Forecasting Future Irrigation Water Sustainability in Upper Bernam River Basin Malaysia

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Abstract: The Bernam river basin where Proton city is located is rapidly developing, changing from agriculture based to an industrial area. Land development can be associated with increased impervious areas causing increase in surface runoff and decrease in ground water recharge. The study area is the main source of irrigation water supply for paddy fields in the downstream of the watershed. The required water for paddy irrigation should be made available continuously for double cropping via maintaining high base flows so that enough water is available for irrigation during the dry season. Soil and Water Assessment Tool (SWAT) model was used to study the effects of land-use changes on water resources sustainability**.** The study results confirmed that change of land-use pattern altered the runoff volume. In the year 2020 runoff is predicted to increase in the rainy season due to large increase of land use changes especially urban and forest, which then accelerate runoff and decrease base flow due to an increase in the impervious area. Providing such information in AgriGRID will help planners and decision makers to take the effect of land-use changes into account when formulating future plans for land development and include some structural best management practices (BMPs) within their future plan to control and manage water resources in the watershed.

Keywords: Land-use Change, SWAT, Water Resources Sustainability**.** AgriGRID Malaysia

1. INTRODUCTION

Watershed modeling is one approach to analyze the effect of land use changes on water quality and quantity. The impact of future land-use changes on hydrology and stream stability, with special reference to the urban built-up areas (including impervious surfaces) has been discussed by some researchers. Lorup et al., (1998); Schreider et al., (2002) and Hundecha and Bardossy, (2004) used hydrological models to study the effect of land use change in hydrology. They implemented trend analysis to the bias between the modelled and the observed runoff to investigate changes in the catchment runoff that might arise due to land use changes. A few more attempts to implement hydrological models to investigate the impact of land use change have been reported in De Roo et al. (2001); Burns et al., (2005); Siriwardena et al., (2006); Shi et al., (2007); Podwojewski et al., (2008) and Olivera and DeFee, (2007).

The Soil and Water Assessment Tool (SWAT) predicts the impact of land management practices on water, sediment, and agricultural chemical yields in watersheds with varying soils, land use, and management conditions over time (Arnold et al., 1998). It is a continuous time model that operates on a daily time step at basin scale. The model is able to forecast and simulate the long-term impacts of land use change on water quantity and quality. It has been extensively used and tested since 1993 by mainly hydrologists for soft engineering related issues (Demirel et al., 2009). Fohrer et al., (2001) used SWAT model for the predication of the impact of land use changes. Mishra et al., (2007) used SWAT model to study the impact of land use changes in mixed land-use watershed. The study results showed that the mixed land use watershed displayed a synchronized runoff response to monsoon rains. Measured runoff and sediment yield varied from one sub-watershed to another. The sub watersheds with relatively high forest cover showed significantly less runoff and sediment yield whereas a sub-watershed with more area under cultivation produced higher runoff and higher sediment yield. Cao et al., (2008) used SWAT model to simulate two land cover scenarios, a prehistoric land cover and a potential maximum plantation pine cover to study and evaluate the impacts of land cover change on total water yields, groundwater flow, and quick flow in the Motueka River catchment, New Zealand. The results showed that the annual total water yields, quick flow and base flow decreased moderately in the two scenarios when compared with the current actual land use.

The paper present results of a study on the effects of land-use changes on water resources sustainability and stream flow quantity especially during dry season.

2. METHODOLOGY

2.1 Study area

The Upper Bernam River Basin is a source of irrigation water supply for 20,000 ha rice granary. This gives the basin its importance in irrigation water supply (Figure 1). It was selected to develop, apply and evaluate the proposed methodology of this study. The study area is located in southeast Perak and northeast Selangor, Malaysia, between 03 36´ 23´´ to 04 08´ 55´´ North and 101 19´ 53´´ to 101 40´ 33´´ East. The total area is 10978 km^2

The study area consisted of mainly hill rainforests, hill and upper forest and lowland plantation, rubber and oil palm. Other land covers that can be found are grassland, tin mining area, orchards, and urbanized built up areas, especially along the river banks or roadsides. Land use map were classify into ten classes (forest, oil palm, rubber, urban area, orchard, swamp, grass, water, open new land and mining area)

2.2 Model description

SWAT is a river basin scale model that operates on a daily time-step (Arnold et al., 1998) developed to quantify the influence of land use practices on large, complex watersheds and to predict the effect of management decisions on the water production. It can also take into account the effects on the fluxes of sediment, nutrients and pesticide existing in the watershed. The model can do this prediction with reasonable accuracy on large, ungaged river basins. It was developed at the University of Texas, USA and is freely distributed on the internet. Spread all over the world the academic community has been improving and adjusting the model continually. A comprehensive description of all the components in SWAT can be found in the literature (e.g. Arnold and Allen, 1996; Srinivasan et al., 1998).

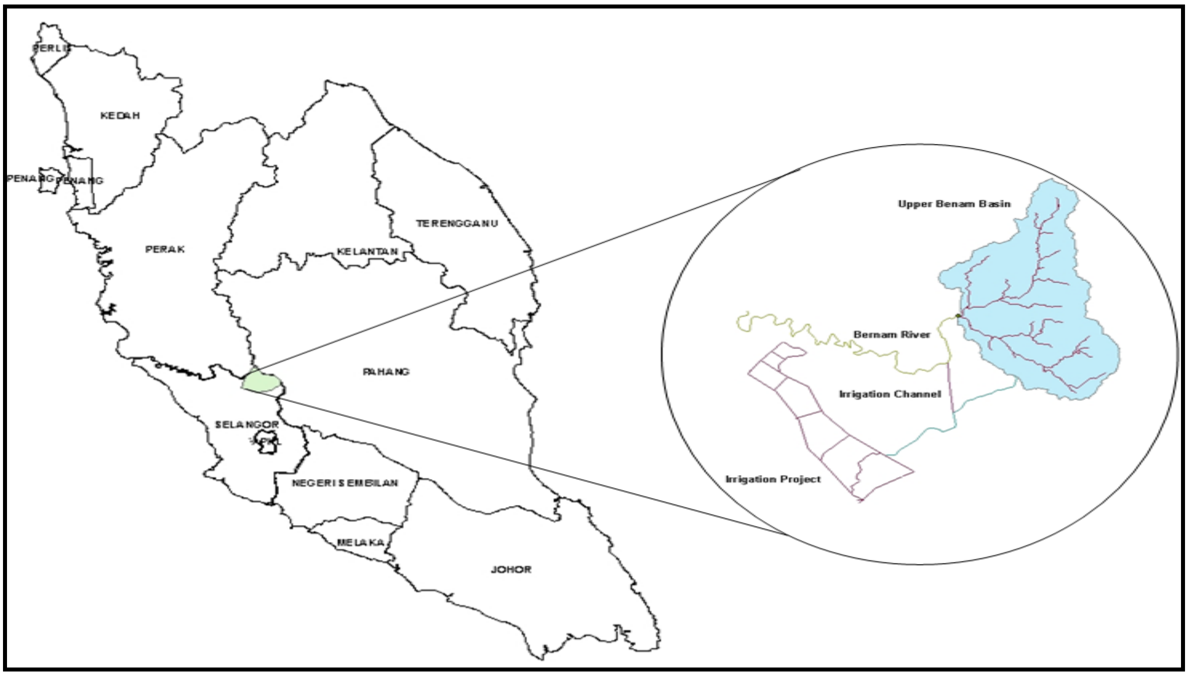

Figure1. Location map of the study area

2.3 Data required

Precipitation is the key input variable that drives flow and mass transport in hydrological systems. There are 8 gauging stations within the area having long records for use in a long-term modelling study. Rainfall and runoff data for the period of 1980-2007 were collected from the Department of Irrigation and Drainage (DID), Malaysia, weather data for the period of 1980-2007 were collected from the Meteorological Department Malaysia (MMD). Land use maps were obtained from the Department of Agriculture (DOA) and future land use maps were obtained from the Department of Town and Country Planning (DTCM), Malaysia. DEM (Digital Elevation Model) was from The Shuttle Radar Topography Mission (SRTM). DEM data of 90 x 90 m which later resample to 30m resolution was downloaded from USGS website. Obtained data are shown in Table 1.

Table 1. Data obtained for the study area

Type of data	Period	Source	Remarks
Rainfall	**1981-2007**	**DID**	**8 stations (Daily Record)**
Runoff	**1981-2007**	**DID**	**One station (Daily Record)**
Weather	**1981-2007**	**MMD**	**3 Stations (Daily Record)**
Land use	**1984, 2000**	**DOA**	**Digital Map**
Soil	**1970**	**DOA**	**Digital Map**
Future land use	**2020**	**DTCP**	**Digital Map**

2.4 Model calibration and validation

The entire Upper Benam watershed was divided into 45 sub-watersheds based on similar land use for the SWAT simulation. For the model calibration and validation as described by Santhi (2001), base flow was separated from the measured stream flow at station SKC Bridge station and simulated stream flows using an automated digital filter technique (Nathan and McMahon, 1990; Arnold and Allen, 1999). Calibration parameters for various model outputs were constrained within the ranges described by Santhi, (2001).

Model outputs were calibrated to fall within a percentage of average measured values. Stream flow was calibrated for this study. Surface runoff was calibrated until average measured and simulated surface runoff was within 15 percent. The same criteria were applied to base flow, and surface runoff was continually rechecked as the base flow calibration variables also affect surface runoff. Annual and monthly stream flow from the SKC Bridge station, and SWAT simulation were calibrated (Figures 2 and 3) for the period from 1981 to 2004.

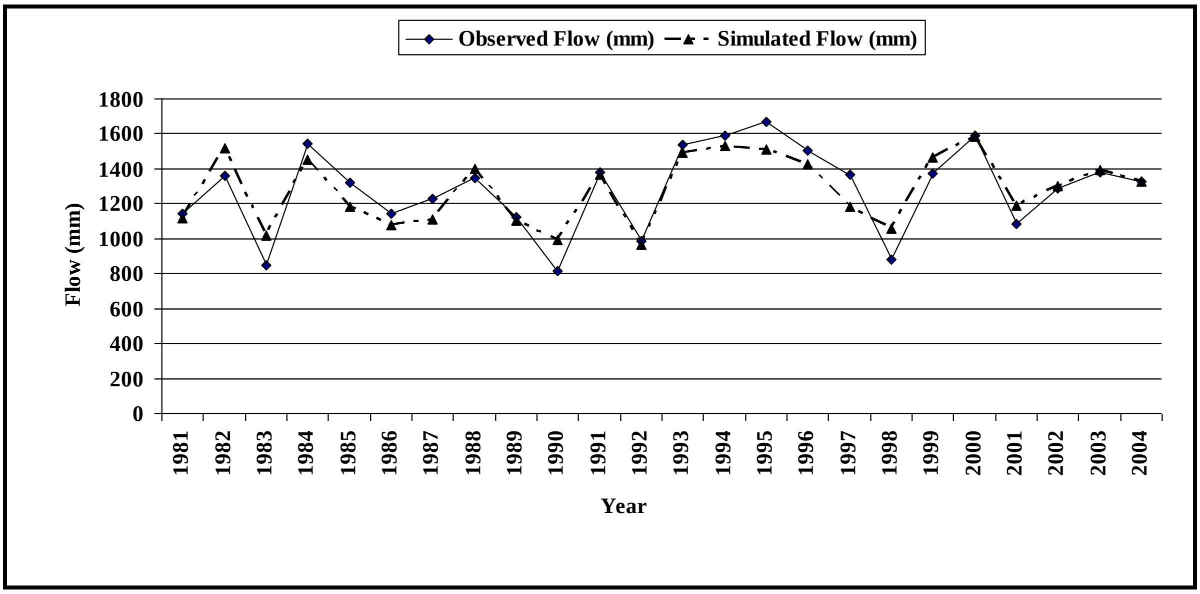

Figure 2. Observed and Simulated Annual Flow at SKC Bridge Station during Calibration Period

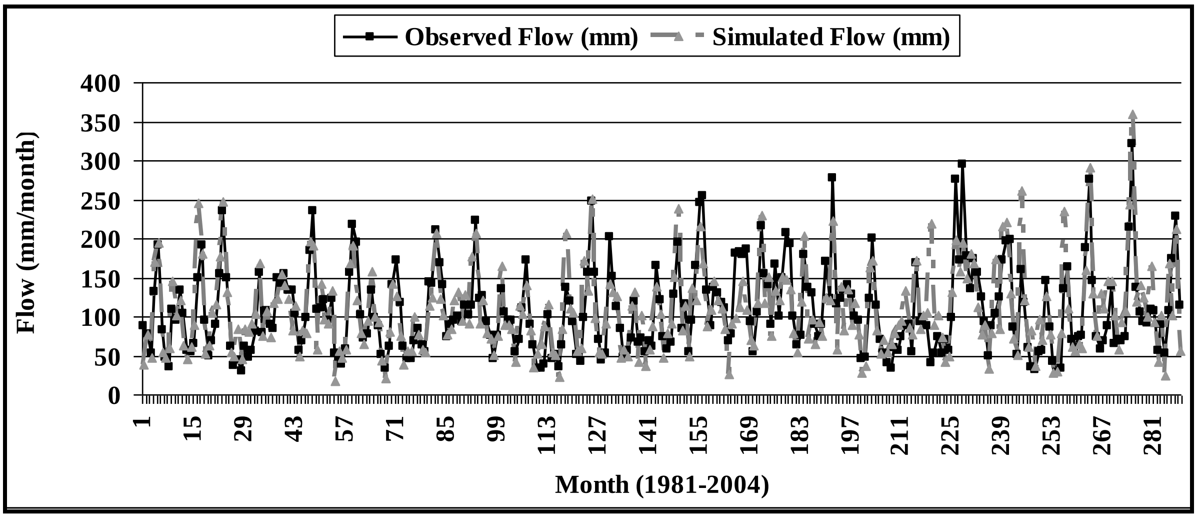

Figure 3. Observed and Simulated Monthly Flow at SKC Bridge Station during Calibration Period

In the validation process, the model is operated with input parameters set during the calibration process without any change and the results are compared to the remaining observational data to evaluate the model prediction. Annual and monthly measurements for the period from 2005 through 2007 were used to validate the model (Figures 4 and 5). The same statistical measures were used to assess the model prediction.

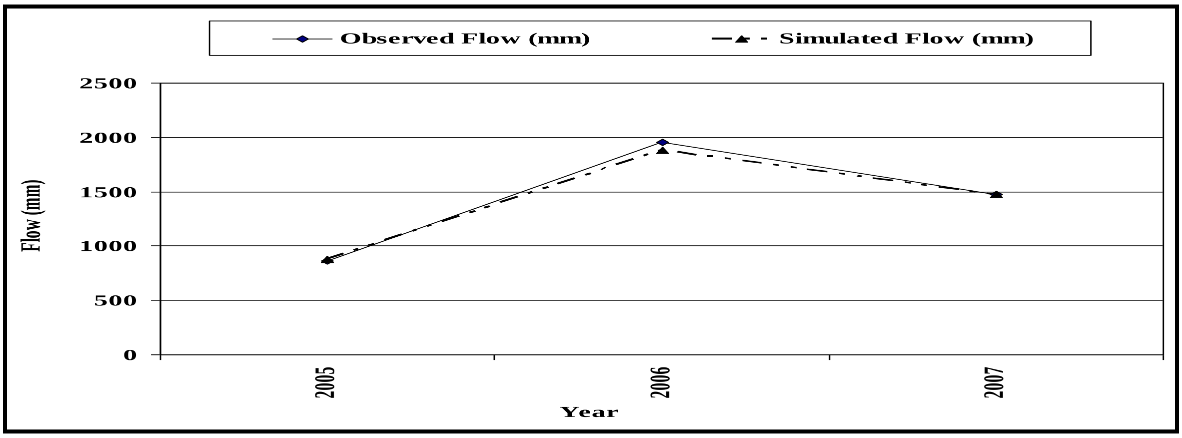

Figure 4. Observed and Simulated Annual Flow at SKC Bridge Station during Validation Period

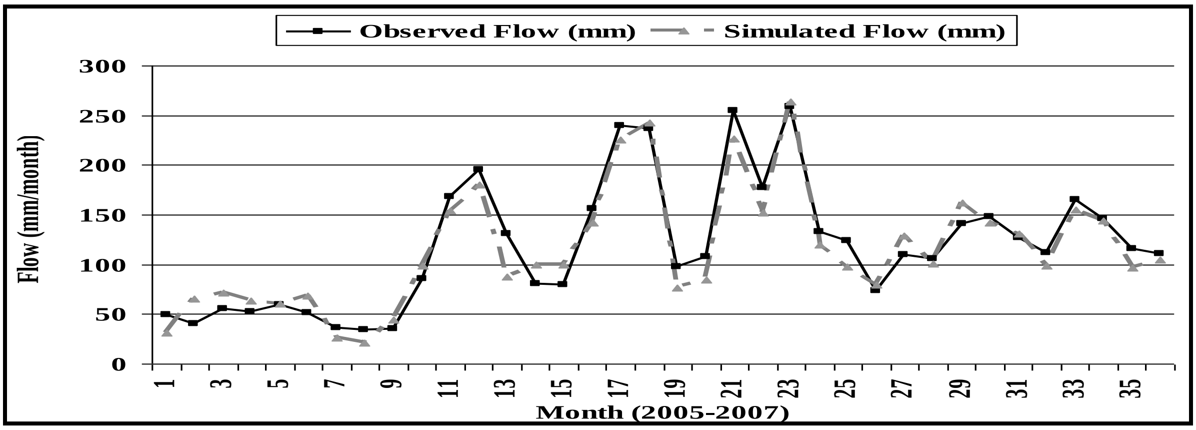

Figure 5. Observed and Simulated Monthly Flow at SKC Bridge Station during Validation Period

3. RESULTS AND DISCUSSION

The objective of this study was to study the effect of land-use change on water resources sustainability and stream flow quantity therefore SWAT model was calibrated and validated for flow in the river basin where water quantity problem becomes critical with time. Monthly simulated flow was compared with observed values at the SKC Bridge gauging station for the calibration and validation period.

In most instances, simulated flow was closer to the measured value during the calibration period. Model validation was done for the years of 2005, 2006 and 2007 in annual and monthly time steps. In general, simulated flow was closer to the measured values during the validation. SWAT predictions are acceptable, especially given the approximations and spatial variability involved in simulating a large complex system or watershed. The calibrated model was used to study the effects of future land use on stream flow quantity.

3.1 Changes of land use pattern from 1984 to 2000

Many factors affect runoff including land-use, topography, rainfall, drainage network patterns and so on. In the Bernam watershed land use changes are considered the main factor affecting rainfall-runoff relationship (Alansi et al. 2009). Figures 7 to 10 show that from1984 to 2020, the urban area and oil palm have increased while the rest of land use/land covers have decreased. Details of percentages of the main land-use areas to total watershed area are shown in Table 2.

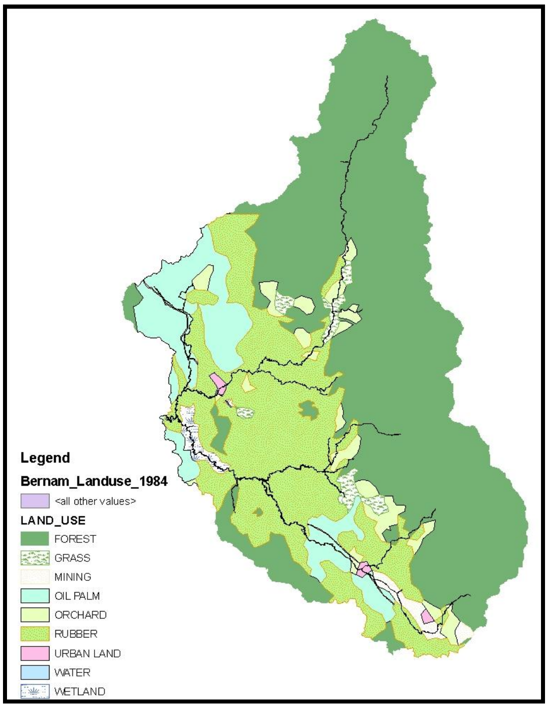

Figure 7: Land use map for the year 1984

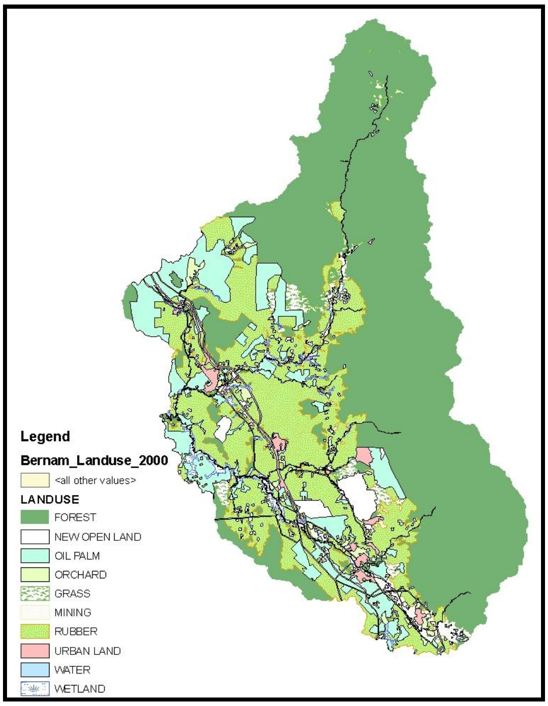

Figure 8: Land use map for the year 2000

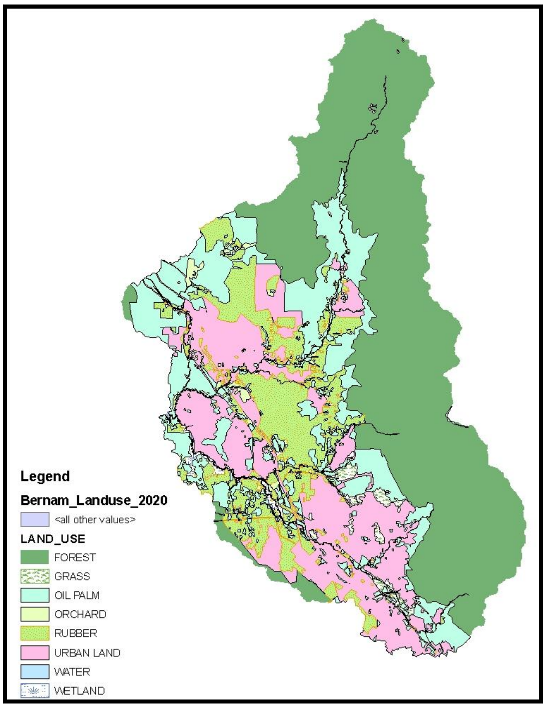

Figure 9. Land use map for the year 2020

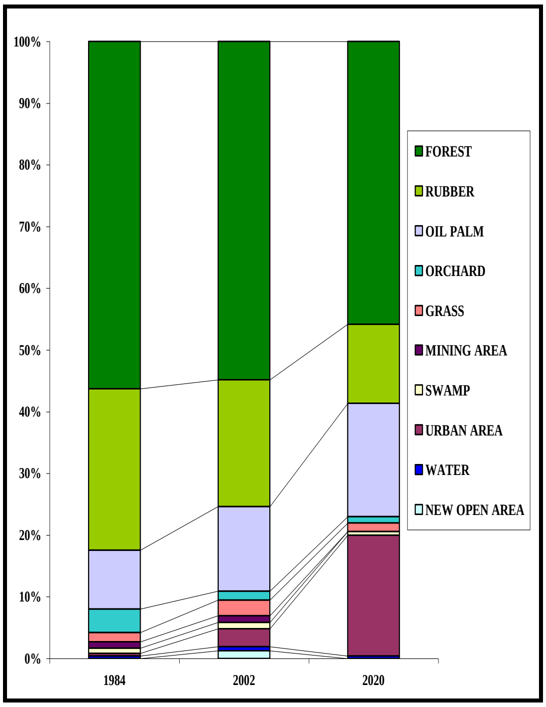

Figure 10. Percentages of land use changes

Table 2. Percentage of main land-use areas to total watershed area

Land-use	1984	2000	2020
Urban area	0.46	2.37	19.63
Oil palm	9.59	10.15	18.4
Rubber	26.15	24.00	12.82
Forest	56.93	54.89	45.88
Orchard	3.82	1.71	1.06

3.2 Effect of future land-use on water resources sustainability

Estimating of stream flow is an important process to study the effect of future land use change on stream flow quantity. This has been performed via SWAT model in Upper Bernam watershed to ensure the water is enough for the paddy fields in the downstream of the watershed.

As mentioned earlier, two steps have been taken for forecasting process, validate model forecasting in the year of 2007 and compare it with observed data then forecast for the year of 2020. Comparison between the years of 1984, 2000, 2007 and 2020 has been performed to study the stream flow pattern. From Figure 11 it is clear that stream flow in the year 2020 has significant increases in the rainy seasons than in the years 1984, 2000 and 2007, while it decrease in the dry seasons.

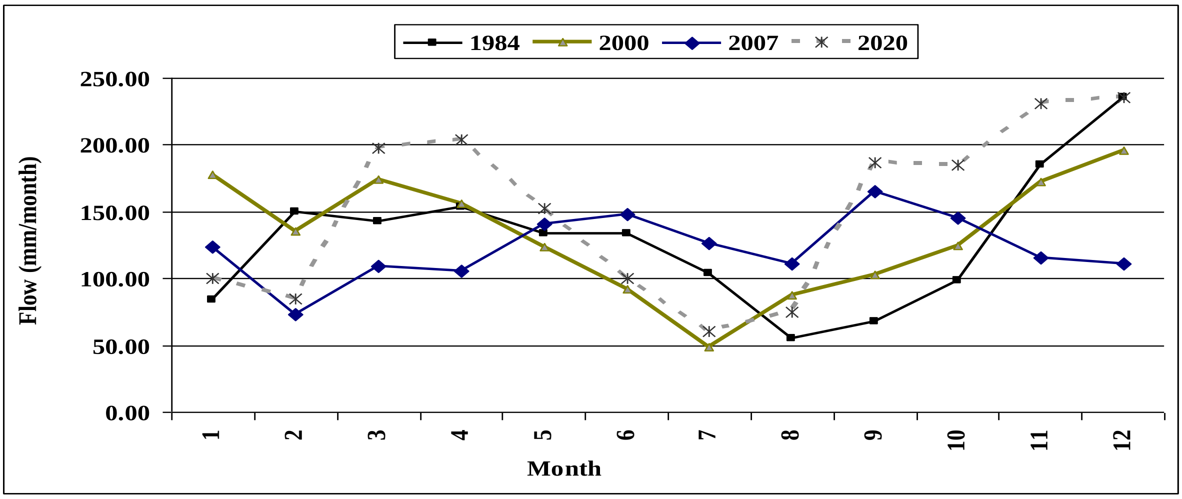

Figure 11. Monthly Flow of the years of 1984, 200, 2007 and 2020

The reasons for more runoff in the year 2020 may be as follows:

1. Increase of the urban areas over other land use change to reach 19.63% of the total watershed area.
2. Increase of oil palm area to reach 18.40% of the total watershed area.
3. Decrease of forest area which highly increase runoff and decrease base flow during dry season.

4. CONCLUSION

From 1984 to 2020, land-use pattern in the study area has undergone obvious transformations. The proportion of area under urban and oil palm increased, and the proportion of rubber and forest reduced. The change of land-use pattern altered the runoff amount. In the year 2020 predicted runoff has been increase in the rainy season due to large increase of land use changes especially urban and forest, which then accelerate runoff and decrease base flow due to an increase in the impervious area. In order to increase runoff during dry season, more attention should be paid to land-use pattern and some structural best management practices (BMPs) should be built to control and manage water resources in the watershed.

5. ACKNOWLEDGEMENTS:

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