Evaluation of Crop Water Requirements for Yazagyo Irrigated Area, Myanmar

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Abstract. Accurate estimation of crop water requirements (ETc) is essential for the irrigation scheduling and water management of Yazagyo irrigated area, Myanmar. FAO defined the crop water requirements as the depth of water needed to meet the water loss through evapotranspiration of a crop, being disease-free, growing in large fields under non-restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment. It is essential to have a clear idea about the optimum water requirement for proposed crops under adaptable climatic conditions. The optimal crop water requirement mainly depends upon the accurate estimation of evapotranspiration and crop coefficient. To perform in this study, firstly Meteorological data of Kalay Station, in Myanmar are collected from 1995 to 2018. On the other hand, the different kinds of crops such as paddy, groundnut, sesame, sunflower, bean, and pea are considered for the estimation of seasonal crop water requirements for this area. Based on the crop growth stages in this area, crop coefficient curves are developed and crop coefficients are determined for each crop according to FAO manual. By using monthly crop coefficients and CROPWAT 8.0 software, reference crop evapotranspiration, crop water requirements and total irrigation requirements are presented for the selected area.

1. Introduction
Myanmar has a hot wet climate and is an agricultural country. It has the most valuable resources i.e, agricultural, forest and mineral and so on. Agricultural occupies a dominant position in the development of the national economy of Myanmar and definite bearings on other socio-economic activities. The agricultural sector basically supports improvement in the foreign exchange earning by the increased production of major crops. It can grow different kinds of crops on her wealth land in both tropical and temperate climates at every part of the country. It grows such as cereal crops, industrial crops, vegetables, fruits and flowers different cropping systems. The economy and trade sector is remained dominate force in the nation. In order to increase the agricultural products for rising demand of a growing population, double crop cultivation and other crops have been initiated by implementing the large-scale irrigation system. In Myanmar, annual rainfall varies from 20-50 inches in the central dry zone, 80-140 inches in the delta areas, 50-150 inches the hilly regions, and 100-200 inches in the coastal areas. Even though the rainfall is sufficient for the cultivation of paddy in the monsoon season, irrigation is required in the hot dry season and even in areas of abundant rainfall, if a second crop is to be successfully developed. In the central dry zone where rainfall is inadequate, irrigation is essential for crop cultivation even in the wet season. The purpose of irrigation is to provide the best possible moisture contents required for the desired growth, yield and quality of plants. To achieve higher production of desired
crops, the suitable water application programmes should also be adopted. Therefore irrigation has become an input of agricultural production and where natural conditions are unfavorable, the most important one. The crop water requirements is essential for the irrigation scheduling and water management. The aim of the study is to calculate the crop water and irrigation requirements for Yazagyo Irrigated Area.

2. Location of the Project
The Yazagyo Dam is situated between latitude (North) 23˚ 08’ and 09˚ and longitude (East) 94˚ 57’ and 58˚. The Yazagyo Dam site is located on the Nerinzara Creek which drains about two miles away from the Yazagyo village. Yazagyo Dam is situated near Yazagyo village, Kalay Township, Kalay District, Sagaing Division. The main Dam constructed across the Nerinzara Creek. The reservoir has a full storage capacity of 52000 Acres-feet with catchments area of 130 Square-miles. The reservoir has a dead storage capacity of 8000 Acres-feet and water spread area of 980 Acres when it is full. In upper Myanmar, Yazagyo Dam supply water to irrigated area of about 8000 Acres. The Location Map of Yazagyo Irrigated Area is shown in Figure 1.

![Location Map of Yazagyo Irrigated Area](image)

3. Evapotranspiration Process
Evaporation and Transpiration occur simultaneously and there is no easy way of distinguish between the two processes. Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process.
3.1. Evaporation
Evaporation is the process whereby liquid water is converted to water vapour (vaporization) and removed from the evaporating surface (vapour removal). Water evaporates from a variety of surface, such as lakes, rivers, pavements, soil and wet vegetation.

3.2. Transpiration
Transpiration is the process by which water vapour leaves the living plant body and enters the atmosphere. The vaporization occurs within the leaf, namely in the intercellular spaces, and the vapour exchange with the atmosphere is controlled by the stomata aperture. Transpiration is also determined by the soil water content and the ability of the soil to conduct water to the roots.

4. Calculation of Reference Crop Evapotranspiration
The crop evapotranspiration ($ET_c$) is also estimated by using FAO Penman-Monteith Method (CROPWAT 8.0 software). In the estimation of crop water requirements of existing cropping pattern with CROPWAT 8.0 software, the effective rainfall data, crop data, and soil type data are required. In the case of non-rice crop, crop name, planting date, crop coefficient ($K_c$), stages length, rooting depth, critical depletion fraction ($\rho$), yield response factor and crop height data are necessary. In the case of rice crop, the additional data such as planting date in case of direct sowing or transplanting data in case of sowing in nursery area, duration of nursery and land preparation (including puddling) stages, dry and wet crop coefficient and puddling depth are needed.

4.1. Collection of Meteorological Data
The necessary meteorological data is obtained from the Department of Meteorology and Hydrology, Kalay. The temperature, wind speed data, relative humidity and evaporation are based on Kalay station. The data of sunshine is based on Kalawa station. Those stations are situated in the nearest area of the project. Mean monthly maximum and minimum temperature are calculated from recorded maximum and minimum monthly temperature. Mean monthly relative humidity ($RH_{mean}$) is recorded at 9:30 am & 6:30 pm and calculated from $RH_{max}$ and $RH_{min}$. The wind speed data recorded at 10 ft height and are converted to 2 m height. The wind speeds are measured at 9:30 am of $U_{day}$ and at 6:30 pm of $U_{night}$.

4.2. Crop Types and Crop Patterns
There are several crops planting in Kalay. However, monsoon paddy, summer paddy, bean, pea, sunflower, groundnut and sesame are planted in Yazagyo irrigated area. To calculate crop evapotranspiration, the proposed crop patterns are described in Table 1. These patterns should be used alternatively to treat the land.

| Table 1. Proposed crop patterns |
|---------------------------------|
| Data | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec |
| Pattern1 | Sunflower | Monsoon Paddy |
| Pattern2 | Seasame, Beem | Monsoon Paddy |
| Pattern3 | Summer Paddy | Monsoon Paddy |
| Pattern4 | Pea | Monsoon Paddy |
| Pattern5 | Groundnut | Monsoon Paddy |
4.3. Length of Crop Growth Stages
Crop growth stages divided into four stages such as initial stage, crop development stage, mid-season stage and late season stage. Among these crop development stages, the crop growth stages of crops that are selected in proposed cropping patterns such as monsoon paddy, summer paddy, sesame, sunflower, bean, pea and groundnut are listed in the following Table 2.

| Name of crops | Initial (days) | Development (days) | Mid-season (days) | Late-season (days) | Total (days) |
|---------------|----------------|--------------------|-------------------|--------------------|--------------|
| Summer Paddy  | 30             | 25                 | 30                | 20                 | 105          |
| Monsoon Paddy | 30             | 30                 | 45                | 30                 | 135          |
| Sunflower     | 25             | 35                 | 45                | 25                 | 130          |
| Sesame        | 15             | 25                 | 35                | 15                 | 90           |
| Pea           | 35             | 25                 | 30                | 20                 | 110          |
| Bean          | 20             | 30                 | 30                | 10                 | 90           |
| Groundnut     | 35             | 45                 | 35                | 25                 | 140          |

4.4. Crop Coefficient (K<sub>c</sub>)
The crop coefficient (K<sub>c</sub>) varies according to the growing stages. Only three values for K<sub>c</sub> are required during the initial stage, the mid-season stage and the end of the late season stage. The K<sub>c</sub> values for each crop are considered as per FAO. Dry and wet crop coefficients are required in the case of rice crop although only crop coefficient is necessary in non-rice crop. The necessary crop coefficient values of all proposed crop types which may be used in CROPWAT 8.0 software calculation are shown in Table 3.

| Name of crops | K<sub>c</sub><sub>ini</sub> | K<sub>c</sub><sub>mid</sub> | K<sub>c</sub><sub>end</sub> |
|---------------|--------------------------|--------------------------|--------------------------|
| Summer Paddy  | 1.1                      | 1.11                     | 1                        |
| Monsoon Paddy | 1.1                      | 1.05                     | 1                        |
| Sunflower     | 0.6                      | 1.15                     | 0.35                     |
| Sesame        | 0.6                      | 1.1                      | 0.25                     |
| Pea           | 0.6                      | 1                        | 0.35                     |
| Bean          | 0.48                     | 1.05                     | 0.9                      |
| Groundnut     | 0.62                     | 1.15                     | 0.6                      |

The values of Maximum Crop Height (m), Maximum Root Depth (m), Critical Depletion Fraction (ρ) and Yield Response (f) factor are described in Table 4.
Table 4. Values for Crop Height, Rooting Depth, Critical Depletion and Yield Response

| Name of crops | Crop Height(m) | Rooting Depth(m) | Critical Depletion Fraction(ρ) | Yield Response(f) |
|---------------|----------------|------------------|-------------------------------|-------------------|
| Paddy         | 1              | 0.10 - 0.60      | 0.2                           | 1.10              |
| Sunflower     | 2              | 0.80 - 1.50      | 0.8                           | 0.95              |
| Sesame        | 0.2            | 1.00 - 1.50      | 0.6                           | 0.95              |
| Pea           | 0.4            | 0.60 - 1.00      | 0.35                          | 1.00              |
| Bean          | 0.4            | 0.50 - 0.90      | 0.45                          | 1.15              |
| Groundnut     | 0.4            | 0.30 - 0.80      | 0.5                           | 0.7               |

5. Crop Water and Irrigation Requirements

For calculating the crop water requirements for various crops the data to be incorporated in CROPWAT 8.0 step by step depending on the cropping programme. The crop data required are the crop planting dates, the crop coefficient (Kc) values at the different growth stages, the length of growth stages, the crop rooting depth at the different growth stages, the allowable soil moisture depletion levels and the yield response factors. After the input of the crop data, CROPWAT 8.0 proceeds to calculate the crop water and irrigation requirements of the given cropping pattern, using the entered crop data and the ETo and effective rainfall values calculated earlier. The monthly reference evapotranspiration (ETo) is obtained according to Penman-Monteith Method using CROPWAT 8.0. Reference evapotranspiration (ETo) for monthly data are shown in Table 5.

Table 5. Reference evapotranspiration (ETo)

| Month   | Min Temp °C | Max Temp °C | Humidity % | Wind km/day | Sun hours | Rad MJ/m²/day | ETo mm/day |
|---------|-------------|-------------|------------|-------------|-----------|---------------|------------|
| January | 10.1        | 27.9        | 76         | 24          | 7.2       | 14.7          | 2.18       |
| February| 11.4        | 32.1        | 67         | 26          | 8.2       | 17.8          | 2.91       |
| March   | 14.1        | 36.3        | 58         | 35          | 7.6       | 19.2          | 3.69       |
| April   | 18.8        | 38.8        | 56         | 45          | 7.6       | 20.8          | 4.53       |
| May     | 22.1        | 38.8        | 65         | 45          | 6.7       | 20.0          | 4.66       |
| June    | 24.1        | 35.9        | 79         | 37          | 4.1       | 16.2          | 3.81       |
| July    | 24.3        | 34.7        | 82         | 31          | 3.4       | 15.0          | 3.49       |
| August  | 24.1        | 34.3        | 84         | 32          | 3.8       | 15.2          | 3.47       |
| September| 23.1      | 34.4        | 84         | 30          | 4.0       | 14.5          | 3.27       |
| October | 21.2        | 33.0        | 82         | 30          | 5.8       | 15.2          | 3.21       |
| November| 16.2        | 30.7        | 80         | 25          | 5.7       | 13.2          | 2.52       |
| December| 11.0        | 27.8        | 79         | 25          | 6.0       | 12.7          | 2.05       |
| Average | 18.4        | 33.7        | 74         | 32          | 5.8       | 16.2          | 3.32       |
The result of effective rainfall for Kalay Station (2017) calculated by CROPWAT 8.0 software is shown in Figure 2.

![Figure 2. Effective Rainfall for Kalay Station (2017)](image)

The monthly irrigation requirements for different patterns are described in Figure 3.

![Figure 3. Monthly irrigation requirements](image)
6. Discussion and Conclusion
Crop water requirement is an essential part of the irrigation project. In this study, mean monthly meteorological data are calculated from 1995 to 2018 monthly data. By using this monthly data and CROPWAT 8.0 software, the monthly reference crop evapotranspiration (ET\(_o\)) can be calculated. Using monthly crop water requirement(ET\(_c\)) are estimated based on FAO Penman-Monteith method from evaporation and rainfall data of meteorological station Kalay. And then crop type and crop pattern are considered on cultivation area. Length of growth stages, crop development stages, crop coefficient (K\(_c\)) values are based on FAO irrigation and drainage paper 56. The crop water and irrigation requirements for the proposed crops have been calculated with the help of CROPWAT 8.0. By using the crop water requirement, the crops are irrigated with the adequate and accurate amount of water and crop yield will be increased. Thus, irrigation schedule decreases the ill effect of inadequate and over irrigation for crops.

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