Potential Applications of the SWAT Model for Sustainable Soil and Water Resources Management in Southeast Asia

By

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Sustainable soil and water resources management

- Can be broadly defined as the effective and efficient planning, development and utilization of soil and water resources for economic development without causing adverse environmental consequences
- SSWRM could be a major contribution to the UN MDGs on environmental sustainability

Importance of hydrologic info in sustainable soil and water resources mgt.

- In Southeast Asia, water-dependent agricultural and industrial development would necessitate reliable hydrologic information
- Reliable hydrologic information could serve as basis for proper planning and engineering design to meet the water demands and satisfy intended targets

Importance of hydrologic info in sustainable soil and water resources mgt.

- Formulation of sound policies and the effective governance of water resources also require adequate hydrologic information
- Prior implementation of water resources projects would normally require prediction of any adverse environmental impacts to serve as basis for developing appropriate mitigating measures

Importance of hydrologic info in sustainable soil and water resources mgt.

- Even the concept of IWRM (Integrated Water Resources Management) of the Global Water Partnership would require adequate hydrologic information over space and time for it to work

Hydrologic modeling as key to sustainable soil and water resources mgt.

- All these issues and concerns can be conveniently addressed through the use of mathematical hydrologic models
- Among the most widely-used hydrologic models include the **SWAT** model

The SWAT Model

SWAT (Soil and Water Assessment Tool)

-*a physically-based, river basin-scale, continuous-event hydrologic model developed to quantify the impact of land management practices on water, sediment and agricultural chemical yields in large, complex watersheds with varying soils, land use and management conditions over long periods of time* (Arnold et al., 1998)

Strengths of SWAT

- SWAT is capable of modeling the various physical processes associated with water movement, sediment transport, crop growth, nutrient cycling among others in a given watershed.
- SWAT can deal with ungauged watersheds and with very large, complex watersheds.
- SWAT can be used to study long term impacts of activities and processes in a given watershed.

Applicability of SWAT

- SWAT has proven its applicability in many different countries around the world as evidenced by more than 250 peer-reviewed published articles to date (Gassman et al., 2007)

Applicability of SWAT

- Other than the United States, the SWAT model has been used in
  - Europe (e.g. van Griensven, 2006),
  - Australia (e.g. Sun and Cornish, 2006) and
  - Africa (e.g. Schuol et al., 2008)
- It has been applied in countries like
  - Canada (e.g. Mapfumo et al., 2004)
  - New Zealand (e.g. Cao et al., 2008)
  - India (e.g. Mishra et al., 2007)
  - China (e.g. Wei Quyang et al., 2008) and
  - Korea (e.g. Seo et al., 2008).

SWAT in Southeast Asia

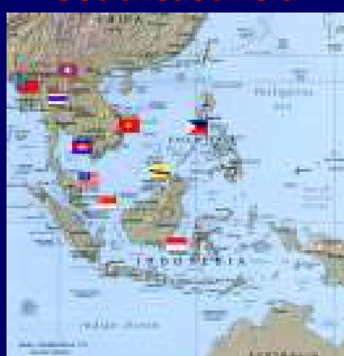
- In Southeast Asia, its full blown application in Southeast Asia is practically just beginning (although work has started in some countries during this decade)
- But still no refereed publication on SWAT in SEA exists

Objective of Presentation

To present the potential applications of the SWAT model in Southeast Asia and highlight its role in addressing the most relevant and pressing issues and concerns associated with soil and water resources utilization and management in this region

Southeast Asia and its Land and Water Resources

Southeast Asia



Source: ASEAN (2008)

Southeast Asia

Source: www.maptown.com (2008)

Distribution of land area in Southeast Asia

Country	Total Area (sq. km)
Brunei Darussalam	5,765
Cambodia	181,035
Indonesia	1,890,754
Lao PDR	236,800
Malaysia	330,257
Myanmar	676,577
Philippines	300,000
Singapore	697
Thailand	513,254
Vietnam	330,363
Total	4,465,502

Source: ASEAN (2008)

Water resources in SEA

- **Average annual precipitation in SEA: 1,877 mm (FAO, 2008)**
- **Average annual volume of water resource in SA: 6,476 km^3 or about 15% of the world's total (ASEAN, 2008)**

Major River Basins in Southeast Asia

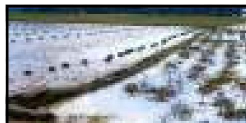
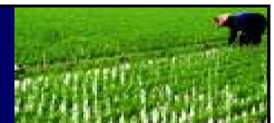
Source: www.un.org (2008)

Features of Major River Basins in Mainland SEA

River Basin	Annual Average Discharge (m^3/s)	Length (km)	River Basin (km^2)
Irrawaddy	13,000	2,170	411,000
Salween	4,980	2,400	271,866
Chao Phraya	954	365	160,079
Mekong	15,000	4,350	805,627
Red River	4,340	1,200	169,000

Source: FAO (2008)

Soil and Water Resources Issues and Concerns in SEA and Potential SWAT Applications

Increasing use of soil and water resources for agriculture and food security


Agricultural land use in Southeast Asian countries as percentage of total land area

Country	1990	1995	2005
Brunei Darussalam	2.5	2.8	4.7
Cambodia	25.2	25.9	30.3
Indonesia	24.9	23.3	26.4
Lao PDR	7.2	7.4	8.5
Malaysia	22.0	24.0	24.0
Myanmar	15.9	15.9	17.1
Philippines	37.4	37.7	40.9
Singapore	3.0	1.8	1.1
Thailand	41.9	41.5	36.4
Vietnam	20.7	21.7	29.5

Source: ADB (2008)

Distribution of irrigated areas in Southeast Asia

Country	Total Irrigated Area (has)
Brunei Darussalam	1,000
Cambodia	284,172
Indonesia	4,459,000
Lao PDR	295,535
Malaysia	362,600
Myanmar	1,841,320
Philippines	1,550,000
Singapore	-
Thailand	4, 985,708
Vietnam	3,000,000
Total	11,793,627

Source: FAO (2008)

Water resources, agriculture and food security issues in SEA

- More than 90% of freshwater withdrawals in SEA is used for agriculture (FAO, 2008)
- Irrigation development for rice production is a continuing activity in SEA countries as actual IA < potential IA
- Rice producing countries in SEA (Thailand and Vietnam) are among the major players in the world rice trade
- Rice export supplies from Thailand, Vietnam, China, India and US= ¾ of world rice supply
- Water resources in SEA would play a key role in addressing food security issues

Potential SWAT application for food security issues in SEA

- Generation of sufficiently long streamflow time series for dependable flow analysis (e.g. flow duration analysis, frequency analysis) for gauged and ungauged watersheds
- Reliable estimates of dependable flow are necessary for a more accurate estimation of irrigable areas and for proper irrigation system planning, design and operation
- Crop modeling for yield maximization

Occasional flooding in major river basins

Occasional Flooding in SEA

- Heavy rainfall occurrences coupled with forest denudation result to occasional flooding esp in low-lying areas in SEA
- The extensive plains of the Mekong river, Red river and Irrawaddy river are frequently subjected to flooding (FAO, 2008)
- More so in archipelagic countries like the Philippines which is exposed to numerous typhoons and monsoon rains every year; and in downstream countries like Vietnam

Potential SWAT application for flooding issues in SEA

- Simulation of flood discharges with maximum probable precipitation
- Prediction of flood peaks under varying land cover conditions and management practices in any watershed in SEA
- Generation of annual series of flood discharge values can then be used for flood frequency analysis to generate extreme values at various return periods for flood mitigating purposes

Potential SWAT application for flooding issues in SEA

- Determination and evaluation of best management practices (BMPs)
- Simulation of drainage

Water quality degradation

Water quality issues in Southeast Asia

- Physical contaminants due to heavy siltation have been observed in many Southeast Asian waterways during heavy rainfall periods
- Chemical contaminants from agrochemical application have also been detected in river systems in Southeast Asian countries
- Biological contaminants like *E. coli* have been detected in some rivers in SEA

Potential SWAT application for water quality issues in SEA

- Simulation of water quality effects of agricultural management practices in SEA watersheds
- Simulation and prediction of loading of nutrients, pesticides and pathogens in river systems under various modeling scenarios
- Simulation/determination of BMPs to minimize adverse water quality problems in river basins

Soil erosion and degradation

Soil erosion in Southeast Asia

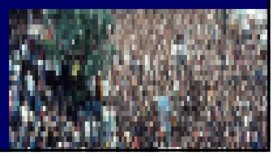
- Soil erosion and the eventual siltation of waterways are prevalent in many SEA during heavy rainfall periods
- In the Philippines alone, about 16 million cu. m. of soil due to erosion from the major river basins covering about 4.7 million hectares of watershed area lead to the sedimentation of the National Irrigation Systems and hydraulic structures (NWRB, 2004)
- Erosion has been observed even in small upland watersheds in the Philippines under VAF systems

Potential SWAT application for soil erosion issues in SEA

- Simulation of sediment yield resulting from soil erosion under prevailing management and land cover conditions
- Prediction of sediment yield under various land use scenarios e.g. forest to agricultural, vegetable-agroforestry (VAF) systems, etc.
- Long term simulation of sediment yield in ungauged and complex watersheds
- Simulation of BMPs


Increasing pressure on water resources due to rapidly growing population





Population in Southeast Asian countries in million

Country	1990	2000	2007
Brunei Darussalam	0.3	0.3	0.4
Cambodia	8.6	12.6	14.4
Indonesia	179.4	205.8	224.9
Lao PDR	4.1	5.1	5.9
Malaysia	18.1	23.5	27.2
Myanmar	40.8	50.1	57.7
Philippines	60.9	76.9	88.6
Singapore	3.0	4.0	4.6
Thailand	55.8	62.2	65.8
Vietnam	66.0	77.6	85.2
Total	436.8	517.9	574.0

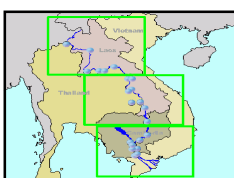
Source: ADB (2008)

Population and water supply in SEA

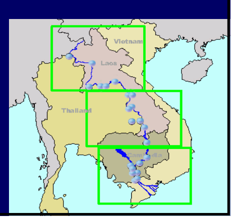
- SEA Population: 574 million as of 2007; 80% are in Indonesia, Philippines, Vietnam and Thailand
- Average rate of population growth in SEA: 1.8% (ADB, 2008)
- Population increase will not only exert pressure on water resources for food production but also for domestic water supply and other uses associated with population increase

Potential SWAT application for water supply issues in SEA

- Generation of long term streamflow time series for water supply analysis (e.g. mass curve analysis, residual mass analysis, etc.)
- Estimation of recharge in aquifers
- SWAT simulations could serve as basis for sound policy formulation on sustainable water resources allocation and distribution



Transboundary issues



Transboundary issues in SEA

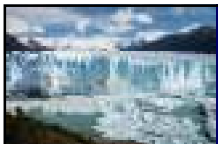
Source: www.un.org (2008)

Transboundary issues in SEA

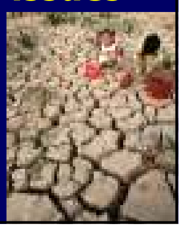
- The major river basins in SEA (Irrawady, Salween, Chao Phraya, Mekong and Red river basins) all pass through different countries
- Intergovernmental agreements and management bodies e.g. the Mekong River Commission are necessary to ensure proper water management and avoid water conflicts

Potential SWAT application for transboundary issues in SEA

- Simulation and prediction of streamflow, sediment yield, water quality and other hydrologic parameters at any arbitrarily selected point along the river crossing various countries
- Generation of hydrologic data for use in further analysis and basis for estimating parameters for planning, design and operation e.g. dependable flow, flood flow, sediment yield, water quality, etc. at any point along the river
- Simulation of BMPs



Climate change and climate variability issues



Climate change and climate variability issues in SEA

- Southeast Asia is among the most vulnerable to climate change due to proximity to oceans and seas
- Projected sea level rise can easily lead to submergence of low-lying coastal areas in SEA countries
- Projected temperature increase due to global warming would also alter the behavior of the hydrologic systems in SEA
- Climate variability e.g. El Niño and La Niña bring drought and excessive precipitation, respectively

Drought Occurrence in the Philippines over the Last 3 Decades due to El Niño

Event	Areas affected
1968-1969	Bicol and the rest of the Philippines except Ilocos and Cagayan Valley
1972-1973	Central Luzon, Visayas and Mindanao
1976-1977	Mindanao except Davao
1982-1983	
(Oct 1982-March 1983)	Central Luzon, southern Tagalog, northern Visayas, western Mindanao, Ilocos, Cagayan Valley, Bicol
(April-September 1983)	Cagayan Valley, parts of Ilocos
1986-1987	
(Oct 1986-Mar 1987)	Western Luzon, Bicol
(April-September 1987)	Most of Luzon, central Visayas, northeastern Mindanao
1989-1990 (Oct 89-Mar 90)	Cagayan Valley, Panay Island, Guimaras, northern Palawan, western Mindanao
1991-1992	Central Luzon, southern Tagalog, northern Visayas, western Mindanao, Cagayan Valley, Parts of Ilocos
1994-1995	Ilocos, Cagayan Valley, central Luzon, southern Tagalog, Visayas, western Mindanao
1997-1998	Northern Mindanao, southern Mindanao, eastern Visayas

Source: PAGASA and Monsalud et al. (2003)

Potential SWAT application for climate change and climatic variability issues in SEA

- SWAT has a built-in capability for simulating climate change impacts on water resources; SWAT can also be linked to climate change models
- Prediction of effects of climatic variability such as El Niño and La Niña on hydrology and water quality can be done by SWAT

Other potential applications of SWAT in Southeast Asia

- Other SWAT applications in SEA are virtually countless
- Global applications and future trends in SWAT application have been documented and published by Gassman et al. (2007)
- SWAT related articles are also compiled at the SWAT website

Constraints in the Applicability of SWAT in Southeast Asia

Some Constraints in the applicability of SWAT in SEA

- Hydrologic data: availability, reliability, adequacy
- Hardware and software problems
- Manpower capability
- Lack of hydrologic research useful for SWAT modeling
- Lack of financial and/or institutional support
- Peace and order situation in some watersheds

CONCLUDING REMARKS

❖ SWAT is a powerful tool that can be used for sustainable soil and water resources management in Southeast Asia

❖ Being a heavy user of water resources and playing a key role in global food security, Southeast Asia should take advantage of the availability and power of the SWAT model to address the various issues and concerns peculiar to the region including transnational boundary issues, food security, land use change, climate change and climate variability, rapidly growing population, soil erosion and water quality degradation, flood and drought occurrences, among others

CONCLUDING REMARKS (cont'd)

❖ Many other specific applications of the SWAT model can be made in Southeast Asian watersheds capitalizing on the strengths and capabilities of this model

❖ Despite some constraints in SWAT model application in some SEA watersheds, SWAT is generally applicable in Southeast Asia

CONCLUDING REMARKS (cont'd)

❖ Relevant hydrologic research in Southeast should be given due financial and institutional support to reduce and eventually eliminate the impediments to the full application of SWAT in this region

❖ While some work on SWAT modeling has started in a number of Southeast Asian countries, its full application in the whole region is yet to be realized

❖ It is only a matter of time when peer-reviewed articles on SWAT application in SEA evolve in published literature.

CONCLUDING REMARKS (cont'd)

- Finally, all these modeling and simulation work should find their way to the drawing boards of policy makers and natural resources managers for only in having adequate hydrologic information including those generated by SWAT model simulation can water resources policies be truly sound and governance of water resources be more effective.

Thanks!!!

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