Water management of irrigation system in the lower Myanmar
-Water management in the Ngamoeyeik irrigation system-

農業土木学コース　水利用学研究室　AUNG THAN OO

1. Introduction

Myanmar is primarily an agricultural country and the economy of the nation is also mainly depends on the agricultural products. To increase the agricultural productions for the rising demand of a growing population, double crop cultivation of paddy rice and other crops has been introduced by implementing the large-scale irrigation systems. In the large irrigation system the proper water management system is essential to develop the effective use of water resources.

The objective of this research is to study the water management of irrigation system in the lower Myanmar. The study area is the Ngamoeyeik irrigation system, which is in the lower part of Myanmar. It is one of the large-scale irrigation systems, which have been implemented for the provision of adequate water for the agricultural purposes. The irrigation supply and water management of this system have been operated since 1995. Since it was a newly established irrigation system the concrete rules and practices of irrigation operation and water management have not been developed well. The irrigation operation and management were performed with the trials and experiences.

In this research, water management of the Ngamoeyeik irrigation system was studied in three levels:

(1) Water management of reservoir
(2) Water management of canal system and
(3) Water management of terminal system.

For the water management of reservoir, the analysis of rainfall, estimation of inflow for storage of reservoir and investigation of storage utilization were studied. For the water management of canal system, the irrigation water supply and distribution systems of the canal systems were studied. For the water management of terminal system, estimation of the reference crop evapotranspiration, ET_o, for the water requirements of the fields and on-farm irrigation layout of the test farm were studied.

2. Description of the study area and materials

Fig.1 shows the location and layout of the Ngamoeyeik Irrigation system. It is located in Hlegu, which is about 47 km northeast of Yangon, the capital of Myanmar. The catchment area of Ngamoeyeik reservoir is 414.5 km^2 and the usable storage volume is 222 million m^3. This irrigation scheme was designed to irrigate the 22,000 ha of the cultivable area. The main purpose of Ngamoeyeik irrigation project is to store the rainwater during monsoon and to utilize the storage water in pre-monsoon for double crop cultivation.

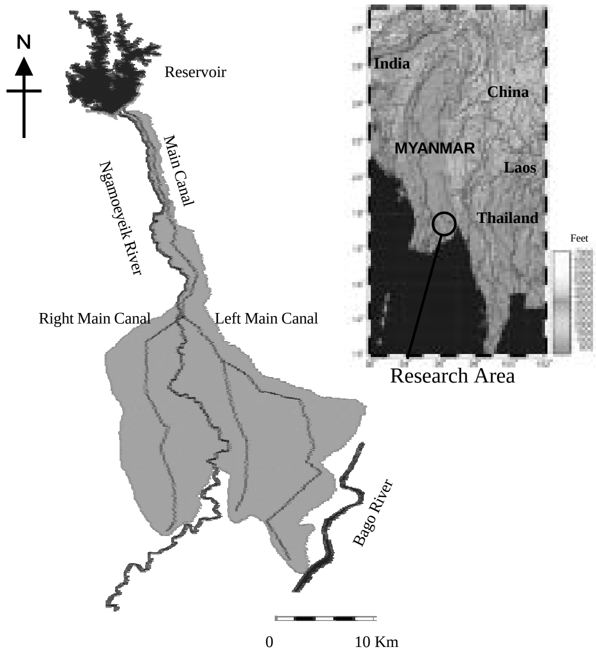

Fig.1 Ngamoeyeik irrigation system

The daily meteorological data of project area, Hlegu, and nearby station, Hmawbi, were used for the analysis of rainfall. Hmawbi station is located about 31 km in the west of the study area and, where the long- term meteorological data were recorded. The daily- observed reservoir management data ; inflow, storage, irrigation release and other outflow data, were utilized for the estimation of inflow and storage utilization.

The daily irrigation supply discharge and water depth data of canal systems were utilized for the analyses of water supply and water distribution systems of canals.

The daily weather data of near station such as maximum and minimum temperature, relative humidity, wind speed, maximum sunshine hours and pan evaporation data were used for the estimation of reference evapotranspiration. The topographic map and already designed canal layout map data of the test farm in the terminal system were utilized for the study of on- farm irrigation facilities layout.

3. Water management of reservoir

3.1. Rainfall analysis

Fig.2.1 shows the monthly rainfall of study area. Most of the rainfall usually occurs during the monsoon season (May to October) and no rainfall occurs in the pre-monsoon season (November to April). The annual average rainfall during monsoon season is about 2400 mm. Fig.2.2 shows the average monthly rainfall during monsoon. Maximum rainfall usually occurred in July with the amount of 600 mm. Fig.2.3 shows the average number of rainy days during the monsoon period. The average number of rainy days which rainfall amount exceeds 5 mm was about 18 days. The average daily rainfall during monsoon season was approximately 18- 30 mm. Hence the available rainfall is sufficient for rainy rice cultivation in the monsoon season.

The critical rainfall amount was investigated for the long- term period. Fig.3 shows the annual rainfall of two stations. There were 3 drought years in the near station with the minimum annual rainfall of 1872 mm, 1909 mm and 2004 mm in 1957, 1979 and 1998 years, respectively. The total rainfall amount of the study area was 1830 mm in 1998. The year 1998 was the third event of least rainfall in the both stations during 41 years.

The rainfall relationship and rainfall patterns were analyzed using the same period data of two stations for 4 years (1996-1999). The analyses were made in the daily, 5- day, 10- day and monthly- scales. Fig.4 shows the 10- day average rainfall of the two stations. The study area has a high correlation relationship of rainfall to the near station, Hmawbi. Hence the long- term daily rainfall data of nearby station can be used for the analyses and estimation of inflow for the reservoir.

3.2. Estimation of reservoir inflow

Fig.5 shows the relationship of rainfall and reservoir inflow smoothing into the 16- days scale. The rainfall losses occurred in the initial period of monsoon season. Runoff model for reservoir inflow was estab-

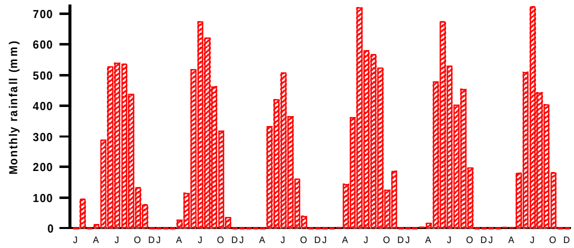

Fig.2.1. Monthly rainfall of resrvoir site, Hlegu (1996-2001)

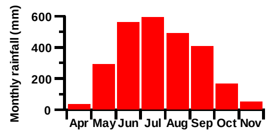

Fig.2.2. Average monthly rainfall during monsoon season

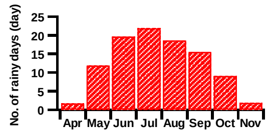

Fig.2.3. Average number of rainy days during monsoon season

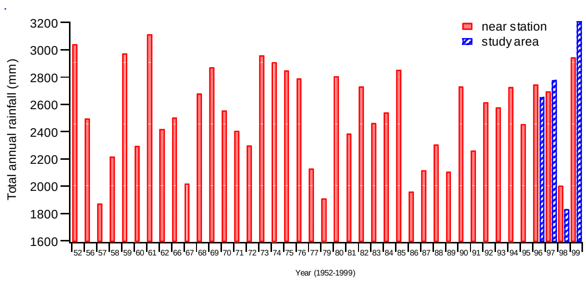

Fig.3. Annual rainfall of study area and near station (1952~1999)

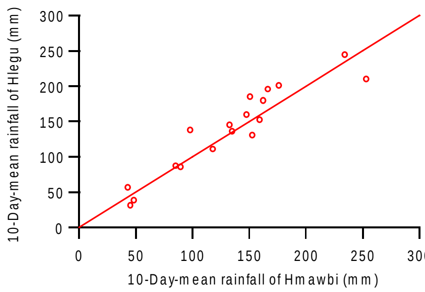

Fig.4. Rainfall relationship of Hlegu and Hmawbi in 10-day- scale

lished applying the unit hydrograph models.

Firstly, estimation of effective rainfall was assessed using observed rainfall and inflow data. Secondly, the unit hydrograph was established. Thirdly, the available reservoir inflow amount was predicted utilizing the long period daily rainfall data to the established model.

(1) Estimation of effective rainfall

From the observed rainfall- inflow relationships, the total excess rainfall or effective rainfall (R_e) expression was developed as a power regression expression described below.

$$\sum R_e = 0.0022 \sum R^{1.7242}$$

where R is the cumulative observed rainfall, R_e is the cumulative effective rainfall. Using the above expression, the amount of effective rainfall for the reservoir was estimated.

Fig.6 shows the estimated cumulative effective rainfall (R_e) and observed cumulative inflow curves plotted versus with the cumulative rainfall (R). The estimated cumulative effective rainfall (R_e) was fit with the observed cumulative inflow for all years.

(2) Modeling of reservoir inflow estimation

The unit hydrograph model was expressed as follows;

$$Q_n = \sum_{m=1}^{n \le M} R_{em} U_{n-m+1}$$

$$Q_n \; ; n = 1, \dots, N \; , \; N : \text{pulses of runoff}$$

$$M : \text{pulses of excess rainfall}$$

The unit hydrograph ordinates U_i (i = 1,….., M) were determined using the least square method. Here, M = 11 was selected for the best fit model. Fig. 7 shows the assessed unit hydrograph of the Ngamoeyeik basin area with the duration of 11 days. The estimated inflow was verified with the observed inflow data. Fig.8 shows the comparison of estimated inflow and observed inflow for the years of 1996, 1998 and 2001. The estimated inflow values were nearly fit to the observed inflow data in all periods of consideration.

(3) Prediction of available reservoir inflow

The available amount of inflow for reservoir was estimated for the long- term period applying the established unit hydrograph model. The 41 years daily observed rainfall data of nearby station were applied to this model. It was found that the sufficient amount of inflow could be available for the reservoir even in the drought years.

From these results, the required rainfall amount for the inflow of reservoir was estimated as a rainfall indicator. The inflow was begun to increase when the accumulative rainfall amount approached 600 mm, around 45 days of monsoon began. The storage came to full level when the accumulative rainfall approached about 1650 mm. The initial rainfall losses were supposed to be occurred by the absorption of basin surface area and percolations into the catchment area due to the extreme dryness of longer dry period.

3.3. Storage utilization

Water budget calculations were made for the storage utilization of reservoir. Fig.9 shows the storage curves of Ngamoeyeik reservoir for 6 years. The reservoir storage utilization is almost the same pattern in every year, though there were some differences at the end of irrigation seasons.

Fig.10 shows the total volume of irrigation release and duration of irrigation period for 6 years. The irrigation release amounts were ranging from 160 to 220

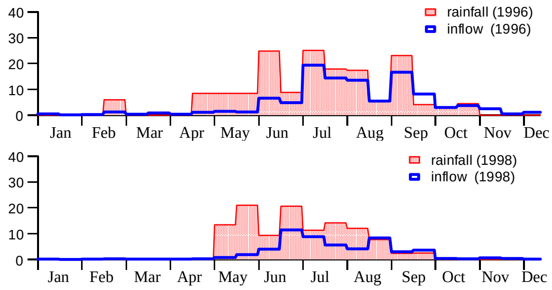

Fig.5. Observed rainfall and inflow smoothing in 16- days scale

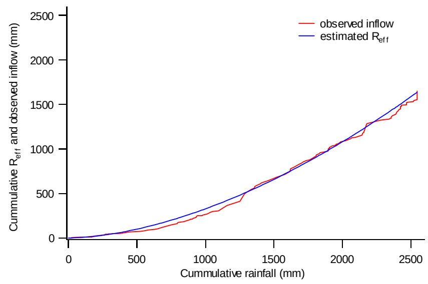

Fig.6. Estimated cumulative excess rainfall and observed inflow vs. observed rainfall

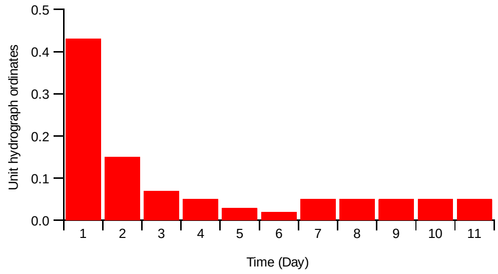

Fig.7. Uunit hydrograph with duration

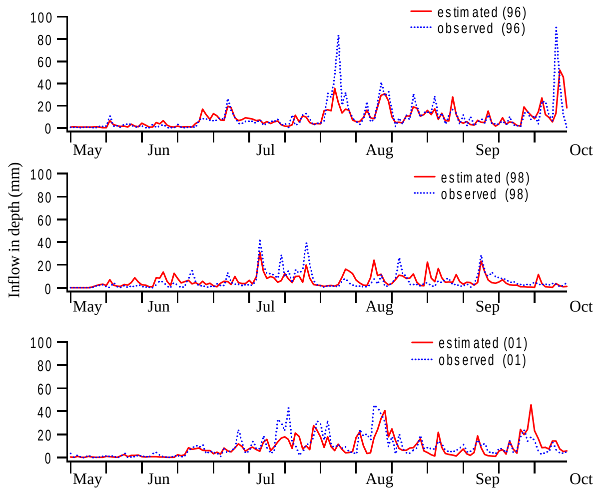

Fig.8. Estimated and observed inflow in daily scale (1996, 1998, 2001)

million m^3. The irrigation durations ranged from 145 days to 185 days. In the early years (1996-2000), the total irrigation volumes were associated with the duration of irrigation periods. However, in the recent years of 2001 and 2002, the irrigation release volume was lower and irrigation duration was longer. The average daily release discharge in the recent 2 years was about 10 m^3 s^{-1}.

The irrigation release pattern was proposed for the maximum water use of reservoir operation. Fig.11 shows the proposed typical irrigation release pattern for the pre-monsoon irrigation season. The irrigation season could be distinguished into 4 irrigation periods for the reservoir operation as the first period (P1), second period (P2), third period (P3) and fourth irrigation period (P4).

The first irrigation period, P1 was the initial or preliminary irrigation period for the preparation works. The second irrigation period, P2 and third irrigation period, P3 were the maximum irrigation supply periods for the maximum requirements of the entire irrigation command area. The irrigation release drops occurred at the end of P2 period because of the less irrigation demands before the maturing stages of summer rice paddy. The fourth irrigation period, P4 was the supplementary supply period for the late cultivated areas. The estimated total release volume was 180 million m^3 for the total irrigation duration 165 days.

4. Water management of canal system

The water supply depths and water distribution patterns of main canals and their distributaries or secondary canals were investigated utilizing the 3 years daily irrigation supply data and applying the statistical analysis methods.

Fig.12 shows the layout of canal systems. Fig.13 shows the water supply depths in the upstream and downstream reach, M-1 and M-2, of main canal for 2 years, 2000 and 2002. The irrigation supply and water distribution pattern in the canal system were different in every year.

Fig.14 shows the mean daily supply depths of canals in the main canal system from the head to tail in order. The water supply in the main canal was flowed at a mean depth 1.5 m in the head reach and ranging from 1.8 to 2.0 m in the tail reach. The supply was

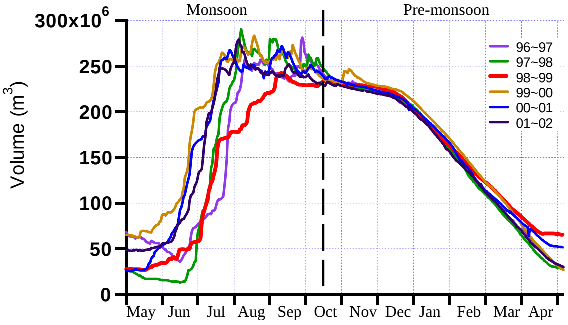

Fig.9. Annual storage curves of Ngamoeyeik reservoir (1996-2002)

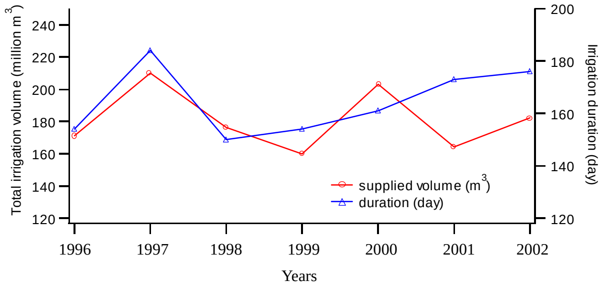

Fig.10. Total irrigation release volume and duration (1996-2002)

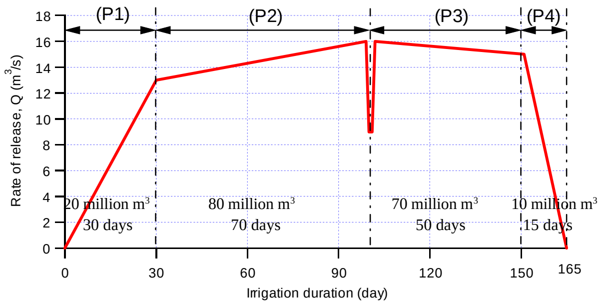

Fig.11. Proposed irrigation release pattern with irrigation duration

controlled at nearly constant depth both in the head and tail portions during the maximum supply periods. In the year 2002, the supplied depth in the tail reach of main canal system, M-2, was increased than the depth in the head reach, M-1, regulating the gates to supply more water to the distributaries. On the other hands, in

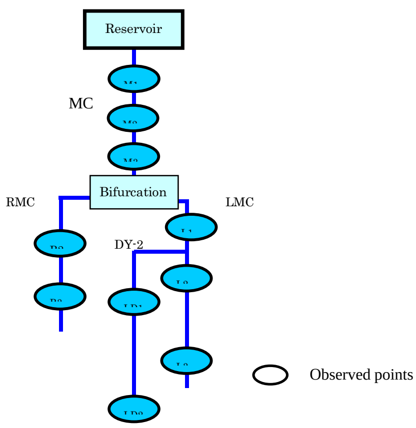

Fig.12. Layout of main canal systems

the diversion canals, the mean supply depths were nearly the same in every year.

Fig.15 shows the water supply depth of main and diversion canals from the head to tail of the right main canal system in year 2000. The water supply in the head portion of right main canal, R-1 was supplied at the almost constant depth of 1.5 m throughout the supply period. In the tail reach the mean supply ranged from 0.6 to 0.8 m. The water supply in tail portion was rotational supply with changing the depth differences approximately 0.5 m.

The water distributions in the diversion canals,DY-1 and DY-8, were operated in rotational distribution system. As the conclusions, the maximum supply water was controlled with the nearly constant depth in the main canals and rotational water distribution system was practised in the downstream reaches.

5. Water management of terminal system

5.1. Estimation of reference crop evapotranspiration

The reference crop evapotranspiration, ET_o, was estimated to understand the water requirements of terminal fields. The FAO modified Penman- Monteith method was applied for the estimation using the daily observed weather parameters. The expression for calculation of reference ET_o was described as

$$ET_o = W \cdot Rn + (1 - W) \cdot f(u) \cdot (ea - ed)$$

ET_o ; evapotranspiration for reference crop, ea ; saturation vapour pressure, ed ; vapour pressure from dry and wet bulb temperature, f (u) ; values of wind function for wind run at a 2 m height, W ; value of weighting factor.

The estimated values were averaged into 5- day and 10- day scales for the irrigation season. Fig.16 shows the estimated mean value of reference evapotranspiration, ET_o in 10- day scale for the irrigation season. The estimated reference ET_o values were nearly same pattern in all years.

The estimated ET_o in monthly average values were compared with the observed pan evaporation data (Eva) and other estimated ET_o data of International Water Management Institute (IWMI). Fig.17 shows the monthly average reference ET_o comparing with the other data of Eva and ET_o. The estimated reference ET_o values were found to be similar to the observed pan evaporation data and the ET_o of the IWMI. The estimated maximum ET_o value was 5.7 mm day^{-1} and it

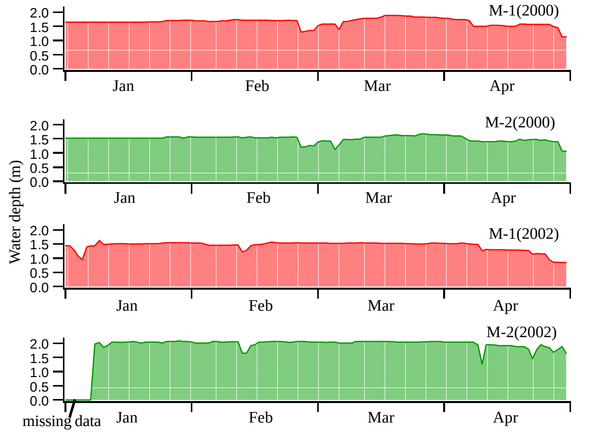

Fig.13. Water supply depth of Main Canal system

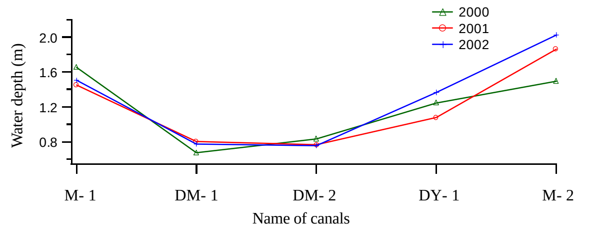

Fig.14. Mean supply depth in the Main Canal system

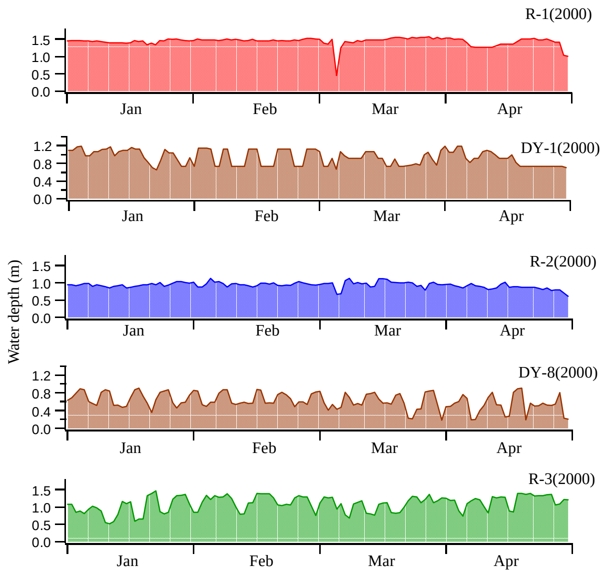

Fig.15. Water supply depth of Right Main Canal

was occurred in April, the hottest month in Myanmar. The observed maximum pan evaporation was 6.5 mm day^{-1} in April.

The maximum evaporation and reference ET_o usually occurred during the growing season of summer rice paddy (February-March). In the other months, the reference ET_o and observed evaporation were as low as to about 3.5 - 4.0 mm day^{-1} because of the monsoon rains.

The observed Pan evaporation data could be used applying the empirical coefficients related to ET_o in the estimation of crop water requirements for other irrigation systems of the nearly same climate regions, where the complete meteorological data are not available.

The actual crop water requirements, ET_{crop} or ET_c can be calculated using the estimated values of ET_o and corresponding crop coefficients. The more accurate irrigation demands can be estimated using the estimated ET_o values for the better irrigation supply and management for terminal fields.

5.2. The canal layout of test farm in terminal system

The topographic map and already designed canal layout map of a test farm in terminal system were studied for the terminal facilities management. The graphical visualization maps of test farm were developed applying image processing methods.

Fig.18 shows the 2- dimensional graph of canal layout. The irrigation canal alignments were laid on the high land area for the gravitational irrigation supply. And the drainage canals were laid on the lower land for the proper drainage of the irrigated water.

Hence it was observed that the designed canals and drainage layout system of test farm were properly functioned. The effective water management could be operated in this irrigation command area because of the well-designed irrigation facilities. From this visualization map, the required information could be obtained for the preparations of irrigation planning and water management of the terminal fields.

6. Conclusions

1) The initial rainfall losses of Ngamoeyeik basin area was approximately 600 mm. When cumulative rainfall approached to 1650 mm, the storage came to full level of this reservoir. The sufficient storage amount was available even in the drought year. The utilization of storage was similar pattern in every year. The irrigation release pattern was proposed for the maximum use of reservoir storage. The proposed total release volume was 180 million m^3 for irrigation duration of 165 days.

2) Water supply in the main canals was controlled at a constant depth. In the tail reach of main canals and diversion canals, water supply was operated with rotational distribution system.

3) The estimated reference ET_o of nearby station might be utilized for the estimation of crop water requirements in the study area. From the visualization map of the

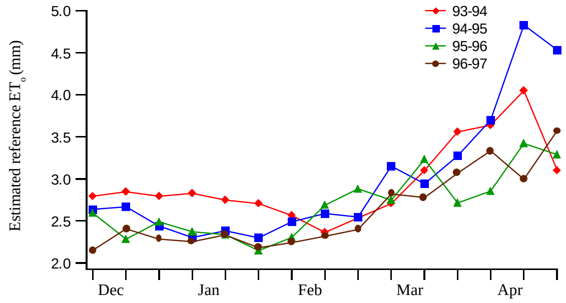

Fig.16. Estimated mean reference evapotranspiration (ET_o) in 10- day scale

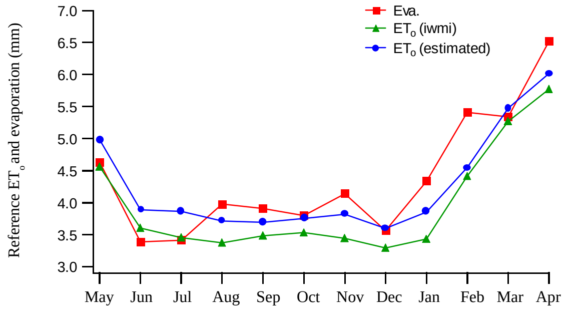

Fig.17. Estimated monthly mean ET_o and observed evaporation

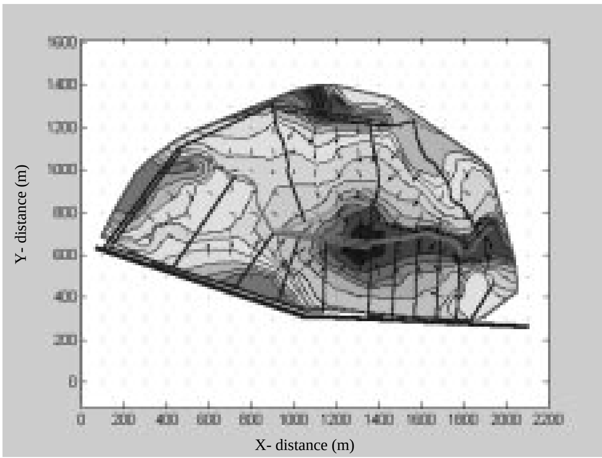

Fig.18. 2-Dimensional information map of the test farm

test farm, the required information could be obtained for the preparations of irrigation planning and water management of the terminal fields.

References

1. Chow, V. T., Maidment, D. R., and Mays, L.W., Applied Hydrology, McGraw- Hill, New York, 1988.
2. Doorenbos, J., Pruitt, W.O., Crop water requirements, FAO irrigation and drainage paper 24 (revised), Food and Agriculture Organization of the United Nations, Rome, Italy, 1977.
3. FAO. Burma Ngamoyeik Multipurpose Project Pre- Feasibility Report, Unpublished. FAO project TCP/BUR/0111(T), 1983.
4. The Japanese Society of Irrigation, Drainage and Reclamation Engineering, Advanced Paddy Field Engineering, JSIDRE, SHINZAN- SHA Sci. & Tech. Publishing Co., Ltd, Tokyo, 1999.
5. Ministry of Agriculture and Irrigation (MOAI). Information on Myanma Agriculture, Department of Agricultural Planning, MOAI, Union of Myanmar, Third Edition, 1999.
6. Ministry of Agriculture and Irrigation . Outline of The Irrigation Department, Irrigation Department, MOAI, Union of Myanmar, 1999.