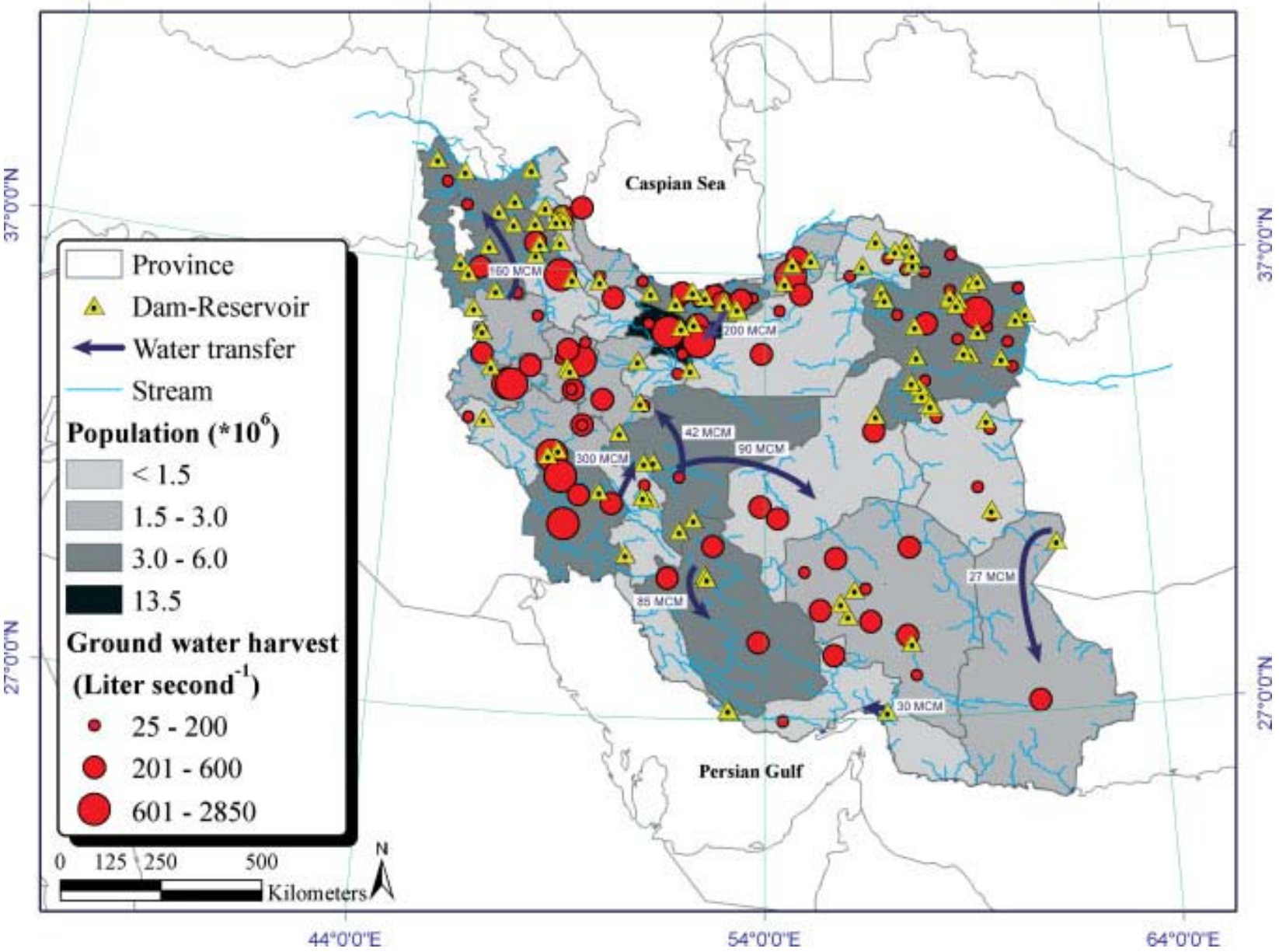

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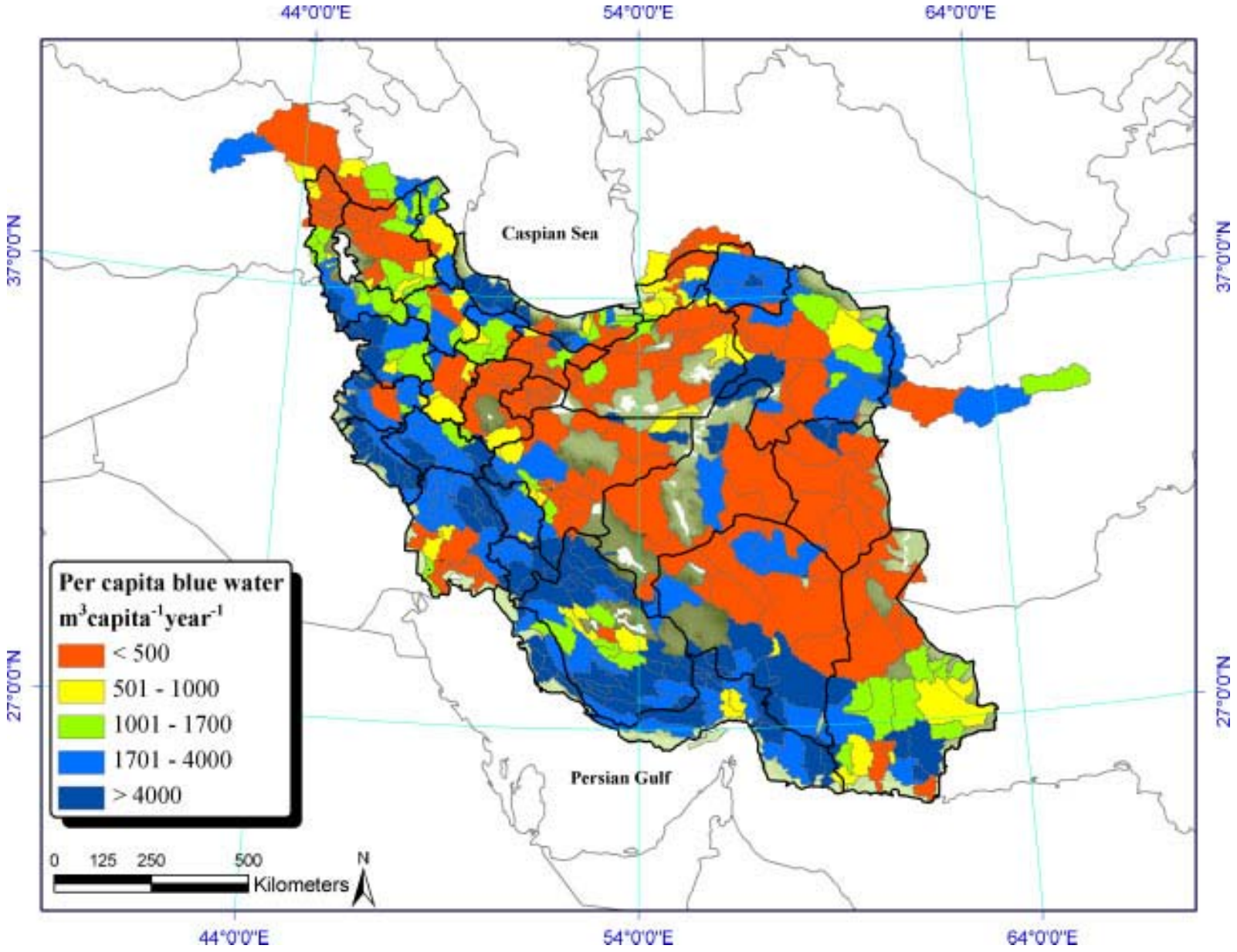

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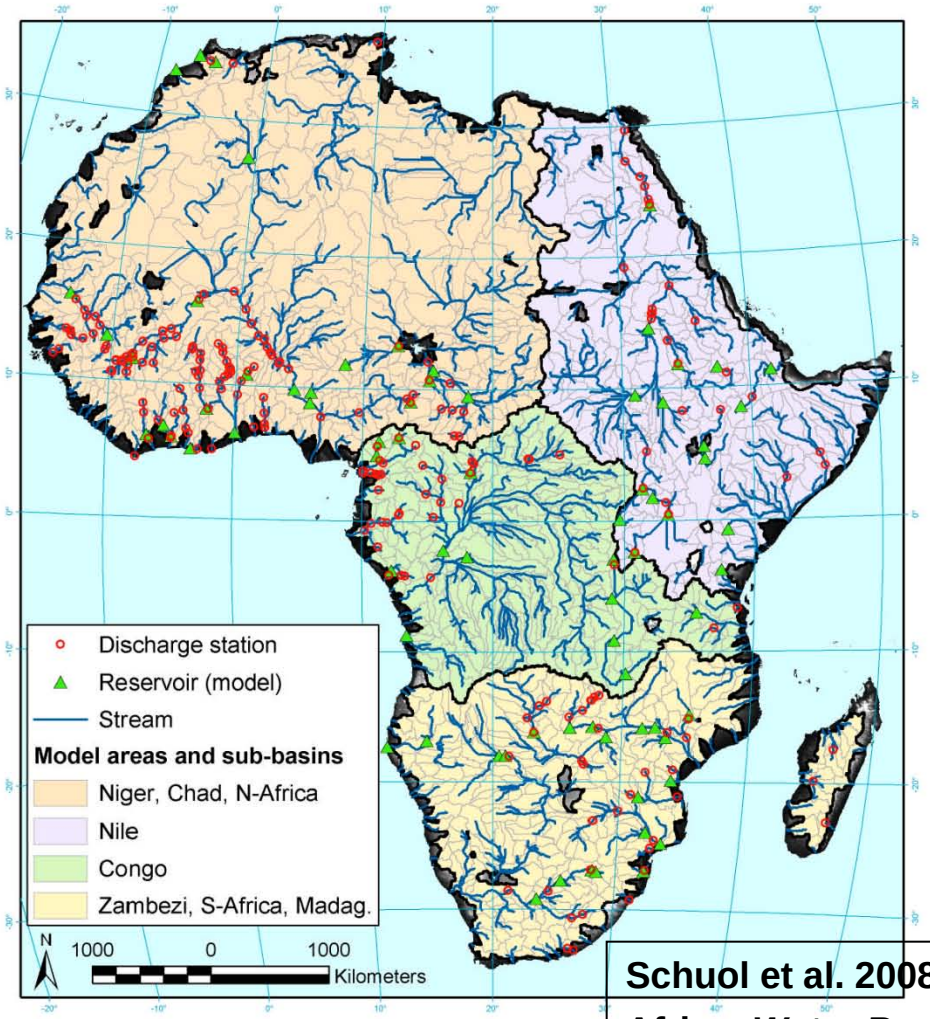
The Africa continental model

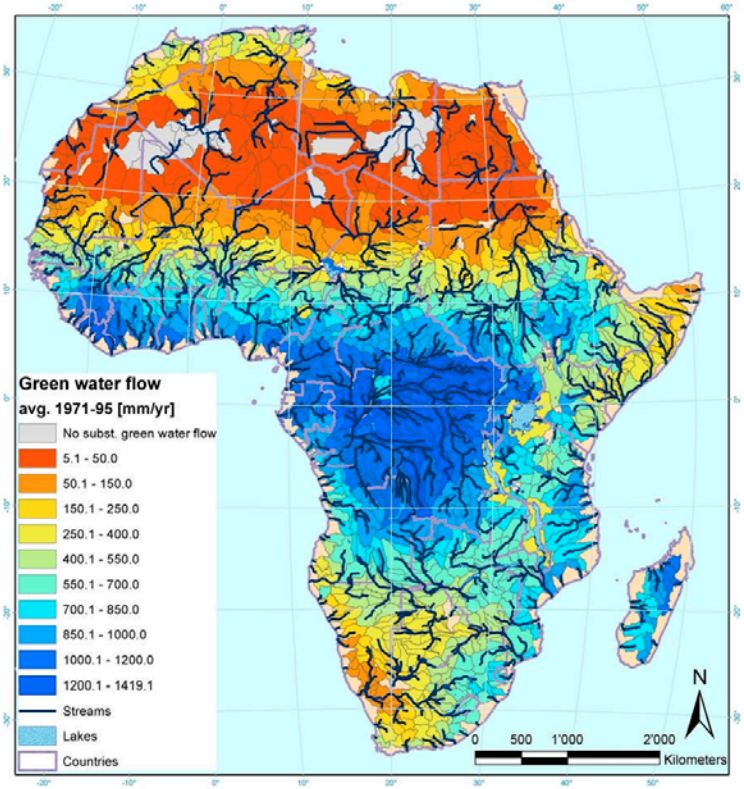


- Delineation of Africa into 1496 sub-basins using the **ArcSWAT interface**
- Use dominant soil, landuse and slope in each subbasin
- 64 reservoirs with a volume >1km^3 are included
- 208 stations with monthly observed river discharge
- Divided the continent into **4 model areas**, which are independently calibrated and validated but within the same model frame

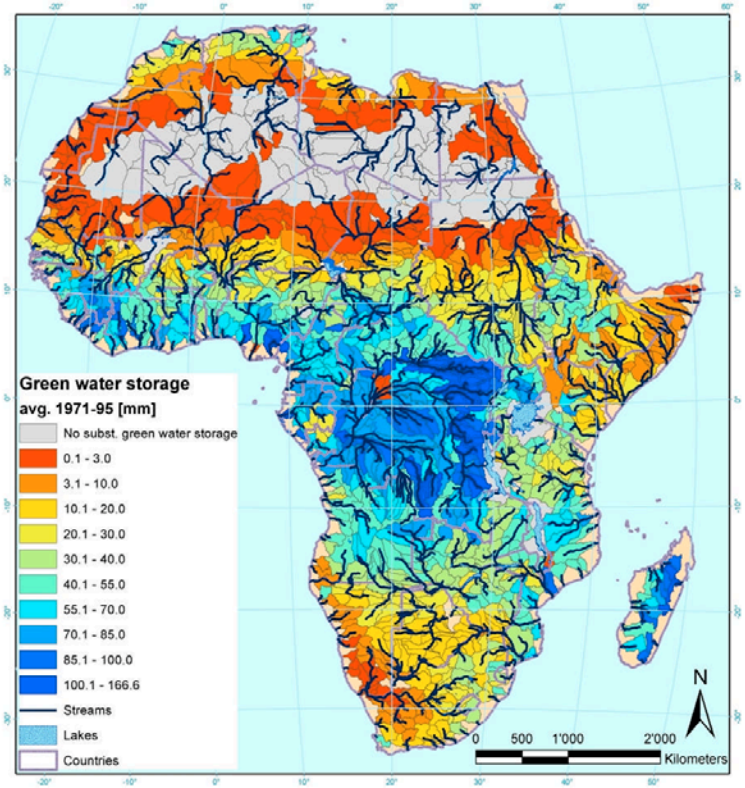
Schuol et al. 2008. Modeling blue and green water availability in Africa. *Water Resources Research.* 10.1029/2007WR006609.

The continental picture: Green water

Green water flow



Green water storage



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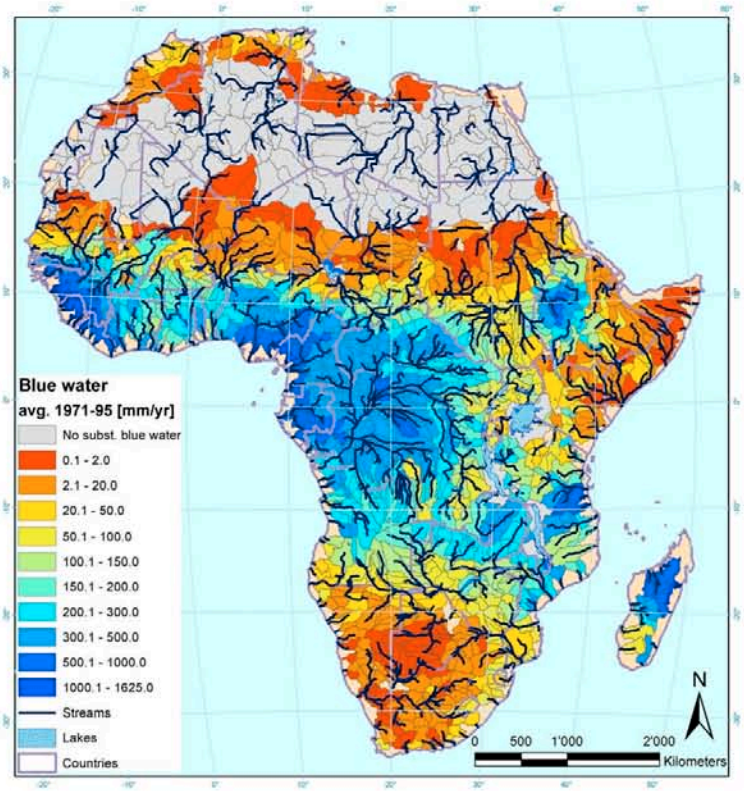
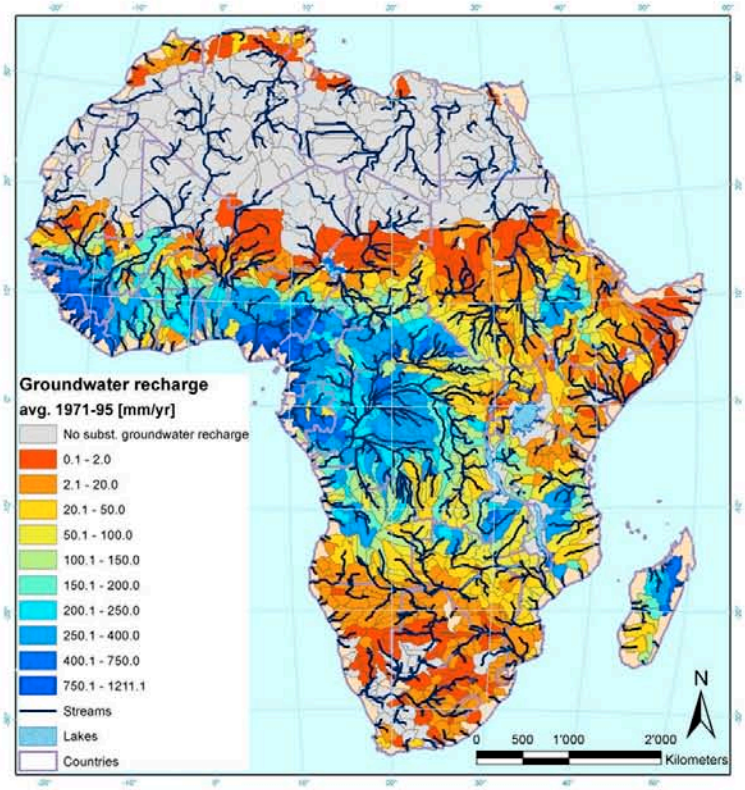
The continental picture: Blue water

Blue water flow



Groundwater recharge



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