WORKSHOP REPORT

APPLICATION OF SOIL AND WATER ASSESSMENT TOOL (SWAT) FOR MODELLING HYDROLOGICAL OUTPUTS IN TANA RIVER BASIN

Institute of Climate Change and Adaptation (ICCA), 13- 17 February 2017

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Preface

WISE-UP to climate' is a project that demonstrates natural infrastructure as a 'nature-based solution' for climate change adaptation and sustainable development. This report presents a summary of the proceedings of the stakeholder-training workshop on the application of Soil and Water Assessment Tool (SWAT) for modelling hydrological outputs in Tana River basin that took place in Nairobi Kenya from 13th to 17th February 2017. The workshop was hosted by the African Collaborative Center for Earth System Sciences (ACCESS) and attended by stakeholder groups working in the Tana River basin. The workshop served both as a capacity building and a technical project implementation activity where partners and potential users WISE-UP end product were meant to gain skills on water resources modeling and the value of the data collected by the individual stakeholder groups within the river basin.

The main goal of this training was to build capacity of key stakeholders of the WISE-UP to climate project in the Tana River basin on the climate and hydrological modelling techniques using the Soil and Water Assessment Tool (SWAT). The participants were also trained on the preprocessing of the datasets to input in to the SWAT model for particular sub-basins within the Tana catchment and analysis of the SWAT outputs from those specific sub basins within the Tana Catchment for the period 1979 to 1985. The model configuration and validation was carried out by International Water Management Institute (IWMI) a key partner in the WISE UP project who have over the last four years worked on the Eco-hydrology of the Tana river catchment.

The SWAT training workshop was composed of participants with basic knowledge of GIS from various institutions namely:- Kenya Electricity Generating Company (KENGEN), Ministry of Water & Irrigation, Tana and Athi Development Authority (TARDA), National Irrigation Board (NIB), Kenya Wildlife Service (KWS), Water Resources Management Authority (WRMA), and Kenya Meteorological Department (KMD).

The SWAT training workshop was preceded by a brief official opening ceremony, which was presided over Prof. Eric Odada, Director, ACCESS. The participants were guided through a brief introduction, mentioning their area of expertise, the institution they are representing and their expectations that led to an outcome mapping for the workshop.

The training comprised of three sessions. There were lectures, hands on training and individual presentations of lesson learned. The first session was dedicated to general overview of SWAT Modeling Tool (Arc SWAT, as an extension in ArcGIS Software), its data input requirements, preparation and model setup for Tana River Basin in Kenya. This also included display of catchment delineation, land use, soil data and weather data products, simulations, model calibration and validation. The second session was on the application of ArcSWAT for modeling hydrological outputs in Tana River basin using the preprocessed data. The inputs to the ArcSWAT model included the (DEM), land use and soil raster files and climate data on daily time steps for the period 01/01/1979 to 31/12/2014. The final session was dedicated to the participants to give their respective subbasin output presentations, insights, challenges, applications of the SWAT model at the work places and future recommendations.

The SWAT which is a physically based model proved to be computationally efficient tool that can be applied by the hydrological community in the watershed delineation. It can also be used in the analysis of the impacts of land management practices on water, agricultural chemical yields, sediment in large, complex watersheds with varying land use, soil and management conditions over long periods of time.

The participants appreciated timely organization of the training. They however wished that more emphasis were done on the data preprocessing since it contained the core part of running the SWAT model. They also wished that more time could be allocated for the whole training since the tool was new to them. They further promised to share the skills learnt with their colleagues at their respective work places and requested an establishment of user forums and also involvement of stakeholders to share the knowledge and pose questions.

The training would not have been successful without the support of the IWMI in the initial data preparation by Tracy Baker and Aditya Sood; ACCESS secretariat, Institute of Climate Change

Adaptation (ICCA) at the University of Nairobi.

Acronyms

ACCESS	the African Collaborative Center for Earth System Science
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
ArcSWAT	ArcGIS Soil and Water Assessment Tool
AVSWAT	ArcView Soil and Water Assessment Tool
AWC	Available Water Capacity
CN2	Curve Number of Moisture Condition II
DEM	Digital Elevation Model
EPCO	Plant Uptake Compensation Factor
ESCO	Soil Evaporation Compensation Factor
FAO	Food and Agriculture Organization
GDEM	Global Digital Elevation Model
HRUs	Hydrological Response Units
IUCN	international Union for Conservation of Nature
IWMI	International Water Management Institute
KENSOTER	Kenya Soil and Terrain
MWSWAT	Map Window Soil and Water Assessment Tool
OV_N	Manning's "n" Value for Overland Flow
PCs	Personal Computers
PET	Potential Evapotranspiration
QGIS	Quantum Geographic Information System
QSWAT	QGIS Soil and Water Assessment Tool
SURLAG	Surface Runoff Lag Coefficient
SWAT	Soil and Water Assessment Tool
TARDA	Tana and Athi Rivers Development Authority
UTM	Universal Transverse Mercator
WGEN	Weather Generator

WISE-UP to Climate Change: Water Infrastructure Solutions from Ecosystem Services Uner Pinning Climate Resilient Policies and Programmes

WRI	World Resource Institute
WRUA	Water Resource Users Association, (Kenya)

1. Introduction

The numerous challenges brought about by climate change and rational/ sustainable use of water resources require a multidisciplinary approach to address. A fundamental step to adapting to the impacts of climate change is the ability to provide reliable climate and hydrological data as well as the tools and software for analyzing the data to support adaptation planning.

However, the majority of the relevant institutions do not have access to reliable and robust climate data that are useful for supporting adaptation planning. There is also the lack of technical capacity within most of our institutions to develop and manage high-resolution climate scenarios and related impacts and vulnerability assessment products for adaption planning.

It has emerged from the recent engagements with the key stakeholders of the WISE-UP project in the Tana River Basin that there is no consensus on which of the climate and horological datasets, tools to analyze these datasets, and outputs from these tools, offer a universally acceptable product for shared decision-making, even where similar tools (e.g. SWAT model) are used to derive the products. The stakeholders also expressed a need for capacity building in climate and hydrological modelling techniques.

This training workshop was therefore organized as part of capacity development for stakeholders of the WISE-UP to climate project in the Tana River basin. The overarching aim of the WISE-UP to climate project is to *"Increase adaptive through recognition and inclusion of the ecosystem services provided by natural infrastructure in investment strategies for climate change adaptation and through optimization with built infrastructure planning and development"*

2. Objectives of the workshop

The overall objective of the SWAT training workshop was to enhance the existing capacity of stakeholders for the WISE-UP project in Tana River basin to develop hydro climatic products, based on a common understanding of the data issues and constraints, to support climate change adaptation planning in water sector, using the best available data and tools and methods.

The specific objectives/expectations of the training was enable the participant understand the basic functions of SWAT model, enable them to develop competence in data preparation for SWAT model application and to be able to generate water yields/scenarios using SWAT model.

3. Workshop Methodology, data and tools

The training workshop focused primarily on hands-on training sessions on how to preprocess the datasets required in the running the ArcSWAT model and the entire step by step running process of the model. Running SWAT model begins from setting up the SWAT project for the specific area of study, Watershed Delineation, Hydrological Response Units (HRUs) Analysis, Writing Input Tables and finally SWAT Simulation. The other aspect focused on the analysis and visualization of the SWAT outputs. Resource persons made power point presentations on relevant topics prior to hands on training on the application of SWAT for modelling hydrological outputs with specific reference on in Tana River basin.

The datasets used to run the SWAT model to the end for the period 01/01/1971 to 31/12/2014 for the whole Tana River Basin during the hands on exercises were already preprocessed and only a theoretical presentation on the preprocessing procedures as carried out by IWMI was made. Later on there were hands on exercises on the preprocessing of the datasets for the specific sub basins within the larger Tana River basin.

The preprocessing on the ArcGIS platform begun with downloading the DEM raster file from the Global DEM – GDEM and extracting for the individual sub basin. The DEM was used for delineation of the catchment and definition of the stream network. The land use and soil shapefiles were downloaded from http://www.waterbase.org/download_data.html. They were clipped to individual sub basins, converted to raster files and projected to Arc 1960 UTM Zone 37S. All the preprocessed datasets together with the prepared weather data and the weather generator were used to run the SWAT model and produce the output in monthly format and other necessary reports.

4. Training output

By the end of the SWAT training workshop, the participants were expected to gain skills and knowledge on:-

i. Basic functions of the SWAT model
ii. Data preprocessing for Arc SWAT model application
iii. Generation of water yields/scenarios using SWAT model
iv. Model calibration and validation of the SWAT model

During the official opening, the Director ACCESS spoke on the role of water, energy and food together in a "nexus" framework and underscored management approaches that focus on increasing resource use efficiencies, which in turn reduce environmental pressures and maximize the benefits from scarce resources. *Here is a full extract of Prof. Odada's speech*:

Distinguished Participants, Dear ACCESS Colleagues, Achieving water, energy and food security for every Kenyan is one of the greatest challenges the Government is facing to-day. ACCESS and its consortium partners like IUCN recognizes that water, energy and food are increasingly interrelated. Therefore considering water, energy and food together in a "nexus" framework is both necessary and forward looking.

Such an approach focuses on increasing resource use efficiencies, which in turn reduce environmental pressures and maximize the benefits from scarce resources. A nexus approach can also produce benefits a cross sectors through cooperation and can help with identifying different interactions between interdependent social and environmental systems. Despite this, the strong linkages between water, energy and food are seldom understood and are rarely incorporated in the development of county and national water, food or energy security strategies.

The nexus is calling for broad involvement of stakeholders to collectively work toward sustainable development. The purpose of this SWAT Training Workshop, therefore, is to help you develop analytical systems approaches as pathway or platform to accelerate water governance in the Tana River Catchment. Its specific aims are to help you develop analytical systems approaches necessary for building water, energy and food management capabilities in your various institutions by obtaining needed modelling tools, practices and policies. In addition, the workshop will also help you build management capabilities and develop peer relationships across water, energy, food and nature conservation within the various sectors operating in the Tana River Catchment Basin.

In conclusion, understanding the nexus is needed to develop policies, strategies and investments to exploit synergies and mitigate trade-offs to meet increasing demand without compromising sustainability. The nexus perspective thus helps to move beyond silos and ivory towers that preclude interdisciplinary solutions. It opens the eyes for mutually beneficial responses and the potential of cooperation. We need to think and act interlinked to realize direct and indirect synergy potentials. It is thus important to incorporate the nexus in the County, National and Regional planning activities focusing on water, food or energy.

It is now my pleasure and honour to declare this SWAT Training workshop officially open, and thank you for your kind attention.

Day 1: General Overview of the SWAT model

5. Hydrological modelling and application lectures

After the official opening of the workshop, the participants stated their areas of expertise and expectations of the training. The first lecture to introduce the training was on general overview of the SWAT model.

5.1 General Overview of the Soil and Water Assessment Tool (SWAT model by *Eugene Mwandoe Mnyamwezi, Ministry of Water and Irrigation*

SWAT is a wide-ranging model that can be applied to predict 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. It requires a diversity of information in order to run. Due to its variety data requirements, novice users may feel a little bit overwhelmed when they first begin to use the model.

There are different types of SWAT models that can be downloaded freely from the internet. There is the QSWAT that works on the QGIS platform and the MWSWAT that works on the Map Window interface. The QGIS and the Map Window are free sources. There is the Arc SWAT that runs on the ArcGIS platform. ArcGIS is however commercial and therefore limits the usage of the Arc SWAT. In this training the ArcGIS was provided and therefore Arc SWAT was used in the training.

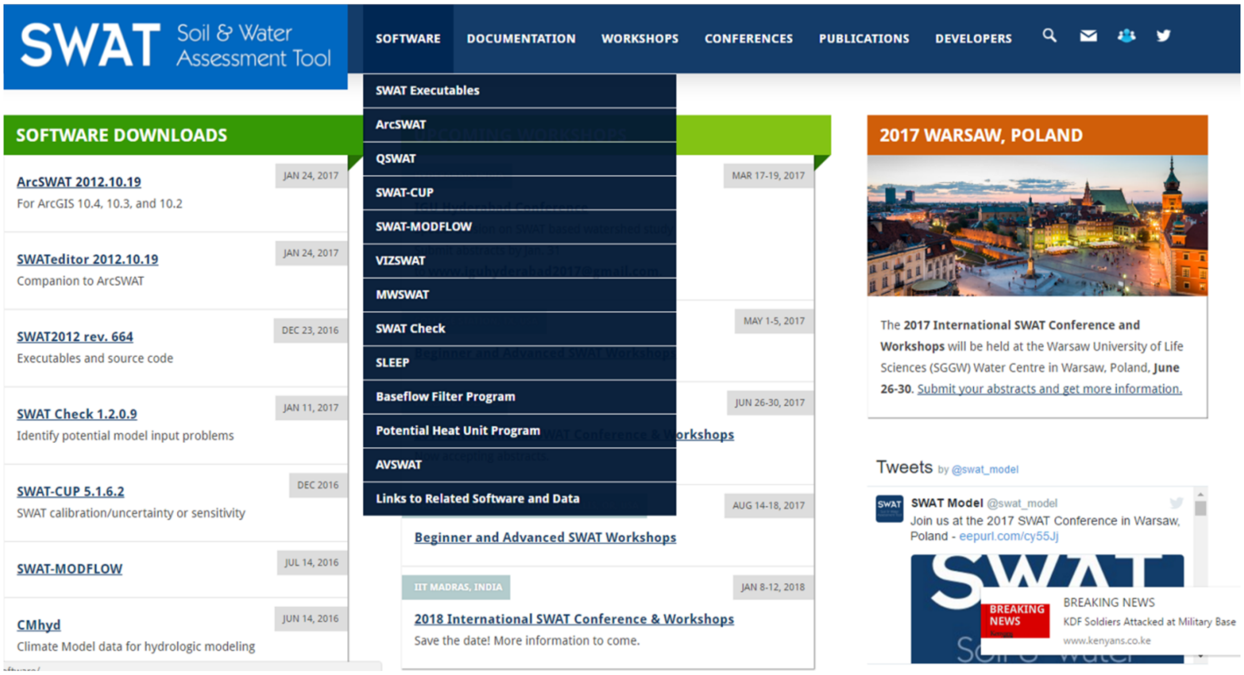

Figure 1: GIS interfaces that are compatible with SWAT: http://swat.tamu.edu/

5.1.1 SWAT data requirements

To run the SWAT model, there are specific datasets with correct format that are required. These datasets include: Digital Elevation Model (DEM), Land Use and Soil. SWAT also requires weather data (Precipitation, Temperature -- both minimum and maximum, solar, wind and relative humidity) on daily time steps.

For simulation, a watershed is subdivided into a number of homogenous sub basins (HRUs) having unique areas in land cover, soil and management within the sub basin. The loading and movement of runoff, sediment, nutrient and pesticide loadings to the main channel in each sub basin is simulated considering the effects of several physical processes that influence the hydrology.

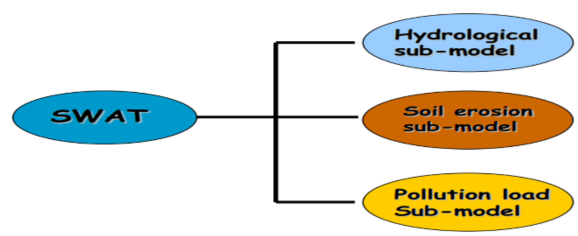

Figure 2: SWAT Process Models

The SWAT user's manual, version 2000 (Neitsch et al., 2002) can be downloaded from the SWAT website http://swat.tamu.edu/documentation/2012-io and referred to for more details about the capabilities of the SWAT model.

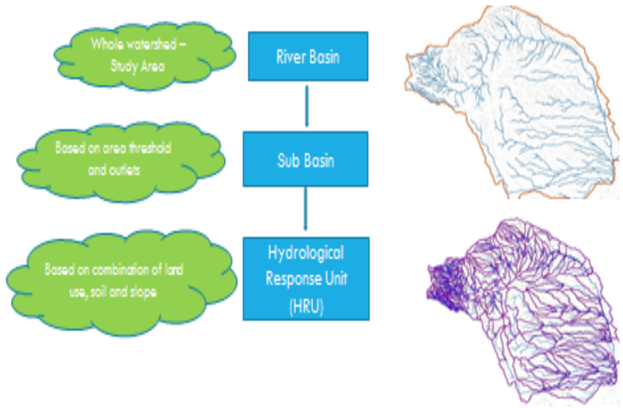

Figure 3: SWAT - Spatial Hierarchy

5.1.2 SWAT model installation and system requirements

The aim of this session was to help the individual participants who brought their Personal Computers (PCs) that have genuine ArcGIS to install the ArcSWAT that was to be used during the training. Those who didn't bring their PCs were helped in locating the files and directories of the SWAT inputs ready for the hands on exercise of running the SWAT model and making it easier to navigate around. This session was also used to copy the correct files to be used during the hands on work to the individual PCs and desktops. This exercise was aided by the facilitators.

5.2 Pre-processing Tana Basin Data for SWAT model application; *DEM, LandUse/LandCover Data, Soil data and Climate data by Dickens Odeny, National Museums, Kenya*

The dataset requirements for running SWAT model include: Digital Elevation Model (DEM) data, Land use data, Soil data and Weather data. For the preprocessing process to be successful and lesser complicated for the SWAT model users, the basic knowledge and skills in GIS software are key.

The dataset format that is accepted by the SWAT is the grid format. Determination of the UTM Zone location for the specific Watershed is key and for the case of the Tana River basin Arc 1960 UTM Zone 37S was used. This projection and transformation of the coordinate system is only successful if the Grid file has a defined coordinate system. If this is not the case, then definition of the coordinated system is necessary to allow the projection and transformation process. The projection and transformation of the coordinate system is necessary for the DEM, LandUse/LandCover and Soil grid files.

5.2.1 Pre-processing DEM

Sources of the DEM include, Global DEM – GDEM, Global Land Cover Facility, etc., to check the spatial reference of the DEM, it is imported on the ArcMap viewer.

5.2.2 Pre-processing soil data

Sources of Soil Data include, KENSOTER, http://www.waterbase.org/download_data.html etc., The Soil layer attributes can viewed by loading the soil later map on the ArcMap and oppening the attribute table. This session was done through a power point presenation and some hands exercises. The participants loaded the alredy prepared soil data and were able to view the soil layer attributes for the Tana River basin. For the soil layer to be used in the SWAT model it has to be in grid format.

A look up table for the soil dataset is created by exploring the soil data for the watershed (Tana River Basin and FAO/Global soil data. A new attribute (Character- text) to the soil layer of the watershed is added and assigned values to each soil texture.

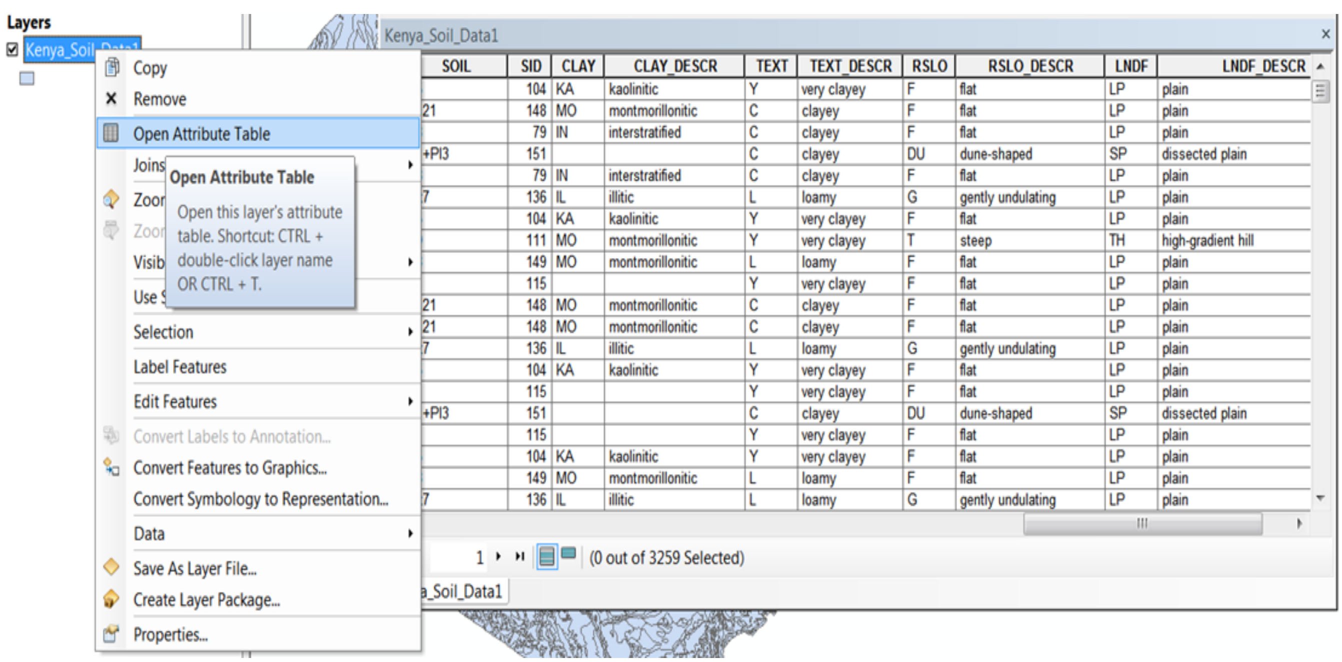

Figure 4: Soil Layer Attributes

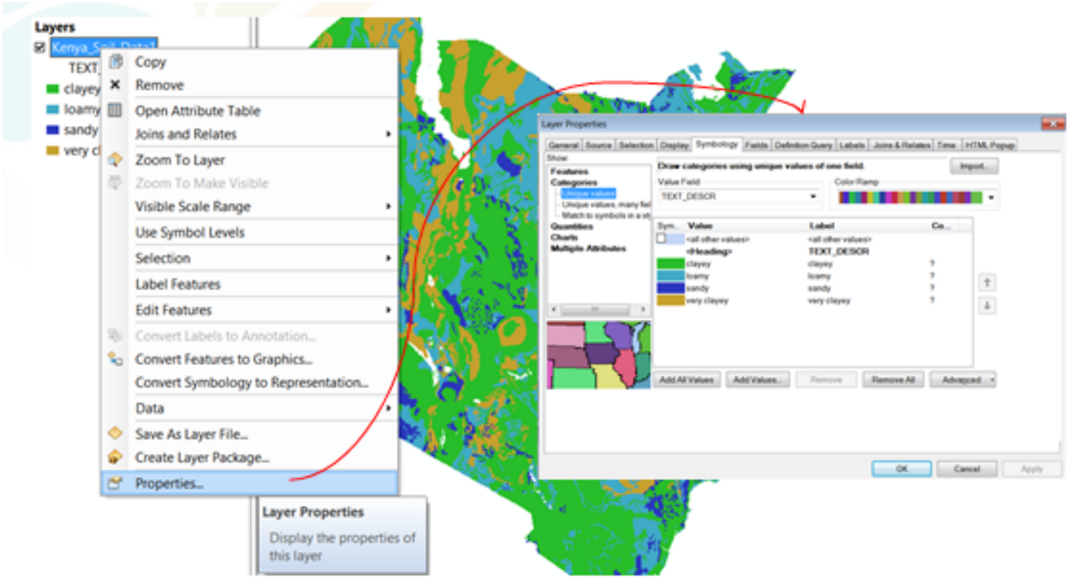

Figure 5: Visualizing the spatial distribution of Soil

5.2.3 Pre-processing of landuse data

Sources of Landuse Data/Layer are Satellite images – classification, World Resource Institute (WRI), FAO, Local Institutions, etc.

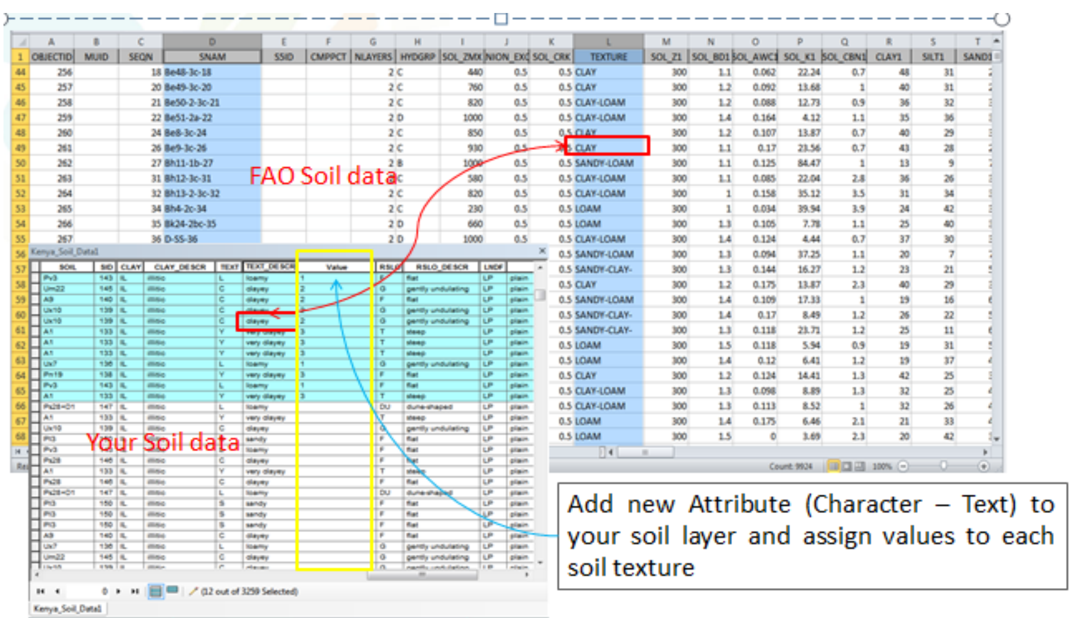

Figure 6: Watershed soil data and FAO/ Global soil data

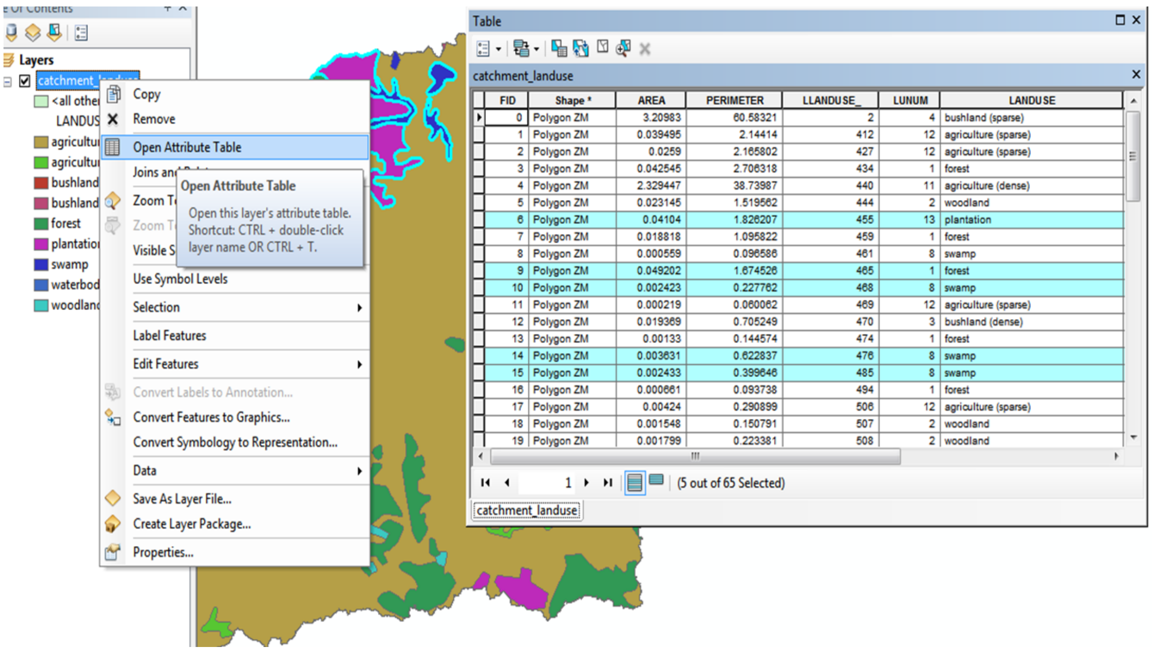

Figure 7: Checking LandUse attributes

The landuse classes for the watershed need to match with the SWAT landUse codes and a lookup table prepared.

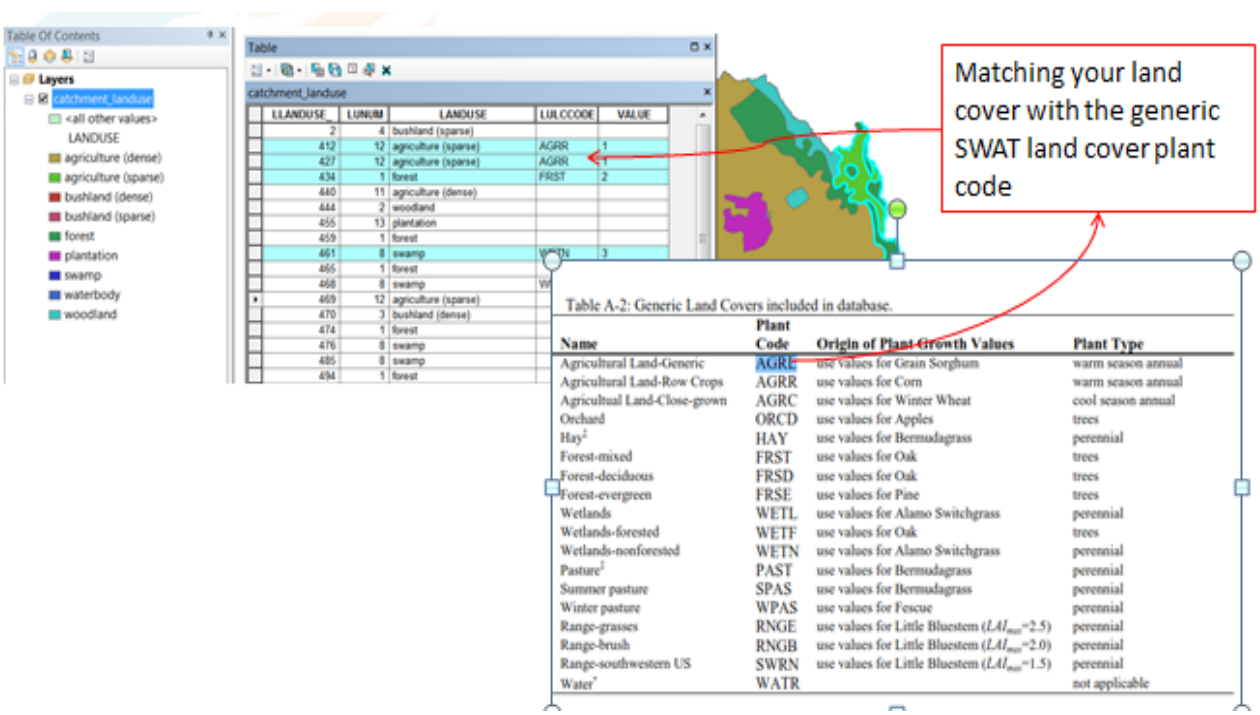

Figure 8: Matching the watershed landuse classes with SWAT landuse codes

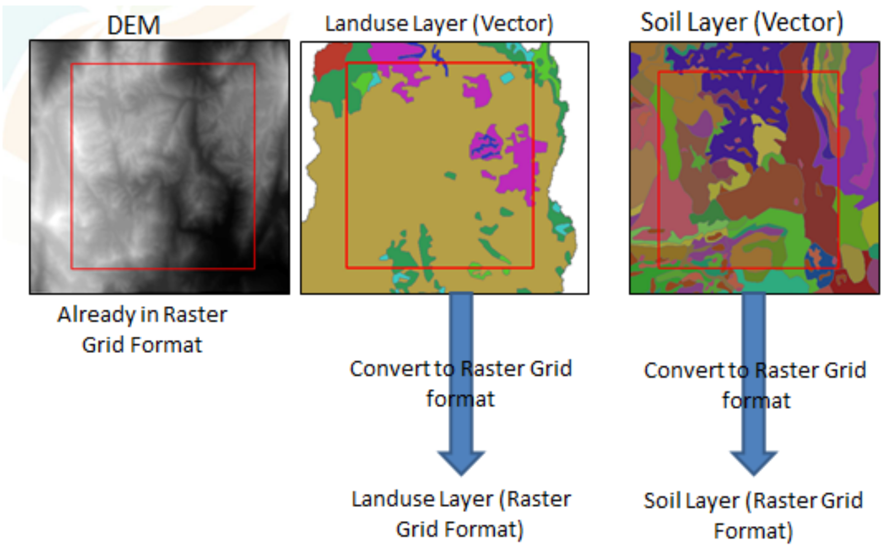

Figure 9: Creating Subset and Conversion of formats

5.2.4 Creating Subset and Conversion of formats

With a larger DEM raster file and larger soil and landuse maps, it is necessary to create a subset of these files and convert them in to grid formats. This is done through clipping/ masking to the extent of working area.

5.2.5 Pre-processing of weather data

The weather data that is used in running the SWAT model are Temperature (degree C), Precipitation (mm/day), Wind speed (m/s), Solar radiation (MJ/m) and Relative humidity (fractional). In creating the text files of the weather location/ station information, correct georeferencing of the location of the weather station is necessary with the required formatting.

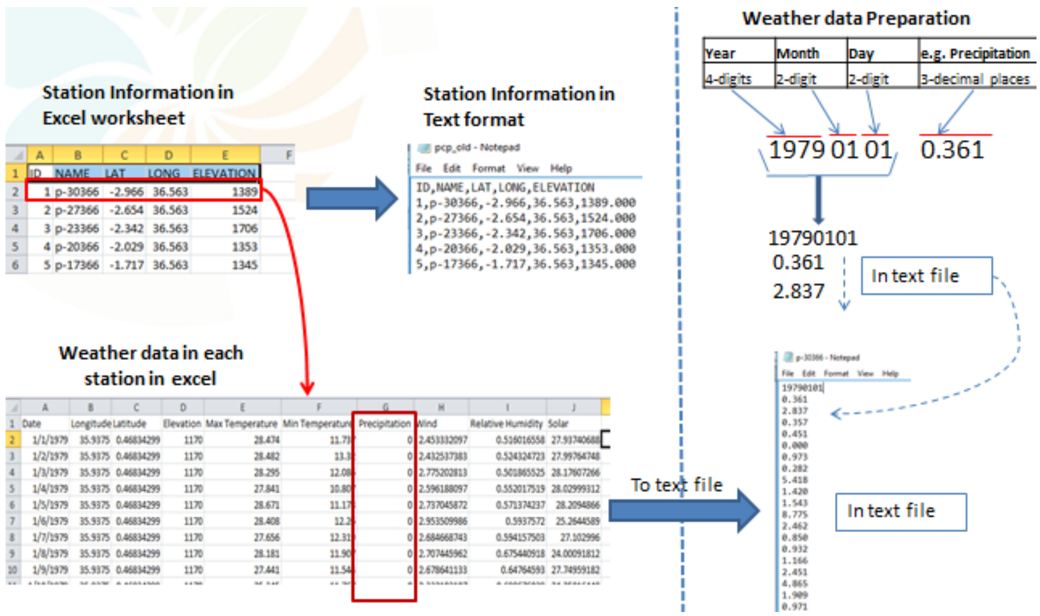

Figure 10: Creating text file of weather location/station information

Day 2: ArcSWAT

6.1 Introduction to ArcSWAT by *Dr. Alfred Opere: Department of Meteorology, University of Nairobi*

The ArcSWAT ArcGIS extension is a graphical user interface for the SWAT model. This extension evolved from the AVSWAT2000 an ArcView extension developed for an earlier version of SWAT. The interface requires the designation of various datasets as well as the simulation period in order to ensure a successful simulation.

6.1.1 User Support

ArcSWAT interface is public domain software. SWAT user website, discussion forums and several user groups provide the support to the use of this tool. Links to SWAT related user sites include:

- For SWAT user web site the link is: http://www.btc.tamus.edu/swat/
- For SWAT forums and User Groups the link is: http://www.btc.tamus.edu/swat/userforums.html
- ArcSWAT Google user group: http://groups.google.com/group/ArcSWAT

- ArcSWAT user web site: http://www.btc.tamus.edu/swat/ArcSWAT.html

6.1.2 Key ArcSWAT Procedures

- Select the ArcSWAT extension
- Delineate the watershed
- Define the HRUs
- Edit the SWAT databases, this is however optional
- Define the weather data
- Apply the default input file writer
- Edit the default input files (Optional)
- Setup the SWAT Run, this requires specification of simulation period. PET calculation method e.t.c., and run SWAT
- Apply a calibration tool (Optional)
- Analyze the SWAT output

6.1.3 Getting Started with ArcSWAT

The ArcSWAT interface is started by opening an empty document of ArcMap and clicking on the tools menu and then extensions. The spatial Analyst, SWAT project Manager and SWAT watershed Delineator need to enabled for ArcSWAT to run.

6.1.4 ArcSWAT Toolbar Items

This was a theoretical session to introduce the participants to the functionality of the different menus available from the ArcSWAT Toolbar.

The menus include:

- ➢ SWAT project setup menu, this contains items that control the setup and management of SWAT projects.
- ➢ Then there is the Watershed Delineator menu which contains all the commands required to perform subasin delineation and evaluate the results.
- ➢ The other menu is the HRU Analysis Menu which contains all the commands that perform the land use, soils and slope analysis used to generate SWAT HRUs.
- ➢ The Write Input Tables Menu contains commands which generate the ArcSWAT geodatabase files used by the interface to store input values for the SWAT model.
- ➢ There is also the Edit SWAT input Menu which allows the user to edit the SWT model databases and the watershed database files containing

the current inputs for the SWAT model.

- Finally, the SWAT Simulation Menu allows the user to run the SWAT model and perform sensitivity analysis and calibration.

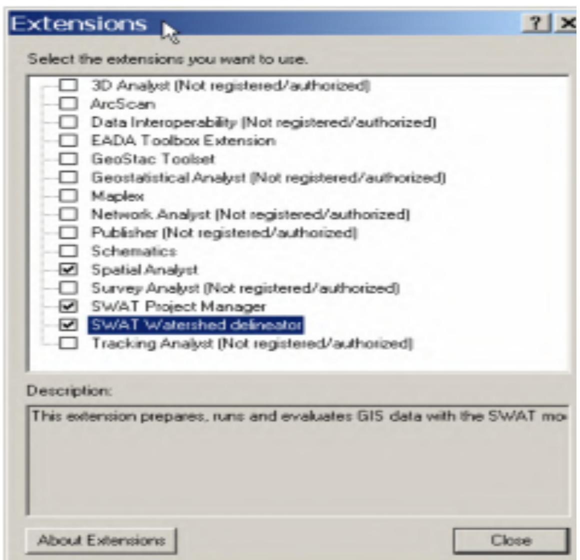

Figure 11: Enabling the Extensions necessary for ArcSWAT to Run

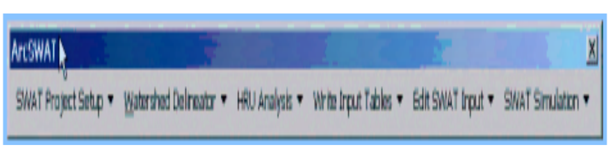

Figure 12: ArcSWAT Toolbar

Figure 13: The Watershed Delineator Menu

6.2 Practical session I: Setting Up new SWAT project and Watershed Delineation Using ArcSWAT by *Purity Mueni: Department of Meteorology, University of Nairobi*

The hands-on exercises followed immediately after the lecture on the introduction to ArcSWAT and the functionality of its menus. This session began with setting up new SWAT project for the Tana River basin. The participants were guided through the use of SWAT Project Setup menu (See Manual) to set up their individual SWAT projects. Using the already preprocessed DEM for the Tana River Basin, the participants were then guided through the use of Watershed Delineator Menu (See Manual). The process of delineation helps the user in segmenting watersheds into several hydrologically connected sub-watersheds for use in modelling the watershed using SWAT. The watershed delineation process resulted to 29 sub basins. The watershed had a minimum elevation of 2 Meters, maximum elevation of 4875 Meters, mean elevation of 589.24 meters and standard deviation of 578.73 meters.

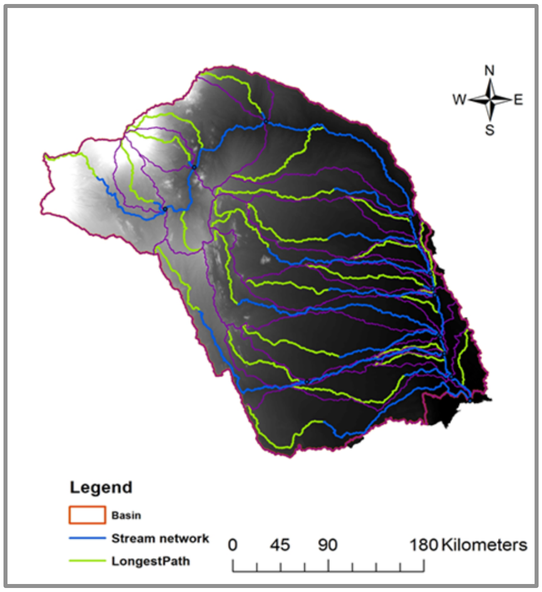

Figure 14: Delineated Watershed and derived stream network in Tana River Basin

6.3 Practical Session II: Hands on Exercises in HRU Analysis by *Purity Mueni: Department of Meteorology, University of Nairobi*

The HRU Analysis menu on the ArcSWAT toolbar aids in the characterization of land use, soil and slope for a particular. The user is in a position to load land use and soil layers in to the current project which has already been delineated. Under the HRU Analysis menu, the user is also able to evaluate slope characteristics, and determine the land use/soil/slope class combinations and distributions for the delineated watershed.

Using the preprocessed land use and soil data, the participants were guided through the use of the HRU analysis menu (See manual). They were able to do the land use, soils and slope definition. A detailed report that describes the land use, soil and slope class distribution within the Tana River basin and within the 29 subbasins was added to the current project. The land use, soils and slope definition resulted to a watershed with an area of 9330968.5426 ha with detailed information of the land use, soils and slope distribution. Once the land use, soil and slope were overlaid, the participants were able to specify the criteria to use in determination of HRU distribution.

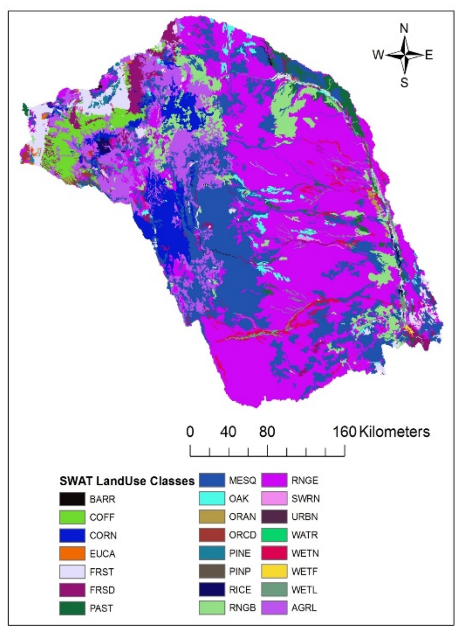

Figure 15: Reclassified Land Use Map in Tana River Basin

In this session, the participants used the multiple HRUs option to determine the HRU distribution. 10 percentage thresholds for the land use, soil and slope were used and this resulted to 493 HRUs and a detailed report of the number of HRUs within each of the 29 subasins and the distribution of landuse, soils and slope with the each subbasin and the HRUs.

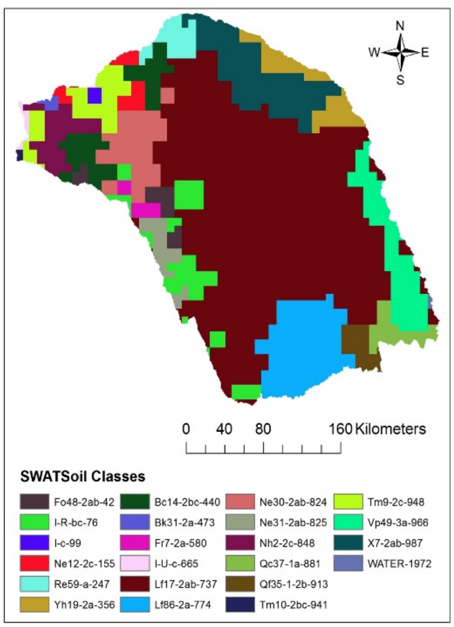

Figure 16: Reclassified soils grid theme in Tana River Basin

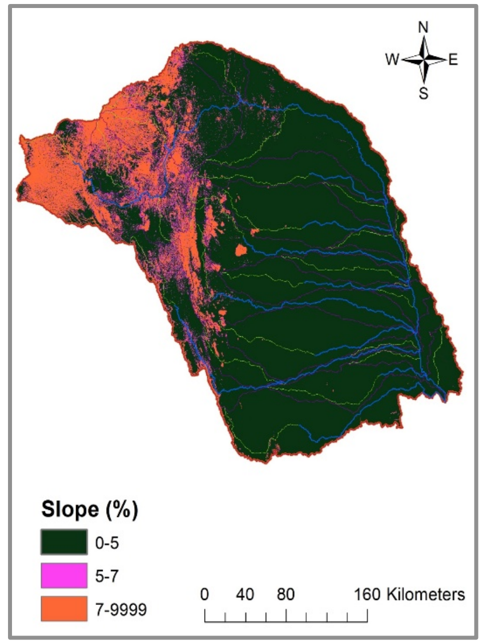

Figure 17: Layer of the units with unique combination of landuse, soil and slope within each subbasin in Tana River Basin

6.4 Elaboration on Catchment Delineation and HRU Reports by *Eugene Mwandoe Mnyamwezi, Ministry of Water and Irrigation*

One or more unique land use/soil/slope combinations (HRUs) can be created for each subbasin. The subdivision of the watershed in to areas having unique land use, soil and slope combinations is necessary to enable the SWAT model to reflect differences in evapotranspiration and other hydrologic conditions for different land covers/crop and soils.

	Area [ha]	Area[acres]	
Watershed	9330968.5426	23057289.8173	

	Area [ha]	Area[acres]	%Wat.Area
LANDUSE:			
Honey Mesquite --> MESQ	2202683.6619	5442941.4628	23.61
Oak --> OAK	40944.4818	101175.8617	0.44
Range-Grasses --> RNGE	4290041.2930	10600906.5371	45.98
Coffee --> COFF	253233.4705	625752.5674	2.71
Corn --> CORN	442929.7858	1094501.6471	4.75
Forest-Mixed --> FRST	267209.9018	660289.0279	2.86
Forest-Deciduous --> FRSD	203322.5270	502420.1303	2.18
Agricultural Land-Generic --> AGRL	896703.8184	2215799.9705	9.61
Range-Brush --> RNGB	515882.0492	1274770.3378	5.53
Rice --> RICE	24755.7525	61172.7022	0.27
Pasture --> PAST	112960.5880	279131.2610	1.21
Wetlands-Non-Forested --> WETN	44863.8694	110860.8645	0.48
Wetlands-Mixed --> WETL	27775.1593	68633.8073	0.30
Orange --> ORAN	7662.1840	18933.6398	0.08
SOILS:			
Lf17-2ab-737	4746421.1917	11728644.0858	50.87
Re59-a-247	143489.6738	354570.1584	1.54
X7-2ab-987	712622.8164	1760926.6104	7.64
Bc14-2bc-440	354852.4636	876858.1803	3.80
Ne12-2c-155	110679.2935	273494.0683	1.19
Ne30-2ab-824	406095.0785	1003481.2438	4.35
Tm9-2c-948	258281.8168	638227.2834	2.77
Nh2-2c-848	276308.5175	682772.1621	2.96
I-c-99	16052.5758	39666.7173	0.17
Fo48-2ab-42	111867.7458	276430.7933	1.20
Yh19-2a-356	243345.1218	601317.9631	2.61
Bk31-2a-473	10377.9260	25644.3741	0.11
I-U-c-665	17754.6059	43872.5190	0.19
I-R-bc-76	386644.9825	955419.0840	4.14
Fr7-2a-580	53366.5760	131871.4775	0.57
Vp49-3a-966	379023.8519	936586.8892	4.06
Lf86-2a-774	730030.8247	1803942.6693	7.82
Qf35-1-2b-913	121744.3704	300836.4264	1.30
Qc37-1a-881	91660.7572	226498.3142	0.98
Ne31-2ab-825	155814.7783	385026.1080	1.67
WATER-1972	4533.5745	11202.6893	0.05
SLOPE:			
0-5	7828161.4767	19343778.4170	83.89
7-9999	1071034.0980	2646578.8077	11.48
5-7	431772.9680	1066932.5925	4.63

Figure 18: LandUseSoils Report for Tana River Basin

		Area [ha]	Area[acres]	%Wat.Area	%Sub.Area	
SUBBASIN #	1	203185.8955	502082.5071	2.18		
LANDUSE:						
	Honey Mesquite --> MESQ	49747.3560	122928.2040	0.53	24.48	
	Oak --> OAK	21444.8747	52991.3576	0.23	10.55	
	Range-Grasses --> RNGE	131377.7377	324640.9588	1.41	64.66	
SOILS:						
	Lf17-2ab-737	6960.9003	17200.7327	0.07	3.43	
	Re59-a-247	30201.9328	74630.4860	0.32	14.86	
	X7-2ab-987	165407.1353	408729.3017	1.77	81.41	
SLOPE:						
	0-5	198654.4695	490885.1270	2.13	97.77	
	7-9999	1998.4314	4938.2240	0.02	0.98	
	5-7	1917.0674	4737.1695	0.02	0.94	
HRUs						
1	Honey Mesquite --> MESQ/Lf17-2ab-737/0-5	6960.9003	17200.7327	0.07	3.43	1
2	Honey Mesquite --> MESQ/Re59-a-247/0-5	3511.0726	8676.0360	0.04	1.73	2
3	Honey Mesquite --> MESQ/X7-2ab-987/0-5	39275.3831	97051.4353	0.42	19.33	3
4	Oak --> OAK/Re59-a-247/7-9999	177.4279	438.4332	0.00	0.09	4
5	Oak --> OAK/Re59-a-247/5-7	290.5037	717.8492	0.00	0.14	5
6	Oak --> OAK/Re59-a-247/0-5	1236.4795	3055.4026	0.01	0.61	6
7	Oak --> OAK/X7-2ab-987/0-5	19740.4636	48779.6726	0.21	9.72	7
8	Range-Grasses --> RNGE/Re59-a-247/0-5	21538.8818	53223.6540	0.23	10.60	8
9	Range-Grasses --> RNGE/Re59-a-247/5-7	1626.5637	4019.3203	0.02	0.80	9
10	Range-Grasses --> RNGE/Re59-a-247/7-9999	1821.0035	4499.7907	0.02	0.90	10
11	Range-Grasses --> RNGE/X7-2ab-987/0-5	106391.2887	262898.1938	1.14	52.36	11

Figure 19: HRULandUseSoils Report for Subbasin #1 in Tana River Basin

Within the 29 subbasins, runoff is predicted separately for each HRU. This is eventually routed to obtain the total runoff for the whole Tana River Basin. The accuracy of load predictions is increased and this also provides a much better physical description of the water balance. The LandUseSoils report indicates that the Tana watershed had an area of 9330968.5426 ha. It also shows the percentage distribution of landuse, soils and slope in comparison with the whole watershed. The report shows the area of each subbasin in comparison with the whole watershed and the distribution of land use, soils and slope within each subasin.

HRULandUseSoils report on the other hand indicates the number of HRUs in the Tana

River Basin. 493 HRUs were generated. This report also gives a detailed description of the distribution of these HRUs in to the 29 subbasins within the Tana River Basin and the distribution of the land use, soils and the slope after the overlay process.

Day 3: ArcSWAT: Loading Climate Data into the Tana River Basin Project

7.1 Practical session III: Hands on Exercises in Writing Input Tables (Loading the Climate Data) by *Dickens Odeny, National Museums, Kenya*

With a quick reminder on the required climate data to be used in running the SWAT model and how it is prepared; the participants were introduced to the use of the Write Input Tables menu on the ArcSWAT toolbar. Using the already prepared data for the Tana River Basin, the participants were able to define the weather data for the watershed simulation by loading all the available data and specifying the weather to be used to generate various weather parameters (see manual). In this exercise WGEN_User option was used. After the loading of the climate data (Rainfall, Temperature, Wind speed, solar radiation and Relative Humidity data) was successful, the participants then were able to use the Write SWAT Input Tables menu under the main Write input tables. This process was successful to most of the participants.

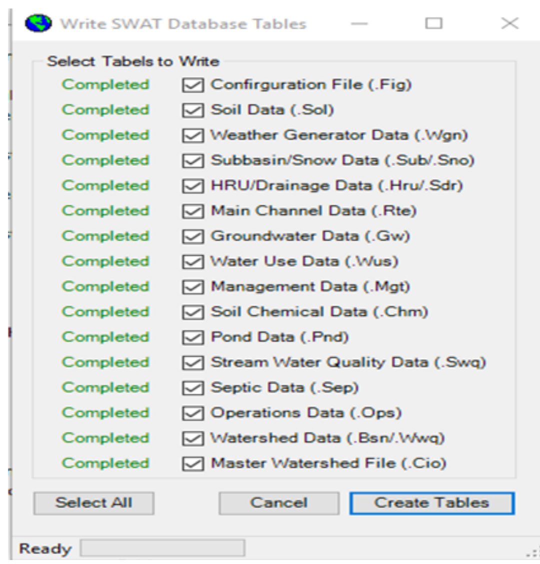

Figure 20: Building selected Tables

7.2 Practical session IV: Hands on Exercises in SWAT Simulation by *Dickens Odeny, National Museums, Kenya*

The SWAT simulation session followed for the majority who were able to write the SWAT input tables. Most of the participants were successful in writing the SWAT input tables and therefore were introduced to the use of the SWAT Simulation menu on the ArcSWAT toolbar. This menu allows the user to finalize the setup of the input for the SWAT model and eventually run the model, read SWAT output and do a manual calibration. The period of simulation was set to be **1/1/1979** for the starting date and **7/13/2014** for the ending date and the printout settings were set to be monthly (See Manual). There were 36 number of years in run and the area of the watershed was produced in Kilometers (93399.688 km^2).

The SWAT output text files can be imported to an access database. The output can also be exported to excel and analyzed depending the user's objectives or the user can download the SWATPlot tool freely available online and use it to analyze the SWAT output. The average monthly basin values were exported to excel and plotted (Figure 22)

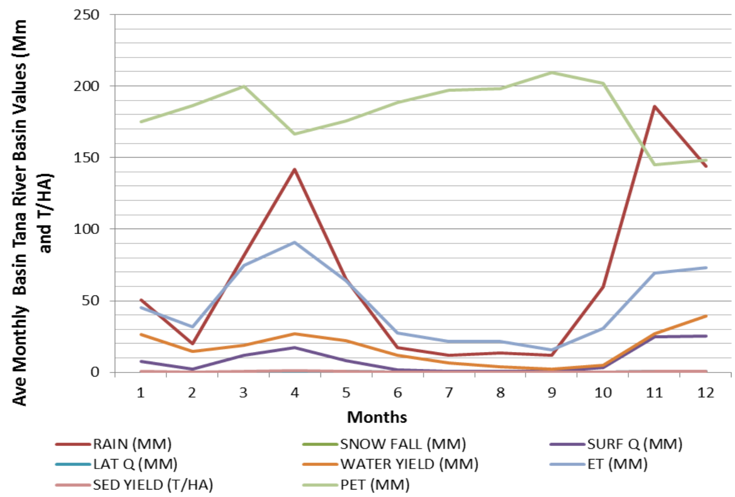

Figure 21: The average monthly Tana River basin values

7.3 Setting up group and individual works for Tana Basins by *Dr. Alfred Opere: Department of Meteorology, University of Nairobi*

The participants were issued with the specific sub basins to work on during this session. There were some who worked individually and some worked as a group. To run the SWAT model for their individual subbasins, they were required to preprocess the DEM, landUse and soil data.

Number of years in run: 36
Area of watershed: 93309.688 km2

1

SWAT May 20 2015 VER 2015/Rev 637

General Input/Output section (file.cio):
3/6/2017 12:00:00 AM ARCGIS-SWAT interface AV

Annual Summary for Watershed in year 1 of simulation

UNIT TIME	PREC	SURQ	LATQ	GWQ	PERCO LATE	TILE Q	SW	ET	PET	WATER YIELD	SED YIELD	NO3 SURQ	NO3 LATQ	NO3 PERC	NO3 CROP	N ORGANIC	P SOLUBLE	P ORGANIC	TILENO3
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	------------------(kg nutrient/ha)						--------------------	(kg/ha)
1	218.66	30.79	0.50	2.90	44.31	0.00	117.91	75.21	134.96	31.29	6.87	0.01	0.01	12.11	0.00	9.31	0.01	1.14	0.00
2	75.46	9.10	0.68	17.98	15.18	0.00	100.38	68.20	152.32	30.79	3.21	0.00	0.01	1.98	0.42	2.62	0.00	0.32	0.00
3	182.43	39.76	0.48	20.81	30.22	0.00	108.44	103.82	173.75	59.09	1.86	0.14	0.01	1.98	32.10	1.09	0.01	0.13	0.00
4	239.20	46.19	1.05	26.03	60.35	0.00	122.94	116.89	137.14	73.42	1.81	0.06	0.00	0.50	8.05	1.31	0.01	0.16	0.00
5	125.16	12.99	0.84	39.41	33.41	0.00	110.58	90.46	119.97	57.32	0.30	0.00	0.00	0.14	1.12	0.15	0.00	0.02	0.00
6	20.43	1.32	0.41	32.03	3.60	0.00	77.33	48.49	160.25	35.56	0.09	0.01	0.00	0.05	0.88	0.02	0.00	0.00	0.00
7	11.65	0.19	0.24	15.90	1.16	0.00	53.39	34.09	182.95	17.56	0.02	0.00	0.00	0.02	2.24	0.01	0.00	0.00	0.00
8	15.42	0.22	0.22	4.33	1.86	0.00	27.35	39.21	183.17	5.77	0.02	0.00	0.00	0.03	1.39	0.01	0.00	0.00	0.00
9	11.71	0.14	0.13	1.88	0.76	0.00	13.41	24.66	198.23	2.91	0.01	0.00	0.00	0.01	0.92	0.00	0.00	0.00	0.00
10	105.17	7.00	0.44	1.42	6.51	0.00	59.54	44.87	178.93	9.29	0.24	0.01	0.00	0.09	0.71	0.17	0.00	0.03	0.00
11	270.13	65.10	1.34	11.23	60.72	0.00	126.67	75.73	128.08	77.91	1.74	0.02	0.00	0.59	0.29	2.26	0.01	0.36	0.00
12	238.70	58.98	0.89	29.65	82.46	0.00	139.99	82.84	132.84	85.90	1.54	0.04	0.00	1.39	0.14	0.91	0.01	0.16	0.00
1979	1514.13	271.77	7.22	203.55	340.53	0.00	139.99	804.47	1882.60	486.82	17.72	0.29	0.04	18.89	48.26	17.85	0.05	2.33	0.00

1

SWAT May 20 2015 VER 2015/Rev 637

General Input/Output section (file.cio):
3/6/2017 12:00:00 AM ARCGIS-SWAT interface AV

Annual Summary for Watershed in year 2 of simulation

UNIT TIME	PREC	SURQ	LATQ	GWQ	PERCO LATE	TILE Q	SW	ET	PET	WATER YIELD	SED YIELD	NO3 SURQ	NO3 LATQ	NO3 PERC	NO3 CROP	N ORGANIC	P SOLUBLE	P ORGANIC	TILENO3
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	------------------(kg nutrient/ha)						--------------------	(kg/ha)
1	21.07	0.88	0.46	42.01	1.50	0.00	111.96	46.61	172.77	49.83	0.06	0.01	0.00	0.02	0.00	0.06	0.00	0.01	0.00
2	30.95	2.84	0.25	26.16	4.33	0.00	95.58	40.00	162.85	30.75	0.19	0.00	0.00	0.08	2.18	0.13	0.00	0.02	0.00
3	66.88	7.89	0.18	10.46	3.11	0.00	65.00	86.20	204.16	17.71	0.37	0.18	0.00	0.12	16.31	0.22	0.00	0.03	0.00
4	126.35	11.56	0.64	7.12	17.79	0.00	58.18	103.18	166.95	22.24	0.37	0.01	0.00	0.33	8.22	0.27	0.00	0.04	0.00
5	72.78	8.89	0.75	11.41	11.74	0.00	35.74	73.86	183.71	22.17	0.29	0.02	0.00	0.13	1.75	0.26	0.00	0.04	0.00
6	12.04	0.54	0.27	8.57	1.68	0.00	24.79	20.56	189.24	10.19	0.02	0.00	0.00	0.01	1.27	0.01	0.00	0.00	0.00
7	8.97	0.01	0.17	4.38	0.55	0.00	14.58	18.56	197.83	5.25	0.00	0.00	0.00	0.00	3.17	0.00	0.00	0.00	0.00
8	30.31	0.60	0.14	2.02	0.59	0.00	13.21	30.35	181.37	3.30	0.04	0.00	0.00	0.00	1.43	0.01	0.00	0.00	0.00
9	12.48	0.01	0.06	0.64	0.03	0.00	8.23	17.39	194.80	1.11	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00
10	25.38	0.98	0.18	0.35	1.82	0.00	13.77	16.82	220.41	1.81	0.03	0.00	0.00	0.00	0.43	0.01	0.00	0.00	0.00
11	275.49	47.52	0.94	2.90	36.60	0.00	117.51	86.35	134.37	48.12	1.30	0.03	0.00	0.69	0.15	0.95	0.01	0.19	0.00
12	105.76	12.25	0.58	13.86	24.24	0.00	112.31	74.06	150.35	30.52	0.29	0.01	0.00	0.48	0.08	0.14	0.00	0.03	0.00
1980	788.46	93.97	4.61	129.89	103.97	0.00	112.31	613.94	2158.81	243.00	2.97	0.25	0.02	1.87	35.67	2.05	0.02	0.36	0.00

1

SWAT May 20 2015 VER 2015/Rev 637

General Input/Output section (file.cio):
3/6/2017 12:00:00 AM ARCGIS-SWAT interface AV

Figure 22: Output.std report for 1979 and 1980 for the Tana River Basin

7.4 Group and individual work: Hands on exercises on pre-processing the pilot Tana basins' input data for SWAT model application (DEM, landuse/landcover data, soil data and climate data)

This session was steered by all the facilitators. It started from downloading the map, extracting by mask using the subbasin shapefile for the DEM and then performing coordinate projection and transformation. For the Land use and soils, the participants were required to clip the land use and soil layer using the subbasin shapefile and performing the coordinate transformation and projection and later converting them into raster files. The participants used the already prepared climate data to define the weather data for the SWAT simulation.

Day 4: SWAT modelling for the Pilot Tana basins (Catchment delineation and HRU analysis)

8.1: Group and individual Work: Hands on Catchment Delineation for the pilot basins

This session was facilitated by all the trainers. The individuals and the groups used their prepared DEM to delineate their catchment. Various results were produced. Some are shown in figures below.

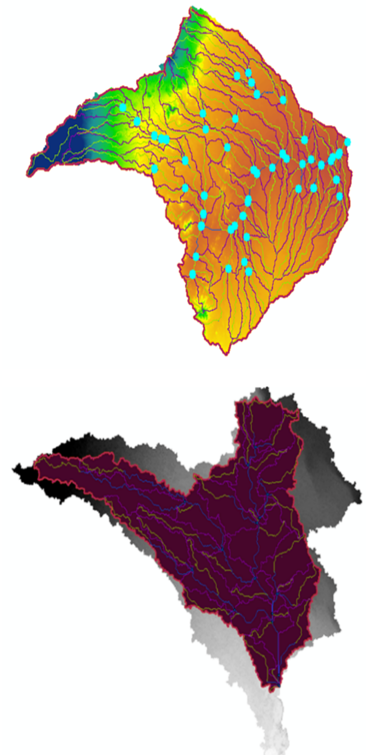

Figure 23: Delineated Catchment for two different subbasins within the Tana River basin from different participants

8.2 SWAT Database Management: *Dickens Odeny, National Museums, Kenya*

This session started with a quick reminder of how the climate data is prepared in order to be used in the SWAT model. The Weather Generator (WGEN) and the process of calculating the parameters in the weather generator was then introduced. WGEN input file contains the statistical data needed to generate representative daily climate data for the subbasins. At least 20 years of records are used to calculate parameters in .wgn file.

8.2.1 Temperature Variables

- TMPMX – is the average or mean daily maximum air temperature for month (^{0}C).
- TMPMX value is calculated by summing the maximum air temperature for every day in the month for all years of record and dividing by the month for all years of record and dividing by the number of days summed.
- TMPMN – is the average or mean daily minimum air temperature for month (^{0}C) (January, December).
- TMPMN value is calculated by summing the minimum air temperature for every day in the month for all years of record and dividing by the number of days summed
- TMPSTDMX – This is the Standard Deviation for daily maximum air temperature in month (0C) (January, December).
- TMPSTDMX quantifies the variability in maximum temperature for each month (January, December)
- TMPSTDMN – This is a Standard Deviation for daily minimum air temperature in month (^{0}C)
- TMPSTDMN is a parameter that quantifies the variability in minimum temperature for each month (January to December)

8.2.2 Precipitation Variables

- PCPMM – The average or mean total monthly precipitation (mm H20).
- PCPSTD – Is the Standard Deviation for daily precipitation in month (mm H20/day) (January to December). PCPSTD quantifies the variability in precipitation for each month.
- PCPSKW – Is the Skew coefficient for daily precipitation in month (January to December). PCPSKW quantifies the symmetry of the precipitation about the monthly mean.
- PR_W1 – Is the probability of a wet day following a dry day (January, December)
- Wet day followed dry day/Dry day
- PR_W2 – Is the probability of a wet day following a wet day in the month (January, December). Wet day followed dry day/Wet day
- PCPD – Is the average number of days of precipitation in month

(January, December). The number of wet days in month/number of years of record

- RAINHHMX – Is the maximum 0.5 hour rainfall in entire period of record for month (mm H2O) (January, December). RAINHHMAX value represents the most extreme 30-minute rainfall intensity recorded in the entire period of record. Use 1/3 of max daily rainfall of a month (for rainy season) if hourly data is absent

8.2.3 Other Weather Data and Variables

- SOLARAV – Is the daily solar radiation for month (MJ/m2/day) (January, December). Sum of the total solar radiation for every day in the month for all years of record and dividing by the number of days summed
- DEWPT – Is the average daily dew point temperature for each month (0C) or relative humidity (fraction) can be input (January, December). Dew point is converted to relative humidity using equation 1:3.5.1 and 1:3.5.2 in the Theoretical Documentation.
- WNDAV – Is the average daily wind speed in month (m/s) (January, December). The average wind speed for day in month

8.3 Group and individual Work: Hands on: HRU Analysis for the pilot basins

This session which was guided through by all the facilitators involved the use of the preprocessed land use and soil data for the specific subbasins by the group and individuals. This resulted to the various outcomes as shown below.

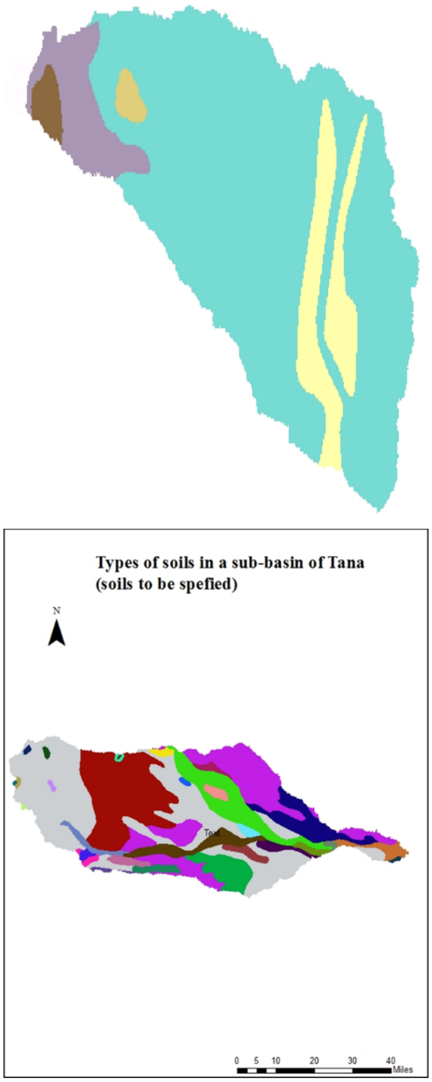

Figure 24: Reclassified Land Use Map and soil grid theme for different pilot basins within the Tana River Basin

Day 5: SWAT Modelling for the Pilot Tana basins (Writing Input Tables and SWAT simulation)

9.1 Writing Input Tables and SWAT simulation

This session involved the use of the WGEN_User option and the already preprocessed climate data. It was guided through by all the facilitators. It was successful to most of the individuals and groups. After all the tables had been created, the participants were in a position to run the SWAT from the period 01/01/1979 to 31/12/1985. Below are some of the results.

```
        Number of years in run:    7
        Area of watershed:     2595.908 km2
1
    SWAT Dec 23 2016    VER 2016/Rev 664

    General Input/Output section (file.cio):
    2/17/2017 12:00:00 AM ARCGIS-SWAT interface AV

Annual Summary for Watershed in year    1 of simulation

UNIT                                PERCO  TILE                          WATER   SED    NO3    NO3    NO3    NO3      N       P       P
TIME   PREC   SURQ   LATQ    GWQ    LATE     Q      SW      ET     PET  YIELD  YIELD   SURQ   LATQ   PERC   CROP ORGANIC SOLUBLE ORGANIC TILENO3
       (mm)   (mm)   (mm)   (mm)   (mm)   (mm)    (mm)    (mm)    (mm)   (mm)  (t/ha) ------------------(kg nutrient/ha)-------------------- (kg/ha)
   1 267.86  18.37   0.01   2.18  62.88   0.00  141.89   97.30  146.24  19.79   0.59   0.01   0.00  20.20   0.00    3.40    0.00    0.42    0.00
   2  80.29   6.26   0.03  24.68  15.64   0.00  123.88   76.38  141.45  32.22   0.19   0.00   0.00   2.68   0.05    1.31    0.00    0.16    0.00
   3 260.45  50.37   0.03  29.44  60.28   0.00  142.21  131.39  157.80  79.27   0.19   0.00   0.00   6.19   6.52    1.44    0.01    0.18    0.00
   4 234.90  16.29   0.05  40.98  72.54   0.00  141.84  146.35  150.49  58.99   0.00   0.00   0.00   4.14   1.67    0.03    0.00    0.00    0.00
   5 112.20   2.01   0.05  50.48   7.76   0.00  122.40  121.85  132.35  54.95   0.00   0.00   0.00   0.36   1.14    0.00    0.00    0.00    0.00
   6   6.61   0.00   0.04  29.72   0.00   0.00   56.98   72.03  123.21  31.37   0.00   0.00   0.00   0.00   1.10    0.00    0.00    0.00    0.00
   7   1.90   0.00   0.03   7.34   0.00   0.00   17.09   41.79  117.34   8.70   0.00   0.00   0.00   0.00   3.94    0.00    0.00    0.00    0.00
   8   3.12   0.00   0.02   0.66   0.00   0.00    9.75   10.45  113.19   1.72   0.00   0.00   0.00   0.00   1.03    0.00    0.00    0.00    0.00
   9   4.39   0.00   0.01   0.00   0.00   0.00    6.76    7.38  127.82   0.78   0.00   0.00   0.00   0.00   0.13    0.00    0.00    0.00    0.00
  10 144.85   1.24   0.01   0.00   0.18   0.00   93.71   56.44  130.54   1.77   0.00   0.00   0.00   0.00   0.05    0.00    0.00    0.00    0.00
  11 383.12  93.04   0.06  30.09 153.00   0.00  133.37   97.25  135.11 124.15   0.01   0.00   0.00   4.35   0.01    0.04    0.02    0.00    0.00
  12 330.25  64.17   0.07  72.56 160.22   0.00  142.64   96.44  133.47 136.91   0.04   0.03   0.00   4.30   0.00    0.22    0.02    0.03    0.00

 1979 1829.94 251.75  0.42 288.13 532.51   0.00  142.64  955.05 1608.99 550.62  1.01   0.04   0.01  42.23  15.64    6.43    0.06    0.79    0.00
1
```

Figure 25: Output report for 1979 from SWAT simulation of one of the pilot basin within the Tana River Basin

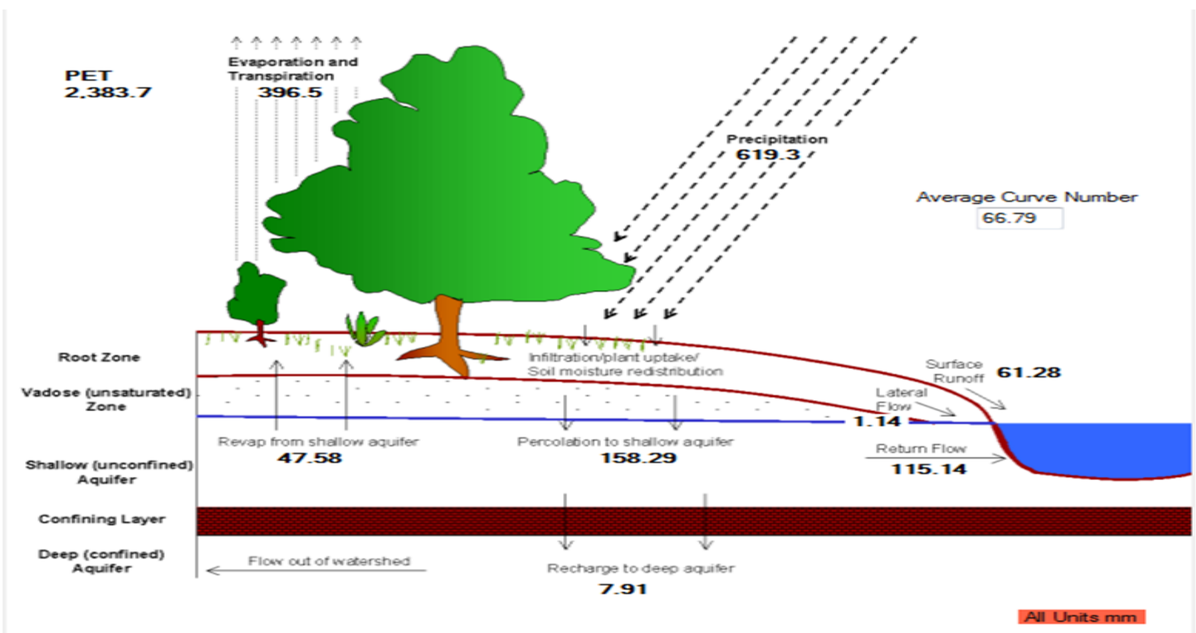

Figure 26: The Hydrology of one of the Pilot basin within the Tana River Basin using SWATCheck

9.2 Model Calibration and Validation: Hands on calibration and validation of the SWAT for pilot basins by *Dickens Odeny, National Museums, Kenya*

9.2.1 SWAT Model Calibration

This session was partly theoretical and hands on work. The manual calibration was active and was used to elaborate how the calibration process is done. SWATCup tool that is freely available on online can also be used in the calibration process was also introduced to the participants.

SWAT model calibration is the parameterization of a model to a given set of local conditions, thereby reducing the prediction uncertainty. It is performed by carefully selecting values for model input parameters (within their respective uncertainty ranges) by comparing model predictions (output) for a given set of assumed conditions with observed data for the same conditions. Below are some of the parameters that can be adjusted in the calibration process

- CN2 – Curve Number of Moisture Condition II
- AWC – Available Water Capacity
- ESCO – Soil Evaporation Compensation Factor
- EPCO – Plant Uptake Compensation Factor
- SURLAG – Surface Runoff Lag Coefficient
- OV_N – Manning's "n" Value for Overland Flow

9.2.2 SWAT Model Validation

Model Validation involves running a model using parameters that were determined during the calibration process, and comparing the predictions to observed data not used in the calibration. Validation process demonstrates that a given site-specific model is capable of making sufficiently accurate simulations, although "sufficiently accurate" can vary based on project goals.

9.2.3 Sensitivity Analysis

It is the process of determining the rate of change in model output with respect to changes in model inputs (parameters). Identification of parameters and parameter precision is required.

- Two types of sensitivity SENSITIVITY ANALYSIS can be performed to provide insight into the sensitivity of the parameters and are necessary steps in model calibration:

  - Local Sensitivity Analysis: performed by changing values of parameter one at a time
  - Global Sensitivity Analysis: performed by allowing all parameter values to change

- The two types of sensitivity analyses may lead to two different results. Sensitivity of one parameter often depends on the value of other related parameters. Global sensitivity analysis; however requires a large number of simulations.

9.3 Individual and Group Presentations and Brainstorming: Discussions on data needs, limitations and applications of the SWAT

In this session the participants presented some of their respective subbasin output, insights, challenges, applications of the SWAT model at the work places and future recommendations.

9.3.1 Challenges and recommendations

- Some felt the process of preparing the inputs files (DEM, Landuse, soils and climate) was the most important part of the training and recommended that in future it be given more weight.
- Prior knowledge of GIS was key for one to benefit from the SWAT modelling and application workshop.
- Since SWAT requires daily continuous climate data, it may be a bigger challenge if one is interested in modelling certain catchments which lack continuous observed data.
- Some participants thought that SWAT is very temperamental and requires careful operations and correctly prepared data.
- To participants the SWAT model was a new tool to them and it involved a lot of maneuverability. They felt that the time allocated for the workshop was not enough to comfortably say they have learned all the processes. A two week SWAT workshop would be better.

9.3.2 Applications of the SWAT model at the work places

- During the participants' presentation session, they mentioned instances they felt SWAT can be applied in their work places.
- SWAT can used understanding the catchment characteristics upstream of hydropower reservoirs and formulation of catchment management strategies to check sedimentation challenges
- It can be applied in evaluating the influence of land use/land cover changes on flooding and estimation of sediment load being shed by the catchment into dams/reservoirs.
- This is a powerful tool to inform policy makers on catchment resources management and can be used in evaluating impacts of WRUA interventions on their sub-catchments.
- SWAT can be applied in Bio physical modeling of the region under TARDA, analyzing impacts of investments and in assessing the economic benefits based on the outputs.
- Getting spatial units in relative and absolute changes in the hydrological response eg the sediment load, erosion runoff influenced by slope landuse and soil.
- SWAT will help in knowing how much fertile, water retaining soils can be saved to increase productivity.
- SWAT will also be applied to know which type of crop to be grown in an area after analyzing the soils water and the weather in an area.

Annex I: Workshop Programme

DAY ONE – 13th February, 2017		
08.30 – 09.00	Registration	**ACCESS Secretariat**
09.00 – 10.00	• Introductions • Welcome address • WISE UP project brief • Objectives of Workshop & Expectations • ACCESS Capacity Development and opening of the workshop	**Dr. Opere** Prof. Wandiga Prof. Olago Dr. Opere Prof. Odada
10.00 – 10.15 TEA BREAK		
10.15 – 10.45	General Overview of the SWAT model	**Eugen Mwandoe**
10.45 – 01.00	SWAT Model Installation and System Requirements	**Mwandoe/Odeny/Opere/Mueni**
01.00 – 02.00 LUNCH BREAK		
02.00 – 03.30	Pre-Processing Tana Basin Data for SWAT Model Application (DEM, LandUse/LandCover Data, Soil data and Climate Data) (ctd’)	**Dickens Odeny**
03.30 – 04.00 HEALTH BREAK		
04.00 – 05.00	Pre-Processing Tana Basin Data for SWAT Model Application (DEM, LandUse/LandCover Data, Soil data and Climate Data).	**Dickens Odeny**
DAY TWO - 14th February, 2017		
08.30 – 09.00	Introduction to ArcSWAT	**Dr. Alfred Opere**
09.00 – 10.00	Hands On Exercises in Catchment Delineation	**Opere/Mueni**
10.00 – 10.15 TEA BREAK		
10.15 – 01.00	Hands On Exercises in Catchment Delineation	**Opere//Mueni**

01.00 – 02.00 LUNCH BREAK		
02.00 – 03.30	Hands On Exercises in HRU Analysis (Loading the LandUse and Soil Data and HRU Definition)	**Mwandoe/Opere**
03.30 – 04.00 HEALTH BREAK		
04.00 – 05.00	Elaboration on Catchment Delineation and HRU Reports	**Mwandoe/Opere**
DAY THREE - 15th February, 2017		
08.30 – 09.00	Hands on Exercises in Writing Input Tables (Loading the Climate Data)	**Odeny/Opere**
09.00 – 10.00	Hands on Exercises inSWAT Simulation	**Opere/Mueni**
10.00 – 10.15 TEA BREAK		
10.15 – 10.45	Setting Up Group Works (Pilot Basins)	**Dr. Alfred Opere**
10.45 – 01.00	Group Work: Hands On Exercises on Pre-Processing the Pilot Tana Basins'Input Data for SWAT Model Application (DEM, LandUse/LandCover Data, Soil data and Climate Data) (ctd')	**Mwandoe/Odeny/Opere/Mueni**
01.00 – 02.00 LUNCH BREAK		
02.00 – 03.30	Group Work: Hands On Exercises on Pre-Processing the Pilot Tana Basins'Input Data for SWAT Model Application (DEM, LandUse/LandCover Data, Soil data and Climate Data) (ctd')	**Mwandoe/Odeny/Opere/Mueni**
03.30 – 04.00 HEALTH BREAK		
04.00 – 05.00	Group Work: Hands On Exercises on Pre-Processing the Pilot Tana Basins'Input Data for SWAT Model Application (DEM, LandUse/LandCover Data, Soil data and Climate Data)	**Mwandoe/Odeny/Opere/Mueni**
DAY FOUR - 16th February, 2017		
08.30 – 10.00	Group Work: Hands on Catchment Delineation	**Mwandoe/Odeny/Opere/Mueni**

10.00 – 10.15 TEA BREAK		
10.15 – 01.00	SWAT DatabaseManagement	**Dickens Odeny**
01.00 – 02.00 LUNCH BREAK		
02.00 – 03.30	Group Work: Hands on: HRU Analysis(ctd’)	**Mwandoe/Odeny/Opere/Mueni**
03.30 – 04.00 HEALTH BREAK		
04.00 – 05.00	Group Work: Hands on: HRU Analysis	**Mwandoe/Odeny/Opere/Mueni**
DAY FIVE - 17th February, 2017		
08.30 – 10.00	Group Work: Hands on Exercises in Writing Input Tables (Loading the Climate Data(ctd’)	**Mwandoe/Odeny/Opere/Mueni**
10.00 – 10.15 TEA BREAK		
10.15 – 10.45	Group Work: Hands on Exercises in Writing Input Tables (Loading the Climate Data) and SWAT Simulation	**Mwandoe/Odeny/Opere/Mueni**
10.45 – 01.00	Group Presentations and Brainstorming: Discussions on data needs, limitations and preparation for SWAT Applications	**Dr. Alfred Opere**
01.00 – 02.00 LUNCH BREAK		
02.00 – 03.30	Model Calibration and Validation: Hands on calibration and validation of the SWAT for pilot basins	**Dickens Odeny**
03.30 – 04.00 HEALTH BREAK		
04.00 – 05.00	• Workshop evaluation/ Assessment questionnaire • Application of SWAT skills in institutions • Recommendations and way forward • Closing remarks and Vote of thanks	**Dr. Alfred Opere** **Dr. Alfred Opere** **Dr. Alfred Opere** **Dr. Lydia Olaka**
05:30	Cocktail reception	**Chiromo club**

Annex II: Workshop Participants

NO	NAME	INSTITUTION	DESIGNATION	CONTACT
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10	Ms. Jane Wambugu	Kenya Wildlife Service	Research Scientist – Wetlands	jane@kws.go.ke 0718983798
11	Ms Eunice Ochieng	Water Resources Management Authority	Senior Water Resources Data Officer.	euniceochieng@yahoo..com 0722806893

NO	NAME	INSTITUTION	DESIGNATION	CONTACT
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22	Dr Lydia Olaka	ACCESS	Facilitator	lydiaolaka@gmail.com 0719858393

Annex III: Workshop in Pictures

Participants during typical working sessions and health break

ACCESS Director, Prof. Eric Odada, opening the workshop