Evaluating water resource sustainability of paddy for one planting schedule in Perlis

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Abstract. The increase industrial and agricultural development, caused by the population growth on the one hand and the limited water resources available on the other hand has caused the groundwaters to be considered as a valuable water supply more than ever. Optimal operating policies are very much essential for sustainable management of reservoir as poor operating policies may lead to over or underuse of water. The purpose of this study was to investigate the water availability of Timah Tasoh Reservoir, water demand for minor scheme paddy, and hence balance the water inflow and outflow from Timah Tasoh Reservoir. The study area for agriculture is the minor scheme for whole Perlis state, and inflow areas are Lubok Sireh, Padang Besar at Titi Keretapi, Wang Kelian and Kaki Bukit. The result shows that the water inflow to Timah Tasoh Reservoir is sufficient to supply for the needs of minor scheme paddy, and hence balance the water inflow and outflow from Timah Tasoh Reservoir. The study area for agriculture is the minor scheme for whole Perlis state, and inflow areas are Lubok Sireh, Padang Besar at Titi Keretapi, Wang Kelian and Kaki Bukit. The result shows that the water inflow to Timah Tasoh Reservoir is sufficient to supply for the needs of minor scheme paddy, and hence balance the water inflow and outflow from Timah Tasoh Reservoir.

1. Introduction

Water demand keeps increasing as the population become more significant from time to time. Large quantities of water are required for agricultural to produce the food needed. Timah Tasoh Reservoir is one of water supply zone existed in Malaysia which utilised as a water catchment for many usages. It is a project created by the Drainage and Irrigation Department (DID) in the state of Perlis. The store zone is partitioned into two classes, which are life and dead reservoirs and the region covered 13.3 million m3 and 6.7 million m3 respectively. Life store zone is the storage of water that can be used while the dead store zone is the storage that required keeping in the reservoir [1]. The agriculture segment is the fundamental driver of the state's financial development, with 48,127ha (58% of the land in Perlis) committed to cultivating in 2014. Based on the of the gross domestic product (GDP) by division 2016 from Department of Statistics Malaysia, the agriculture area in Perlis took 21.6% of the flow of economic activity which is higher than industrial segment.

Water demand of agriculture will be completely fulfilled when the reservoir storage quantity is higher than water provide operation rule curve, while water demand of agriculture has to be rationed when the reservoir storage quantity is lesser than water supply operation rule curve [2]. Moreover, the problem of imbalance of water distribution inside every area may also take place in the conventional
water allocation pattern, which distributes water assets primarily based on the current situation and style of water use. Conceptually, the water balance approach was clear and was an accounting of the inputs and outputs of water. I. Hussain utilized the technique of continuity equation where the difference between \( \Sigma \) inflow and \( \Sigma \) outflow is the rate of change in storage. This equation depends on the assumption of the straightforward and highly restrictive system, which was impenetrable slanted plane surface, limited on each of the four sides with an outlet at one corner. The water balance has separated into two fundamental areas, which are water balance over the surface and water balance underneath the surface. The water requirement of agriculture has separated into net water requirement (the actual water demand is the product of net crop water requirement and the basin's crop area) and gross water demand, the water that required from gross surface water supply and gross groundwater supply which is considering the proficiency of the water system [3]. T. Yong et al. also proposed the similar water balance which water accessible is the distinction between the inflow (Qt) and the outflow (E+Rt). Evaporation (E) is determined by increasing the water surface zone (At) and the dissipation rate (et). There are two limitations in the research, where the reservoir storage must be higher than its dead storage and should not surpass its standard storage. Second, the water discharged should not surpass the reservoir’s greatest release ability [4]. In this study, the water resource sustainability of minor scheme for 1 planting season in Timah Tasoh Reservoir was evaluated by mathematical modelling.

2. Mathematical modelling

2.1. Water availability of Timah Tasoh Reservoir

Figure 1 shows the water component of Timah Tasoh reservoir. In this research, only inflow, precipitation and evaporation is considered, while seepage from the reservoir has been ignored. Water availability equation is given in the following expression:

\[
Q_t = Q_{\text{Begin}} + Q_R + Q_I - (Q_L + Q_D + Q_{\text{End}}) \quad (1)
\]

where
- \( Q_t \) = water availability in Timah Tasoh Reservoir
- \( Q_{\text{Begin}} \) = water storage at the beginning of the month
- \( Q_{\text{End}} \) = water storage at the end of the month
- \( Q_R \) = rainfall catch by the Timah Tasoh Reservoir,
2.2. Irrigation water requirement
The main crop requires water supply from the Timah Tasoh reservoir is paddy. There are two sources of inflow which are irrigation and precipitation while outflow are crop evapotranspiration, surface runoff, seepage and seepage-percolation. Assuming the standing water depth is constant all the time, the following equation shows the relationship between inflow and outflow:

\[ IWR + PREP = EVPT + SURF + SEEP + SEPR \]  (2)

where
- \( IWR \) = irrigation water requirement
- \( PREP \) = precipitation capture by agriculture area
- \( EVPT \) = evapotranspiration of crop
- \( SURF \) = surface runoff
- \( SEEP \) = seepage
- \( SEPR \) = seepage percolation

2.3. Water balance equation
In order to balance the water level in the reservoir and water supply for agriculture, a general equation is needed to calculate it. Based on the continuity equation, total inflow must be equal to total outflow:

\[ \sum Q_{in} = \sum Q_{out} \]  (3)

where \( Q_{in} \) is for total inflow and \( Q_{out} \) is for total outflow of Timah Tasoh reservoir.

The total inflow of reservoir is river inflow and precipitation:

\[ \sum Q_{in} = Q_I + Q_p \]  (4)

The total outflow is the evaporation, gross water requirement from agriculture:

\[ \sum Q_{out} = Q_E + IWR_{gross} \]  (5)

where \( IWR_{gross} \) is for irrigation gross water requirement.

Substituting Equation (4) and Equation (5) into Equation (3), the water balance equation is expressed as below;

\[ Q_I + Q_p = Q_E + IWR_{gross} \]  (6)

Considering the situation when inflow is less than outflow or in reverse conditions, an additional variable was added in Equation (5):

\[ Q_I + Q_p = Q_E + IWR_{gross} - x \]  (7)

where \( x \) is representing the other resource or river, depending on the situation.
The value of $x$ in the equation might be positive or negative depending on the situation. When the inflow of the reservoir is less than outflow of the reservoir, $x$ will become a negative value representing the volume of water required from underground water to balance the water in the reservoir. On the other hand, if the inflow of the reservoir is more than outflow, $x$ will become a positive value indicates that the excess water will be flowing out from the reservoir through a river.

3. Results
Based on Table 1 and Figure 2(a), the amount of water at the end of the month (final water available) are definite from March to July indicates that the water in Timah Tasoh Reservoir is sufficient to supply to outflow. Besides that, the amount of water shows an increasing trend throughout the month. This may be due to the large increase in rainfall from the river into the Timah Tasoh Reservoir due to heavy rainfall in the basin.

**Table 1.** Results of the amount of water available in the Timah Tasoh reservoir for the first planting season

| Type of data                      | February | March | April | May    | June   | July    |
|-----------------------------------|----------|-------|-------|--------|--------|---------|
| Current water available (million m$^3$) | 18.73    | 25.44 | 38.88 | 265.21 | 342.04 | 523.83  |
| Water losses (million m$^3$)      | 3.50     | 3.50  | 3.50  | 3.50   | 3.50   | 3.50    |
| Domestic (million m$^3$)          | 1.74     | 1.74  | 1.74  | 1.74   | 1.74   | 1.74    |
| Agriculture irrigation (million m$^3$) | 6.59    | 9.57  | 5.36  | 4.17   | 2.00   |         |
| Rainfall (million m$^3$)          | 0.107    | 0.080 | 2.419 | 1.970  | 4.606  |         |
| Inflow from the river (million m$^3$) | 18.43   | 28.17 | 234.51| 84.27  | 184.43 |         |
| Final water available (million m$^3$) | 18.73    | 25.44 | 38.88 | 265.21 | 342.04 | 523.83  |

**Figure 2(a).** Amount of water at the end of the month for first planting season

**Figure 2(b).** Water balance for first planting season
According to Figure 2(b), the positive water balance from March to July shows that the water flow is sufficient to supply the outflow without any additional water resources.

It can be seen that the water balance reaches its maximum in May which is 226.33 million m$^3$. This is because the total inflow is much more significant than the total outflow. The total inflow is generally mainly determined by the river inflow, and the river inflow reaches the maximum value of 234.51 million m$^3$ in May. However, the maximum total outflow is in April, which is 14.81 million m$^3$. Therefore, the water balance shows a sudden increase in the trend in May.

In short, the water resources of the Timah Tasoh Reservoir are not only sufficient to meet domestic demand, and cover for the water loss caused by evaporation, but also enough to meet the agricultural irrigation needs of small paddy fields.

4. Conclusion

Based on presented results, it can be concluded that the water availability of Timah Tasoh Reservoir is sufficient to supply for the needs of domestic and agriculture irrigation (Minor Scheme). However, the amount of water calculated at the end of the month exceeded expectations. According to information provided by DID, the Timah Tasoh Reservoir has an emergency level of 29.6 meters and can hold up to 50 million m$^3$ of water at a time. The calculation result shows much more abundant than this value, due to an incomplete part of the equation that solves the water balance. Excess water will be pumped or flowed out to rivers or oceans to avoid excessive water stored. To sum up, the amount of water that exceeds the emergency limit will eventually be discharged to the river or ocean.

Besides that, in the real situation, the purpose served by Timah Tasoh Reservoir is not limited to paddy irrigation and domestic. It covered the industrial supply, other crop irrigation, tourism use, etc. Therefore, the actual total outflow of Timah Tasoh Reservoir is supposed to be higher than the calculated value. However, since the total inflow calculated is much higher than the total outflow, so it has strong evidence to said that the water available in Timah Tasoh Reservoir is sufficiently enough to supply for all the purpose of water supply.

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