ESTIMATING DAILY NET RADIATION FLUX (Rn) USING REMOTE SENSING TECHNIQUE.

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ABSTRACT

Daily net radiation ($R_{24}n$) is key variable in hydrological studies. This study highlight Remote Sensing (Rs) technique for derivation of $R_{24}n$. Satellite image was used in order to determine spatially distributed information on daily net radiation using land surface temperature, albedo and short wave radiation. Reasonable estimates of $R_{24}n$ were obtained for spatially distributed Land use and Land cover (LULC).

ABSTRAK

Sinaran bersih harian ($R_{24}n$) merupakan parameter penting dalam kajian hidrologi. Kajian ini memfokuskan tentang teknik Remote Sensing (Rs) untuk penerbitan nilai $R_{24}n$. Imej satelit di gunakan untuk menentukan taburan maklumat sinaran bersih harian($R_{24}n$) dengan menggunakan suhu permukaan tanah,albedo, dan sinaran gelombang pendek. Anggaran sinaran bersih harian($R_{24}n$) yang munasabah di perolehi untuk kepelbagaian guna dan litupan tanah.

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LIST OF SYMBOLS

P	cathment rainfall
ET	evapotranspiration
Q	surface runoff
L	deep seepage
ΔWS	change in soil moisture storage and
ΔG	change in groundwater storage
ΔS	change in storage,
P	precipitation,
E	evaporation.
T	transpiration,
G	groundwater flow out of the catchments,
Q	surface runoff.
L	losses or hydrological abstractions which equal to the sum of evaporation, transpiration, and infiltration.
a, b	empirical constants converting sunshine hours to short wave radiation.
n	actual duration of bright sunshine in hours for day (month)
N	maximum possible mean daily duration of bright sunshine in hours.
Tm	mean air temperature in degree absolute (°K) for day (month)
e_d	saturation vapour pressure in mm Hg at mean dew point temperature

for the same period.

γ lummer and Pringsheim constant, 117.74 x 10^{-9} gm.cal/cm^2/°K^{-4}

*G*sc solar constant (1,367 W/m^2)

θ solar incidencevangle;

dr inverse relative earth–sun distance is calculated as

J Julian day of the year.

sw atmospheric transmissivity from elevation

Z elevation

a atmospheric emissivity

Ti incident near surface air

Ts incident surface

δ solar declination (rad),

ε latitude of the site;

β always positive and represents downward slope in any direction;

γ deviation of the normal to the surface from the local meridian;

ω solar time angle (rad),

CHAPTER 1

INTRODUCTION

1.0 Introduction

` The only "volume of water" leaving the basin is actual evapotransprirasion (AET) and discharge to the ocean. In order to determine lost of water from land surface, there are in need spatially distributed AET value over the diversity of land surface. One of the variables to derived AET is net radiation (Rn). Rn is key variable in hydrological studies. Measure net radiation data rarely available. In addition, point measurement of net radiation does not represent the diversity of the regional net radiation value which is needed for evapotranspiration (ET) mapping. For years remote sensing have play important role in hydrological study. Remote Sensing (Rs) could provides variable such as Land Use and Land Cover (LULC) status, albedo and emissivity that one useful in derivation of Rn.

Remote sensing is defined as the technique of obtaining information about objects through the analysis of data collected by special instruments that are not in physical contact with the objects of investigation. As such, remote sensing can be regarded as *"reconnaissance from a distance," "teledetection,"*. Remote sensing thus differs from **in situ sensing**, where the instruments are immersed in, or physically touch, the objects of measurement. This characteristic makes it possible to measure, map, and monitor these objects and features using satellite or aircraft-borne **RSS (Remote Sensing)**, satellite image offers a number advantages over conventional survey techniques.

1.1 PROBLEM STATEMENT AND JUSTIFICATION

In hydrological study, in order to produce ET map for large area, Rn value which represent the diversity of LULC are required. In Malaysia practice daily net radiation ($R_{24}n$) estimated based on point sampling (Hydrology produce 17, 1989). This does not represent the diversity of land surface for large area.

1.2 OBJECTIVE OF THE STUDY

This study has two (2) principal objectives:

1. To study the conventional method in ($R_{24}n$) estimation, and
2. To estimate $R_{24}n$ flux using remote sensing technique.

1.3 SCOPE OF THE STUDY

This study was based on;

1. Data image from *Landsat 7 ETM* Satellite, and
2. Any field data involved obtained from literature.

1.4 STUDY AREA

Kuantan District, east cost of Malaysia Peninsular, Latitute 3.75-4.25° N and Longitud 103.25°E Figure 1. This area is lies entirely in the equatorial zone. The climate is governed by the yearly alternation of the northeast and monsoon occurs from November till March, and September. The maximum and minimum mean air temperature is 33.4°C and 22.8°C respectively. The highest and lowest recorded annual rainfall are 5 130mm and 1 350 mm respectively. The mean annual relative air humidity varies between 78 and 87 percent; this high humidity is due to the high temperature and high rate of evaporation. All parts of country receive an average of 1 764 to 2 664 bright sunshine hours a year. Pahang River Basin has relatively diverse land use and land cover (LULC) patterns. LULC include tropical forest, oil palm, rubber tree, tropical peat and residential area.

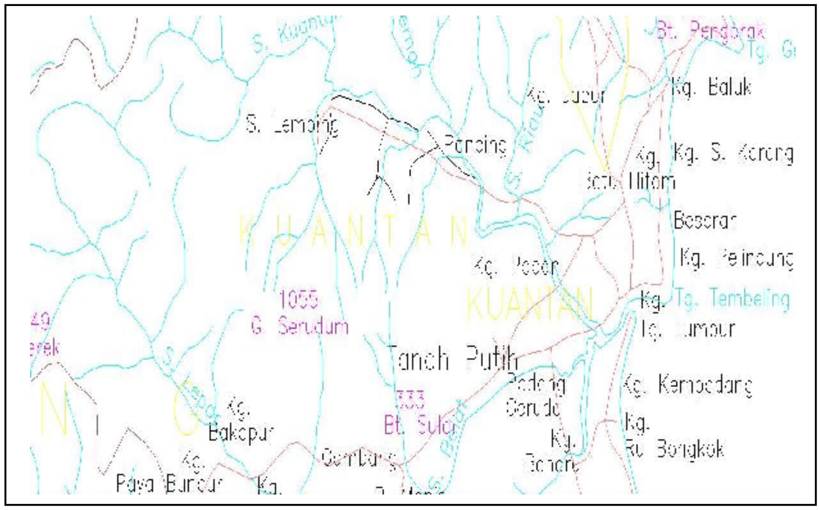

Figure 1.1: Kuantan District, Pahang, Peninsular Malaysia.

1.5 SIGNIFICANT OF THE STUDY

The hydrological study faces a significant "information gap" problem. In most areas in the world, little information has been collected on change in land cover, and specifically data on change in hydrological variables. In cases where measuration has been applied it has usually been conducted for only one point in time. Remote sensing is particularly important in research agenda because it helps fill this information gap. It gives a most reliable value because it judge at every single pixel. In this research RS will give (R_{24}n) value based on pixel size and cover large area.

1.6 OUTLINE OF THE THESIS

Chapter 1 gives the brief of background of the project. The problem statements, scope of study and objective are also discussed in this chapter.

Chapter 2 will discusses about water balance, evapotranspiration process, method for estimate the net radiation flux and all literature review that related in this study.

Chapter 3 will presents the development of methodology, the flow chart of this study with explanation in every single phase. It also describes the data collecting at study area.

Chapter 4 will discusses the result of the project. The discussion is about estimating (NDVI), estimating the value of albedo, estimating the mean of daily net radiation, and also represent the result of ($R_{24}n$).

Chapter 5 will present the conclusion of the project. Suggestion and recommendation for the future work are put forward in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter review of the past research related to the radiation flux, remote sensing, Evapotranspiration, and energy balance. The review is organized chronologically so as to offer approaching to how research works have laid the base for subsequent studies, including the present research effort. The review is fairly detailed so that the present research effort can be properly modified to add to the present body of literature as well as to justify the scope and direction of present research effort. C. F. Shaykewich, (1979).

2.2 WATER RESOURCES

Water resources are sources of water that are useful or potentially useful to humans. Virtually all of these human uses require fresh water. 97% of water on the Earth is salt water, leaving only 3% as fresh water of which slightly over two thirds is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is mainly found as groundwater, with only a small fraction present above ground or in the air. A. Reimer (1979).

Fresh water is a renewable resource, yet the world's supply of clean, fresh water is steadily decreasing. Water demand already exceeds supply in many parts of the world and as the world population continues to rise, so too does the water demand. Awareness of the global importance of preserving water for ecosystem services has only recently emerged as, during the 20th century, more than half the world's wetlands have been lost along with their valuable environmental services. Biodiversity-rich freshwater ecosystems are currently declining faster than marine or land ecosystems. The framework for allocating water resources to water users (where such a framework exists) is known as water rights. R. de Jong (1979).

2.2.1 WATER BALANCE

In hydrology, a water balance equation can be used to describe the flow of water in and out of a system. A *system* can be one of several hydrological domains, such as a column of soil or a drainage basin. A water balance can be used to help manage water supply and predict where there may be water shortages. It is also used in irrigation, flood control and pollution control. The water balance can be illustrated using a water balance graph which plots levels of precipitation and evapotranspiration often on a monthly scale. Several monthly water balance models had been developed for several conditions and purposes. R. de Jong (1979).

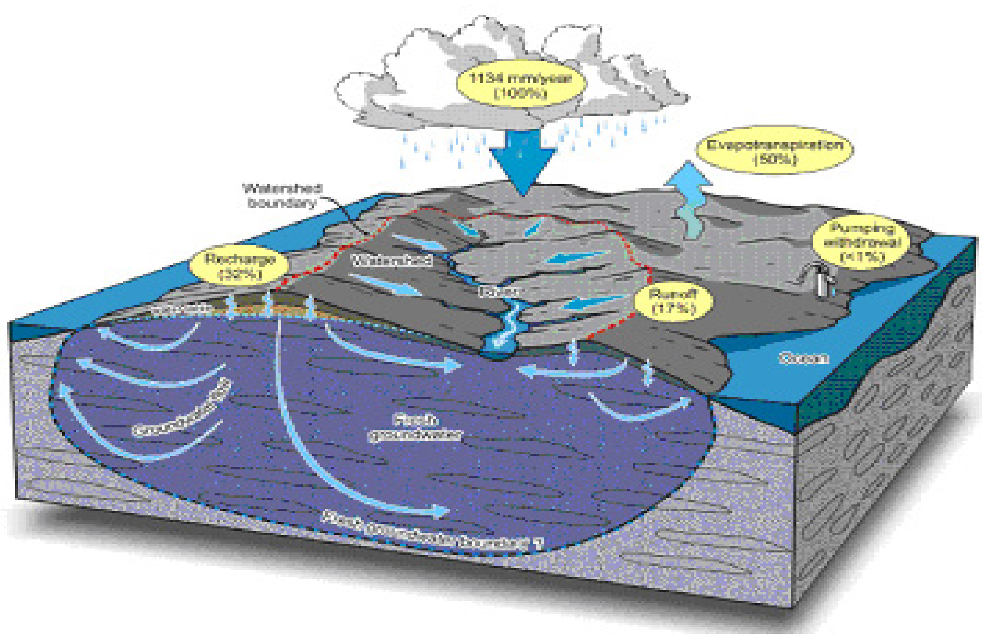

Figure 2.1: Water balance process. (Sources: Water Balance process, Wikipedia)

The interpretation of hydrological cycle within the confines of a catchments leads to the concept of hydrological budget or water budget. Water budget or also called water balance is the accounting of water for a particular catchments, region or even for the whole world. If the hydrological cycle considers all the phenomena of water phases in qualitative manner, the water budget accounts the hydrological cycle in quantitative manner. In other word, it is the mathematical expression of the hydrological cycle.

The water balance equation first considered was:

$$P = ET + Q + L + \Delta WS + \Delta G \qquad \ldots(2.1)$$

Where: P is cathment rainfall, ET is estimate of evapotranspiration, Q is surface runoff, L is deep seepage, ΔWS is change in soil moisture storage and ΔG is change in groundwater storage

The input of the cycle or the inflow of the system is precipitation, either as rainfall, snow or sleet. Then precipitation is distributed as the outflow of the system in terms of surface runoff, evaporation, infiltration to the unsaturated zone, changing its storage, and deep percolation to the saturated zones to form groundwater.

The difference between the inflow, I and the outflow, O of a catchment to the rate of change of storage, ΔS within the catchment for a specified period of time, Δt will form the basis of water budget.

It can simply be written as:

$$I - O = \Delta S/ \Delta t \qquad \ldots(2.2)$$

Or written infinite difference form as:

$$(I_1+I_2)/2-(O_1+O_2)/2 = S\ (S_1-S_2)/\Delta t \qquad \ldots(2.3)$$

Where: subscripts 1 and 2 correspond to values of the quantities at the start and end of the time interval.

The water budget can also be written in terms of both surface water and ground water as:

$$\Delta S = P - (E+T + G + Q) \qquad \ldots(2.4)$$

Where: ΔS is the change in storage, P is precipitation, E is evaporation. T is transpiration, G is groundwater flow out of the catchments, and Q is the surface runoff.

Assuming that (ΔS=0 or no change in storage in a given time span), then equation (eq2.4) becomes:

$$Q= P - L \qquad \ldots(2.5)$$

Where: L is losses or hydrological abstractions which equal to the sum of evaporation, transpiration, and infiltration.

Equation (eq2.4) indicates evapotranspiration (ET) gives significant value in water balance components. Meanwhile, equation (eq2.5) indicates that runoff is equal to precipitation minus all the losses. This concept becomes the basis of many practical applications in engineering related to runoff computations. R. de Jong (1979)

2.3 EVAPOTRANSPIRATION

Evapotranspiration (ET) is a term used to describe the sum of evaporation and plant transpiration from the earth's land surface to atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and waterbodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through stomata in its leaves. Evapotranspiration is an important part of the water cycle. An element (such as a tree) that contributes to evapotranspiration can be called an **evapotranspirator**.

Actual evapotranspiration (AE).

Evaporation is the phase change from a liquid to a gas releasing water from a wet surface into the air above. Similarly, ***transpiration*** is represents a phase change when water is released into the air by plants. ***Evapotranspiration*** is the combined transfer of water into the air by evaporation and transpiration. *Actual evapotranspiration* is the amount of water delivered to the air from these two processes. Actual evapotranspiration is an output of water that is dependent on moisture availability, temperature and humidity. Think of actual evapotranspiration as "water use", that is, water that is actually evaporating and transpiring given the environmental conditions of a place. Actual evapotranspiration increases as temperature increases, so long as there is water to evaporate and for plants to transpire. The amount of evapotranspiration also depends on how much water is available, which depends on the field capacity of soils. In other words, if there is no water, no evaporation or transpiration can occur.

2.3.1 ESTIMATE OF EVAPOTRANSPIRATION

Indirect methods

Pan evaporation data can be used to estimate lake evaporation, but transpiration and evaporation of intercepted rain on vegetation are unknown. There are three general approaches to estimate evapotranspiration indirectly.

Catchment water balance

Evapotranspiration may be estimated by creating an equation of the water balance of a catchment (or watershed). The equation balances the change in water stored within the basin (S) with inputs and exports:

$$\Delta S = P - ET - Q - D \qquad \ldots(2.6)$$

The input is precipitation (P), and the exports are evapotranspiration (which is to be estimated), streamflow (Q), and groundwater recharge (D). If the change in storage, precipitation, streamflow, and groundwater recharge are all estimated, the missing flux, ET, can be estimated by rearranging the above equation as follows:

$$ET = P - \Delta S - Q - D \quad \text{...(2.7)}$$

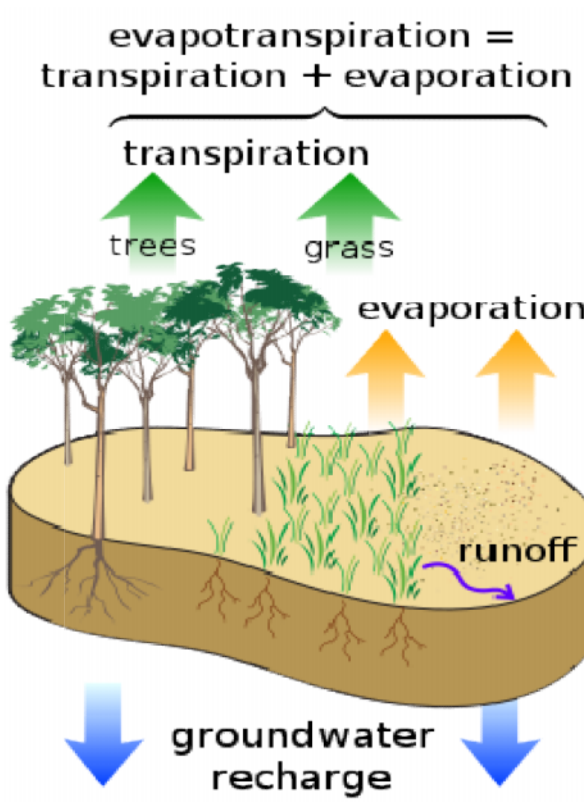

Figure 2.2: Estimating of evapotranspiration. (Source: Evapotranspiration process)

2.3.2 ENERGY BALANCE

Evapotranspiration (*ET*) is one of the main water balance components, and its actual value appears to be the most difficult to measure directly. The dependency of hydrological processes on meteorology and climate makes ET, spatially and temporally variable. The interaction between the spatial and temporal dimension of evaporation processes result in a complex methodology for ET assessment (Bastiaanssen, et al 1998). Nowadays many researches have been done to drive spatially distributed ET over large scales using surface energy balance and remote sensing data. The measurements of thermal infrared, infrared and visible bands of remote sensing data are inputs for the parameterization of the energy balance components in ET calculation. It has an advantage of measuring repeatedly the same area with large coverage and on pixel based.

The exchange processes occurring at the land surface are of paramount importance for the re-distribution of moisture and heat in soil and atmosphere. In any given system at the earth's surface, evapotransporation is the connecting link between the water budget and the energy budget. For a simple lumped system, when effects of unsteadiness, ice melt, photosynthesis and lateral advection can be neglected, the energy balance is (Brutsaert, 1984):

$$Rn = H + \lambda E + G_0 \quad \ldots(2.8)$$

Where: R_n is the net radiation (W m^{-2}); G_0 is the ground heat flux (W m^{-2}); H is the sensible heat flux (W m^{-2}), and λE is the latent heat flux (W m^{-2}), with λ the latent heat of vaporization (J kg^{-1}) and E the evaporation rate by mass (kg s^{-1} m^{-2}). For this formulation of the energy balance, R_n is positive when directed toward the ground surface, whereas G_0, H, and λE are positive when directed away from the ground surface. Although at any instant in time the energy balance may not actually have closure (sum of all energy fluxes exactly equals the net radiation), other components that could contribute to the land surface energy balance, such as biochemical processes, are often neglected in remote sensing energy flux models.

For the regional land surface heat fluxes, the energy balance equation can be rewritten as (e.g. Bastiaanssen, 1995).

$$R_n(x,y) = H(x,y) + \lambda E(x,y) + G_0(x,y) \text{ (Wm}^{-2}\text{)} \quad \ldots(2.9)$$

Bastiaanssen et al.(2000) have been developed the model, “Surface Energy Balance Algorithm for Land”(SEBAL), which estimates energy partitioning at the regional scale with using satellite image a minimal requirement for field data. This algorithm is based on the use of surface, a vegetation index and land surface temperature and provides enough information for the parameterization of the energy balance fluxes, e.g., radiation, sensible and soil heat as shown. This algorithm has been applied in many studies to estimate ET, but also as a tool to estimate other components of the water balance at large scales. It is based on the parameterization of energy fluxes as indicated in this section. The terms of the incoming radiation equation are based on field data and the outgoing terms on RS estimated surface, surface emissivity and land surface temperature. The soil heat flux is estimated empirically, taking surface heating, soil moisture and intercepted solar radiation into consideration. Sensible heat is computed from flux inversions for dry non-evaporating land units and wet evaporating land surfaces. Roughness length is derived from an empirical vegetation index based relation. ET is the residual of the energy balance.

2.4 NET RADIATION

2.4.1 ESTIMATE THE NET RADIATION FLUX

Rosenberg et al. (1983) study about net radiation at the surface of the Earth, when estimated from relationships employed in the equation of Penman, is found to be greater than the values of net radiation that are measured. Since the net short-wave (solar) radiation is well estimated when derived from Penman relationships, the problem is identified as an overestimate of the net long-wave radiation and primarily as an underestimate of the outgoing long-wave radiation from the surface of the Earth.

Allen et al, (2005) describe the net radiation (*Rn*) is the key variable in hydrological studies. Measured net radiation data are rarely available and are often subject to error due to equipment calibration or failure. In addition, point measurements of net radiation do not represent the diversity of the regional net radiation values which are needed for large scale evapotranspiration mapping.

2.4.2 Rn USING PENMAN METHOD.

Net Radiation (Rn)

The amount of energy or extra terrestrial radiation reaching the outer limit of the atmosphere (Rn) dependent on latitude and the time of year only. The amount of solar radiation (Rs) that penetrates the atmosphere and reaches the ground is much less than Ra and largely dependent on cloud cover. It can be estimated by the empirical formula:-

$$Rs = Ra\,(a + b\,n/N) \qquad \text{.....(2.10)}$$

Where a, b = empirical constants converting sunshine hours to short wave radiation.

n = actual duration of bright sunshine in hours for day (month)

N = maximum possible mean daily duration of bright sunshine in hours.

A part of Rs is reflected by the evaporating surface as shortwave radiation. The net amount Rns of shortwave radiation retained at the evaporating surface is:-

$$Rns = Rs\,(1 - r) = Ra\,(1 - r)\,(a + b\,n/N) \qquad \text{.....(2.11)}$$

Where r = reflection coefficient or albedo

Some of the net incoming shortwave radiation Rns is reradiated (day and night) as longwave radiation, and the process is most rapid during cloudless and dry weather. The atmosphere itself reradiates but is normally less than the upcoming longwave earth radiation. Empirically, the outward longwave radiation, Rni can be computed from:

$$Rni = \gamma T_m^4\,(0.56 - 0.092\sqrt{e_d})(0.1 + 0.9[n/N]) \qquad \text{.....(2.12)}$$

Where

Tm = mean air temperature in degree absolute (°K) for day (month)

e_d = saturation vapour pressure in mm Hg at mean dew point temperature for the same period.

γ = lummer and Pringsheim constant, 117.74×10^{-9} gm.cal/cm^2/°K^{-4}

Total net radiation is then:

$$Rn = Rns - Rni \qquad \text{.....(2.13)}$$