CLIVET PROJECT WORKSHOP 30TH AUGUST - 2ND SEPTEMBER 2011, IRINGA & DAR ES SALAAM

EXPERIENCES ON HYDROLOGICAL MODELING WITH SWAT MODEL IN TANZANIA

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Presentation Outline

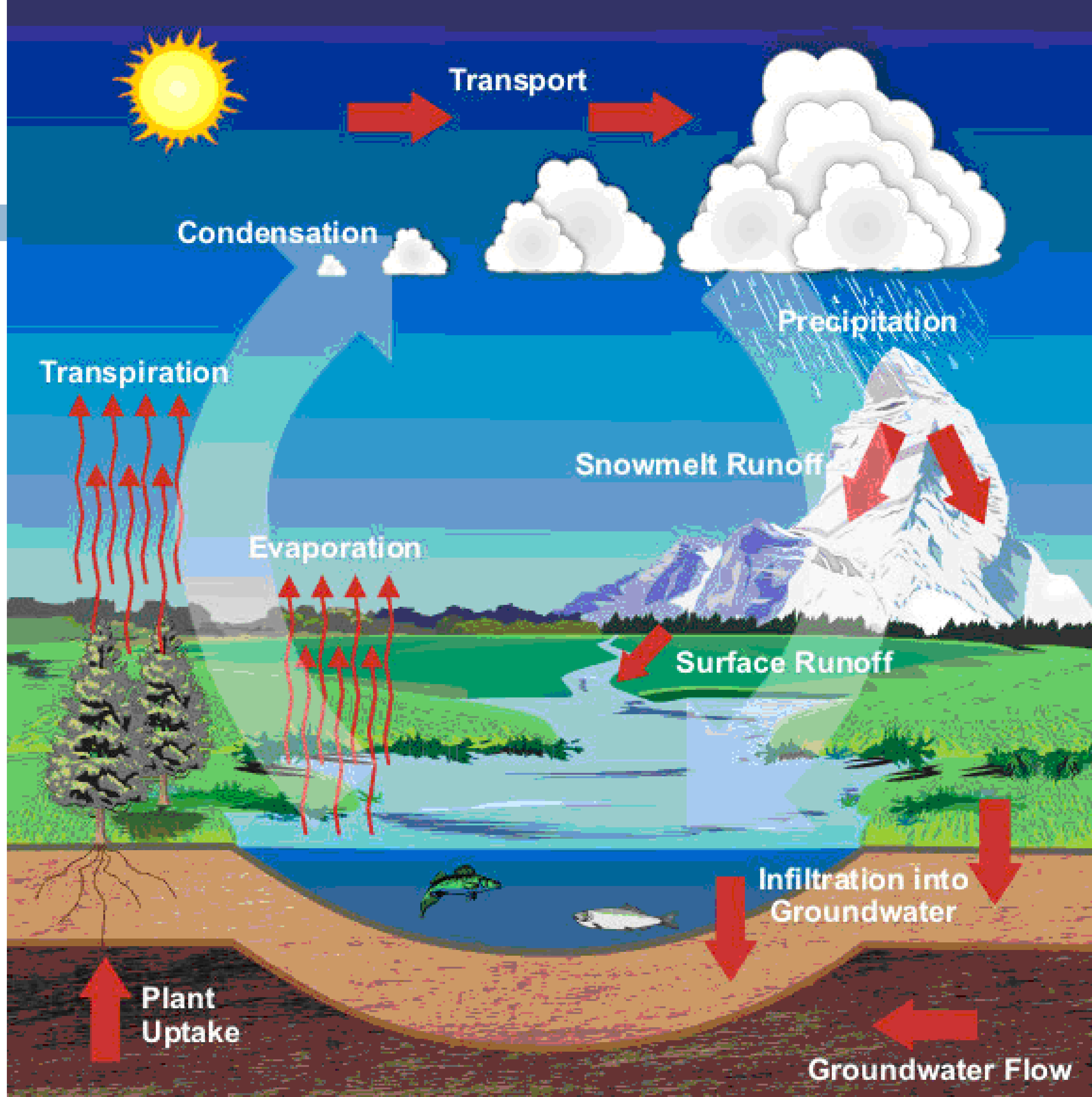
- Objectives of the Presentation
- Impact Related to Hydrological Characteristics
- Hydrological System
- Impact Assessment Concepts & Tools
- Hydrological & Hydraulic Modeling Concepts
- Sample SWAT Model Applications in Tanzania
  - Recommendations on Controls from Case Studies

Aims of the Presentation

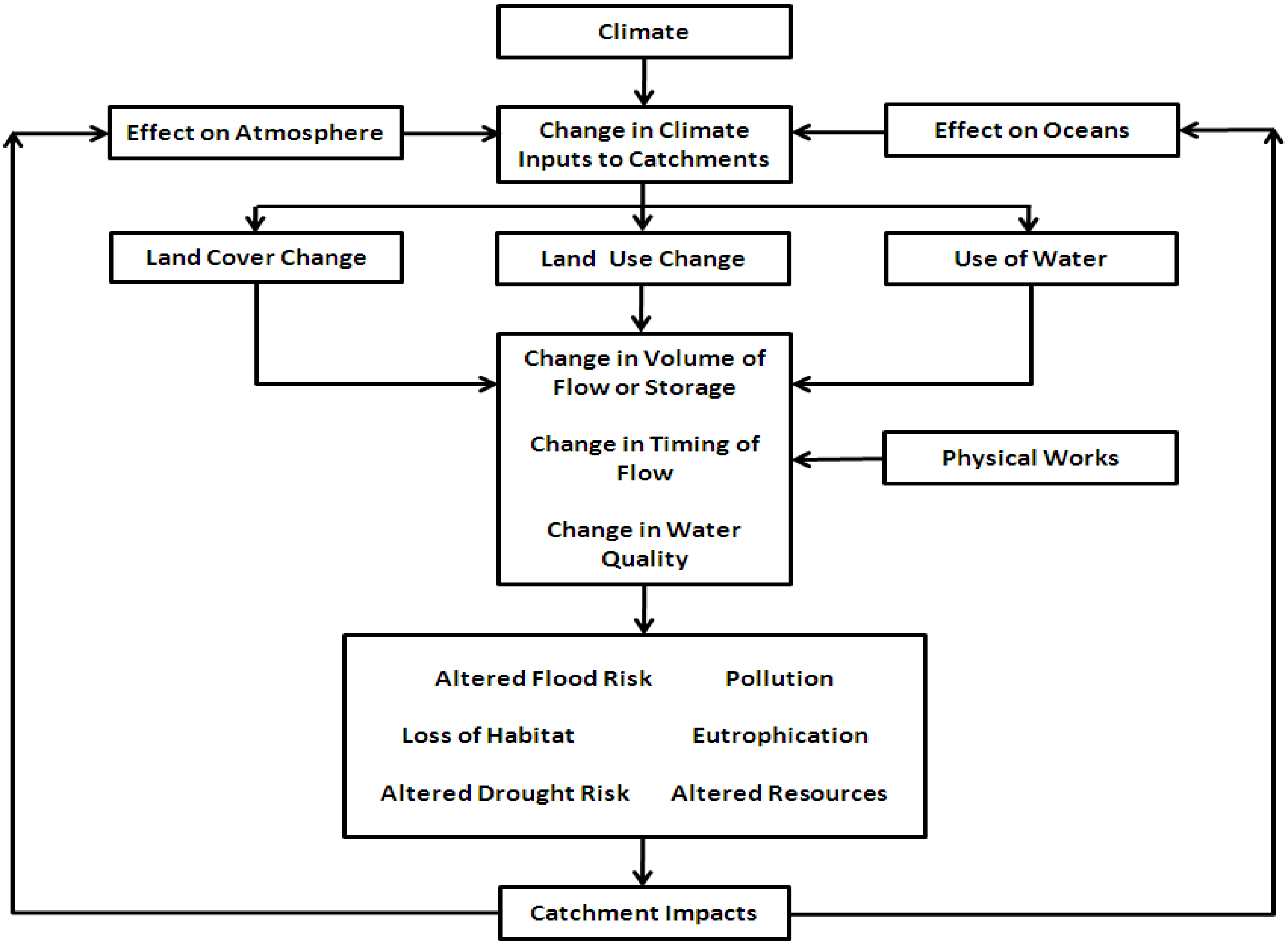
- Rudimentary inform a wide range of model users or stakeholders on the local capacity and challenges for impact assessment models (e.g. SWAT) in Tanzania

- Some experiences on SWAT & other tools are drawn in order to inform:
  - Capacity built on hydrological, management & impact models
  - Baseline model to address specific issues (e.g. extremes, agricultural water, food security, pollution) & for the measurement of the impact of objectives of the National Action Plan of Action (NAPA); ASDP; NSGRP/*Mkukuta*; *Kilimo Kwanza* initiative, etc.
  - Improvements that are needed in collection of data

Hydrological System



Hydrological Impacts Concepts



Tools for Impact Assessments

- Tools includes data, suite of models, expertise & other resources for impacts assessments:
- Operated within prescribed physical principles and management procedures to inform decision makers, who need to inform designated stakeholders
- The tools are used in managing or simulating the main or sub-components of the water environment:
  - Catchment hydrology: surface & subsurface water
  - Current/future water supply/demand; Op. rules

Need for Impacts Assessment Tools

- Understanding impacts of various drivers of change (e.g. population dynamics, land use change, climate change, etc.) on water resources quality & quantity, so that we can develop pragmatic mitigation or adaptation approaches
- Due to limitation of resources, one area of research to hydrological modelling is to test & validate the applicability of the models in data scarce catchments in Tanzania & in the region that were developed & tested in data rich developing countries

Need for Impact Assessments in Tanzania

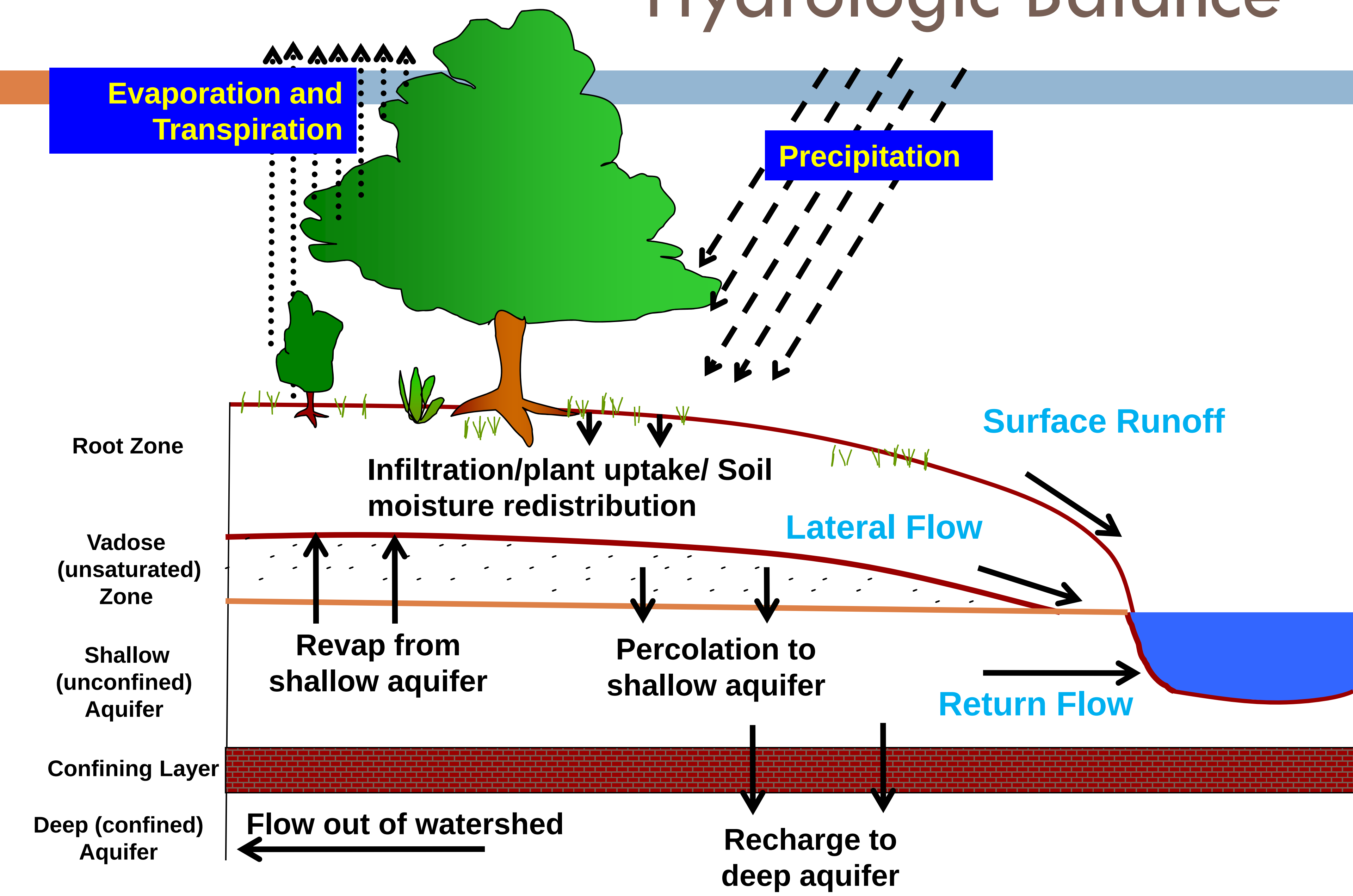
- Because of spatial variability of climate change impacts on water, We need to understand the scale better through high resolution based analysis and the local or social impacts

- Climatic extremes, such as floods and droughts, affect a large numbers of people because of:
  - Lack of planning
  - Increase of settlements in high-risk zones
  - An increase in poverty
  - Limited access to education, health, etc.

Hydrological Modeling Concepts

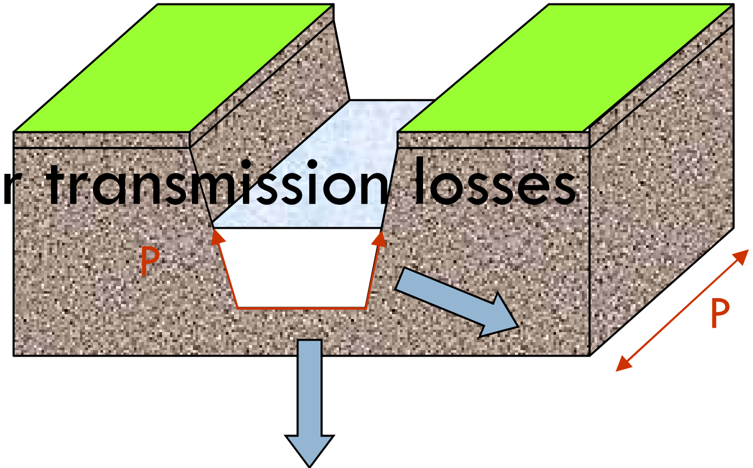
- Inputs (mainly rainfall and energy)
  - Weather elements (e.g. solar radiation; rainfall; wind speed; humidity; air temperature or pan evaporation)
  - Topographic, Land use/cover and soil maps
  - Point and Non-point sources of pollution
- Governing equations (WITH PARAMETERS):
  - 1-D to 3-D Richard's equation or its simplifications
- Outputs:
- Evapo-transpiration and pollutant loads
- River flow and subsurface water variables (moisture)

Hydrologic Balance

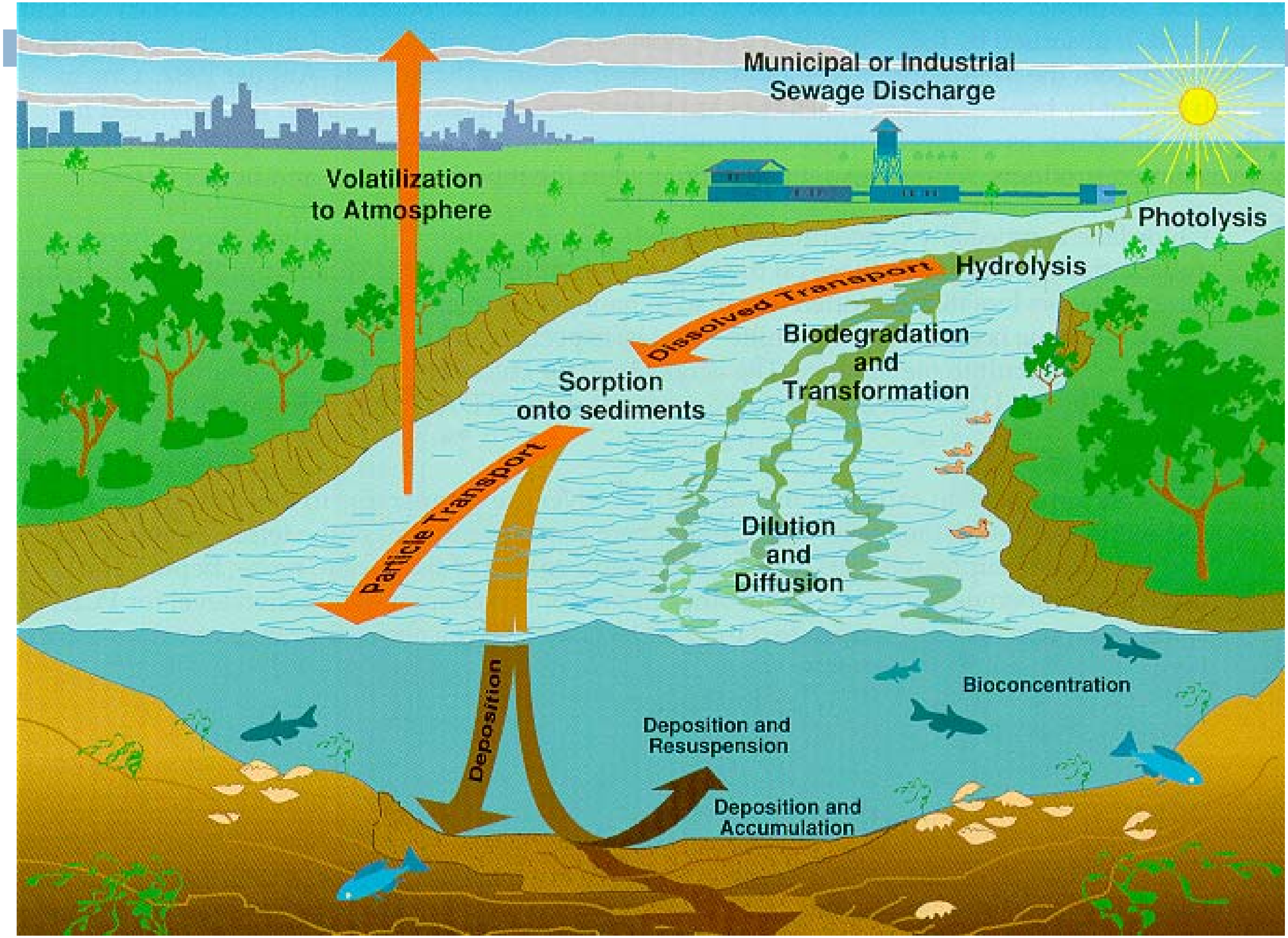


Hydraulic Modeling Concepts

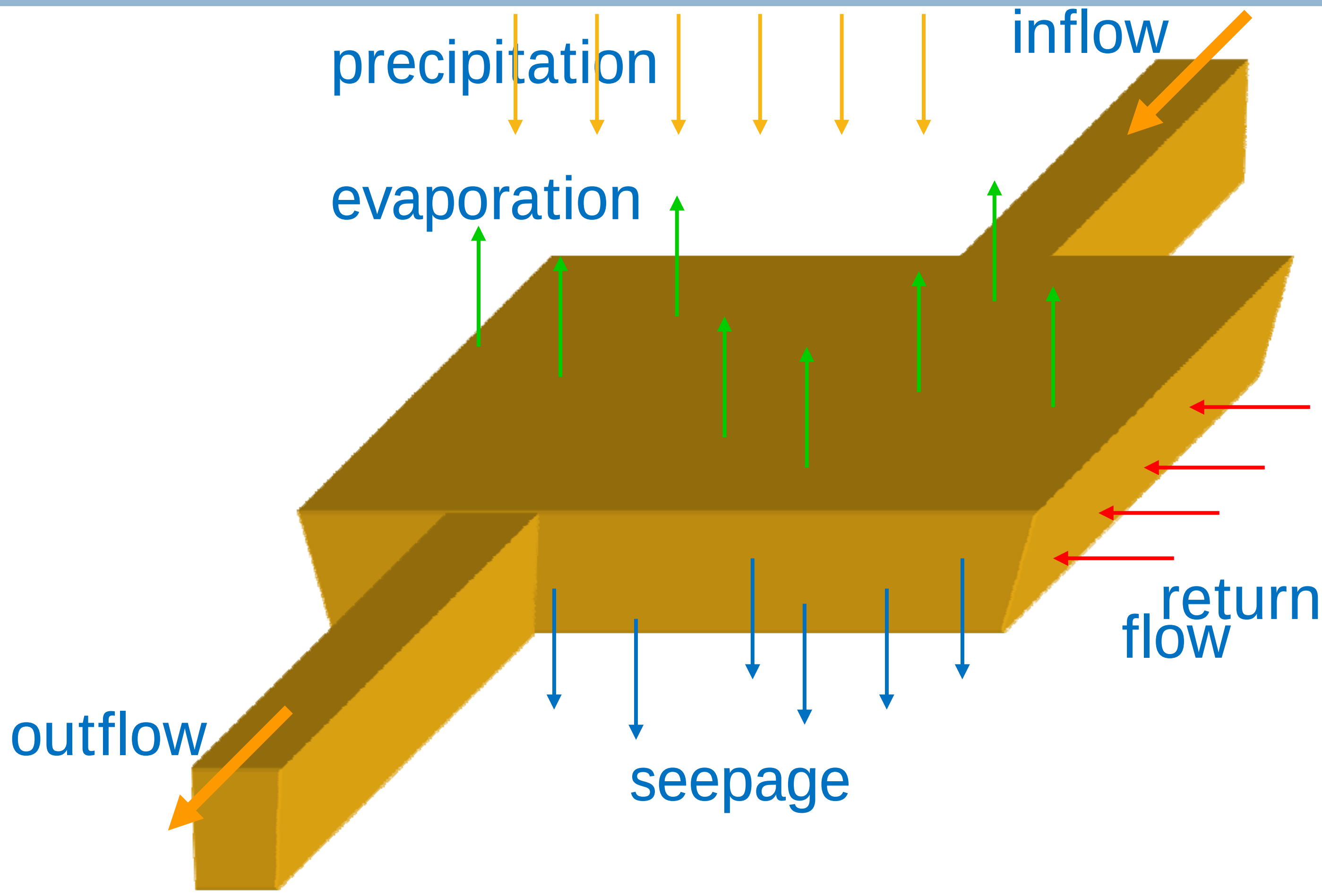
- Inputs
  - River network, reaches and bottom slopes data
  - River flow (rating curves) and river cross-section data
  - Point and Non-point sources of pollution
- Governing equations (WITH PARAMETERS):
  - 1-D to 3-D Saint Venant's equation or its simplifications
- Outputs:
- River or return flows & outflows or transmission losses
- Sediment yield or pollutant loads



Channel Processes



Reservoir Routing Concept



Department's Experiences on Tools

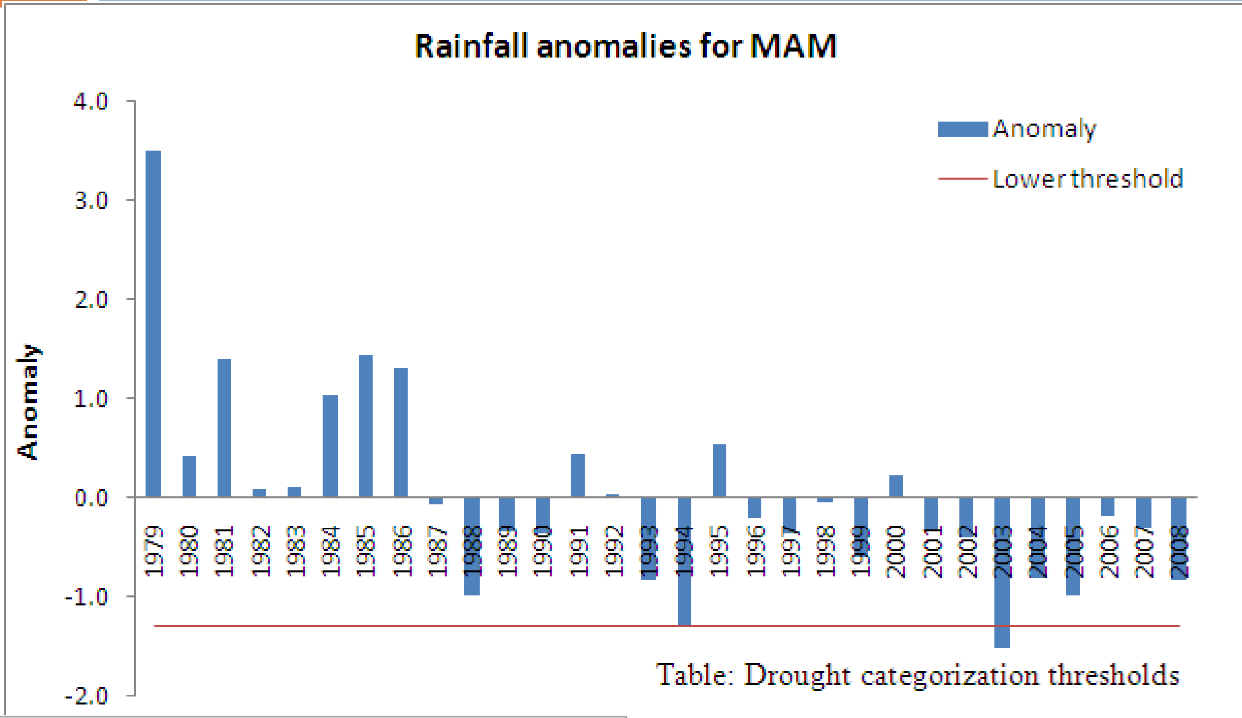
- Flood magnitude & risk quantification and mapping (e.g. Routing & Inundated areas):
  - HEC-HMS;HEC-RAS; HEC-ResSIM; HSPF
- Point & Non-point pollution quantification:
  - STELLA; QUAL2-E; HSPF; SWAT
- Environmental flows requirement:
  - BBM; Desktop Reserve Model

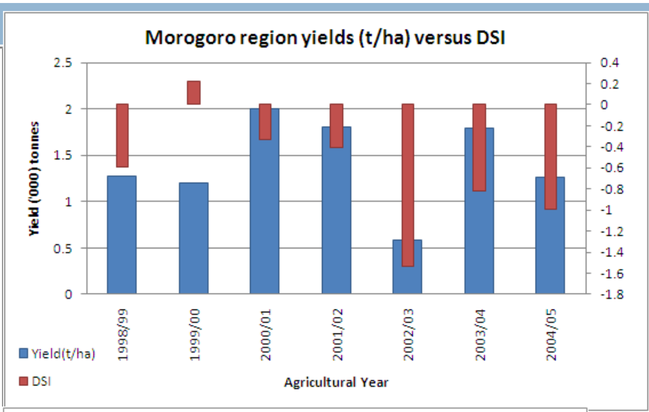
Department's Experiences on Tools

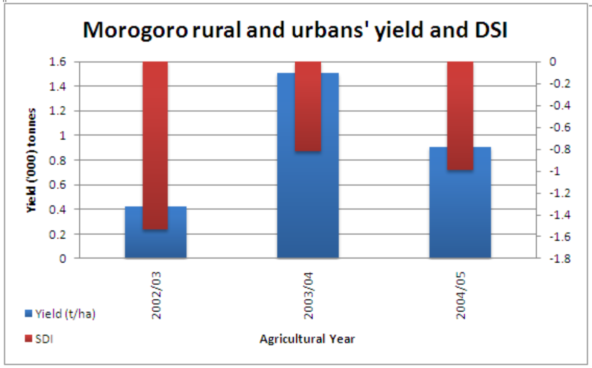
- Drought types, magnitude & risk quantification and mapping (e.g. Severities & Extents):
  - SPI; DSI; SWAT, ArcView; ArcGIS; Surfer

- Water resources quantification & allocation:
  - HSPF; MIKE SHE?; PITMAN; SWAT
  - WEAP (Scenario & planning model)
  - WAFLEX (Excel based water allocation model)

Drought Severity, Maize Yields & NDVI







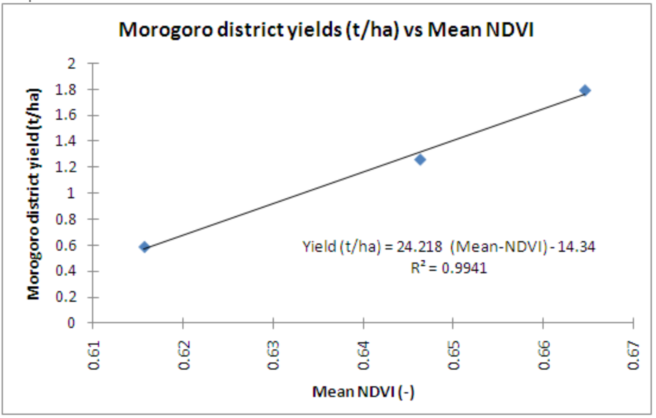


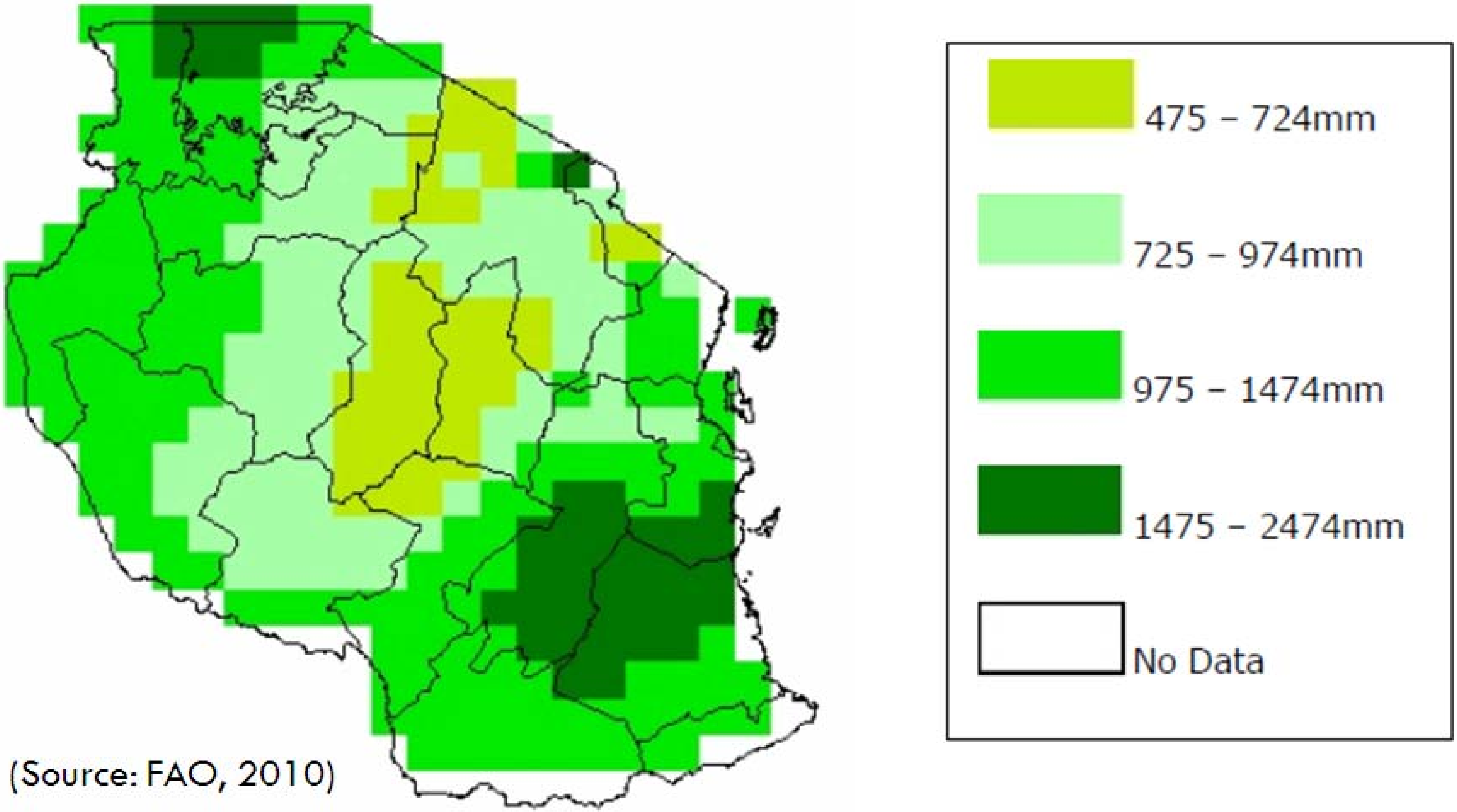
Table: Drought categorization thresholds

Percentage rainfall relative to mean	**Physical conditions**	**Estimated Anomaly Threshold**
> 175 Extremely wet	Extremely wet	> 1.41
> 150 Very wet	Very wet	> 1.11
125 Near normal	Near normal	0.53
100 Normal	Normal	0.02
75 Near normal	Near normal	-1.02
< 50 Severe drought	Severe drought	-1.84
< 25 Extreme drought	Extreme drought	< -1.84

Note: The estimated anomaly thresholds are only a guideline for the physical conditions. The percentage rainfall relative to mean was the driving factor for the physical conditions categorization and the anomalies were based on means and standard deviations for particular seasons or years of computation.

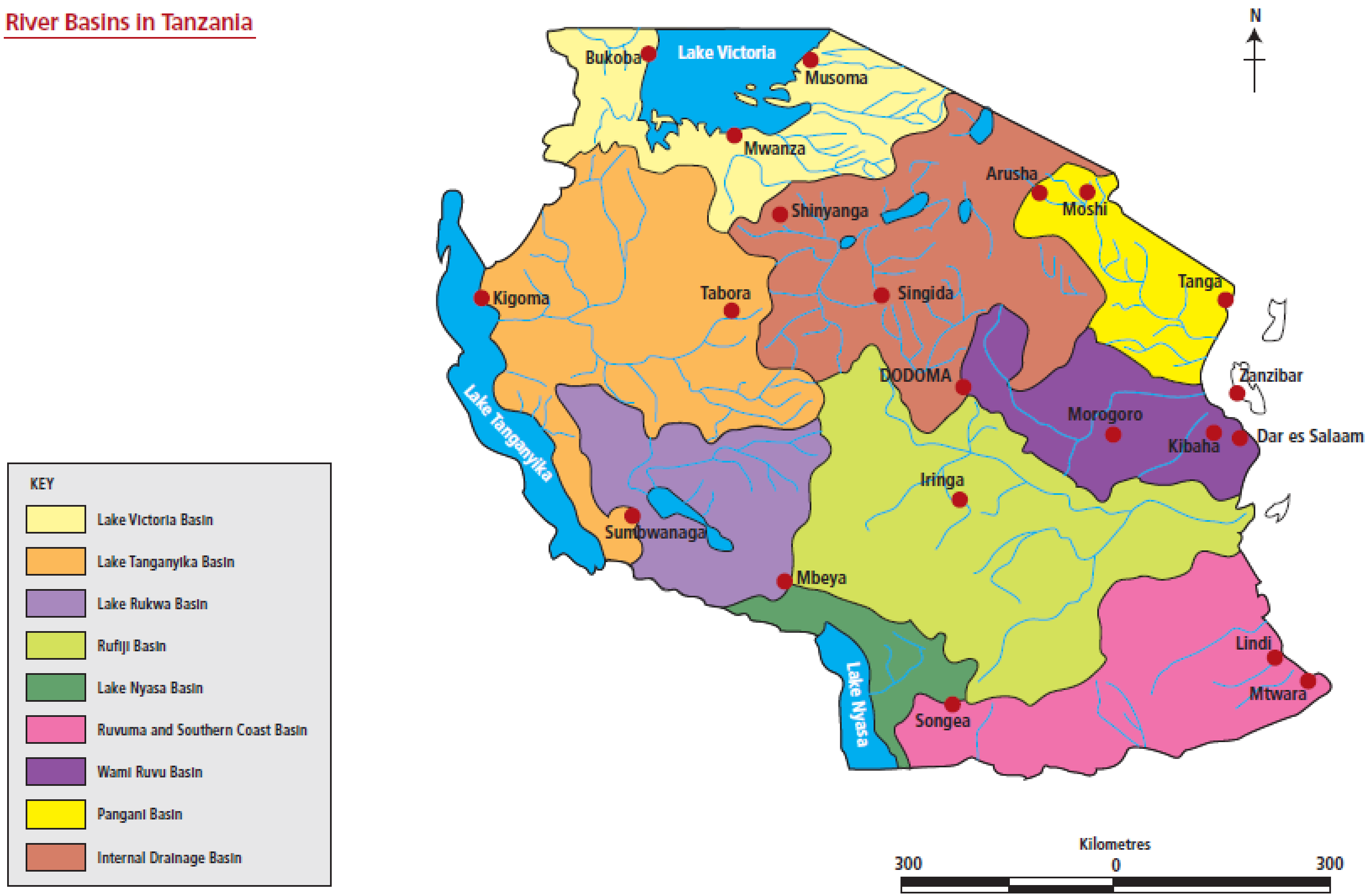
Agricultural Seasons in Tanzania

Annual Average Rainfall Distribution



(Source: FAO, 2010)

Drainage River Basins in Tanzania



Source: Ministry of Water and Livestock Development, Water Resources Division

Impact Assessments in Tanzania

- Some Projected Climate Change Impacts:
  - Increased frequency of heavy rainfall leading to higher risk of floods
  - Land under extreme droughts to increase, reducing ground water recharge
  - Reduced water quality in lakes and rivers (erosion transported pollutants)

SWAT Model in a Nutshell

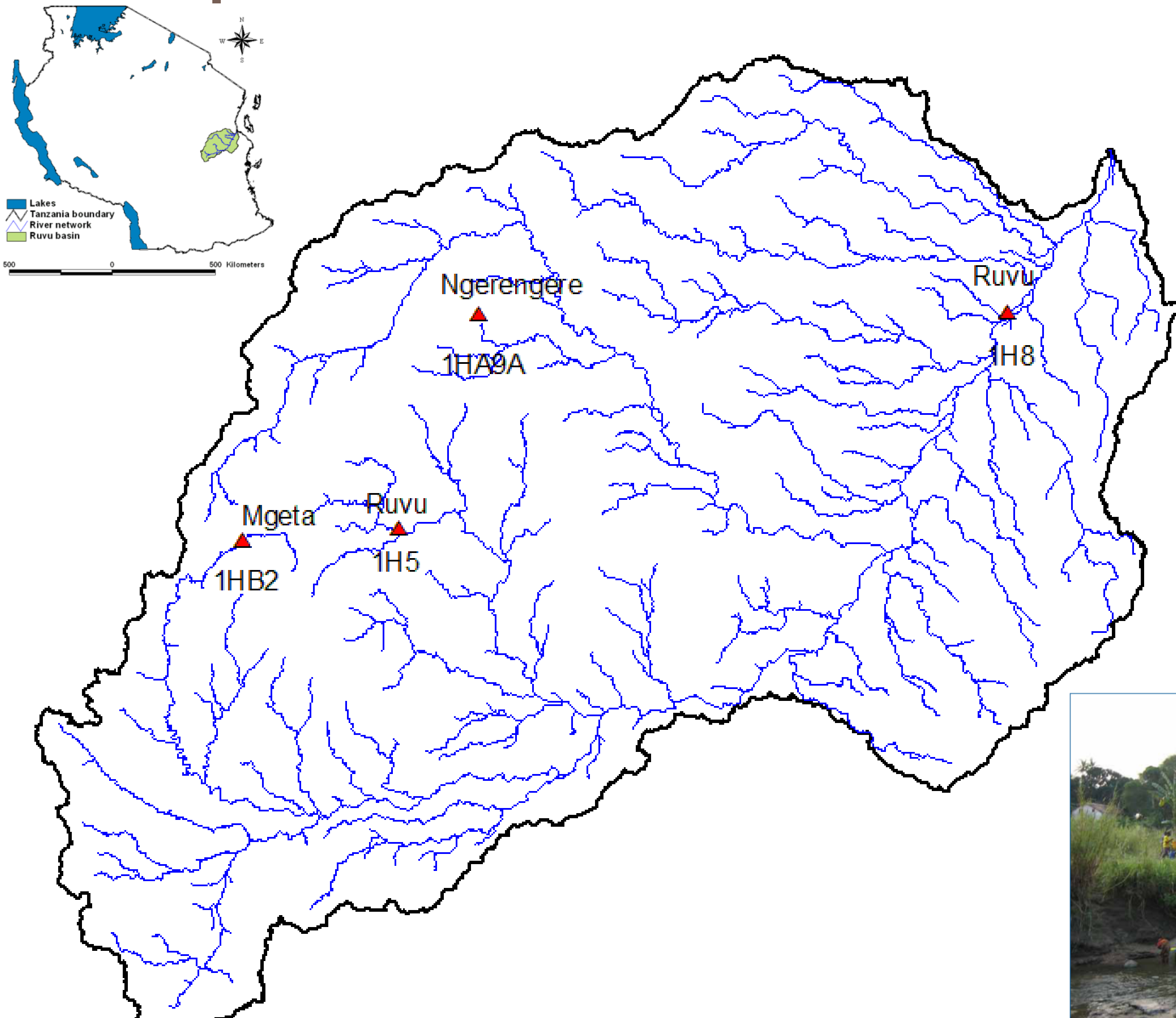
- Catchment scale model
  - Can predict the impact of land management practices (human activities) & climate change over time on : water, sediment & agriculture
- Model operation (AVSWAT; AVSWATX; ARCSWAT; MWSWAT) :
  - Physically based input
  - Long term simulations, Continuous time : Daily / hourly time step
  - Computationally efficient : Semi-distributed & Conceptual sub-models
  - Weather generator using monthly statistics of weather data: Filling of missing weather data

Sample SWAT Model Applications

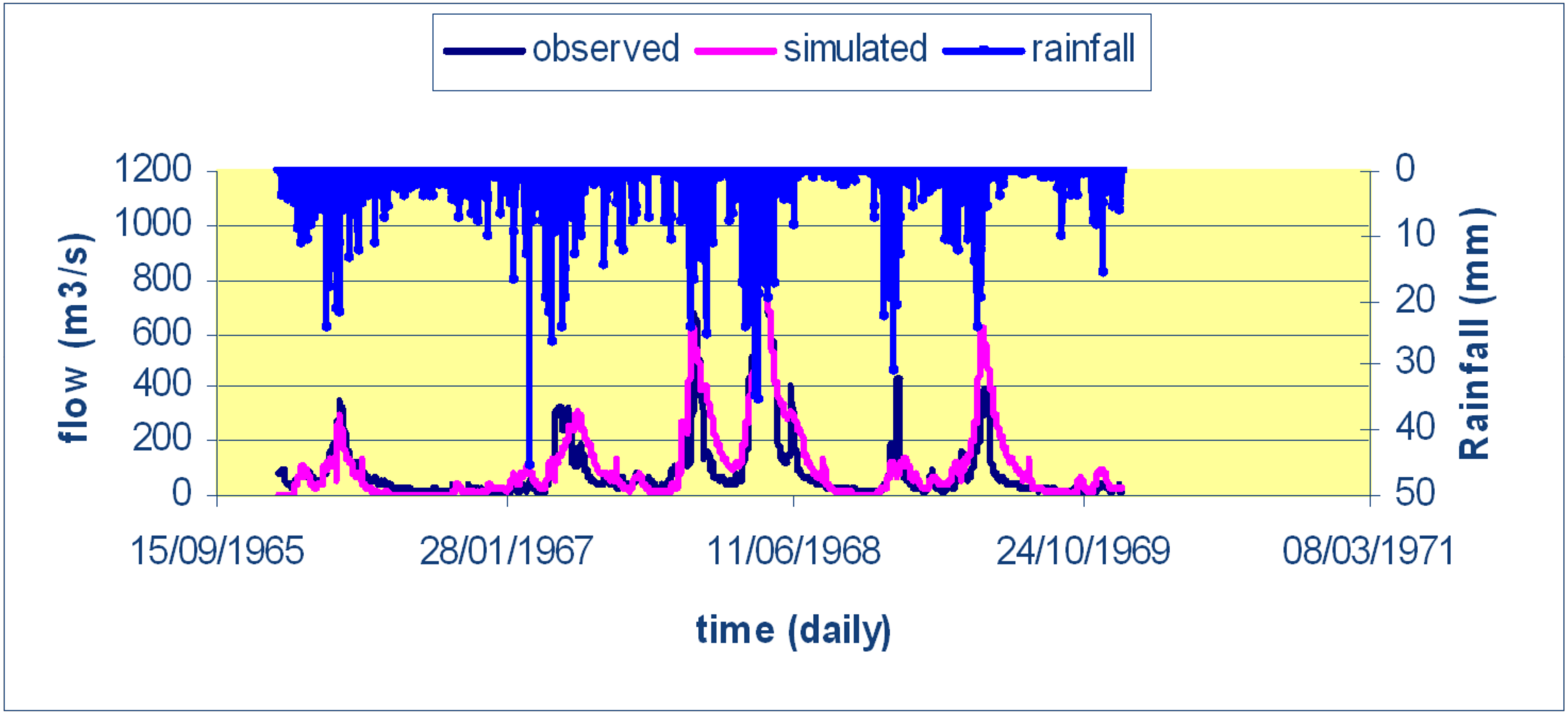
Sample SWAT applications at the Department of WRE

River Basin	Area (km^2)	Simulation Types	Mode	Model Structure	Time Step	Period	NSE (%)	Remarks on model controlling factors
Kagera at Kigali	13,691	Hydrology	Test or Prediction	Dominant	Monthly; Warm-up	1973-1984	Cal:63%; Val:51%	Weather data & Groundwater parameters were **very important**
Kagera at Kyaka	53,087	Hydrology & Sediment load	Test, Scenario & Impact on yields	Dominant	Monthly	1975-1988	Flow:50%; Sed:43%	Rainfall data, Surface water & Soil parameters were **very important**
Simiyu at Ndagalu	5,000	Hydrology	Test or Prediction	Dominant & Multiple	Daily	1976-1983	Cal:14%; Val:36% & Cal:13%; Val:41%	Rainfall data & Surface water parameters were **very important**
Ruvu at 1H10 (Mikula)	5,780	Hydrology & Land cover change	Test & Impact on streamflow	Dominant	Daily	1980-1984	Cal:48%; Val:43%	Rainfall data, Surface water, Soil & Groundwater parameters were **very important; Overestimated flows during extreme rainfall events**
Ruvu at 1H8 (Morogoro Road Bridge)	15,190	Hydrology & Climate change	Test, Scenario & Impact on streamflow	Multiple	Daily & Monthly	1966-1972	Cal:64%; Val:52% & Cal:73%; Val:58%	Rainfall data, Surface water, Soil & Routing parameters were **very important; Peaks were underestimated;**
Ruvu at 1H5 (Kibungo)	420	Hydrology & Agricultural droughts	Test or Prediction	Dominant	Daily & Monthly	1977-1984	Cal:42%; Val:42%	Rainfall data, Surface water, Soil & Groundwater parameters were **very important; Overestimated flows during extreme rainfall events**
Kihansi at NC3 (Kihansi)	581	Hydrology & Land cover change	Test & Impact on streamflow	Dominant	Daily	1997-2004	Cal:58%; Val:89%	Weather data, Surface water & Soil parameters were **very important; Peaks were underestimated**

Sample: Ruvu Basin Streamflow Impact



Observed & Simulated daily flows at 1H8



Lessons Learnt

- SWAT model particularly on its runoff component has shown that a **similar** set of important parameters can be identified by using either observed data or without it based on sensitivity analysis results
- This result suggests that SWAT model can be used in un-gauged catchments for hydrologic prediction
- Optimized parameters have physical meaning & can be related directly to hydrological controlling factors
- Our capacity at WRED can be a framework for exploring challenges & opportunities in WRM

Lessons Learnt and Challenges

- Amazingly powerful tools are available:
  - Data inputs & field validations are the main constrains
  - Great time is needed for model familiazation & calibration
- Despites data and resources constrains:
  - Satisfactory to good results were obtained
  - Model parameters had physical meaning
- Set goals for impact assessments in Tanzania:
  - Climate change scenarios & their projected impacts
  - Integrated tools for physical, social & policy integration


The End !!!
Thank you!
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