UNIVERSITI PUTRA MALAYSIA

WATER BALANCE STUDY FOR THE AGRICULTURAL SECTOR IN MALAYSIA

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ABSTRACT

A thorough water balance study is carried out in Malaysia. Malaysia is gifted with abundant rainfall within Southeast Asia. However, there is an uneven distribution of rainfall in Malaysia, which rendered the Agricultural sector vulnerable to water deficiency. This research focuses more on the water demand and water requirements in the Agricultural Sector.

The water balance study in the Agricultural Sector ranges from the water demand and requirements of livestock, aquaculture, and crops. The water requirement for Oil Palm is prioritized in this study. This study cited some of the ways water balance can be achieved in the Agricultural sector. Cameron Highland in Pahang was selected as the area of study. Spatial data was collected from Cameron Highland and then a SWAT model was set up to observe the Water Delineation of the catchment area and then a manual water balance calculation was conducted using some of the data being provided by the Department of Statistics Malaysia. Physical data, spatial data, and meteorological data was used to evaluate the water balance in Malaysia, more so, in the Agricultural sector. The state of Perak has a water balance of -124 mm/yr, Selangor has -193mm/yr, Maleka has -258mm/yr, Johor has -249 mm/yr, Pahang has -188mm/yr, and Kelantan has -93mm/yr respectively. The water balance evaluation through the manual method indicates that there is a water balance crisis in Malaysia, which needs an immediate attention.

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LIST OF ABBREVIATIONS

FELDA	Federal Land Development Authority
MLD	Millions of Liters per Day
NWRS	National Water Resources Strategy
NAWAB	National Water Balance System
SWAT	Soil and Water Assessment Tool
HRU	Hydrologic Response Unit
USDA	United States Department of Agriculture
ARS	Agricultural Research Service
SWRRB	Simulator for Water Resources in Rural Basins
ET	Evapotranspiration
MODIS	Moderate Resolution Imaging Spectroradiometer
LH-OAT	Latin Hypercube One Factor at a Time
COE	Center of Excellence
ANOVA	Analysis of Variance
JPS	Jabatan Pengiran Dan Saliran Malaysia

CHAPTER ONE

1.0 INTRODCUTION

1.1 BACKGROUND

1.2 RAINFALL DISTRIBUTION IN MALAYSIA

Malaysia is one of the few countries in Southeast Asia that records the highest amount of rainfall of 2500 mm per annum (JPS). Although the amount of rainfall varies amongst the different regions, some regions experience excess rainfall whilst other regions experience some deficiency in down pour. In 2016, Kuching station recorded the most noteworthy yearly precipitation of 5,423.0 mm with an increment of 877.5 mm as compared to 2015 (4,545.5 mm). In the meantime, the most reduced yearly precipitation is recorded at Temerloh station with 1,397.8 mm in 2016 (2015: 1,193.2 mm).However, over the years, the Malaysian government has expressed concerns about the uneven distribution of water in the region (JPS, 2017).

Water resources assessment is carry out using catchments as planning units, but sometimes also administrative boundaries (Alcamo, Flörke, & Märker, 2007) . There is already a scarcity of water in some of the arable areas of interest. Understanding trends in Agriculture use change will provide essential information for Agriculture planning and sustainable water-resource management (Suhaily, Che, & Othman, 2010). This research project seeks to bridge this gap.

In trying to tackle this problem, the Malaysian government has come up with an agenda of developing a water management system commonly referred to as the Development of

National Water Balance Management System (NAWAB), aimed at optimizing water distribution in Malaysia in the event of a prolonged drought in the future. An important aspect of understanding and enhancing the usage of water is to be able to provide determinable approximations of the key areas when it comes to the realm of water balance (Shui, Haque, & Feng, 2006). Per the statistics reported by NAWAB, 70% of the waters from Malaysian rivers are utilize in irrigation, 20% in the industrial sector and the remaining 10% is for domestic use. Amongst other things, they intend to focus on the water requirements of the region, which is the domestic use, industrial use and agricultural use of water. In a bid to facilitate development and financial targets, undisturbed water accommodates new locations too (Mitra et al., 2015)

1.3 WATER DEMAND IN MALAYSIA

Recently, water supply circumstance within the nation has changed from a relative plenitude to one of shortage (Ali, Saadon, Rahman, & Khalid, n.d.). The current residential water request for the bowl is assessed at approximately 300–350 MLD (Ali et al., n.d.). The number one point of worry of the government of Malaysia is to strike a balance between available water resources and how best they can sustained it for long-term uses, specifically for the state of Selangor, where a significant amount of water resource is plummeting. (Ali et al., n.d.). There has been an increasing demand in the domestic usage of water. In 2011, NWRS reported that the domestic demand for water has increased rapidly from 2010 to date. The requisition for water will skyrocket within households come 2050. The 2010 stats reported by NAWAB, has seen that the requisition of water in households and industries stood at 33%. According to (Ali et al., n.d.), Kajang, with a population of 229,655 requires a water of about 25.3 million meter cube in order to sustain the water demands of its inhabitants. (Ali et al., n.d.), further cited that the water demand for Cheras with a population of 163,500 is 18.0 million meter cube.

The Agricultural sector is very demanding of water resources especially when it comes to up-keeping crops for sustainable growth. According to (Mekonnen et al 2010), 30 to 40% of Malaysia's rainfall is use for crop production. For Malaysia, the total consumption for crop production is 54 trillion liters per year, which translates to 1.7 million liters of water per second, is use for crop production (Mekonnen et al 2010). Paddy production in Malaysia consumes nearly 3,000 liters of water for every 1kg of crop yield (Mekonnen et al 2010). (Mekonnen et al 2010) also claimed that, Coffee, cocoa, and rubber are amongst the highest consumers of water, using from 10,000 to 20,000 liters of water for every 1 kg of crop yielded. Oil palm uses about 550 liters of water for every 1kg of crop yield. (Mekonnen et al 2010). However, to produce 1kg of palm oil products requires an additional 4,000 liters of water to extract and process the oil from the oil palm brunches (Mekonnen et al 2010).

To wrap it up, this study seeks to delve into the various water resources available in Malaysia. The research also ought to dig deep into the water demand of the Malaysian populace. From its domestic usage, industrial usage and Agricultural usage. The study will also goes into the specifics of the Agricultural usage of water. For example, the crop water requirements, livestock, etc.

1.4 PROBLEM STATEMENT

According to FELDA, the agricultural sector is experiencing a shortage of water in some of its areas. A research conducted recently has shown that there is a need to channel more water to the Matured Palm Oil planation to achieve a bumper harvest. Matured Oil Palm requires a huge amount of water for it to achieve an optimal growth. However, the water resources found in Matured Oil Palm plantations are minimal. Thus, there is need to build an irrigation system in order to address the water scarcity issues facing the Oil Palms. In this regard, there are some concerns attached to building such irrigation systems, like, how much it will cost and how it will affect the people.

1.5 OBJECTIVES

-To investigate water requirement in the agricultural sector in Malaysia.

-To study water balance model.

-To calculate and evaluate the model.

CHAPTER TWO
2.0 LITERATURE REVIEW

2.1 WATER DEFICIT IN MALAYSIA

In the northern states of the Malaysian Peninsula, particularly in Kedah, water deficit occurs for three months or so each year (Deficit, 2004). Due to the different conditions in different regions in the Malaysian Peninsula, such as Sintok, Kedah, palms may suffer a water deficit of up to three months or more (Deficit, 2004). It is therefore paramount to amend such deficits in water. When evapotranspiration exceeds the precipitation (rainfall or irrigation) rate, water deficit occurs (Deficit, 2004)

Based on the reference data for the year 2000, the comes approximately of the reference Circumstance at the masses advancement at 2.2% shows up the availability of water resources is palatable up to the year 2010 with zero regard of Dismissed Request investigation.. Nevertheless, when the evaluation demonstrate is assessed based on Situation 1 reflected by a noteworthy esteem of Neglected Request within the year 2010 by the sum of 30.7 million cubic meter. This demonstrate deficiencies of water inside the consider in 2010 and a noteworthy drop to a store capacity volume inside the 2009 and 2010 (Ali et al., n.d.).

The Situation 2 comes about demonstrated that the water supply as it were seem oblige up to year 2008. The farming request is deficiently of 10.1 million meter 3d shape and 46.6 million meter 3d shape for the year 2009 and 2010, individually. Around 38.4 million-meter 3d shape inadequately water, request is watch at Kajang request location in 2010 (Ali et al., n.d.). At long last, the climatic variety for Situation 3 is dole out to Situation 1 and Reference Situation in arrange to predict the affect towards the water request and supply, comes about the most noteworthy populace development rate and dryer climate, Neglected Request increments substantially(Ali et al., n.d.).The research found that Langat catchment is moderately delicate to the development of requests, proposing that slight changes in populace will modify the display water accessibility (Ali et al., n.d.). Division of Water Supply, Selangor claimed that the taken a toll of managing with the crises by the Government ran into nearly RM56 million (Ali et al., n.d.)

The presence of water in catchment areas is hindered by a number of environmental components, like soil structure, arrangement of rocks, and vegetative covers that are projected overhead the surface. The available water in catchment areas have the least amount of flowrate during the wet season and off wet season, when the water in and out is computed (Juniata et al., 2018).

One of the ways to alleviate a water deficit is to set up a drip irrigation system (Deficit, 2004). The drip system applies water in small quantities directly to the rooting zone. (Deficit, 2004). Most drip systems require water at only a low pressure of 1.0-1.5 kg cm^2 compared to 3.5 kg cm^2 in standard irrigation (Kumar, n.d.). The disadvantage of this system is that it requires a thorough checking of the drippers, especially for operation after a long pause ((Deficit, 2004). Routine and regular inspections of the inlet and the lines are necessary to ensure that all the palms receive a regular water supply as expected (Deficit, 2004)

The integration of water administration design with territorial spatial plans depends within the third approach. Water back in a territorial framework is considered in excess when the water accessible within the framework is adequate to adjust the water needs of the locale, and considered in shortfall something else (Juniata et al., 2018). (Juniata et al., 2018) further states that Water accessibility is decided employing a runoff coefficient strategy based on arrive utilize and yearly precipitation data. (Henson, 2004) came up with an example of how to determine the water requirement of each oil palm. He made the following calculations: At a planting density of oil palm of 148 per hectare, each palm occupies 10 000 m^2/148= 67.6 m^2. Thus for these palms, only a portion of 67.6 m^2 is occupied. With an estimate of canopy radius about 3.0 m, this is equivalent to 42% of the allotted area being occupied. Therefore, each palm requires 67.6 m^2 x 0.42 x 4 liters m^2 day^{-1}= 113.6 liters per day (Deficit, 2004)

2.2 WATER BALANCE ASSESSMENT BY SPATIAL METHOD

Water use is model individually for the households, industries and agriculture disciplines employing the preponderantly outdated path and the usage of water presence ratios manipulated for various regions amid the interfluve (Mitra et al., 2015). Generally, the method recommended that the interfluve get 327 X 106-meter cube of excess water when satisfying the sectoral demands, however that the Japanese a part of the study space is in deficit (Mitra et al., 2015). By the way, the assessment of the sensitivity is administrated on the method to a couple of deductions inside the model recommended moderated situations would turn out to a gain/loss beginning from -215 X 106-meter cube annually (Mitra et al., 2015)

The major advantage of water balance strategies is that the use of promptly accessible knowledge will be applied speedily and account for all water coming into and going into the system in semi-arid regions. Water balance in oil palm is done by assessing the total water demand, i.e. water losses by surface runoff, deep percolation and evapotranspiration, including transpiration by the palms and ground vegetation, and to draw up a balance against total water input by precipitation and irrigation if applicable (Deficit, 2004).

In any case, the most drawback of those techniques is that revive is that the leftover term, in this manner their precision depends upon the precision of all the inverse water adjust terms. On the off chance that these groundwater adjust methodologies grasp a few spatial averaging, the degree of averaging is regularly vague and depends upon the thickness of perception focuses. Their application is banished to data rare situations.

(Arnold et al., 1999) presented two ways superfluity rainfall can be faked on a huge basin with manifold of rain gages of simulating excess rainfall on a large basin with multiple rain gages and contrasting the simulations. (Simic et al., 2009) considered the application of SWAT within the precipitation smaller than expected prepare. Arnold et al., 2010) given the occasion and testing of a sub-hourly rainfall-runoff demonstrate in SWAT

2.3 SOIL AND WATER ASSESSMENT TOOL (SWAT)

The SWAT model was develop by the USDA-ARS to predict the impact of land management practices on water, sediment, and agricultural chemical yields in massive ungagged basins (Arnold et al., 1998). SWAT incorporates options of many ARS models and may be a direct outgrow of the SWRRB (Simulator for Water Resources in Rural Basins; Williams et al., 1985). Hydrological processes simulated by the model for a selected amount of record embody evapotranspiration (ET), infiltration, percolation losses, surface runoff, channel transmission losses, channel routing, and lateral, shallow formation and deep aquifer flow (Arnold et al., 1996).

For modeling functions in SWAT, a watershed is divided into variety of sub basins (Liew et al., 2003). Every of those individual land use areas is noted as a hydrologic response unit, or HRU (Binger, 1996) and is assumed to be spatially uniform in terms of soil, land use, topographical, and environmental condition information (Liew et al., 2003).

Nowadays, the interpretation algorithms of satellite imagery from the terra moderate resolution imaging spectroradiometer (MODIS) have been approved (Mu et al., 2013) and used by many researchers in assessing the spatio-temporal hydrologic behavior of agricultural catchments (Pervez & Brown, 2010)

Amongst the things Remote Sensing can offer is acute approximations of irrigated fields and to crop water detectors through collecting the phonological advancement of crops via the arrangement of many temporal images.

2.4 SWAT MODEL

The SWAT (Soil and Water Assessment Tool) model is a continuous-time, semi-distributed, process-based river basin model (Srinivasan, Santhi, Harmel, & Griensven, 2012). There are four primary parameters required for the SWAT model, which is the DEM, land use map, soils map, climate information (precipitation, sun oriented radiation, relative stickiness, wind speed) and checking stream gages; those are the fundamental information to run SWAT.

The soil's permeability is further divided into many segments that put into consideration respective soil water activities, which include plant uptake, infiltration, lateral flow, evaporation and percolation. The aspect of the soil percolation of SWAT makes the best use of a container routing strategy to manipulate flow via the root zones. (Neitsch et al., 2005)

2.5 DESCRIPTION OF SWAT MODEL

The operation of the SWAT model is done daily and is intended to foresee the effect of water management, land usage, sediment, and agricultural chemicals produces in unmeasured catchment areas (Thakur, Kant, Hardaha, & Sharma, 2016).
The model is prepared based, computationally effective,
and able of ceaseless recreation over long times.(Thakur et al., 2016).
Major demonstrate components incorporate climate, hydrology, soil temperature and properties, plant development, supplements, pesticides, microscopic organisms, and pathogens, and arrive management.(Thakur et al., 2016). In SWAT, a watershed

is partitioned into different sub watersheds, which are at that point assist subdivided into hydrologic reaction units (HRUs) that comprise of homogeneous arrive utilize, administration, geological, and soil characteristics (Thakur et al., 2016).

The HRUs are represented as a rate of the Sub watershed zone and may not be bordering or spatially recognized inside a SWAT recreation. (Thakur et al., 2016). Then again, a watershed can be subdivided into as it were sub watersheds that are characterized by overwhelming arrive utilize, soil sort, and administration. (Thakur et al., 2016) Water adjust is the driving drive behind all the forms in SWAT since it influences plant development and the development of drugs, supplements, pesticides, and pathogens.(Thakur et al., 2016). Recreation of watershed hydrology is isolated into the arrive stage, which controls the sum of water, silt, supplement, and pesticide loadings to the most channel in each sub bowl, and the in-stream or steering stage, which is the development of water, silt, etc., through the channel organize of the watershed to the outlet.(Thakur et al., 2016)

The hydrologic cycle is climate driven and gives dampness and vitality inputs, such as every day precipitation, maximum/minimum discuss temperature, sun powered radiation, wind speed, and relative mugginess, that control the water adjust (Thakur et al., 2016) . SWAT will browse this ascertained information automatically from files or produce a replica data at runtime from noticeable monthly data (Thakur et al., 2016). Calculated is snow once the weather condition is lower at phase transition, and the soil temperature is analyzed because of its influences maneuverability of water and the pace by which the waste decays in the soil (Thakur et al., 2016).

Hydrologic forms mimicked by SWAT exemplify cover capacity, surface runoff, invasion, evapotranspiration, horizontal stream, tile deplete, conveyance of water interior the profile, immoderate utilize through pumping (on the off chance that any), come back stream, and energize by streaming from surface water bodies, lakes, and tributary channels (Moriasi et al., 2007).

ArcSWAT uses the growth of plants to model and simulate every type of land vegetation and distinguish between yearly and perennial plants. (Thakur et al., 2016) Plant development show is utilized to evaluate the expulsion of water and supplements from the establishment zone, transpiration, and biomass/ abdicate generation. (Thakur et al., 2016). SWAT employments the changed Widespread Soil Misfortune Condition (MUSLE) (Williams and Berndt, 1977) to anticipate silt abdicate from the scene. furthermore, SWAT models the development and change of numerous assortments of gas and phosphorus, pesticides, and silt inside the watershed .(Thakur et al., 2016). SWAT permits the user to outline management practices happening in each HRU (Thakur et al., 2016).

Immediately the filling of water, nutrients, pesticides, and sediments from the land area up to the uppermost channel becomes resolute, the fillings are routed via the reservoirs and streams in the watershed area. (Thakur et al., 2016). The water balance for reservoirs includes inflow, outflow, rainfall on the surface, evaporation, seepage from

the reservoir bottom, and diversion (Documentation, 2009) Gasman presents a outline of
(1) natural condition inputs and HRU hydrologic adjust;
(2) editing, administration inputs, and HRU-level squander misfortunes; and
(3) stream and toxin steering (Gassman et al., 2007). (Arnold et al., 2010) depict current investigation on upgrades to SWAT to course water over discretized scene units that mimic the impacts of spatial arrive utilize changes and arrive administration on the hillslope-valley time (Srinivasan et al., 2012)

2.6 CALIBRATION AND VALIDATION OF SWAT

The input independent variables of SWAT are process-based and has to be instructed in a realistic unlikely range. (Srinivasan et al., 2012). The primary step within the standardization and validation method in SWAT is that the determination of the foremost sensitive parameters for given watershed or sub watershed (Srinivasan et al., 2012).

The client decides which factors to alter based on expert judgment or on affectability investigation. Affectability investigation is the method of deciding the rate of alter in demonstrate yield with regard to changes in show inputs (parameters) (Srinivasan et al., 2012). It is fundamental to recognize key parameters and the parameter exactness required for calibration (Moriasi et al., 2007). In a practical viewpoint, this begin makes a difference confirm the overwhelming forms for the portion of intrigued (Srinivasan et al., 2012).

Two sorts of affectability examination are for the most part performed: nearby, by changing values one at a time, and worldwide, by permitting all parameter values to change (Srinivasan et al., 2012). The two calculations, although, may result in a variety of outcomes (Srinivasan et al., 2012). The sensitivity of one variable is normally dependent on the value of varying interlinked variables, thus, the issue with the singular evaluation is that the correct values of dissimilar variables that are tightened are never noticed. (Srinivasan et al., 2012).

The unfavorable aspect of the global sensitivity analysis is that it desires an oversized range of simulations(Srinivasan et al., 2012). Both methods, in any case, give knowledge into the affectability of the parameters and are essential steps in demonstrate calibration(Srinivasan et al., 2012).

The moment step is the calibration prepare (Srinivasan et al., 2012). Calibration is an effort to better parameterize a model to a given set of local conditions, thereby reducing the prediction uncertainty(Srinivasan et al., 2012). Model calibration is performed by carefully selecting values for model input parameters (within their respective un1494 TRANSACTIONS OF THE ASABE certainty ranges) by comparing model predictions (output) for a given set of assumed conditions with observed data for the same conditions(Srinivasan et al., 2012). The ultimate step is approval for the component of intrigued (streamflow, dregs yields, etc.)(Srinivasan et al., 2012).

Model approval is the method of illustrating that a given site-specific demonstrate is able of making adequately exact reenactments, in spite of the fact that "sufficiently accurate" can change based on extend objectives (Refsgaard, 1997). Approval includes running a demonstrate utilizing parameters that were decided amid the calibration prepare, and comparing the forecasts to watched information not utilized within the calibration(Srinivasan et al., 2012). In general, a decent model standardization and validation ought to involve: (1) determined information that embrace wet, average, and dry years (Gan et al., 1997); (2) multiple analysis techniques (ASCE, 1993; Legates and McCabe, 1999; Boyle et al., 2000); (3) calibrating all constituents to be evaluated; and (4) verification that alternative vital model outputs are cheap (Srinivasan et al., 2012). In general, graphical and statistical methods with some form of objective statistical criteria are used to determine when the model has been calibrated and validated(Srinivasan et al., 2012). Calibration can be accomplished manually or using auto calibration tools in SWAT (van Griensven and Bauwens, 2003; Van Liew et al. (2005) or SWAT-CUP (Abbaspour et al., 2007).

Ideally, calibration and validation should be process and spatially based, while taking into account input, model, and parameter uncertainties(Srinivasan et al., 2012). A great case of process-based standardization includes streamflow. Streamflow forms are comprised of the water adjust inside the arrive area of the geophysics, along side ET, horizontal stream, surface runoff, come back stream, tile stream (on the off chance that show), channel transmission misfortunes, and profound geographical arrangement energize (Srinivasan et al., 2012). If information are offered for every of those processes, they ought to be graduated separately. For sediments, nutrients, pesticides, and bacterium, sources and sinks ought to be thought-about (Srinivasan et al., 2012). If a longer time is available for hydrology than water quality data, it is important to use all the hydrology data available for calibration and validation to capture long-term trends(Srinivasan et al., 2012).

This process-based standardization ought to be done at the sub watershed or landscape level to make sure that variability within the predominant processes for every of the sub-watersheds is captured rather than determinative world(watershed-wide) processes(Srinivasan et al., 2012). There are,
however, typically light ascertained information to alter a full spatial standardization and validation at the watershed scale (Srinivasan et al., 2012). The metrics and ways accustomed compare ascertained information to model predictions are important (Srinivasan et al., 2012). Multiple graphical and applied mathematics ways can be used, like time-series plots, Nash-Sutcliffe potency (NSE; Nash and Sutcliffe, 1970), and p.c bias.

2.7 THE EVAPOTRANSPIRATION OF CROPS AND WATER ACCESSIBILITY FOR OIL PALM WITHIN THE DIFFERENT AREAS IN MALAYSIA

The crop evapotranspiration of mature oil palm has a range from 1,583 to 2,003 mm/year. The highest crop evapotranspiration is observe for areas around Alor Star and the lowest is for areas around Senai. The water availability for oil palm in the different regions follow similar trends as the crop evapotranspiration rates (Arshad, Crop, & Unit, 2014)

Table 1: The ET_o of Crops and Water Accessibility for Oil Palm within Peninsula Malaysia

Stations	Crop Evapotranspiration (mm/year)	Water Availability (%) at Soil Water Storage (75 mm)	Water Availability (%) at Soil Water Storage (200 mm)
Alor Star	2003	66	71
Ipoh	1765	93	100
Subang	1748	100	100
Malacca (coastal)	1998	72	77
Malacca (non-coastal)	1835	76	82
Kluang	1663	89	96
Senai	1583	98	100
Kuantan (coastal)	1848	85	92
Kuantan (non-coastal)	1683	91	99
Kuala Krai	1630	75	83

2.7 CROP COEFFICIENTS

$$ETc = Kc \times ET_o \quad \text{(1)}$$

Kc is the coefficient for crops developing beneath conditions of ideal richness and soil dampness and accomplishing full generation potential.

In creating the trim coefficients for the developing season, distinctive stages of edit improvement are considered:

1. Introductory state: from planting through germination and plant development, and until around 10% ground cover is accomplished. Water misfortune is for all intents and purposes all evaporation.

2. Trim advancement organize: from 10% of ground cover to successful full ground cover. This happens at almost 70% or 80% ground cover. 3. Mid-season arrange from compelling cover to the begin of development. The trim is physiologically competent of the most noteworthy water to utilize amid this time. The edit coefficient is highest

2.8 SEASONAL ETcrop REQUIREMENS FOR MAXIMUM YIELDS OF CROPS

ETo (mm/season) =reference evapotranspiration rate

Kc= Crop Factor

ETcrop= the water requirement of a given crop in mm/season

Table 2: Describes the calculation of the water requirement of a given crop in mm/season

Crop	Seasonal ETo (mm)	Avg. Seasonal ETo (mm)	Kc of crops at mid-season	Avg. Kc of crops at mid-season	ETcrop= Kc(Avg) x ETo(Avg)
Watermelon	400-600	500	0.95-1.05	1	500
Banana	1200-2200	1700	1.0-1.1	1.05	1785
Potatoes	500-700	600	1.05-1.2	1.125	675
Sugarcane	1500-2500	2000	0.7-1.0	0.85	1700
Cotton	700-1300	1000	1.05-1.25	1.15	1150
Maize	500-700	600	1.05-1.2	1.125	675
Cabbage	380-500	440	0.95-1.1	1.025	451
Rice	350-700	525	1.1-1.3	1.2	630
Sorghum	450-650	550	1.0-1.15	1.075	591.25
Tomato	400-600	500	1.05-1.25	1.15	575
Wheat	450-650	550	1.05-1.2	1.125	618.75

2.9 AN APPROXIMATION AMOUNT OF WATER NEEDED TO PRODUCE CROPS & LIVESTOCK

Source: Pimentel and Colleagues (2004)

Crop or Livestock	**Water required (liters Per kilogram)**
Crop;	
Soya beans	2005
Rice	1620
Sorghum	1310
Alfalfa	1120
Wheat	930
Corn	660
Potatoes (dry)	640
Millet	270
Livestock;	
Broiler Chicken	3570
Pig	6020
Beef Cattle	43020
Sheep	51040

2.10 WATER REQUIRED FOR FRUIT TREES

Fruits	**Area (ha)**	**Annual Water Requirement**	**Production (Tones)**
Almonds	9,800	350	20,800
Apple	101,500	625	223,800
Apricot	26,200	450	187,700
Banana	1,400	1,700	23,000
Citrus	1,300	1,050	5,900
Dates	42,300	1,100	224,900
Grapes	12,600	350	48,400
Guava	600	625	2,600
Mango	1,400	625	6,600
Peach	9,400	450	18,500
Pears	100	400	500
plums	3,700	450	26,400
Pomegranate	10,700	350	36,100
Total	221,000		825,200

Source: Agriculture Statistics of Pakistan (MINFAL, 2004) and Irrigation Agronomy-VI (FWM)

2.11 CROP WATER REQUIREMENT OF OIL PALM BASED ON POTENTIAL EVAPOTRANSPIRATION

ETo (mm/year) =reference evapotranspiration rate

Kc= Crop Factor

ETcrop= the water requirement of a given crop in mm/year

The crop factor of Oil Palm is 0.7 (Kumar, n.d.)

STATIONS	ETo (mm/year)	Kc	ETcrop= ETo x Kc
Alor Star	2003	0.7	1402.1
Ipoh	1765	0.7	1235.5
Subang	1748	0.7	1223.6
Malacca (coastal)	1998	0.7	1398.6
Malacca (non-coastal)	1835	0.7	1284.5
Kluang	1663	0.7	1164.1
Senai	1583	0.7	1108.1
Kuantan (coastal)	1848	0.7	1293.6
Kuantan (non-coastal)	1683	0.7	1178.1
Kuala Krai	1630	0.7	1141

Table 3: Describes the water requirement of a given crop in mm/year

An example of calculating unit water budgets for aquaculture ponds.

P= 145 cm/yr

E=117cm/yr

I= 108 cm/yr

B= negligible (omitted)

R= 50cm/yr

Pond data

Pond area= 1ha

Pond depth when filled to intake of overflow structure= 150 cm

For embankment ponds, watershed area is negligible

For watershed ponds, watershed: pond ratio =10:1

Ponds are filled to depth of 140 cm and water is not added when storage capacity less than 10 cm

Ponds do not overflow after rain

Ponds are drained at time when water levels are 10 cm below drains.

- Water is intentionally added to ponds initially to fill them and afterwards to maintain water levels. The amount of water applied to fill ponds (A0 is estimated from pond area and average depth. The quantity of water necessary to maintain water levels (Ai) is:

Ai= (E+I)-P.

Thus, we have:

Total water use = P+R+I+A+ [(E+I)-P]

=145+0+0+140+ [(117+108)-145]

= 365 cm

Pond discharge (Q_p) maybe calculated as follows:

Q_p= OF +D

(Claude E. Boyd, June 2005)

Q_p= Pond discharge; **SFR**= Stream Flow Reduction.

2.12 WATER USE PER HECTAR UNIT OF POND SURFACE AREA AND RESULTING REDUCTION IN SURFACE RUNOFF IN ALABAMA

Pond Type	Water Source	Total	Consumptive	Ground Water	Qp (cm)	SFR (m^3)
Embankment						
Drained	Well	365	220	220	140	0
Undrained	Well	225	130	80	0	5,000
Drained	Stream	365	130	0	140	13,000
Undrained	Stream	225	130	0	0	13,000
Watershed						
Drained	Rainfed	645	130	0	420	13,000
Undrained	Rainfed	645	130	0	420	13,000

Table 4: Describes Water Use per Unit of a Pond Surface Area

2.13 TOTAL AND CONSUMPTIVE WATER USE INDEX AND WATER VALUE INDEX IN POND CULTURE OF CHANNEL CATFISH IN ALABAMA

Pond Type	Water Source	Total	Consumptive (m^3/t)	Water value index ($/m^3)
Embankment				
Drained annually	Well	6,080	3,667	0.390
	Stream	6,080	2,167	0.660
Undrained	Well	3,750	2,167	0.660
	Stream	3,750	2,167	0.660
Watershed				
Drained annually	Rainfed	10,750	2,167	0.660
Undrained	Rainfed	10,750	2,167	0.660

Table 5: Production of 6,000kg/ha/year with crop value of $1.43/kg (Claude E. Boyd, June 2005

2.14 CROP WATER REQUIREMENT OF OIL PALM

Crop Evapotranspiration (mm/year)

DID- Drainage and Irrigation Department (1977), D- Doorenbos and Pruitt (1977), PM-Penman-Monteith (Smith, 1991) (Arshad et al., 2014)

STATIONS	DID	D	PM
Alor Star	1555	2003	1647
Ipoh	1445	1765	1383
Subang	1481	1748	1352
Malacca (coastal)	1463	1998	1351
Malacca (non-coastal)	1463	1835	1351
Kluang	1386	1663	1336
Senai	1354	1583	1164
Kuantan (coastal)	1430	1848	1387
Kuantan (non-coastal)	1430	1683	1387
Kuala Krai	1373	1630	1244

Table 6: Consumptive Use of Water by Oil Palm in Different Regions in Peninsular Malaysia

CHAPTER THREE

3.0 METHODLODOLOGY

3.1 FLOW CHART FOR WATER BALANCE MODEL

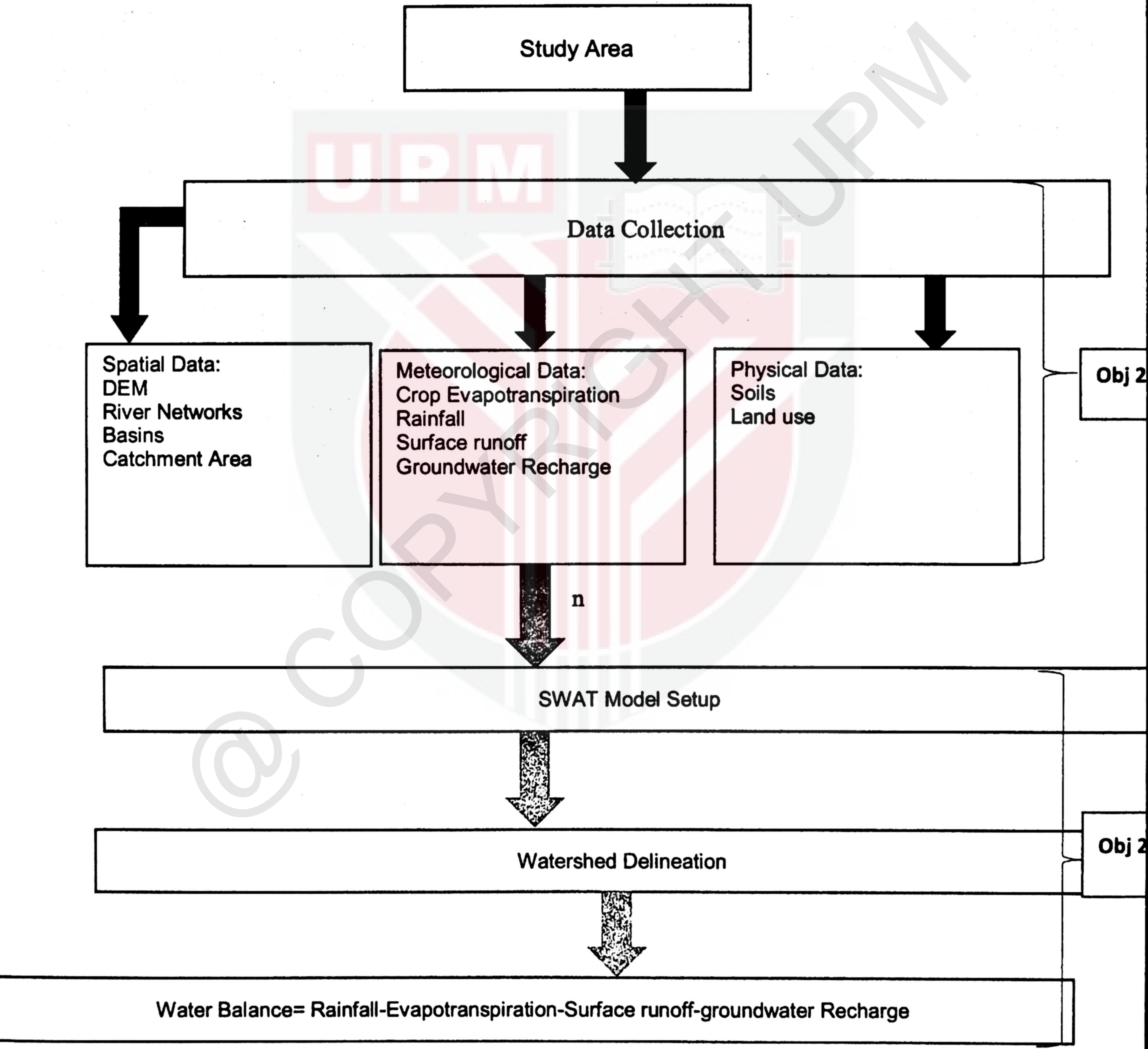


Figure 1: Shows the step by step procedure of the Water Balance Mode

3.2 SPATIAL DATA FROM CAMERON HIGHLANDS IN ARCSWAT

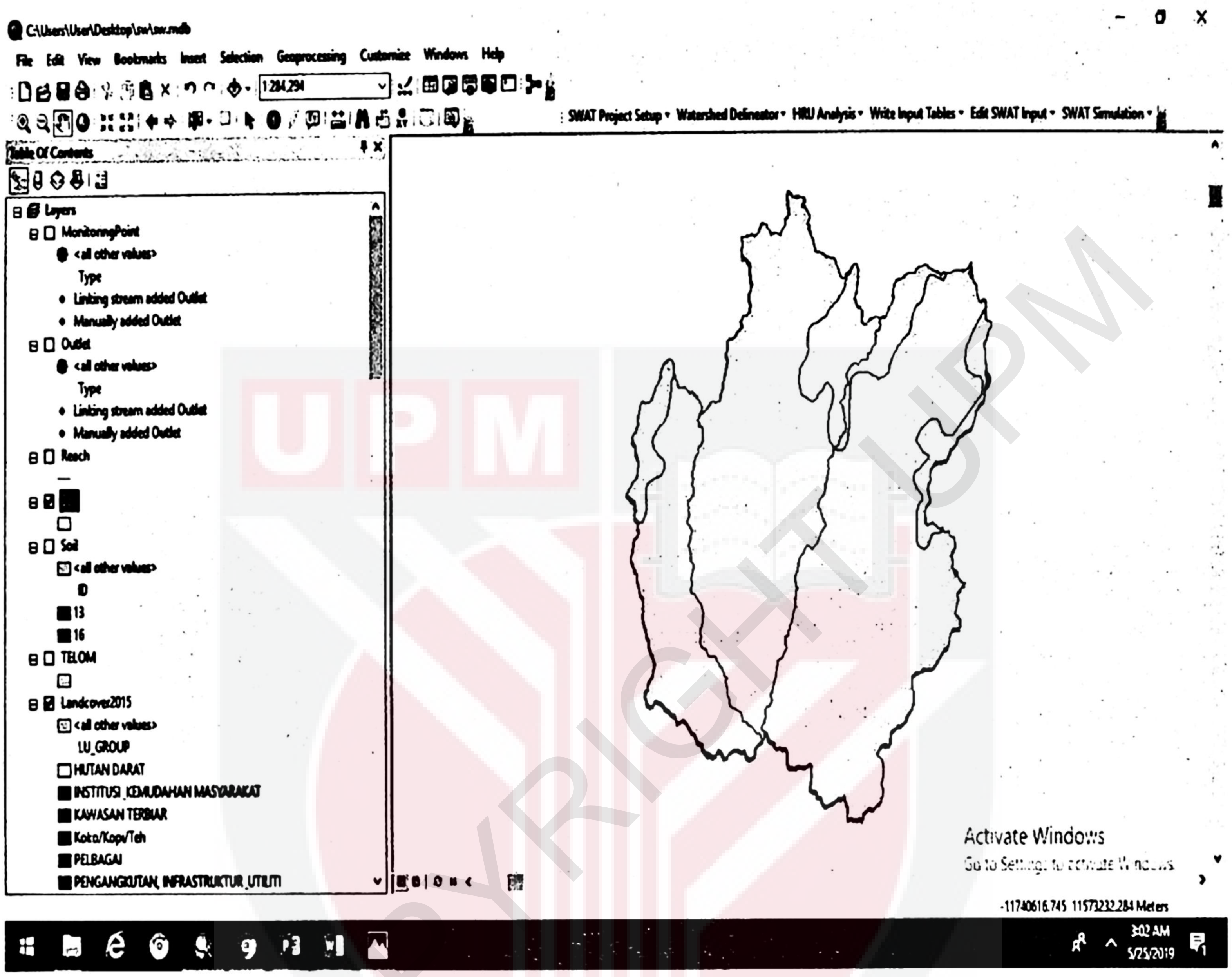


Figure 1: Land Use Map

Land use includes the administration and adjustment of normal environment or wild into built environment such as settlements and semi-natural territories such as arable areas, pastures, and overseen woods. It too has been characterized as "the full of courses of action, exercises, and inputs that individuals embrace in a certain land cover sort.

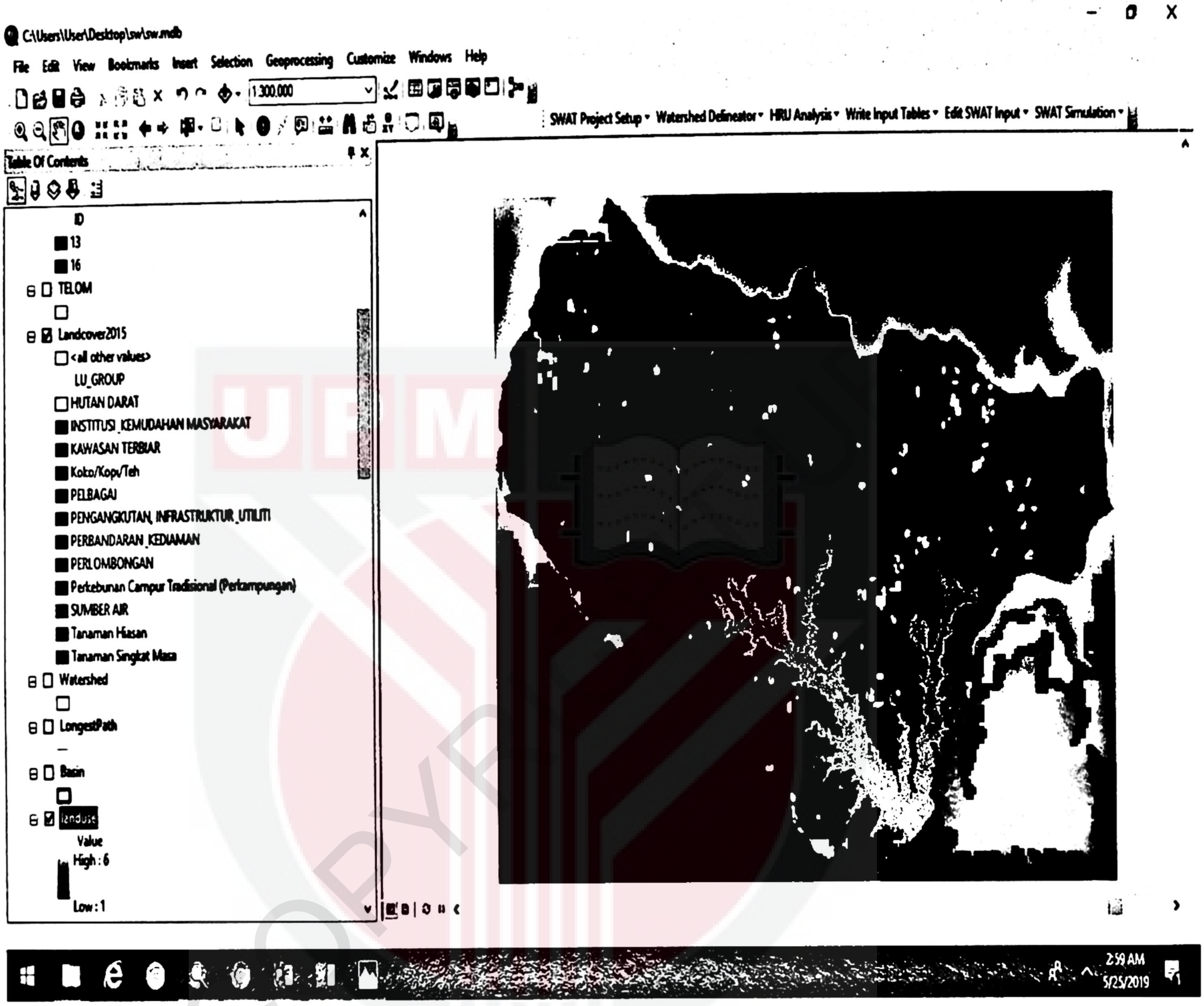


Figure 2: Soil Map

A soil map may be an outline i.e. a topographical representation appearing differing qualities of soil sorts and/or soil properties (soil pH, textures, organic matter, profundities of skylines, etc.) within the zone of interest. It is regularly the conclusion result of a soil overview stock, i.e. soil overview. Soil maps are most commonly utilized for arrive assessment, spatial arranging, agrarian expansion, natural s ecurity and comparable venture

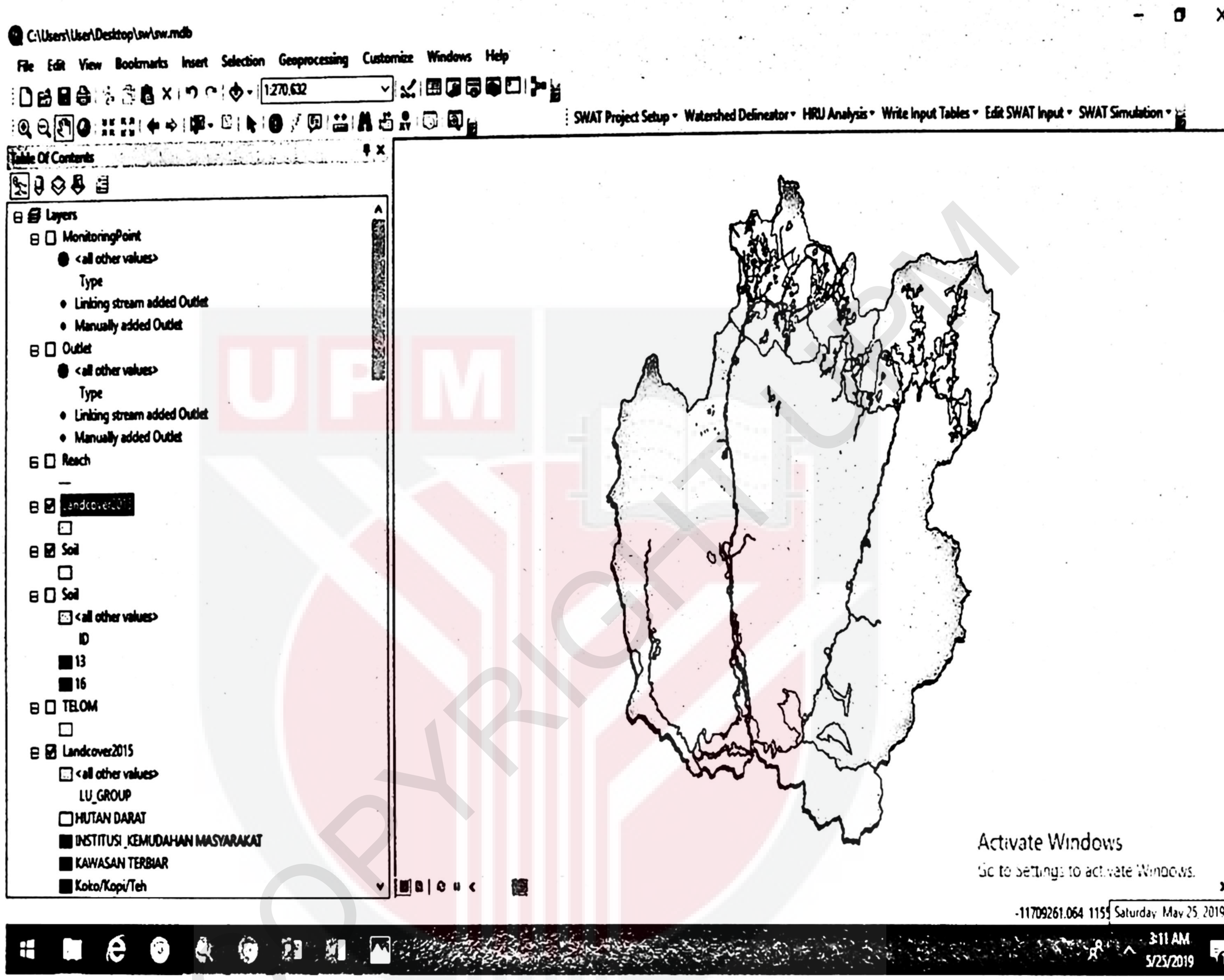


Figure 3: Land Cover

The land cover depicts the real or physical nearness of vegetation (or other materials where vegetation is nonexistent) on the arrive surface. Land cover is additionally regularly portrayed as what can be seen on arrive seen from over. It is one implies to portray scene designs and characteristics that are basic in understanding viewpoints of the environment counting the accessibility of and changes in living space, the potential for scattering of chemicals and other toxins, and potential supporters to climate alter, such as reflectivity of the arrive.

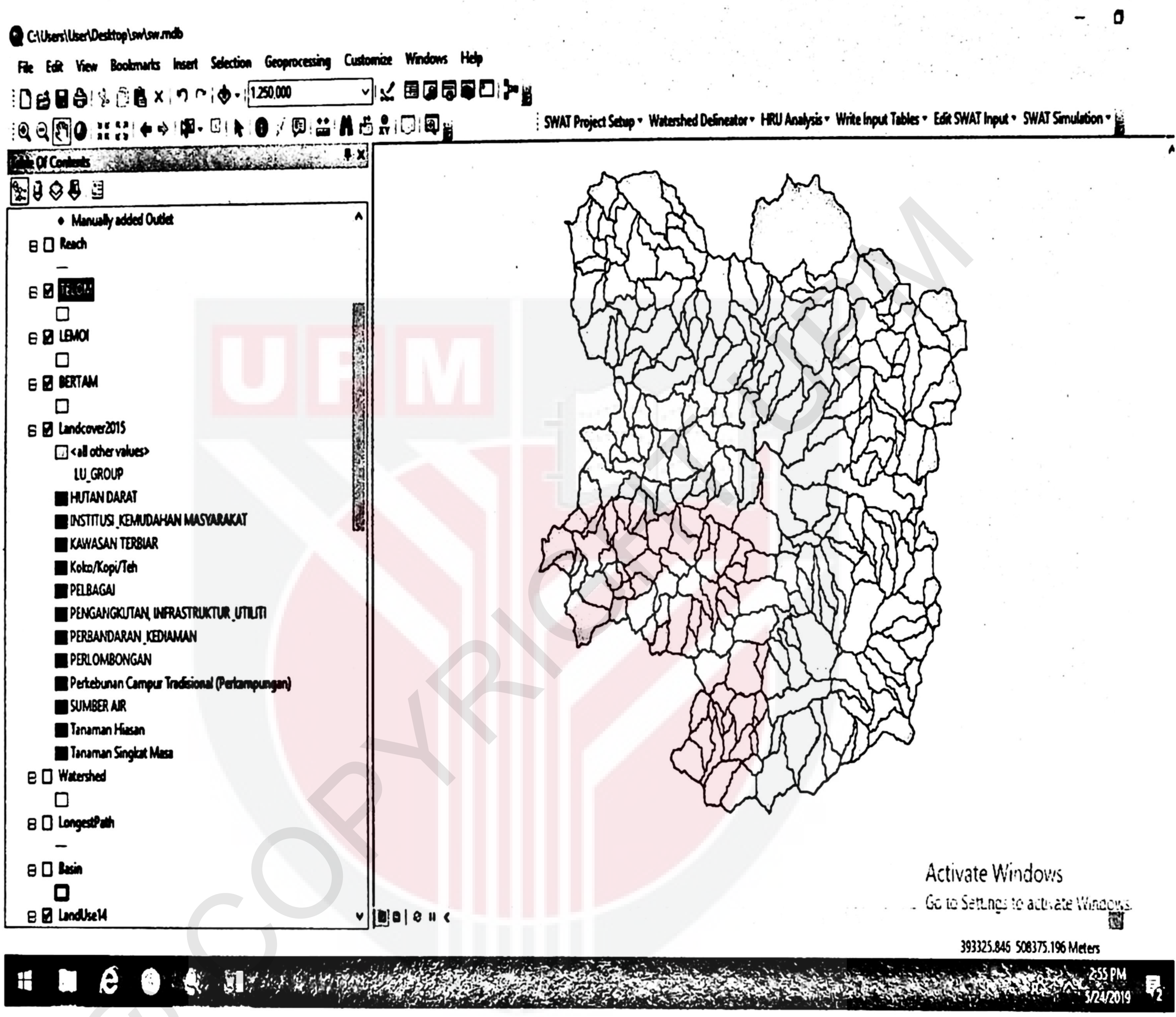


Figure 4: Catchment Areas

Catchment zone is more often than not connected with Waterways in Hydrology, as this region states the locale from a waterway more often than not gets its water or pour out, that can change from streams to lakes be in meters or in km. It is concept beneath Watershed Investigation (in which the catchment region is being dissected with reference to its stream and to get it the pertinence of it with Arrive + Slant + Viewpoint and Course also).

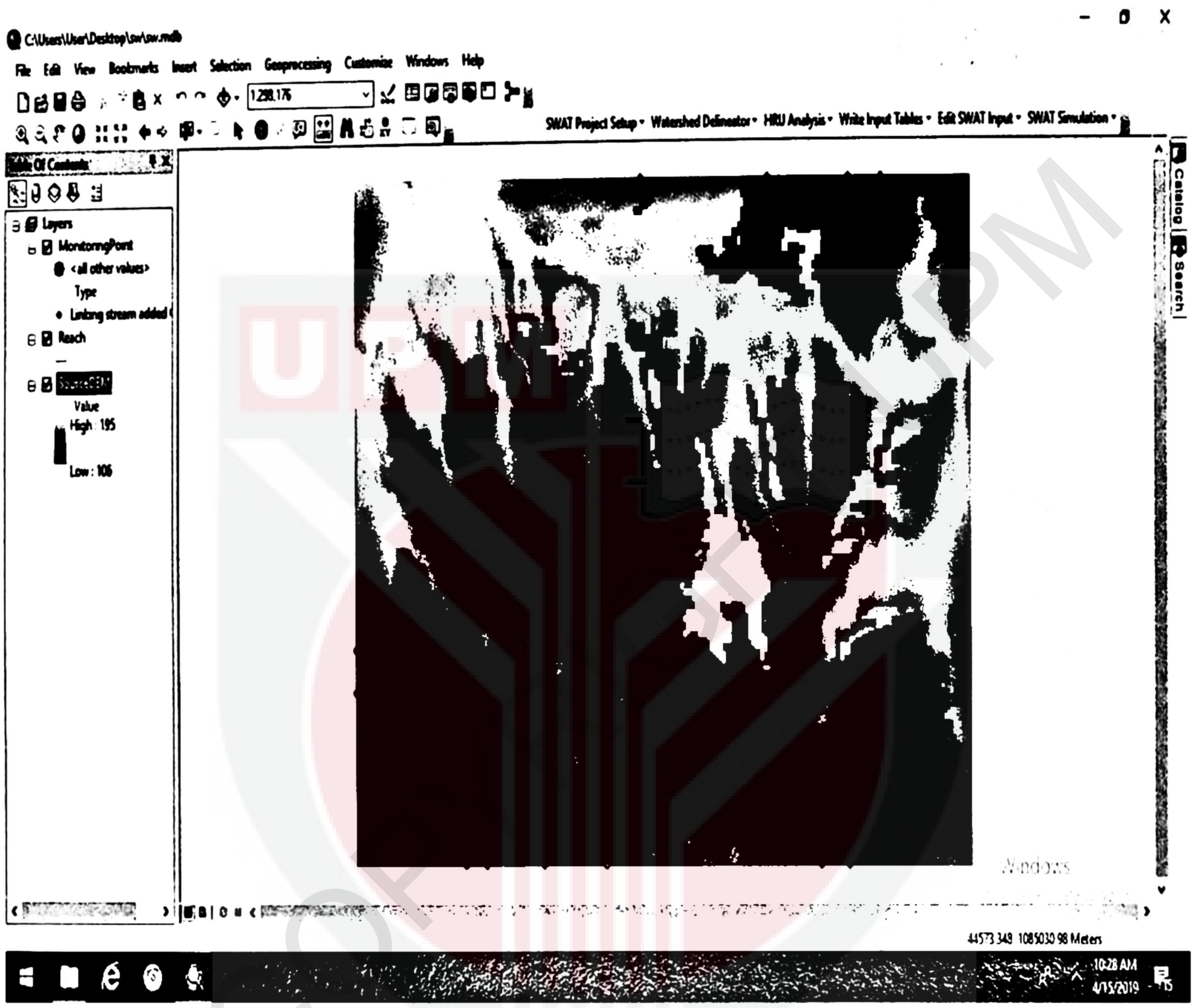


Figure 5: Watershed

A watershed is a zone of land that bolsters all the water running beneath it and depleting off it into a body of water. It combines with other watersheds to make a organize of streams and streams that continuously deplete into bigger water ranges.

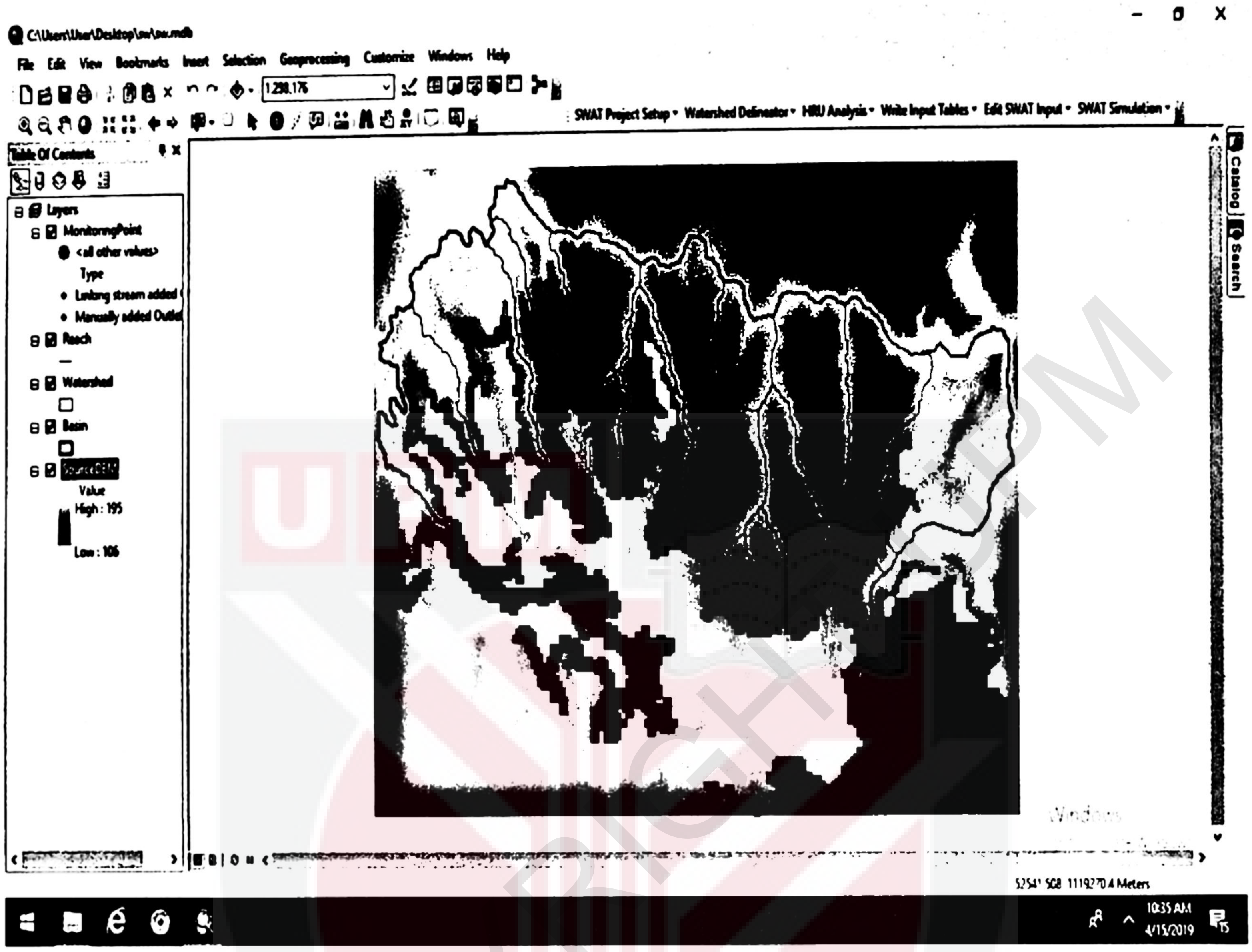


Figure 6: Basin

A drainage basin is any region of arrive where precipitation collects and channels off into a common outlet, such as into a stream, narrows, or other body of water. The seepage basin incorporates all the surface water from rain runoff, snowmelt, and adjacent streams that run downslope towards the shared outlet, as well as the groundwater underneath the earth's surface. Seepage bowls interface into other seepage bowls at lower heights in a progressive design, with littler sub-drainage bowls, which in turn deplete into another common outlet.

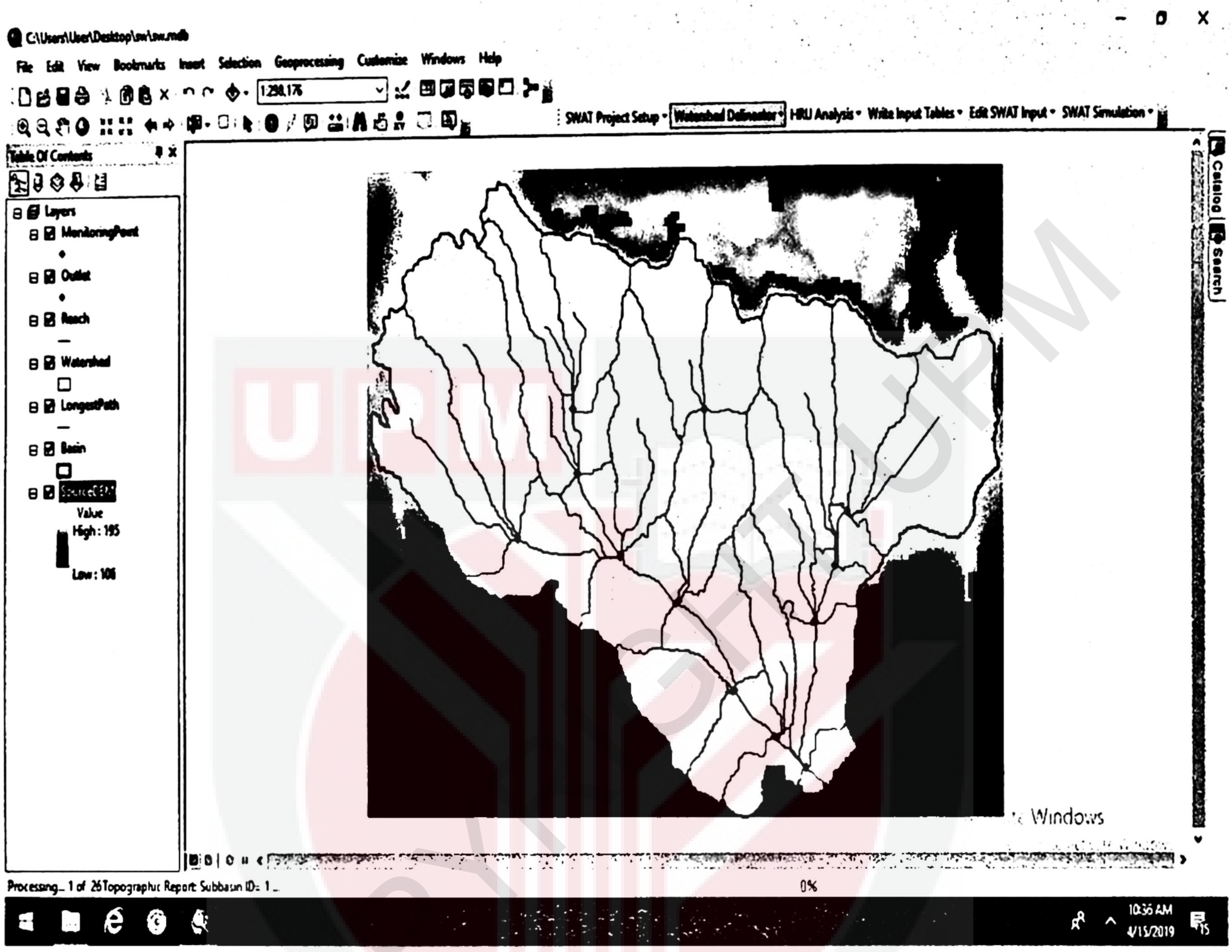


Figure 7: Reach

A reach may be a length of a stream or waterway, ordinarily recommending a level, continuous stretch. The starting and finishing focuses may be chosen for geographic, verifiable or other reasons – and may be based on points of interest such as gaging stations, waterway miles, characteristic highlights, and topography. A reach may too be a region, or broadening, of a stream or waterway channel. This commonly happens after the stream or stream is dammed.

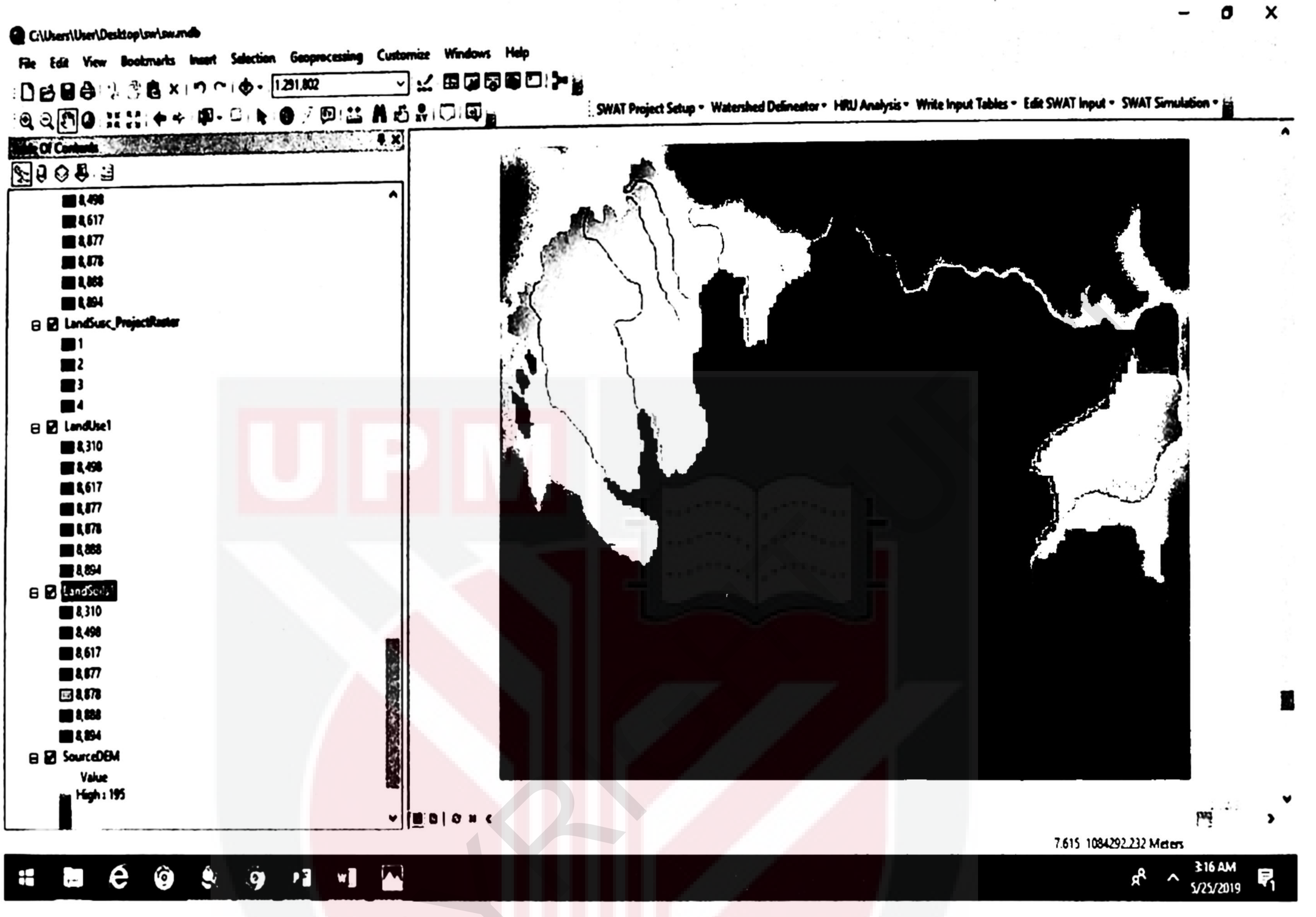


Figure 8: TELCOM Catchment Area

3.3 FLOWCHART FOR SWAT MODEL

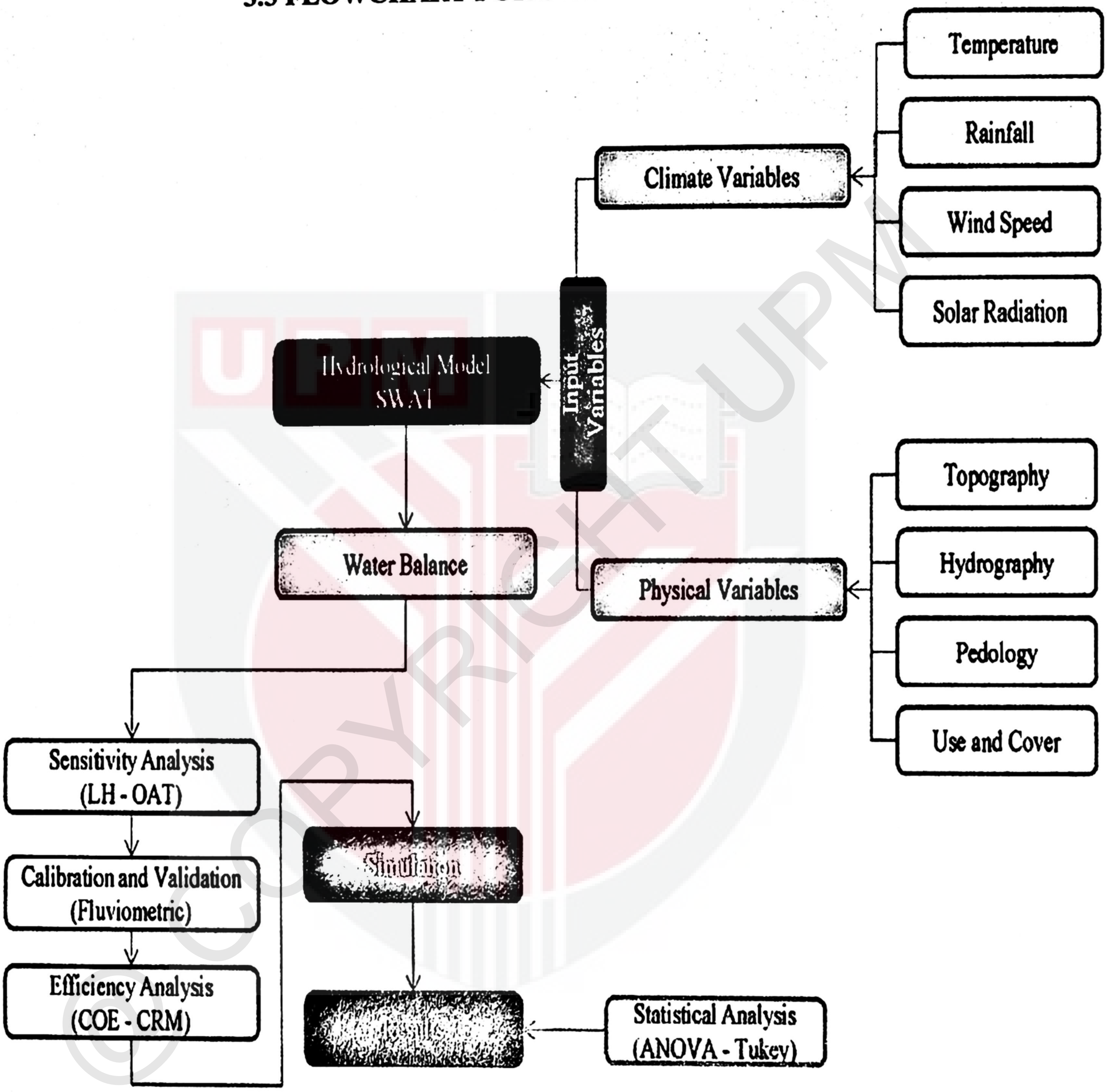


Figure 2: Flowchart of the steps for the adjustment of the hydrological model SWAT (Rodrigues et al., 2015)

4.0 RESULTS AND DISCUSSION

4.1 THE HYDROLOGICAL COMPONENT FOR MALAYSIA

Review of the National Water Resources (2000-2050) and Formulation of National

States	Area (km^2)	Unit in mm per year				Unit in billion (m^3/year)			
		Rainfall	Actual Evaporation	Groundwater Recharge	Surface Runoff	Rainfall	Actual Evaporation	Groundwater Recharge	Surface Runoff
The State of Perlis	823	1,890	1,288	120	471	1.52	1.08	0.12	0.36
The State of Kedah	9,510	2,305	1,432	130	748	21.93	13.60	1.26	7.14
The State of Pulau Pinang	1,055	2,355	1,428	120	798	2.44	1.52	0.11	0.85
The State of Perak	21,025	2,483	1,323	170	992	52.20	27.75	3.56	20.83
Selangor State	8,400	2,195	1,278	150	757	18.36	10.78	1.28	6.40
The State of Negeri Sembilan	6,680	1,825	1,211	130	492	12.21	8.07	0.89	3.30
Melaka State	1,667	1,878	1,214	100	573	3.15	2.03	0.15	0.93
Johor State	19,215	2,475	1,135	200	1,138	47.47	21.70	3.85	21.92
Pahang State	36,140	2,465	1,251	120	1,103	89.24	45.18	4.36	39.78
The State of Terengganu	13,030	3,315	1,467	150	1,691	43.16	19.18	1.97	22.04
Kelantan State	15,100	2,595	1,293	140	1,175	39.28	19.50	2.10	17.65
Peninsular Malaysia	132,645	25,781	14,320	1,530	9,938	330.96	170.39	19.65	141.20
Sabah	73,630	2,562	1,185	190	1,178	188.52	87.61	13.97	86.87
Sarawak	124,460	3,395	1,254	240	2,152	453.20	155.58	29.90	267.59
FT Labun	89	3,105	1,480	153	1,471	0.30	0.15	0.03	0.16
East Malaysia	198,179	9,062	3,899	583	4,801	642.02	243.34	43.90	354.62
Malaysia	330,824	34,843	18,219	2,113	14,739	972.98	413.73	63.55	495.82

Water Resources Policy August 2011

Table 6: Tabulates the Hydrological Components in Malaysia

4.2 CALCULATIION OF WATER BALANCE IN DIFFERENT REGIONS OF PENINSULA MALAYSIA

Water Balance= (Rainfall-Evapotranspiration-Surface runoff-Groundwater Recharge)

Water Balance for Perak (Ipoh Station)

Water Balance (Perak) = (2483-1445-992-170) mm/yr = -124mm/yr

Water Balance for Selangor (Subang Station)

Water Balance (Selangor) = (2195 -1481-757-150) mm/yr= -193mm/yr

Water Balance for Maleka (Maleka Station)

Water Balance (Maleka) = (1878-1463-573-100) mm/yr =-258mm/yr

Water Balance in Johor (Kluang Station)

Water Balance (Johore) = (2475-1386-1138-200) mm/yr=-249mm/yr

Water Balance in Pahang (Kuantan Station)

Water Balance (Pahang) = (2465-1430-1103-120) mm/yr=-188mm/yr

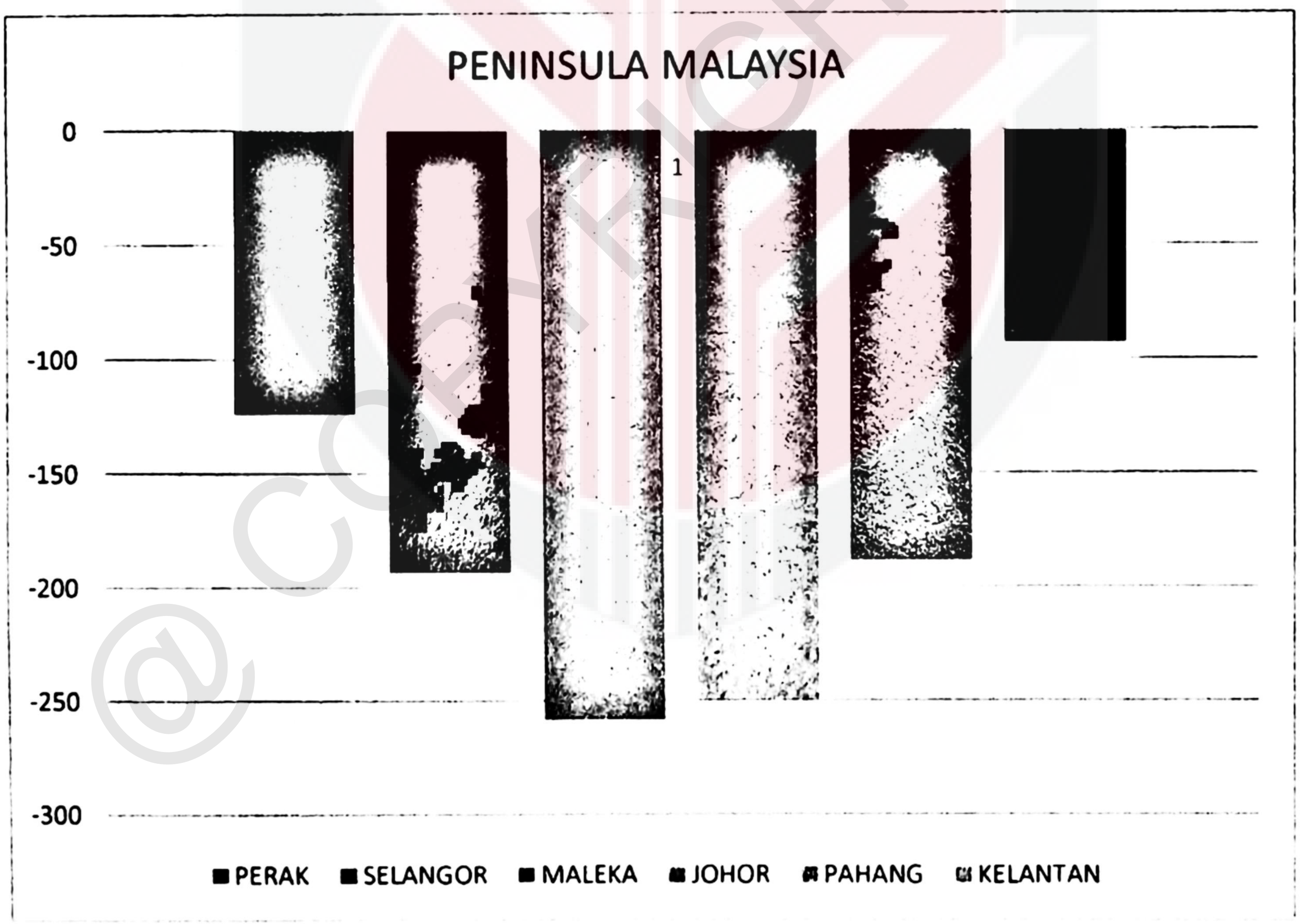
Water Balance in Kelantan (Kuala Krai)

Water Balance (Kelantan) = (2595-1373-1175-140) = -93mm/yr

4.3 WATER BALANCE IN PENINSULAR MALAYSI

Table 7: Shows the Water Balance Value of Different States in Malaysia

STATE	WATER BALANCE (MM/YR)
PERAK	-124
SELANGOR	-193
MALEKA	-258
JOHOR	-249
PAHANG	-188
KELANTAN	-93



CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

A thorough investigation has been done in terms of the water requirements of crops, livestock, and aquaculture. The general water demand and water deficit in Malaysia is also covered in this research. Spatial information from Cameron highland is ran in the ArcSWAT model to produce the water delineation of the study area and that was followed by a manual calculation of the water balance study.

Per the results from the manual calculation of water balance, putting into perspective the amount of rainfall per year in each state, the actual evaporation, groundwater recharge, and surface runoff, it is clear that there is a water balance deficit in majority of the states in Malaysia.

I would strongly recommend for a rigorous research to be make about the factors contributing to water imbalances in Malaysia and how to overcome them. The central government, universities, private organizations should all work hand in glove to ensure that the water balance problem in Malaysia is resolved in the soonest time possible.

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