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Evaluation of Soil Carbon Sequestration in Conservation Agriculture Production and Conventional Tillage Systems in Cambodia Using APEX

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I. Introduction

- Cambodia is one of the world's poorest countries and its population depends heavily on agriculture (USAID/Cambodia, 2013).
- The majority of cultivated areas are now degraded due to improper agricultural production practices.
- The country is suffering Carbon loss due to poorly managed conversion of natural forest into croplands (Belfield et al., 2013).
- Conservation Agriculture (CA) and Conservation Tillage (CT) practices can increase crop productivity and protect natural resources (Prasad, 2016; USEPP, 2016).

I. Introduction (Cont.)

Soil is improved by conservation agriculture, because of:

-minimal soil disturbance,

-crop residue soil cover

-and viable crop rotations

(Uddin, Dhar & Islam, 2016)

With CA, benefits are as follows:

-Active biological activities

-Water saving

-Increasing nutrient in the soil

(Mvumi, Ndoro & Manyiwo, 2017)

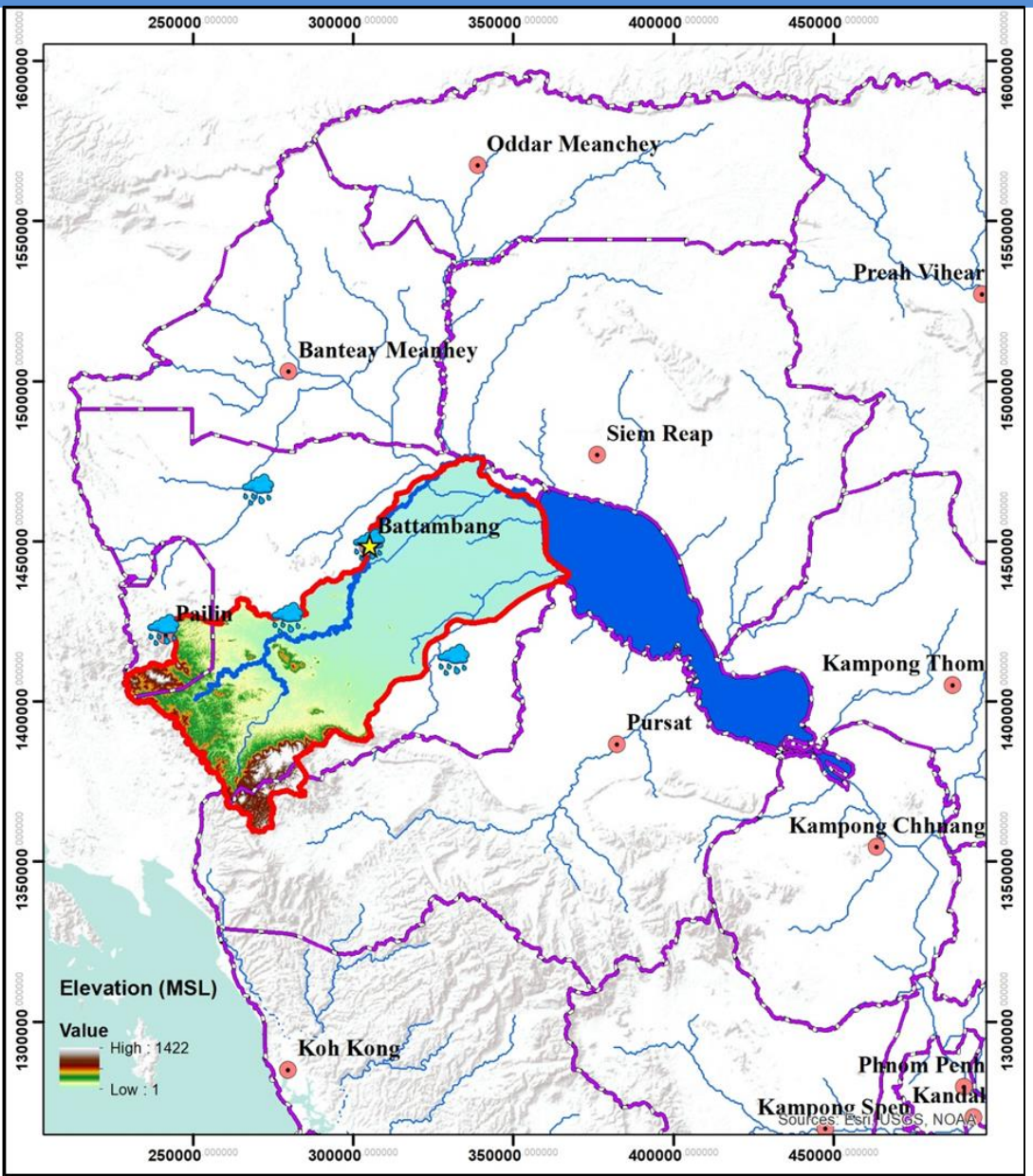
II. Research Objective

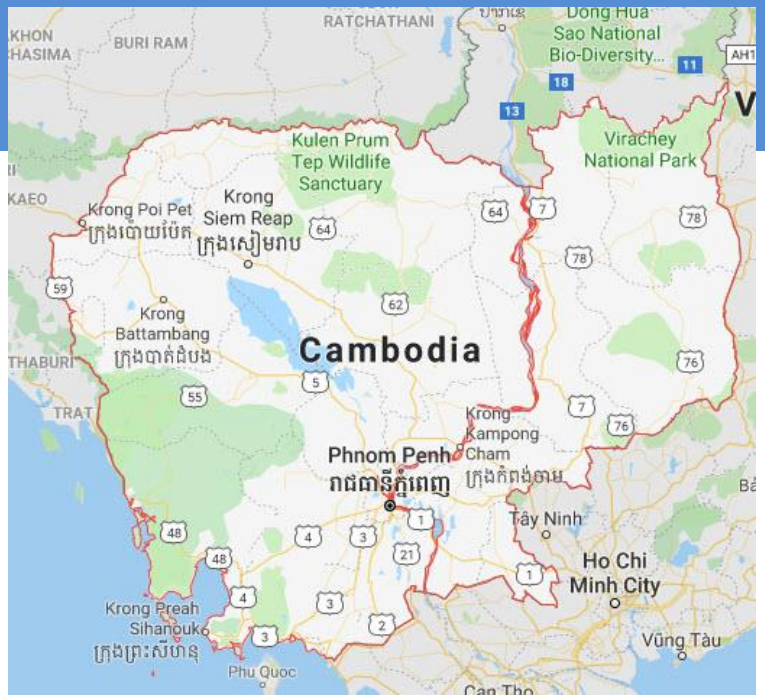
To assess the impact of CA and CT on:

1. Surface runoff,
2. Soil erosion,
3. Crop yield and biomass
4. Nutrient and pesticide transport

from agricultural lands in the Stung Sangker Catchment, Battambang Province, Cambodia

Study Area





- **Location**: *Stung Sangker River Catchment*
- **Catchment Area**: *6051 km²*
- **Annual Rainfall**: *1318 mm/year*
- **Temperature**: *22.17-33.78 °C*
- **Major Crops**: *Rice (wet and dry season), Cassava, Corn, Sugarcane, Rice etc.*

In Battambang Province, Conservation Agriculture experiment under no tillage was done over 10 years since 2010.

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cirad

General Directorate of Agriculture
Ministry of Agriculture, Forestry and Fishery

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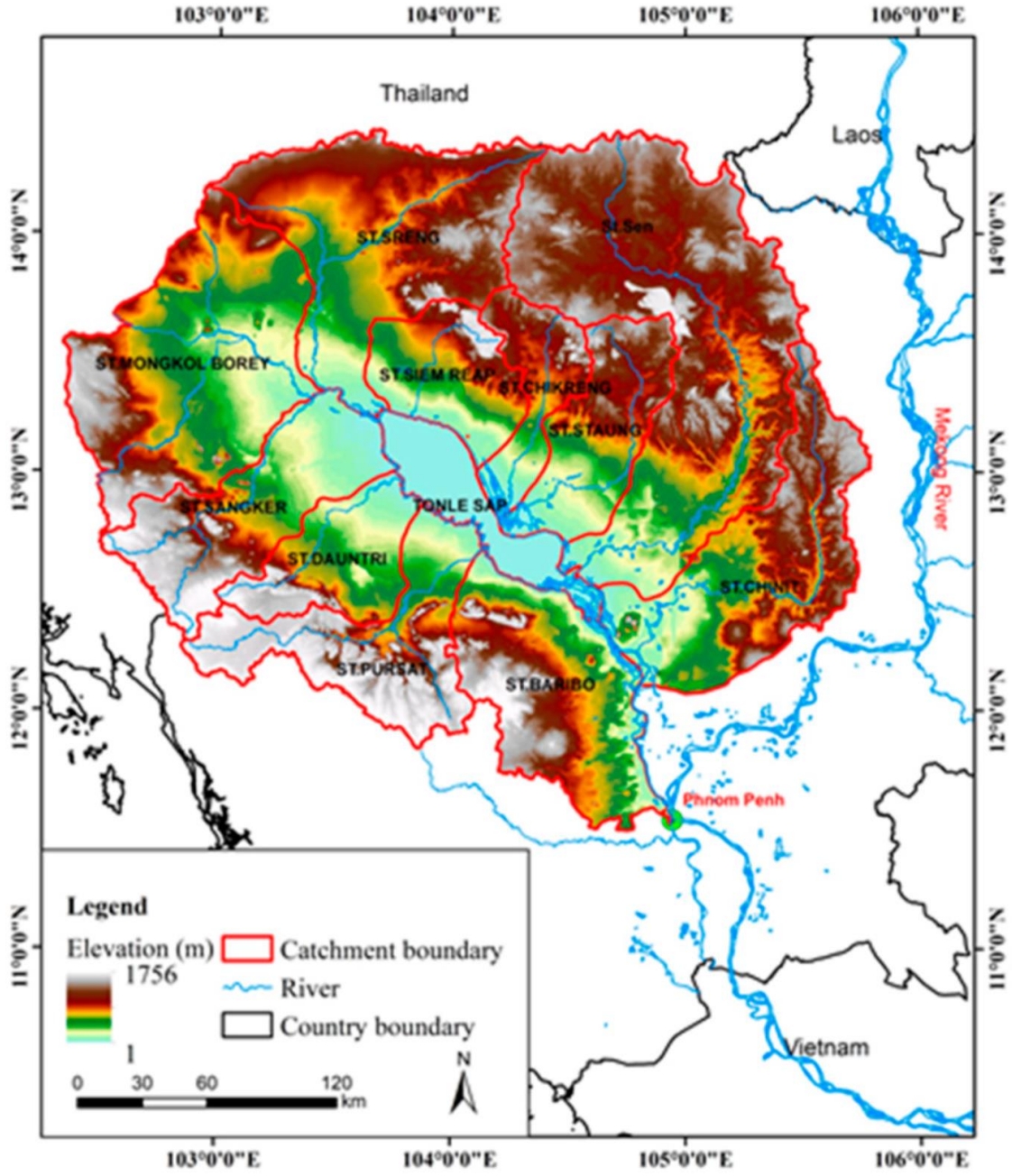
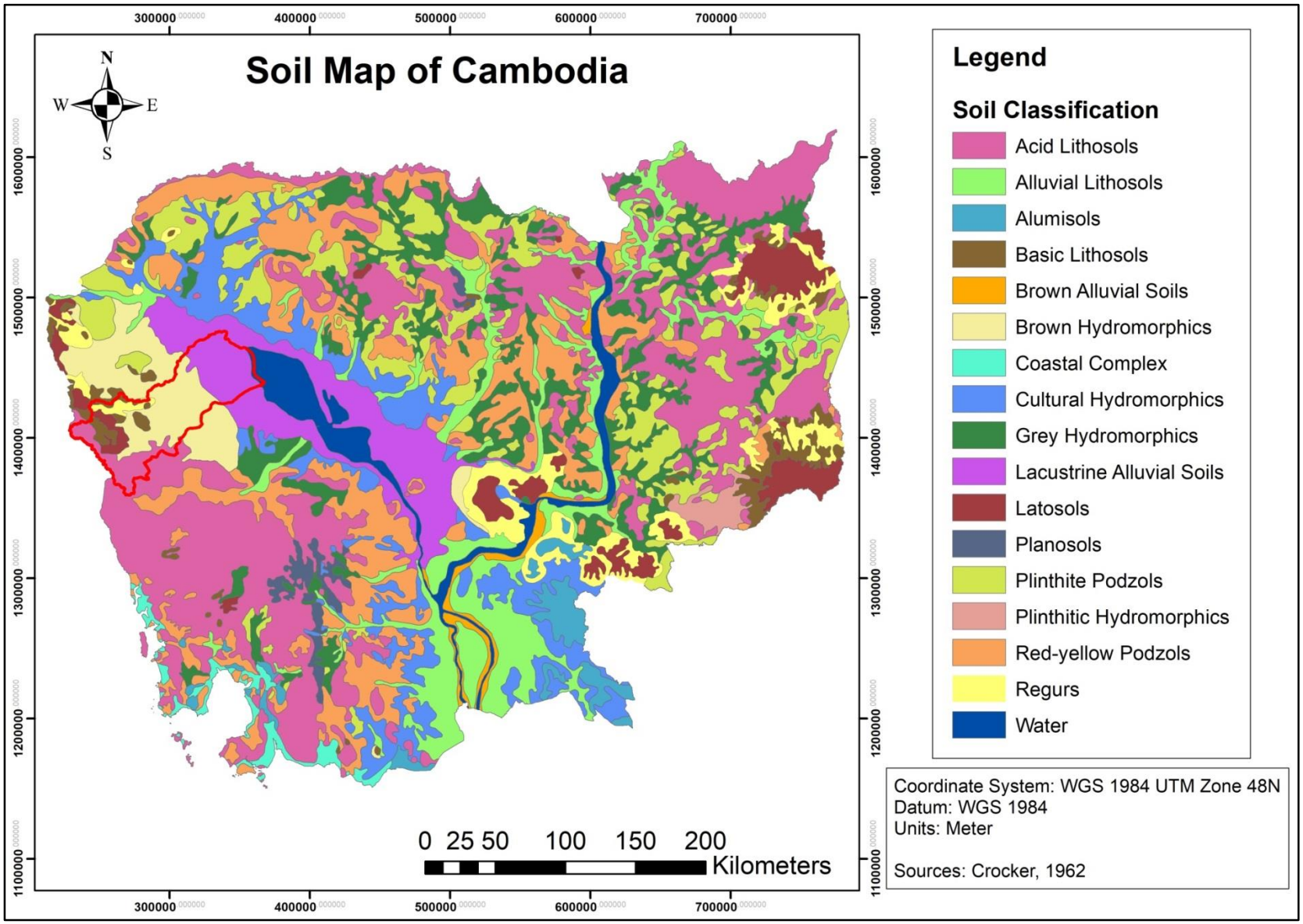
Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification

KANSAS STATE UNIVERSITY

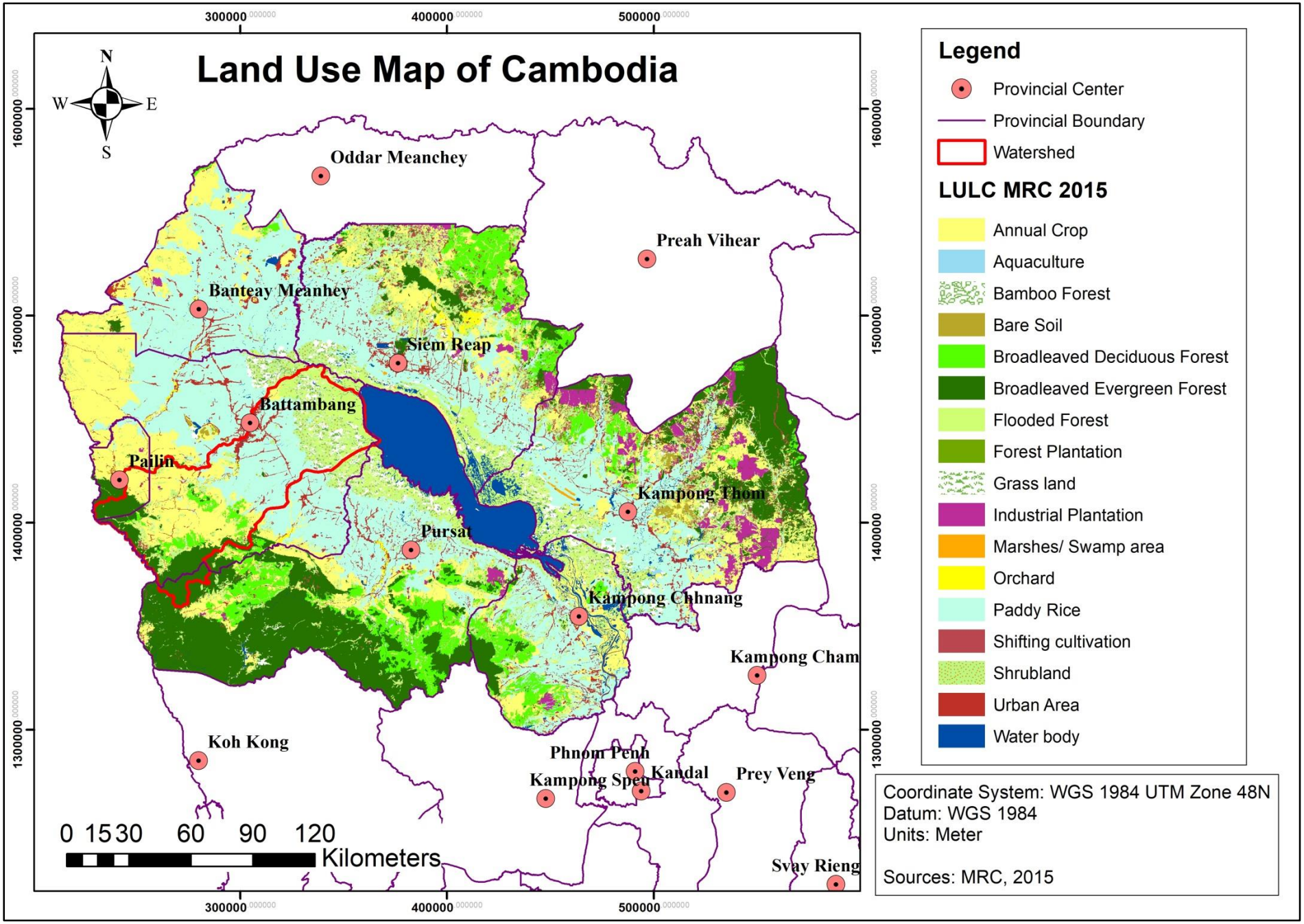
APEX Model Data Inputs



- ***Digital Elevation Model:*** *Resolution (30m x 30m)*
- ***Source:*** *SRTM, United States Geological Survey*



A soils map of 16 soil types developed by Crocker in 1962 and was classified based on the FAO/UNESCO in 1984 with the classification up to two levels (0-30 cm and 30-100 cm)


Land Use Map of Cambodia
N
W
E
S
300000
400000
500000
1600000
1500000
1400000
1300000
Oddar Meanchey
Preah Vihear
Banteay Meanhey
Siem Reap
Battambang
Pailin
Kampong Thom
Pursat
Kampong Chhnang
Kampong Cham
Koh Kong
Phnom Penh
Kandal
Kampong Speu
Prey Veng
Svay Rieng
0 15 30 60 90 120
Kilometers
Legend
Provincial Center
Provincial Boundary
Watershed
LULC MRC 2015
Annual Crop
Aquaculture
Bamboo Forest
Bare Soil
Broadleaved Deciduous Forest
Broadleaved Evergreen Forest
Flooded Forest
Forest Plantation
Grass land
Industrial Plantation
Marshes/ Swamp area
Orchard
Paddy Rice
Shifting cultivation
Shrubland
Urban Area
Water body
Coordinate System: WGS 1984 UTM Zone 48N
Datum: WGS 1984
Units: Meter
Sources: MRC, 2015

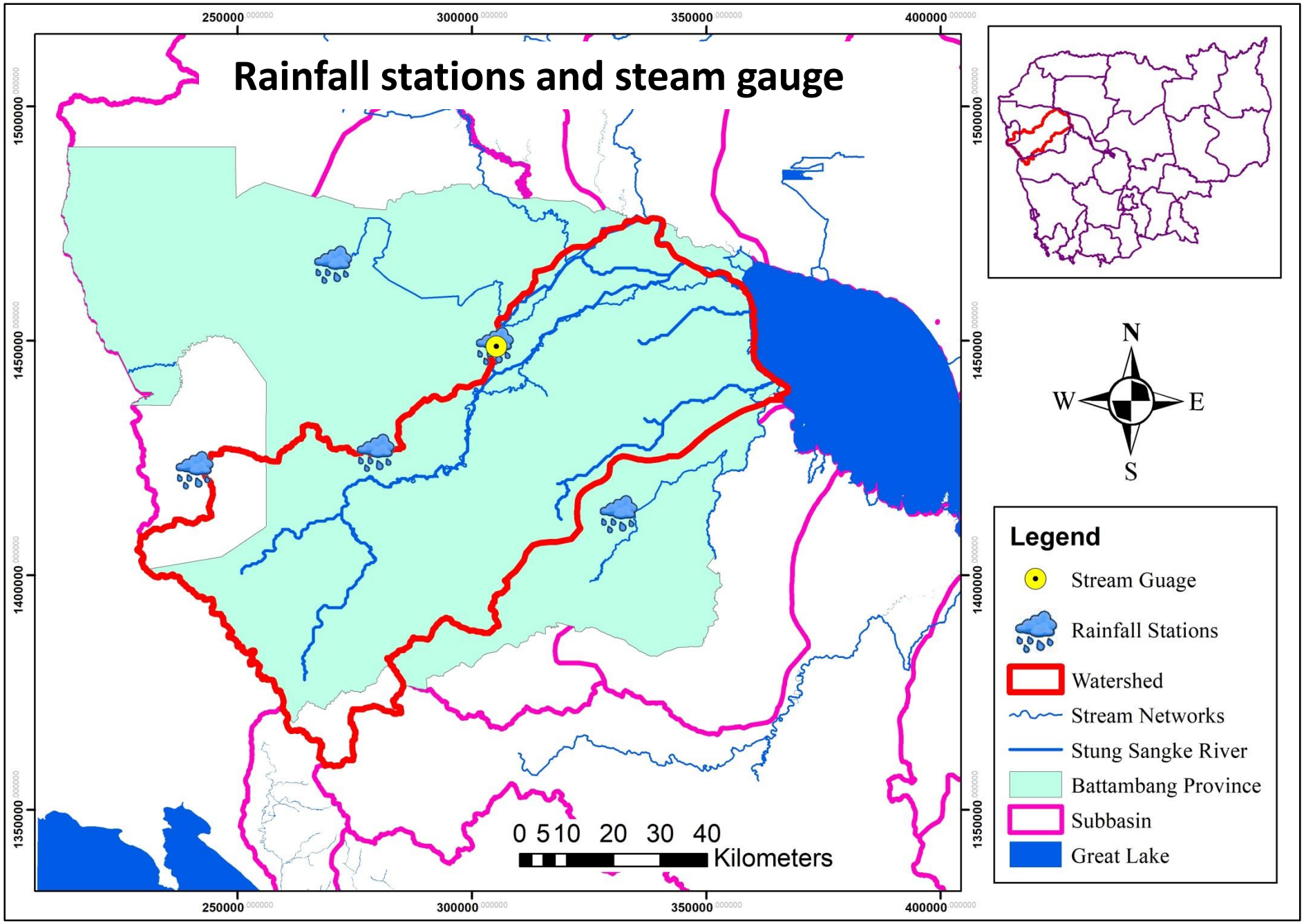
Crop Management Data

Table 3.1: Crop sequence in Cassava-based cropping system in the experimental site (2010-2017)

Cropping system	Crop Sequence							
	2010	2011	2012	2013	2014	2015	2016	2017
Conventional Tillage								
CT1	Cs/Mz	Cs/Mz	Cs/Mz	Cs/Mz	Cs/Mz	Cs/Mz	Cs/Mz	Cs/Mz
CT2	Cs	Cs	Cs	Cs	Cs	Cs	Cs	Cs
Conservation Agriculture								
CA1	Chisel+Cs	Bio p. Millet + C. *juncea* / Mz + Mb	Chisel+Cs	Bio p. Millet + C. *juncea* / Mz + Mb	Chisel+Cs	Bio p. Millet + C. *juncea* / Mz + Mb	Chisel+Cs	Bio p. Millet + C. *juncea* / Mz + Mb
CA2	Bio p. Millet + C. *juncea* / Mz + Mb	Chisel+Cs	Bio p. Millet + C. *juncea* / Mz + Mb	Chisel+CS	Bio p. Millet + C. *juncea* / Mz + Mb	Chisel+Cs	Bio p. Millet + C. *juncea* / Mz + Mb	Chisel+Cs

Mt: millet *(Pennisetum typhoides Burm)*; St: *Stylosanthes guianensis*; *Cr: Crotalaria Juncea*; Cs: cassava (*Manihot esculenta*); Mz: Maize *(Zea mays)*; Mb: Mung bean "/" indicates crop rotation "+" notes integrated crops (the same period)

Crop management practices of Conservation Agriculture (CA) and Conventional Tillage (CT) in Battambang Province (2010-2017) obtained from CIRAD

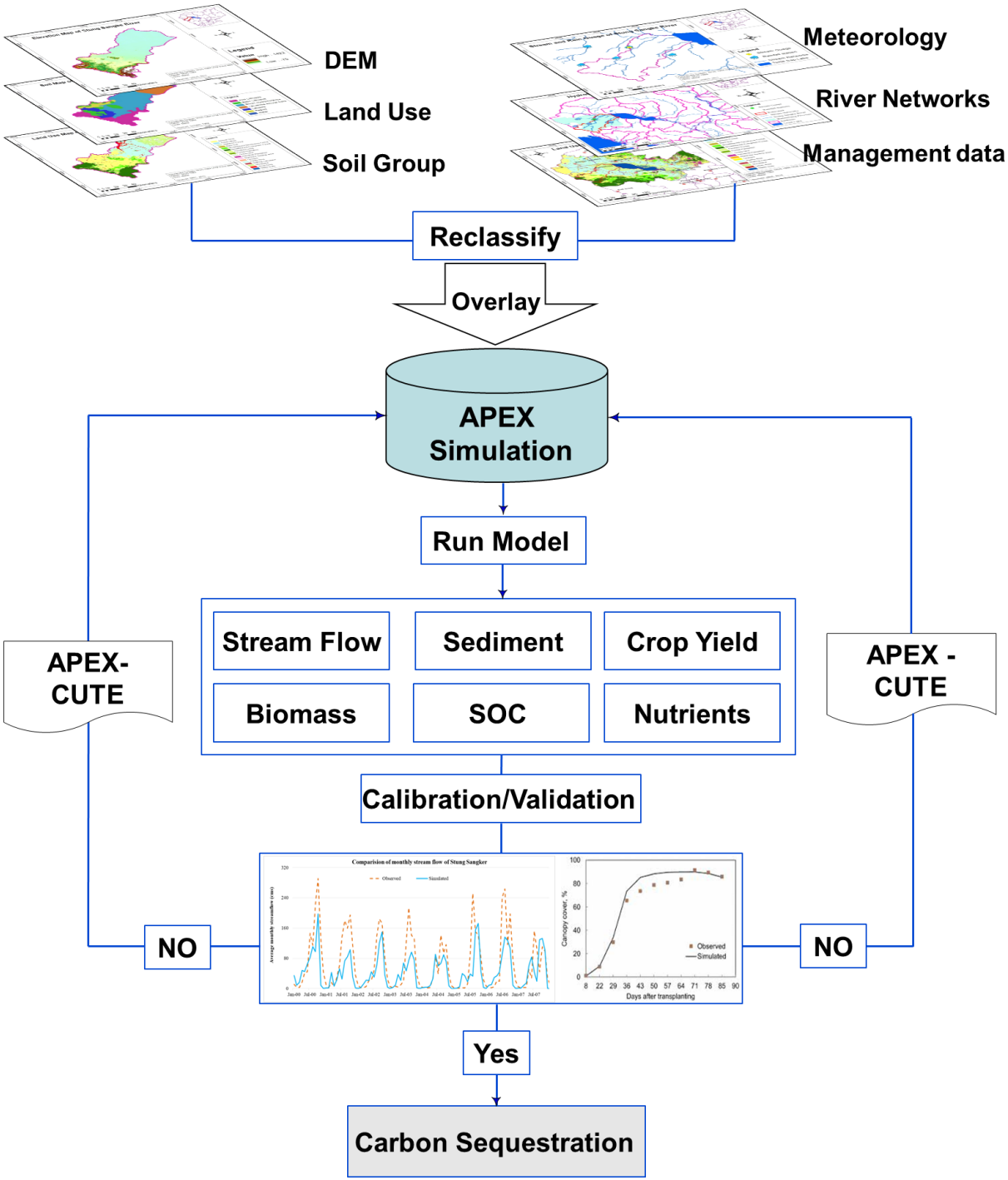

Rainfall stations and steam gauge
250000
300000
350000
400000
1500000
1450000
1400000
1350000
N
W
E
S
Legend
Stream Guage
Rainfall Stations
Watershed
Stream Networks
Stung Sangke River
Battambang Province
Subbasin
Great Lake
0 5 10 20 30 40
Kilometers

Observed Hydrological Data

Rainfall Data					
No	**Station Name**	**Long**	**Lat**	**Province**	**Year**
1	Battambang	103.2000	13.10000	Battambang	1995-2018
2	Palin	102.6115	12.85589	Pailin	2007-2018

Stream Gauge Data					
No	**Station Name**	**Long**	**Lat**	**Observed Discharge (m3/s)**	**Observed Water Level (m)**
1	St. Sangker River	1448764	305290	2000-2010	2010-2016

Rainfall and streamflow data obtained from Ministry of Water Resources and Meteorology (MoWRAM), and satellite image (CHIRPS) done bias correction


DEM
Land Use
Soil Group
Meteorology
River Networks
Management data
Reclassify
Overlay
APEX Simulation
Run Model
Stream Flow
Sediment
Crop Yield
Biomass
SOC
Nutrients
APEX-CUTE
APEX - CUTE
Calibration/Validation
Comparision of monthly stream flow of Stung Sangker
Observed
Simulated
Canopy cover, %
Days after transplanting
NO
NO
Yes
Carbon Sequestration

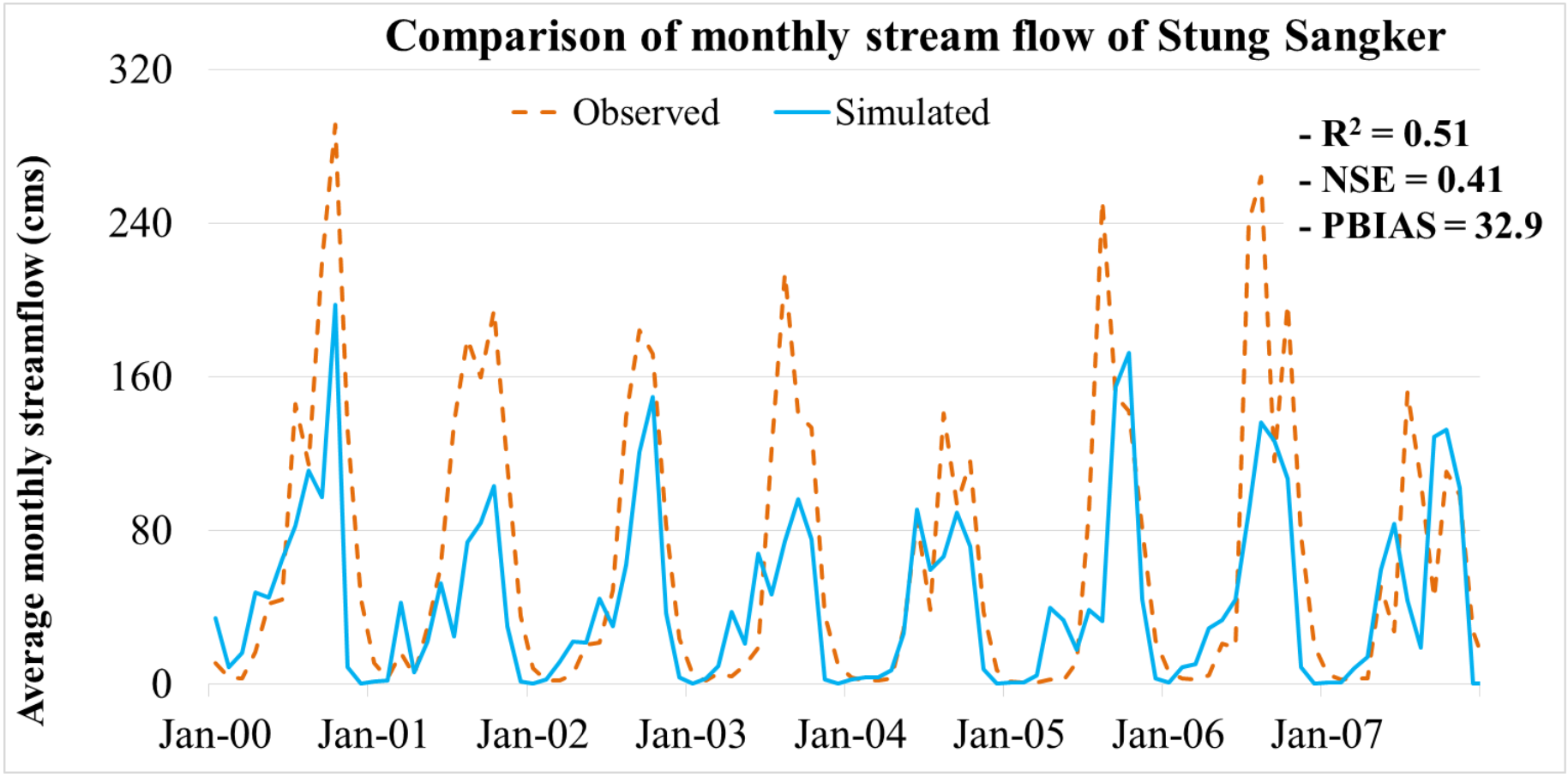
APEX Calibration Parameters

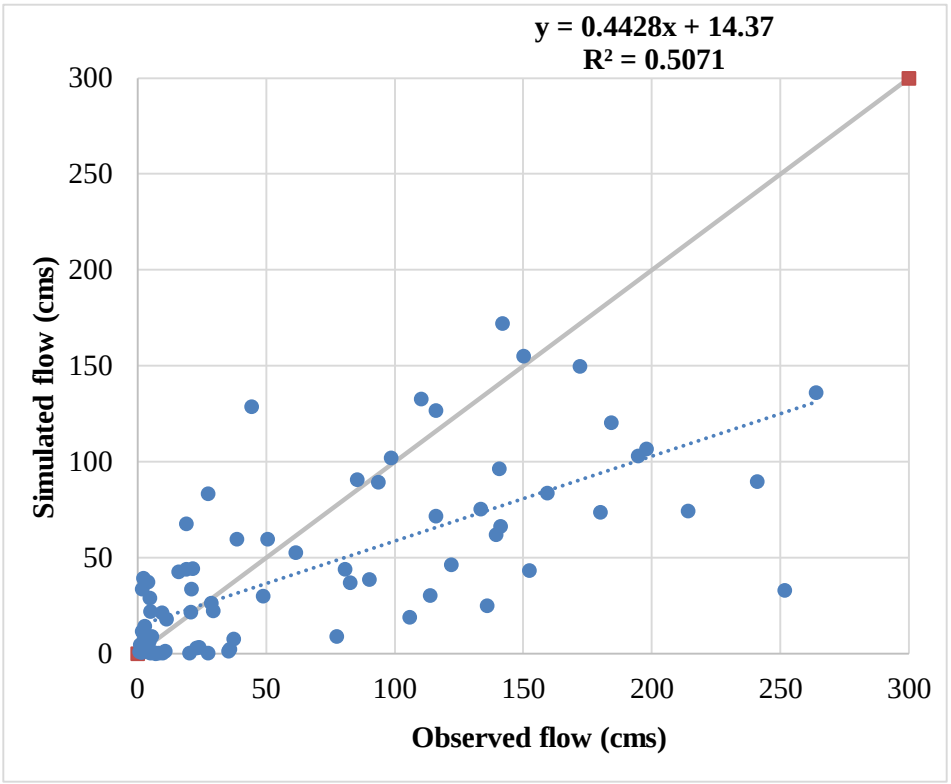
❖ Hydrological Parameters

Parameters	Description	Range	Optimal Value
CN2	Initial condition II curve number (CN2) or landuse number (LUN)(-)	±5	**4**
PARM(92)	Curve number retention parameter coefficient **(1)**	0.8 – 1.5	**0.5**
PARM (20)	Runoff curve number initial abstraction **(0.2)**	0.05 – 0.4	**0.05**
PARM(1)	Canopy PET factor **(2)**	1 - 2	**1.3**
PARM(12)	Soil evaporation coefficient **(1.5)**	1.5 – 2.5	**2.3**
PARM(17)	Evaporation plant cover factor **(0.1)**	0 – 0.5	**0.25**
RFPO	Return flow ratio: (Return flow)/(Return flow + Deep percolation) **(0.5)**	0.05 – 0.95	**0.5**
RFTO	Groundwater residence day **(30)**	10 - 50	30
PARM(40)	Groundwater storage threshold **(0.25)**	0.001 - 1.0	**0.005**

IV. Primary Results

❖ Streamflow Calibration





water

MDPI

Article

Assessing Climate Change Impacts on River Flows in the Tonle Sap Lake Basin, Cambodia

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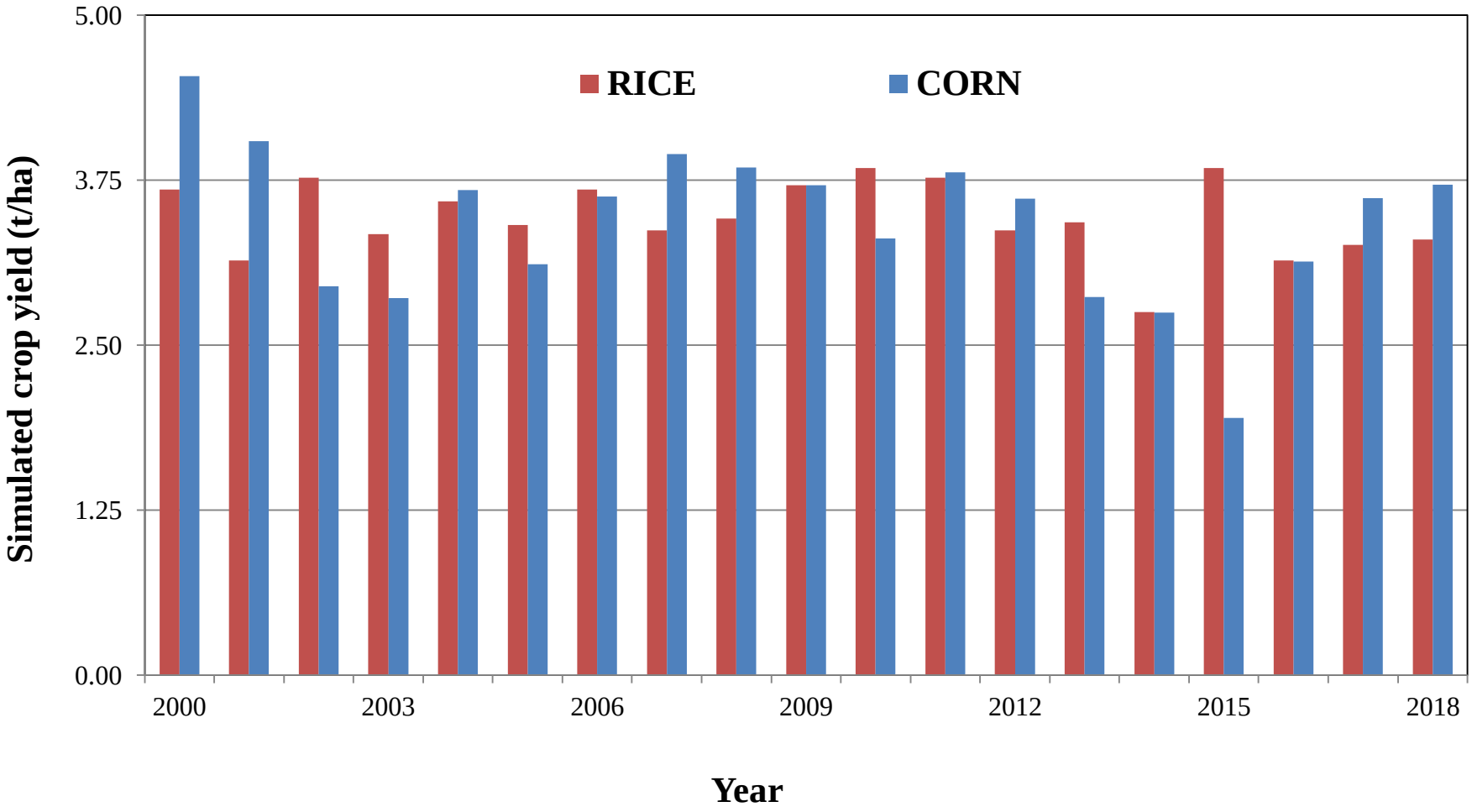
Table 4. Calibration and validation performance (NSE, PBIAS, RSR, and R^2) for monthly time step simulation at all 11 rivers in Tonle Sap Lake Basin.

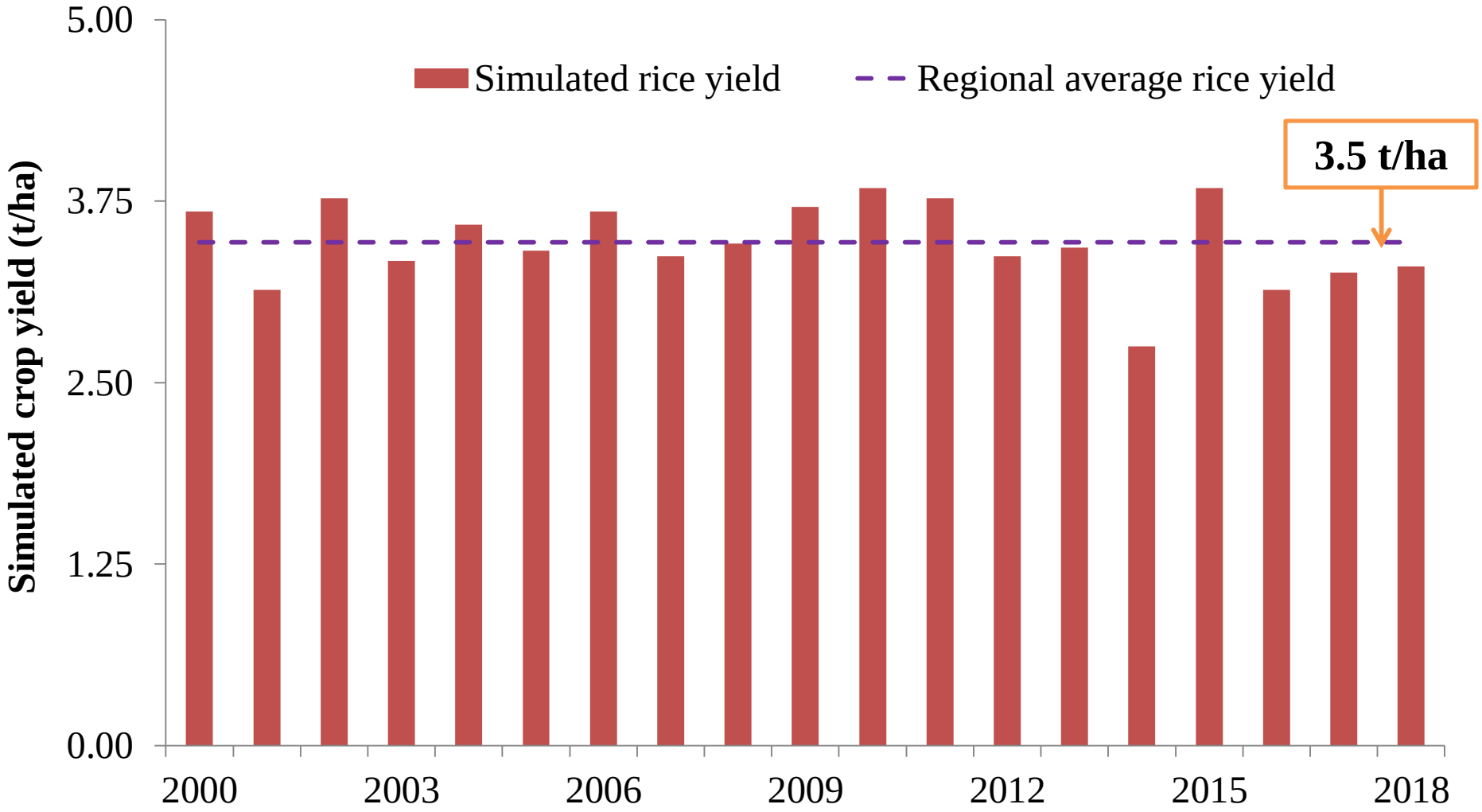
River	Station Name	Calibration Period	NSE	PBIAS	RSR	R^2	Validation Period	NSE	PBIAS	RSR	R^2
ST. Chinit	Kampong Thmar	1997–2003	0.74	−0.20	0.51	0.78	2004–2015	0.61	0.01	0.62	0.61
ST. Sen	Kampong Thom	1995–2003	0.80	−0.13	0.45	0.82	2004–2015	0.87	0.03	0.37	0.87
ST. Staung	Kampong Chen	1997–2003	0.64	−0.18	0.60	0.70	2004–2015	0.68	−0.06	0.56	0.68
ST. Chikreng	Kampong Kdei	1997–2003	−1.96	−1.95	1.72	0.64	2004–2015	0.11	−0.89	0.94	0.48
ST. Siem Reap	Prasat Keo	1999–2003	0.63	−0.16	0.61	0.68	2004–2015	0.64	−0.02	0.60	0.65
ST. Sreng	Kralanh	1997–2003	0.67	−0.21	0.58	0.75	2004–2011	0.71	−0.27	0.54	0.79
ST. Mongkol Borey	Sisophon	1997–2003	0.43	−0.22	0.75	0.49	2004	0.37	−0.27	0.79	0.41
ST. Sangke	Battambang	1997–2003	0.32	−0.30	0.82	0.55	2004–2015	0.19	−0.62	0.90	0.70
ST. Dauntri	Prek Chik	1997–2003	−1.87	−2.26	1.69	0.35	2004, 2007–2008	−1.15	−1.40	1.47	0.35
ST. Pursat	Bac Trakuon	1995–2003	0.71	−0.09	0.54	0.71	2004–2015	0.65	0.01	0.59	0.64
ST. Baribo	Baribo	1998–2003	0.63	0.02	0.61	0.62	2004–2005	0.52	0.20	0.70	0.55

IV. Primary Results

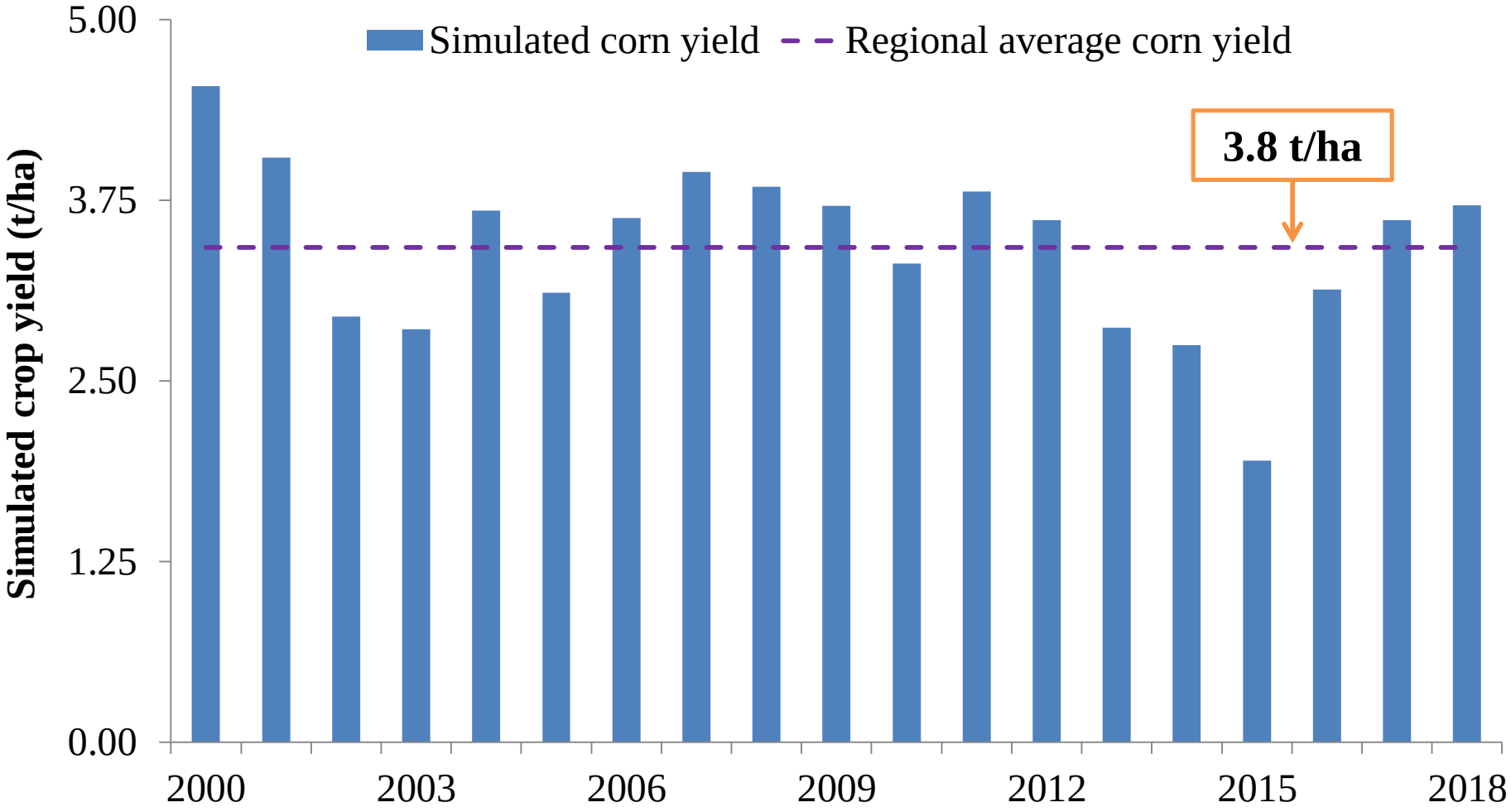
- Simulated crop yields under CA



❖ Comparison of simulated crop yield with regional average crop yield (Rice)

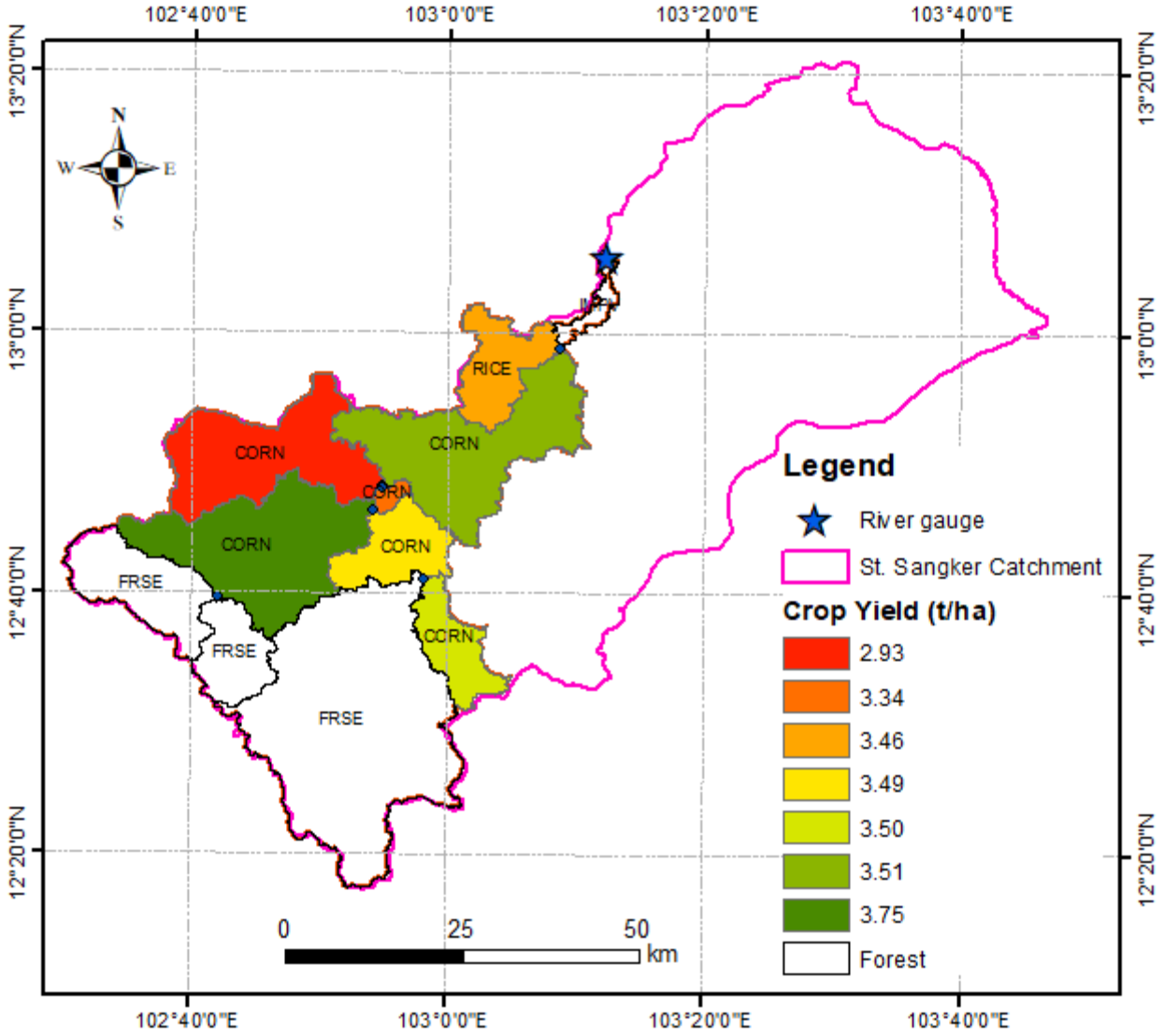


❖ Comparison of simulated crop yield with regional average crop yield (Corn)



IV. Primary Results

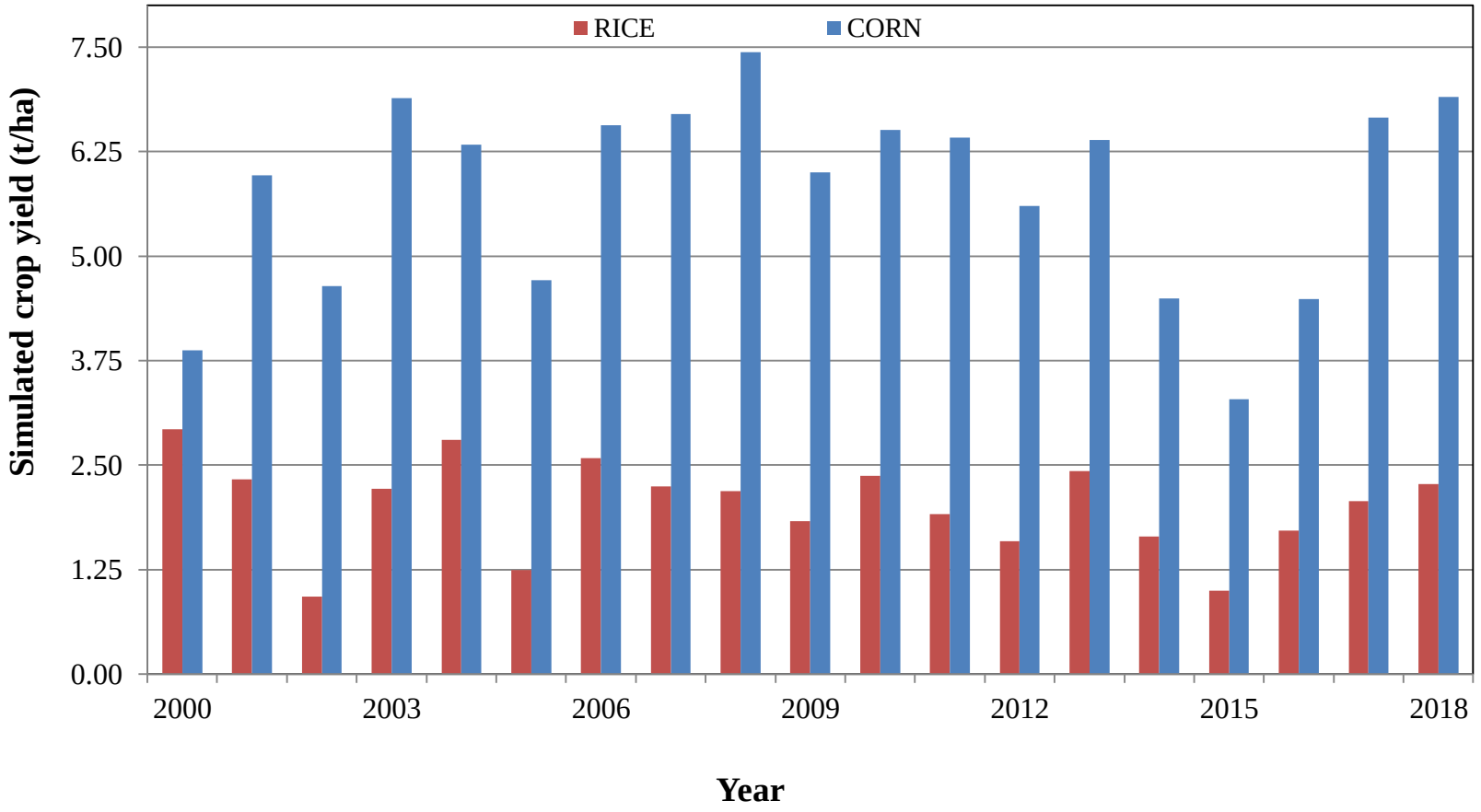
- Simulated crop yields under CA



IV. Primary Results

- Simulated crop yields under CT

  (Not yet calibrated)



V. Conclusion and Further Work

- Simulation of the environmental impacts of sustainable intensification and Conservation Agriculture/Conventional Tillage production system in Cambodia.

- Due to the data availability, the primarily results for the crop management at some sub-catchments could be analyzed, while the rest of it will be done in the future.

- The APEX model has reasonably captured the observed flow and crop yield. In the future, the model will be calibrated for sediment loss and soil nutrient in order to evaluate the effect of CA and CT practices for the entire

V. Conclusion and Further Work

Some of the present challenges and the future direction of this research are listed below:

- Estimating the streamflow of the ungauged area at the downstream of the Stung Sangker River gauging station;
- Calibrating the sediment and soil organic carbon in the watershed; and
- Calibrating the APEX model for the CT practice and evaluating the impact on agricultural production and environmental suitability.

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Thank you very much for your kind attention!

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