CS/AR - 15/97-98

DEVELOPMENT OF DATA SIMULATION MODEL AND IRRIGATION SCHEDULES FOR EASTERN GODAVARI DELTA, ANDHRA PRADESH

आपो हि ष्टा मयोभुव:

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE - 247 667 (U.P.) INDIA

1997-98

Acknowledgments

We express our deep sense of gratitude to Dr. S. M. Seth, Director, National Institute of Hydrology for providing us with the infrastructure and support for conduct of this study as a part of the work program for the year 1997-98 of Deltaic Regional Centre, Kakinada.

We are grateful to Dr. P. V. Seethapathi, Scientist 'F', National Institute of Hydrology, Roorkee for he was instrumental in the formulation and execution of the study. We express our thanks to Mr. Radha Krishna Murthy, Deputy Chief Engineer, Department of Irrigation, Govt. of Andhra Pradesh, Hyderabad for showing interest in initiating the study.

We deeply acknowledge the personal interest took by Dr. Martin Smith, Senior officer, Water Resources Development and Management Service, Land and Water Division, FAO, Rome, Italy for providing us the prototype version of CROPWAT 7.0 for various research applications.

Thanks are also due to the Principal and faculty members of computer Science department, JNTU Engineering College, Kakinada for permitting us to use their computational facilities during the course of the study. Their valuable guidance and suggestions during the development of ANN Model is also acknowledged.

We express our sincere gratitude to the following personal for providing the data required for completion of the study.

- Superintending Engineer, Godavari Irrigation Project, Dowleswaram.
- Executive Engineer, Eastern Godavari Division, Dowleswaram.
- Assistant Director, Agricultural Research and Seed Multiplication Farm, Samalkot.
- Deputy Engineer, Kakinada Sub Division, Indrapalem.
- Assistant Executive Engineer, Kakinada Section , Indrapalem.

We do express our sincere gratitude to the scientists and staff members of Deltaic Regional Centre, Kakinada for providing support in various means throughout the course of the study.

Contents

List of Figures

List of Tables

Abstract

A study has been conducted to develop a data simulation model and irrigation schedules for the Eastern Godavari Delta Irrigation System, Andhra Pradesh. The present system of scheduling in the study area is the traditional procedure and a more scientific scheduling method is proposed so as to result in water saving in irrigation. An artificial neural network (ANN) model has been developed for forecasting the evaporation from rice fields. The performance of the model is evaluated by comparing the results with observed data. The output of this ANN model is then fed to the model 'CROPWAT', a program developed by FAO, to develop the irrigation schedule. The final output of the model is the amount of irrigation to be applied to each field and the time of each irrigation. The water allocation to canal is also computed after developing the schedule. The ANN model has been employed to assist irrigation managers to plan in the beginning of the season, where sufficient data is not available.

Chapter 1

Introduction

Historically, rising demand of water has been met through developing additional water supplies by controlling rivers and building other conveyance facilities. But the best sites for water development have been already utilized in most of the countries and further development is becoming increasingly expensive. The world is entering a new era of water management (David Seckler, 1997) that requires improved physical and economical productivity of water use, in addition to water development programs.

The magnitude and challenge in the new era of water management should not be underestimated. It is commonly thought that, for example, existing uses of water, especially in irrigation, are so inefficient that even small improvements in water use efficiency would generate large amount of additional water supply. While this is true in some cases, it need to be critically examined in some others.

The need to enhance water productivity and maintain water quality requires new and creative approaches to water policy, institutions and technologies. While the former two are more of administrative nature, the later emphasizes the need for advanced research. The increasing use of computers with high speed and large storage facilities are revolutionizing the world today. Information technologies - Geographic Information System, Remote Sensing and Computer modeling - have an important role in the era of water management. These techniques provide the spatial information necessary to more accurately evaluate and monitor the performance of large scale irrigation systems.

However, irrigation water management is a complex task. The complications arise from (i) the stochasticity of the water supplies (ii) stochasticity of the irrigation demands (iii) transit losses which depends on the flow hydraulics and (iv) differential crop responses to the available water supply. To overcome these problems, irrigation managers frame initial operation policies for a season based on the average or probabilistic weather and water supply data. But as the crop growing season progress, *i.e.* in real time, these data have to be corrected depending on the actual weather, crop, water supply and difficulties of system operation.

The present study aims at the analysis of various factors that influence the irrigation operations and development of appropriate mathematical models needed and the associated computer programs. Specifically, the objectives of the present study are:

1. to develop a suitable forecasting model to predict the evaporation from the crop fields, which then can be used for planning of irrigation schedules
2. to develop procedures for the management of irrigation system based on the forecasting models.

The present study is planned to develop operational procedures for canal irrigation systems. Irrigation system in Eastern Godavari Delta (Dowleswaram Irrigation Project, Andhra Pradesh) is selected to provide a case study.

Chapter 2

Review of Literature

The presented study is concerned with management of irrigation water from surface irrigation schemes. Barrages built across the rivers make a temporary storage of water, which is used for raising crops during the dry season or for supplemental irrigation during long dry spells in the monsoon season it self. The capacity of storage and the operation policies are decided based on the quantity and time distribution of river inflows and irrigation demand. The water from the reservoir/barrage is led to the field through a distribution network which includes main canals branches, distributories, minors, sub-minors and outlets.

Irrigation demands depend upon the rainfall, crop type and growth stage and the hydraulics of water distribution network. The last of these determines the actual quantity of water available at the field after allowing for the conveyance losses in the distribution networks. Generally the operational policies of irrigation schemes are derived at the planning stage by analysing historical weather data and using the average of the weather parameters, or the values specified at certain probabilities of occurrence or by using mathematical models. For most of the irrigation projects, the irrigation schedules are prepared in advance. Especially in climates with a wide variability over different years in rainfall, evapotranspiration and reservoir inflows, a fixed irrigation schedule on result in water loss and even in water shortages.

2.1 Estimation of Irrigation Requirements

Water is essential for the structural stability of the biological molecules and performs a vital role as solvent, transporting mineral nutrients throughout the plant body. Furthermore, in all actively growing plants there is a liquid phase continuity (soil-plant-atmosphere continuum) from the water in the soil through the plant and into the atmosphere. This process of transportation of water from the soil to atmosphere through plant is called transpiration. This process is essential for the thermal balance within the plant. The water needed for transpiration is many more times than that needed to sustain growth.

Crop water requirements are defined as "the depth of water needed to meet the water loss through evaporation of a decease-free crop, growing in large fields under non restricting soil conditions including soil water and fertility, and achieving full production potential under the given environment" (Doorenbros and Pruitt, 1977). Irrigation requirement refers to the water requirement of crops, exclusive of effective rainfall and contribution from soil profile (Michael, 1978).

The methods commonly used to estimate crop water requirement in irrigation projects are (i) traditional method (ii) field observation methods (iii) soil water balance methods and (iv) climatological data methods.

2.1.1 Traditional Method

These methods use chart and tables prepared based on experience in the past (Gandhi, 1981). The duty method or area irrigated per duty cusec (AI/DC) method also form part of the traditional methods. Duty is defined as the area of the land that can be irrigated by a flow of one cusec, water thus provided being sufficient for the wealthy growth of crop during the rotation period and AI/DC is the duty on day basis. A serious draw back of this method is that it is crop and location specific and the information can not be utilized at a different site.

2.1.2 Field Observation Method

These are methods based on observing the water used by the crops during a certain period and replenishing the same (WALMI, 1992). The observations of soil moisture content before irrigation are normally necessary. These methods are accurate only in areas where the field measurements are taken.

2.1.3 Soil Water Balance Methods

The quantitative relationship among the different components into which the incident precipitation or other inputs of water are partitioned is called the soil water balance (Eagleson, 1978). The essence of soil water balance is the principle of conservation of mass, applied to the soil water reservoir. By this principle, the difference between all the inputs of water to the soil reservoir and the outputs from it during a certain time interval is equal to the change in soil moisture storage during that interval.

Quantitatively, the daily water balance in the soil reservoir (normally limited to root zone), considering one dimensional flow, is given by,

$$(P + I + U) - (Q + DP + E + T) = DS \qquad (2.1)$$

Where,

P = precipitation, mm
I = irrigation, mm
U = upturned capillary flux into the root zone, mm

Q = deep percolation/drainage out of the root zone, mm
E = evaporation from the soil, mm
T = transpiration from the crop surface, mm
D S = charge in soil moisture storage, mm

2.1.4 Climatological Data Methods

These methods predict the crop water requirements from the climatological data and are now commonly used. These are primarily meant for estimating the evapotranspiration from the climatological factors such as radiation, temperature, wind speed, relative humidity, sunshine hours etc. Several formulae have been developed, considering some or all of these factors in various combinations, such as Penman (1948), Thornthwaite (1948), Blaney-Criddle (1950), Modified Penman (Doorenbrous and Pruit, (1977) and Hargreaves and Samani (1985). Among the various methods, the modified Penman method is by and large widely used in India for major projects during design and management.

2.1.5 Pan Evaporation Method

The National Weather Service class a pan is the standard evaporation measuring device in the united states and several other countries. The Pan evaporation has been widely used as an index of evapotranspiration (Kohles et. al, 1955; Christiansen, 1966; Hargreaves, 1966; Jensen, 1974). The evaporation values obtained from pan evaporimeter is converted into reference crop evapotranspiration using suitable pan factors and then the actual crop water requirement is computed.

In the present study the estimation of water requirements of crop has been computed using climatic data. The model CROPWAT (described in Chapter 5) has been employed to compute the water requirements which uses the principle of Penman-Monteith method. The pan evaporation method has also been employed to develop irrigation schedules for the study area based on simulated data.

Chapter 3

Study Area

3.1 General

The Godavari Delta Irrigation project, located at Dowleswaram near Rajamundry, East Godavari District in Andhra Pradesh is one of the oldest irrigation projects in India. The Dowleswaram barrage was constructed by Sir Arthur Cotton in 1847. Since the storage capacity was not sufficient to meet the irrigation requirements a new barrage was constructed upstream to it and this new barrage started functioning in 1987.

Geographical location of the barrage is $81^0\ 45'$ longitude and $16^0\ 55'$ latitude. The total irrigated area under this barrage is about 10,000,00 acres. The delta areas of this barrage have a well developed canal network. The details of the delta areas are presented in Table 1.

Table 1 Physical characteristics of Godavari Delta Irrigation System

	Eastern Delta	*Central Delta*	*Western Delta*
1. Area (hectares)	1,11,696	82,564	2,10,083
2. Main canal length (Km)	504	382	720
3. Branch canal length (Km)	847	742	1778
4. Water conveyance capacity (cusec)	611.28	413.18	849
5. Duty (cusec)	170	121	258

The present study has been restricted to the Eastern Godavari Delta which consists of a total ayacut of 1,11,696 hectares. The canal network of eastern godavari delta is presented in Fig 1. A pilot study area has been identified to develop the model and validate it, which then can be applied to the total area. The characteristics of the pilot study area is detailed below.

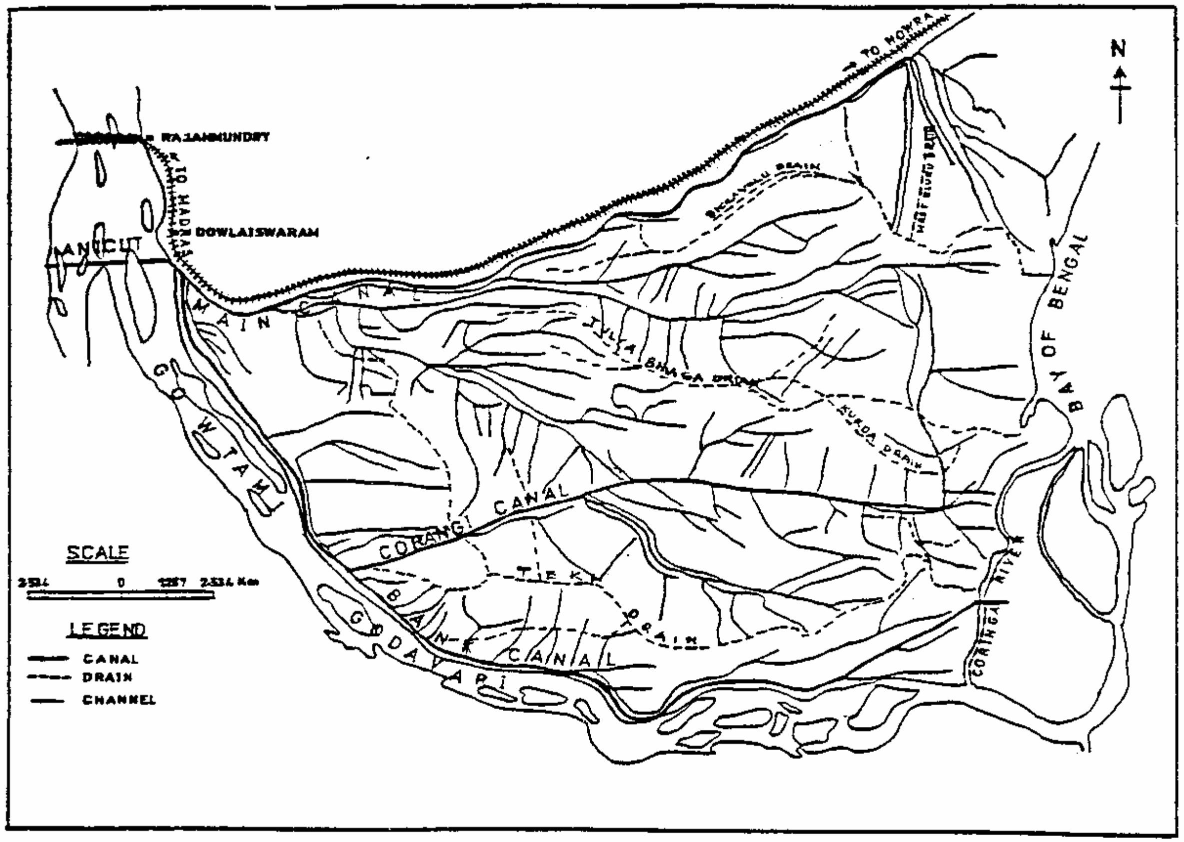


FIG. 1 THE CANAL NETWORK OF EASTERN GODAVARI DELTA, A.P

3.2 Pilot Study Area

The godavari eastern division has been divided into three sub divisions viz. Ramachandrapuram Subdivision, Kakinada Subdivision and Kothipally Subdivision. The pilot study area has been selected as a section of the Kakinada sub division, which serves a command area of 90,008 acres.. In total there are four sections in Kakinada subdivision viz. Kakinda, Bikkavolu, Kovvuru and Tossipudi. The Kakinada section constitutes an ayacut of 19,600 acres. The main canal details of the Kakinada section is presented in Table 2.

Table 2 Physical features of canal system in Kakinada section

Name of Canal	**Ayacut (acres)**
Unduru Main channel	3642
Sarpavaram branch channel	738
Jungaiadoddi branch channel	636
Unduru channel	409
Pindicheru branch channel	261
Valluru kotha kalava	86
Divitilakalava	167
Achampeta branch channel	534
Koppavaram branch channel	402

3.3 Operational features

The water distribution practice in vogue in Eastern Delta is the Sijpali system. According to this, water is allocated on the basis of sanctioned area of each type of crop to be irrigated in a particular season and is supplied in fixed quantity and fixed rotation. Recently this system is under modification with implementing peoples participation in water management.

3.4 Climate

The climate in the study area is generally regarded as unpleasantly hot, which is probably due to the early setting in high temperatures. The maximum temperatures in April and May are of the order of 42-43 ^{0}C. During the rest of the year the temperature ranges from 16^0 C to 38^0 C. The variation of temperature over the years 1990-1993 is presented in Fig 2.

The eastern delta falls under the heavy rainfall zone as the average annual rainfall varies from 1000 to 1200 mm under the influence of both southwest and northeast monsoon. The variation of rainfall for the study period (1990-1993) is illustrated in Fig 3. From the rainfall pattern it is observed that the rainfall is less during the early periods of the year. The southwest monsoon sets in during middle of June which, though precarious, brings a fair quantity of rains to the area upto end of September. The northeast monsoon breaks in October and the rains continue till December.

Being coastal area, eastern Godavari delta is moderate to highly humid and the relative humidity reaches more than 90% in some of the months (see Fig 4). Generally the eastern godavari delta is getting sufficient bright sunshine hours through out the year. The average daily bright sunshine hours is about 7-8 hours/day (see Fig 5). The wind in this area is regarded as medium except during the periods of cyclones. The area is prone to cyclonic storms due to depressions in the Bay of Bengal. The general variation of the wind velocity is depicted in Fig 6, for the period of study.

The evaporation losses in the area is moderately high due to the high temperature. The average annual evaporation observed in the area, as per records at Agricultural Research Farm,

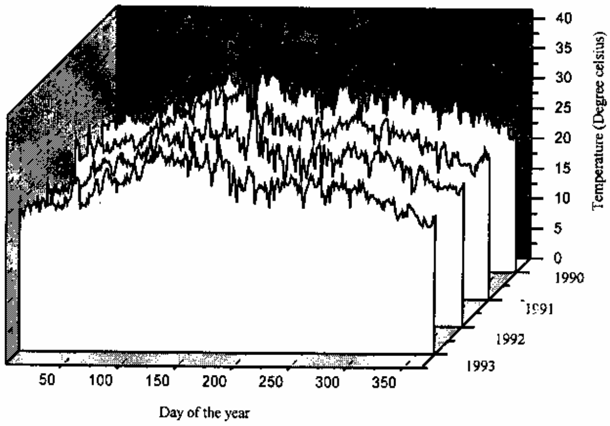


Fig 2 The variation of temperature during the years 1990-1993 in the study area

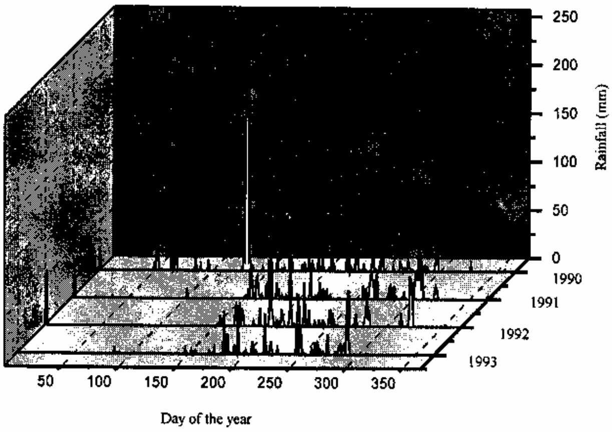


Fig 3 The variation of rainfall during the years 1990-1993 in the study area

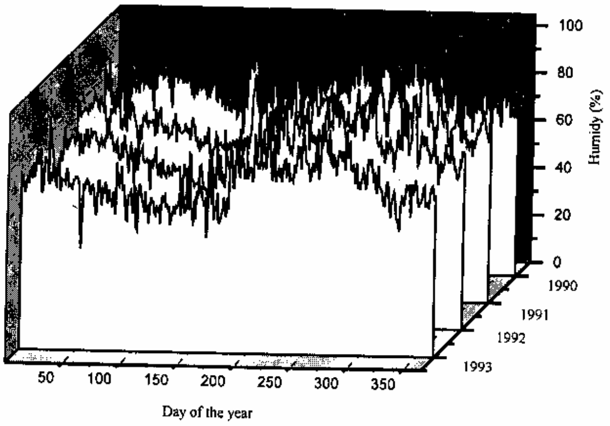


Fig 4 The variation of humidity during the years 1990-1993 in the study area

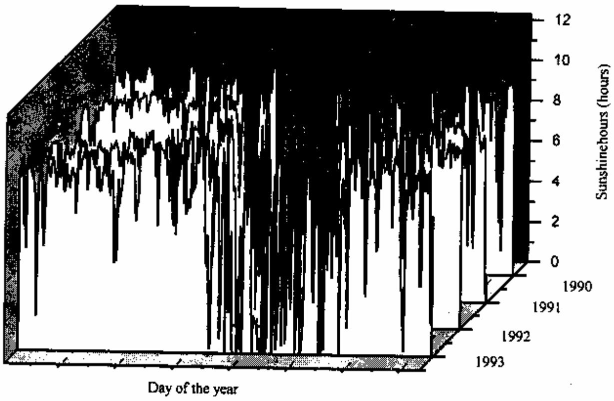


Fig 5 The variation of bright sunshinehours during the years 1990-1993 in the study area

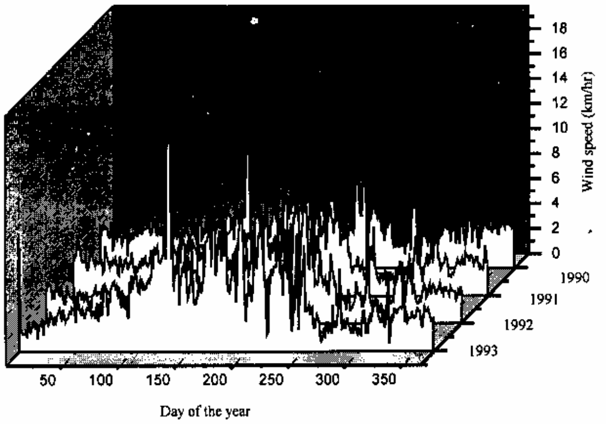


Fig 6 The variation of daily wind speed during the years 1990-1993 in the study area

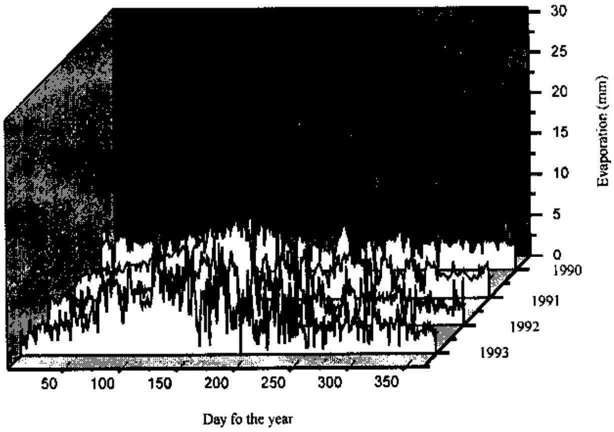


Fig 7 The variation of daily evaporation during the years 1990-1993 in the study area

Samalkot is about 1344 mm. Though the average daily evaporation is varying from 3 to 5 mm, some days it crosses 10 mm. The variation of daily evaporation during the study years is illustrated in the Fig 7.

3.5 Cropping Pattern And Soil

The major crop in the eastern delta is paddy. This is cultivated in both Khariff (June-November) as well as Rabi (December-April). A small portion of the command area (less than 0.5%) is under Sugarcane cultivation. Prior to 1993, during the second crop, only 60% of the command area was given irrigation and the rotation of the cultivated area has been done according to the calendar developed long back by Sir Arthur Cotton. However, after 1993, the policy has been changed to give irrigation water to 100% of the area, and thus naturally bringing the duty down.

The eastern delta mainly consists of black cotton soil, which is moderately permeable to be drained. In delta areas, the soil is having a high percentage of clay.

Chapter 4

Development of Artificial Neural Network (ANN) model

4.1 ANN - The Basics

ANN models have been widely applied in various fields of science and technology involving time series forecasting, pattern recognition and process control. The ANN structure has been mathematically proven to be a universal function approximator that is capable of mapping any complicated non linear function to an arbitrary degree of accuracy. Since late 1980s, ANNs have been successfully used to model a variety of different functions. The network is able to intelligently "learn" these functions through an automatic (unsupervised) or supervised "training process" . However, many issues related to network architecture are still not well understood. Many researches seem to view ANN as a black box approach, that is unable to provide important and useful insights into the underlying nature of the physical process (Judith, 1990).

The basic form of an ANN is called a multi-layer feed forward network (MFN) . The most popular type of MFN, the Three layer Feed-forward Neural Network (TLFNN), is shown in Figure 8. It consists of three layers of processing nodes (neurons) with connections linking the nodes in successive layers. The first layer consists of 'n_0' input nodes, one for each normalized input variable x_i ($i=1,.......,n_0$). The intermediate layer consists of 'n_1' "hidden" nodes, one for each intermediate variable y_i ($i=1,.....,n_1$). Both layers have an additional "bias" node (indicated with input = 1.0) which enables the mapping to represent the output levels associated with zero inputs. The final layer consists of 'n_2' output nodes, one for each output variable z_k = (k = 1,

.....,n_2). The input - hidden layer transformation performs a continuous non-linear mapping of n_o input values

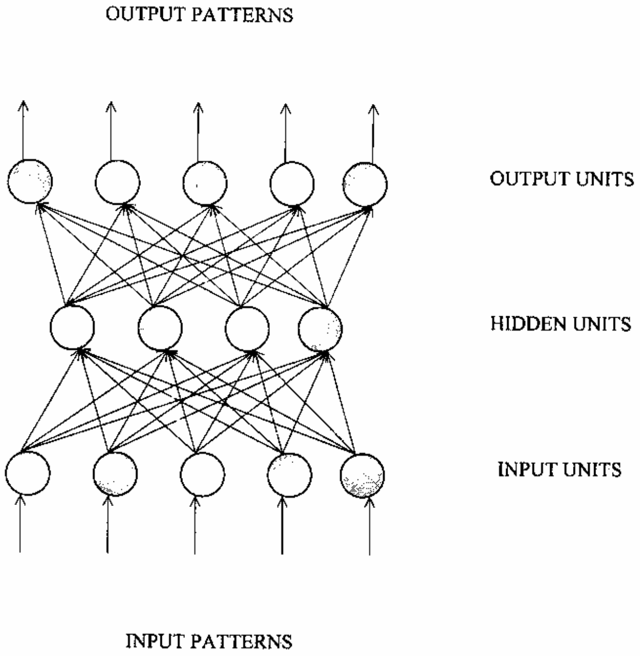


Fig 8 Three Layer Feed Forward Neural Network Structure

(x_i) to the intermediate variables (y_j); the parameters of this transformation are weights (w_{ji}). In a similar fashion, the hidden - output layer transformation performs a (linear or non linear) mapping of the n_1, intermediate variables y_j to the output values (z_k); the parameters of this transformation are the weights (V_{ij}) (Jihu, 1993).

The network output Z_k is computed by the equations,

$$z_k(p) = f\left\{\sum_{j=0}^{n_1} v_{kj} y_j(p)\right\} \tag{4.1}$$

$$y_j(p) = f\left\{\sum_{i=0}^{n_0} w_{ij} x_i(p)\right\} \tag{4.2}$$

where `p' is the number of input-output pattern and the non-linear transformation f (s) at each node is computed using any continuous monotonic function. In the current model the following logistic function is employed.

$$f(s) = \frac{1}{1+\exp(-s)} \tag{4.3}$$

The connection weights (W_{kj}, V_{ji}) are trained by minimizing the square error criterion evaluated over all the input-output patterns.

$$F(w,v) = \frac{1}{2}\sum_{p=1}^{p}\sum_{k=1}^{n_2}\left(t_k(p) - z_k(p)\right)^2 \tag{4.4}$$

where, $t_k(p)$ is the observed output value associated with $z_k(p)$. The response surface associated with this optimization problem is known to contain multiple local minima.

4.2 Back propagation Algorithm (BPA)

Back propagation (back error propagation) is the most widely used of the several network paradigms and has been applied successfully in applications studies in broad range of areas. Its learning procedure is based on a relatively simple concept. If the network gives the worng answer, then the weights are corrected so that error is lessened and as a result future responses of the network are more likely to be correct.

Figure 9 illustrates the back ward propagation step. Here the values are calculated for all processing units and weight changes are calculated for all inter connections. The calculations begins at the out put layer and progress backward through the network to the input layer.

The error correction steps take place after a pattern is presented at the input layer and the forward propagation step is complete. Each processing unit in the output layer produces a single real number for its output, which is compared to the target output specified in the training set (Fig. 10(a)). Based on this difference, an error value is calculated for each unit in the output layer as in Fig. 10(b). Then the weights are adjusted for all of the inter connections.

4.3 Net work training

Back propagation networks are trained by a technique called "supervised learning", whereby the network is presented with a series of pattern pairs - each pair connecting of an input pattern and a target output pattern. Each pattern is a vector of real numbers. The target output pattern is the desired response to the input pattern and is used to determine the error values in the network when the weights are adjusted. The patterns in the training set are presented to the network repeatedly.

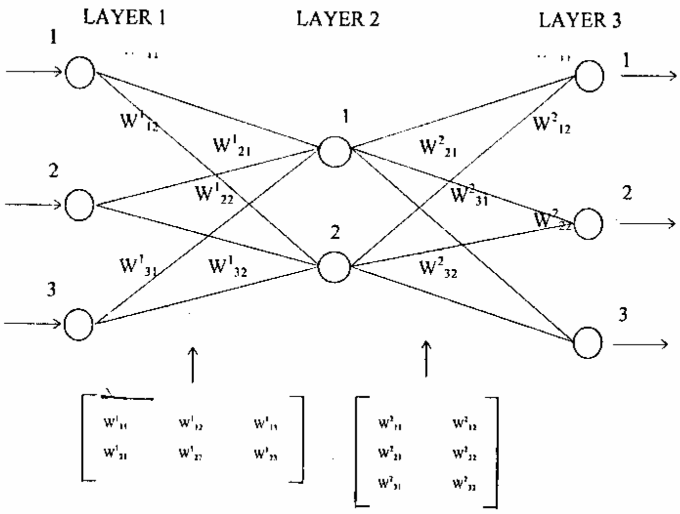


Fig 9 The Three Layer Feed forward Neural Network structure (Jushu *et. al.* 1993)

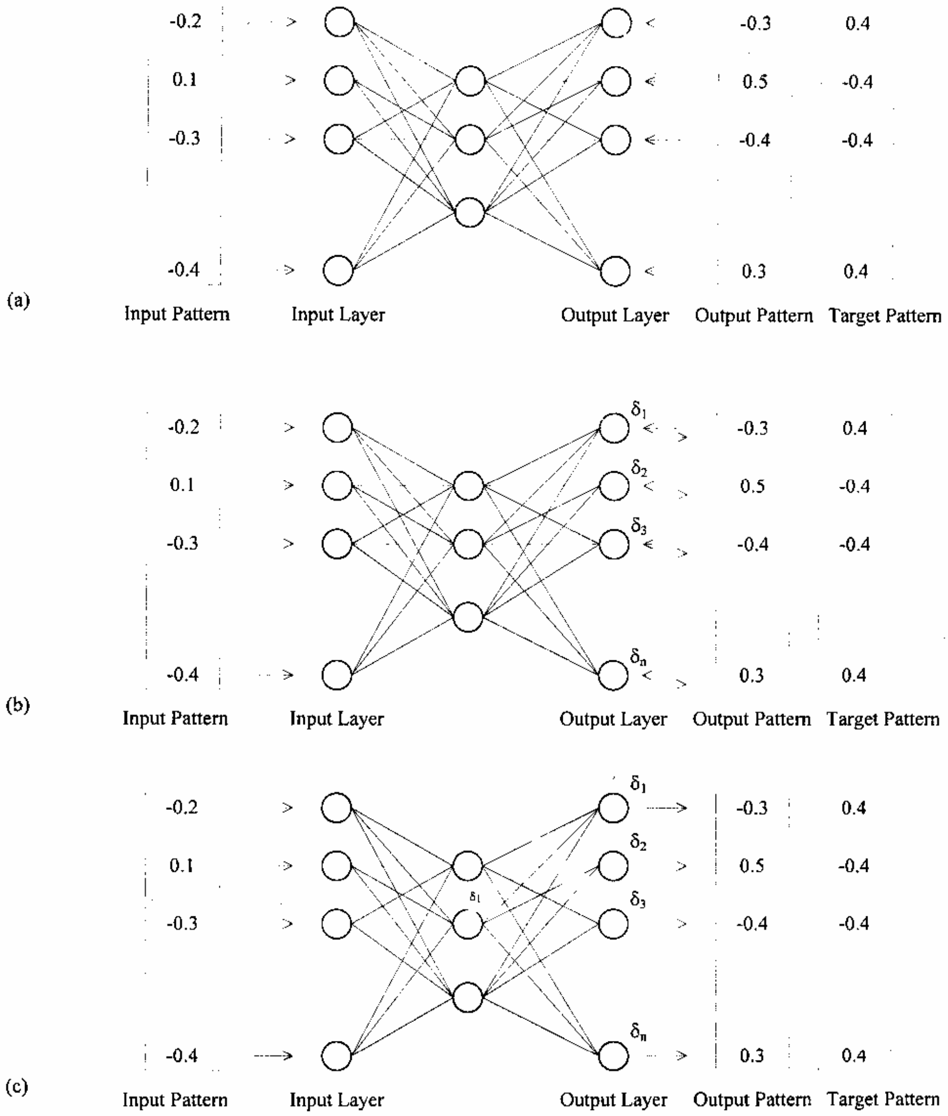


Fig 10 Basic Back Propagation Dynamics (Jishu *et. al.* 1993)

(a) After forward propagation, the target output pattern is compared to the output pattern

(b) δ values are calculated for the output layer and its incoming weights are adjusted

(c) δ values are calculated for the hidden layer and its incoming weights are adjusted

Each training interruption consists of presenting each input-output pattern pair once. When all patterns in the training set have been presented, the training interruption is completed, and the next training iteration is begun. A back propagation example might entail hundreds or thousands of training iterations.

4.4 Convergence

When a network is trained successfully, it produces correct answers more and more often as the training session progresses. It is important then to have a quantitative measure of learning. The root mean squared (RMS) error is usually calculated to reflect the degree to which learning has taken place in the network. The RMS is computed by the equation,

$$RMS = \sqrt{\frac{\sum_p \sum_j \left(t_{jp} - x_{jp}\right)^2}{m_p n_0}} \qquad (4.5)$$

This measure reflects with what ease the network is getting the correct answers. As the network learns, the RMS error decreases. Generally an RMS value below 0.1 indicates that a network has learned its training set. The network gets closer and closer to the target value incrementally with each step. It is possible then to define a cut off point when the network outputs is said to match the target values. Convergence is a process where by the RMS value for the network gets closes to zero. Convergence is not always easy to achieve because the process may take an exceedingly long time and some times gets stuck in local minimum and stops learning all together.

It is possible to represent convergence intuitively in terms of walking about a mountainous terrain. The terrain is the graph of RMS values as a function of all of the weights in the network.

Using this analogy, the BPA is seeking a minimum height in the mountainous terrain. Ideally we seek a global minimum - the bottom of the valley that is lowest in the entire terrain. This corresponds to the lowest RMS value possible. Unfortunately it is possible to encounter a local minimum - a valley that is not the lowest possible in the entire terrain. Neverthless, a local minimum is surrounded by a higher ground, and the network usually does not leave a local minimum by the standard BPA described. Special techniques should be used to get out a local minimum.

The appearance of local minimum is not always a significant problem. Back propagation networks typically coverage to a good RMS value when the training examples are clearly distinguishable. When a local minimum is encountered, the network may be able to avoid entering that local minimum by changing the learning parameters or the number of hidden units. These techniques tend to change the scenario involved in moving about on the "mountainous terrain" and may cause the network to avoid the local minimum.

The convergence process of BPA is basically the same as the gradient decent method, which derives from traditional statistical methodology.

4.5 Current Model structure and input variables

The TLFNN model described above has been implemented with back propagation algorithm tc get the daily evaporation values from various climatic factors. The specific structure used tc generate the results in this study depicted in (Fig 11). The network structure consists of 4

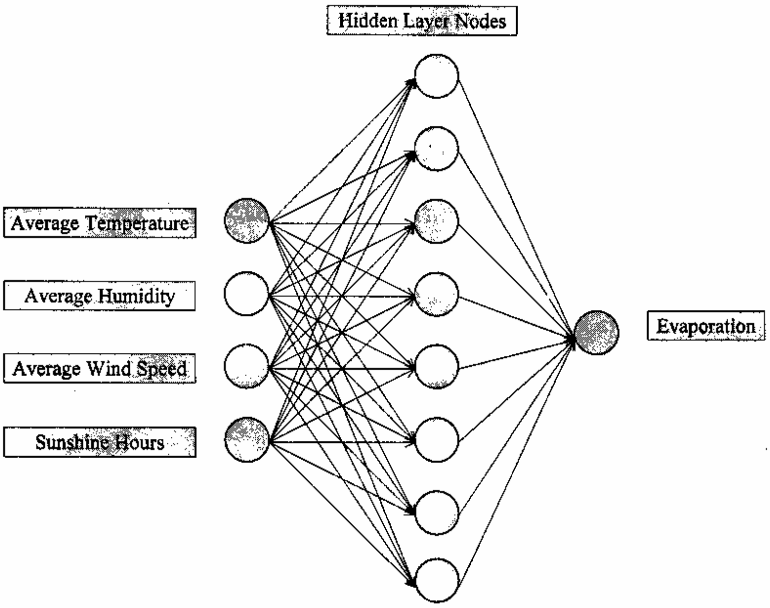


Fig 11 Current ANN Model Structure

normalized input variables (n_0=6) in the input layer, 8 hidden layers (n_1=8) and one output layer (n_2 = 1).

The most important requirement of successful estimation of evaporation using this model is the selection of input variables that provide sufficient information to enable proper evaporation estimations. It has been reported that the evaporation is influenced by the air temperature, humidity, sunshine hours, wind velocity (Jensen, 1992). The current model has been designed to take care of all these parameters as input to predict the evaporation reasonably well.

The inputs variables to the model are normalized values of daily mean temperature (^{0}C), mean relative humidity (%), wind velocity (kmph), and bright sunshine hours (hours) during the day. The normalization to each data input variable is done by the function.

$$t_i = \frac{T_i - T_{\min}}{(T_{max} - T_{\min})} \tag{4.6}$$

Normalization means that the length of input vector is 1.0, such as $\|X\| = 1.0$, where

$$\|X\| = \sqrt{\left(\sum_i x_i^2\right)} = \tag{4.7}$$

With normalization, the input variables are put on a unit sphere.

4.6 Model Testing

The developed ANN model has been tested for the popular exclusive or (XOR) problem. The XOR pattern recognition consists of an input target mapping represented by four pairs: (X_1,X_2,t) = [(0,0),0], [(0,1),1], [(1,0), 1], [(1,1,) 1]. In actual practice of training the desired targets 0 and 1 are represented by 0.1 and 0.9 respectively. An ANN (2,4,1) structure was used to solve the problem. The implemented algorithm was performing well in this case.

4.7 Results and Discussions

The model was ued to estimate the evaporation from climatic parameters, as explained above. The data for four years (1990 - 1993) were used in the study. The data for the year 1990 were used for calibrating the model and the remaining three years data were used for validation of the model. Based on experimentation the learning parameters, viz. learning rate and moment factor for the network, have been set to 0.019 and 0.013 respectively. The cutoff for the RMS error has been fixed to 0.08.

The ANN (4,8,1) structure was used to estimate the evaporation from the climatic parameters. The inputs to the model were normalized values of average daily temperature, average relative humidity, wind velocity and sunshine hours. The normalisation of the data has been done using equation 4.6. The data for the year 1990 was used to train the network model and data for balance three years (i.e. 1991 - 1993) were used to validate the model. The resulted network out put were transformed again to real life values, by doing the inverse transformations. The resulted estimates of the evaporation from the ANN model is depicted in Fig 12 to 16.

Figure 12 illustrates the results of the model. The simulated and observed evaporation are presented for all the four years (1990-1993). The data for year 1990 has been used for training the network and the results of training are depicted in Fig 13. From the Fig 13, it may be observed

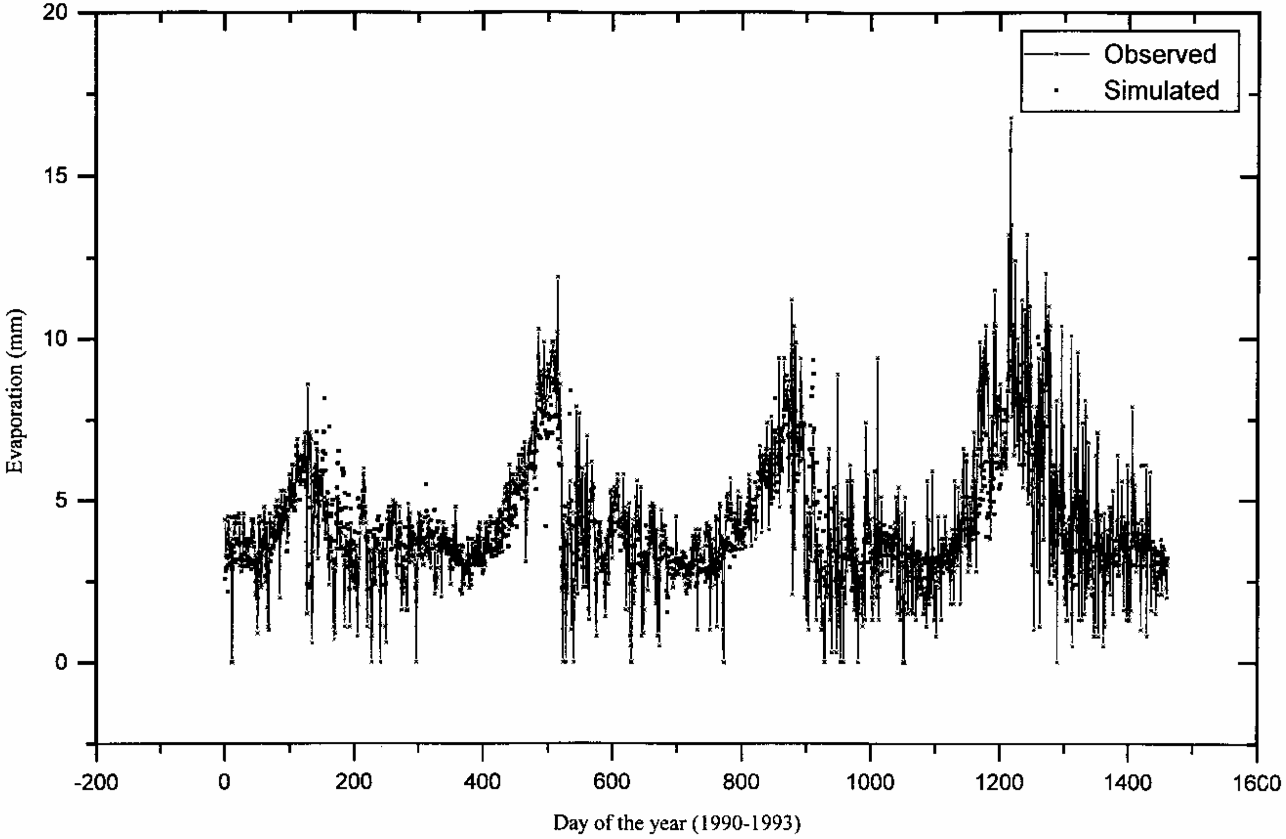


Fig 12 Simulated and observed evaporation for the years 1990-1993

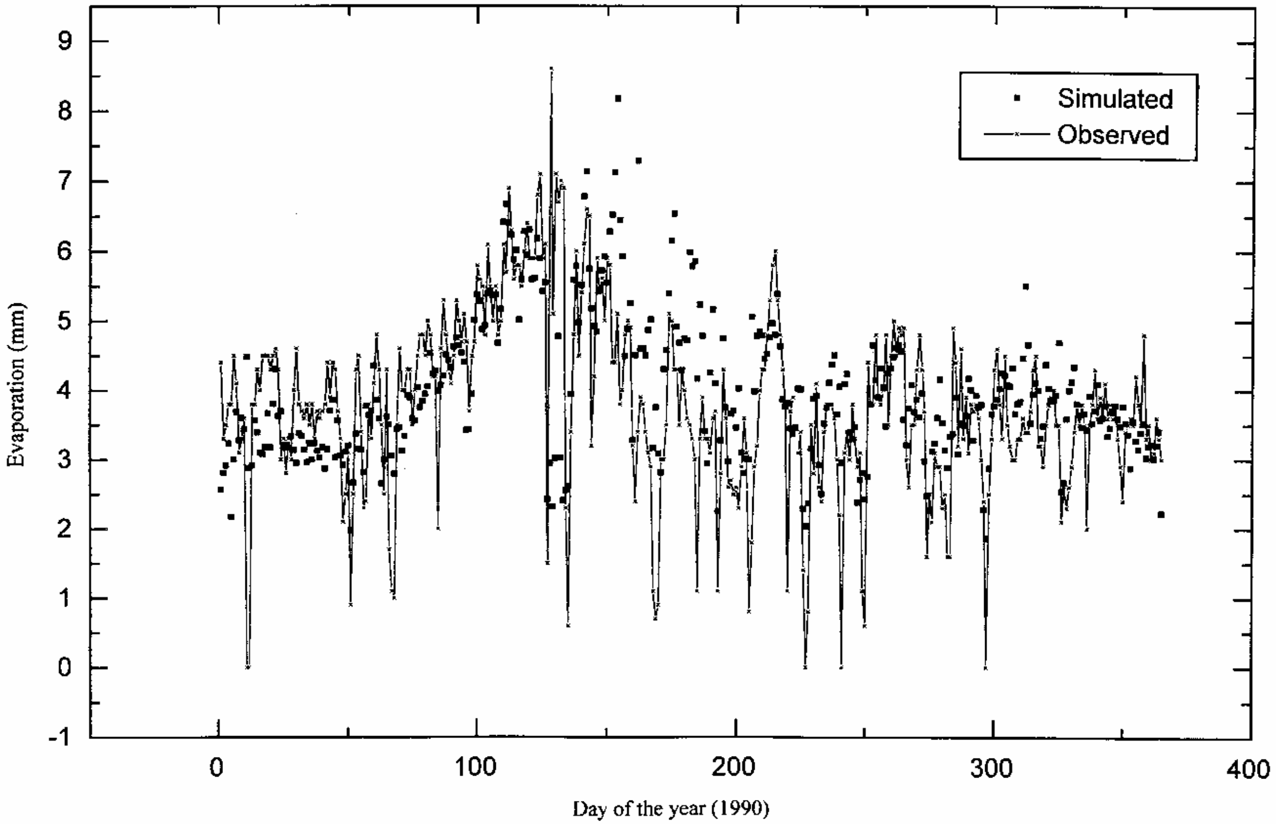


Fig 13 Simulated and observed evaporation for the year 1990

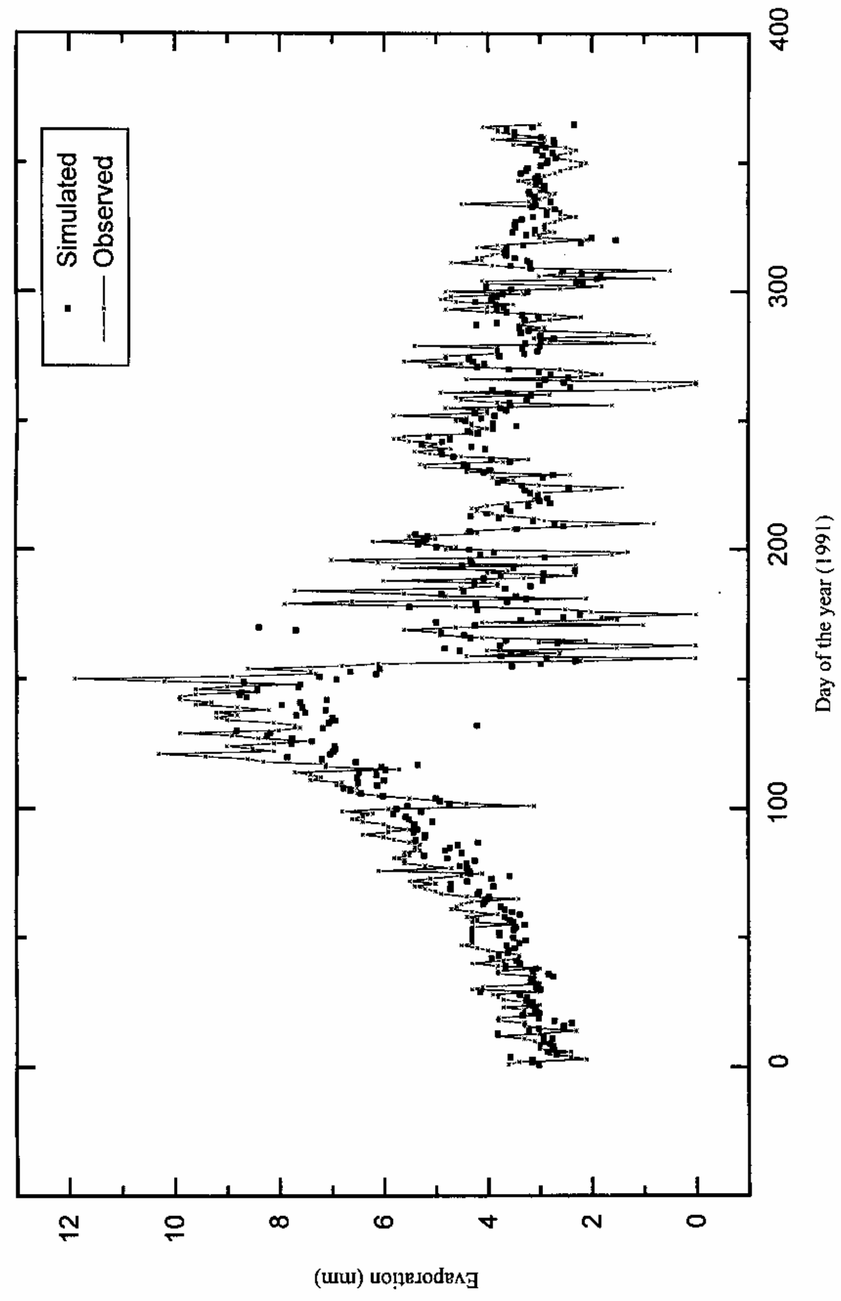


Fig 14 Simulated and observed evaporation for the year 1991

Table 2(a) Observed and Simulated values of monthly Evaporation for the year 1991

Observed	Computed
3.25	3.06
3.86	3.41
5.11	4.36
6.49	5.90
8.93	7.52
3.80	4.26
4.17	3.95
3.95	3.79
3.54	3.60
3.46	3.41
3.07	2.99
2.95	3.01

Table 2(b) Observed and Simulated values of monthly Evaporation for the year 1993

Observed	Simulated
3.15	3.003
3.82	4.03
4.96	6.95
6.86	8.15
8.14	8.68
7.69	6.93
4.2	4.7
3.9	4.63
3.32	3.29
3.59	3.77
3.67	3.67
3.24	2.99

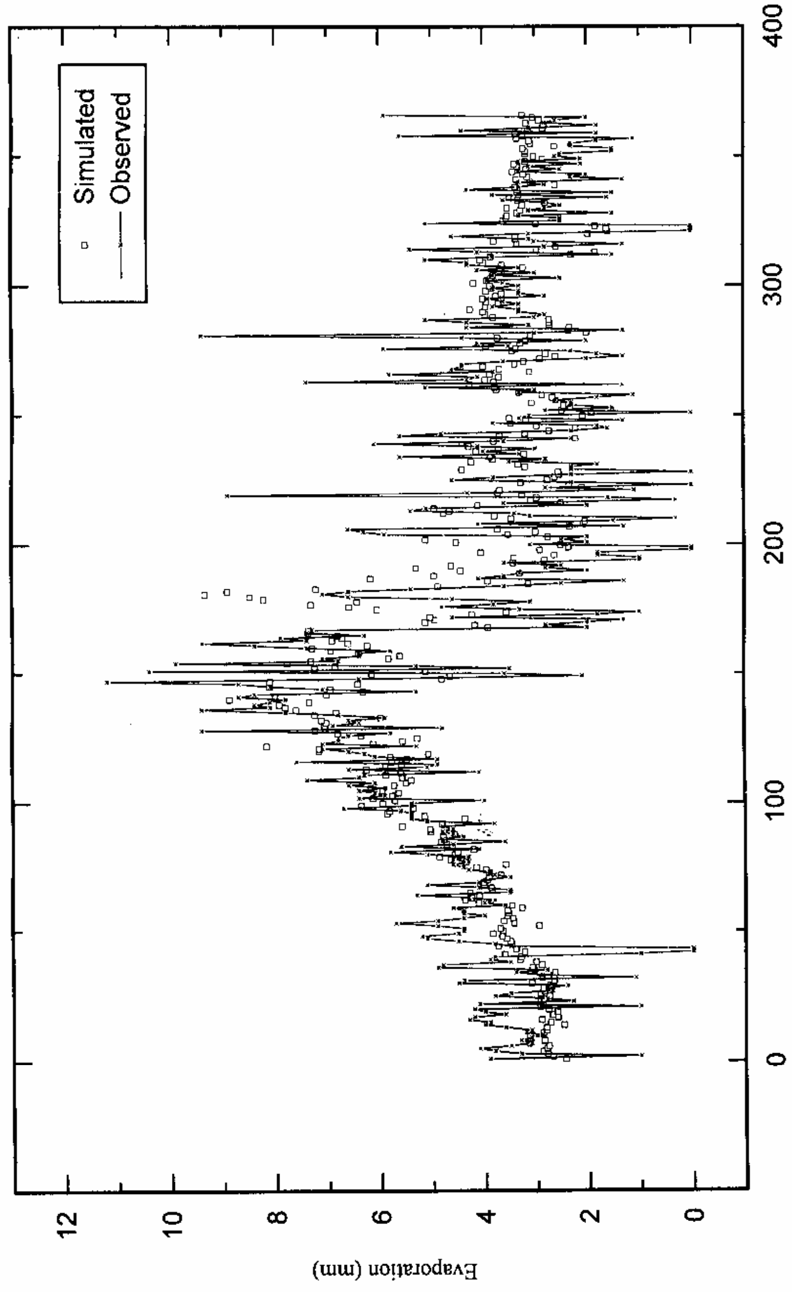


Fig 15 Simulated and observed evaporation for the year 1992

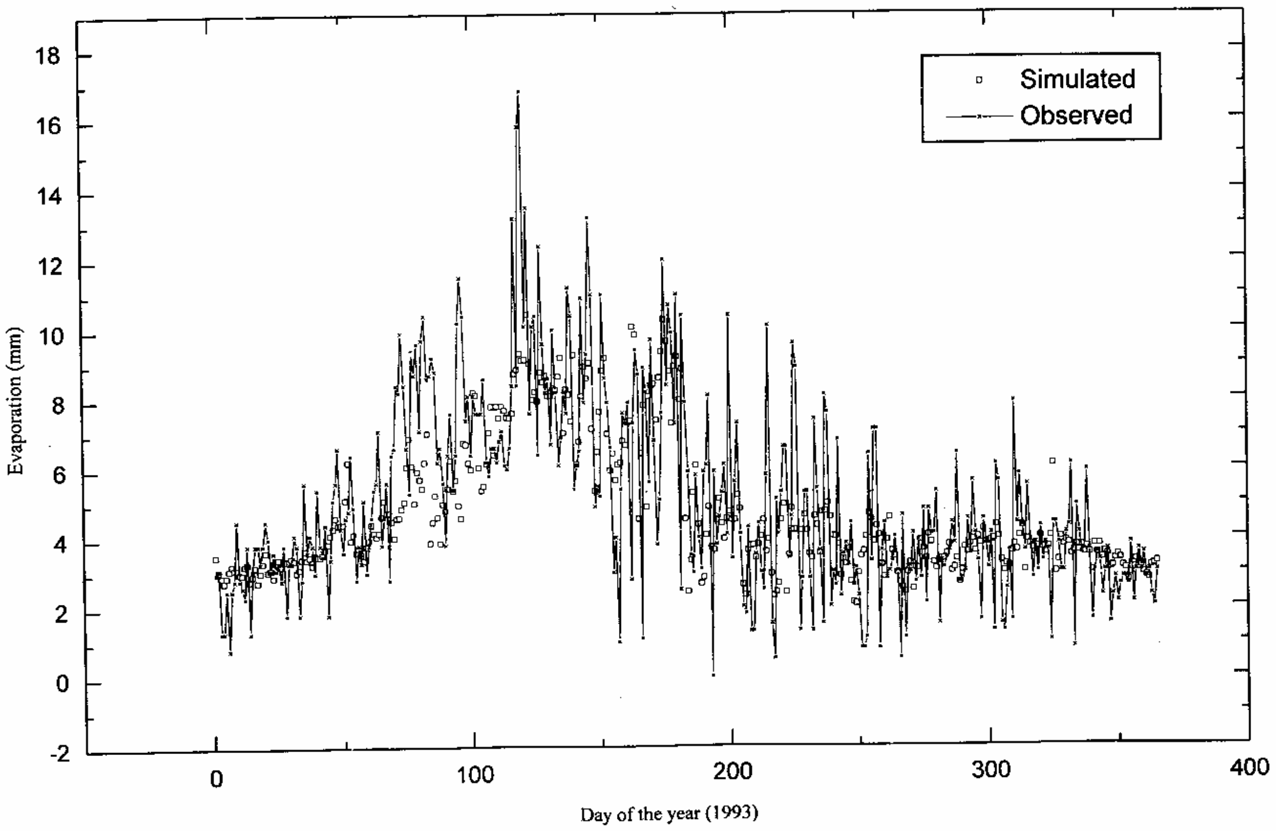


Fig 16 Simulated and observed evaporation for the year 1993

that the model could simulate the evaporation to a satisfactory level. The RMS error at which the iterations were stopped is 0.0079 and the number of iterations to reach this cut off level were 40000. Trials were done by changing the learning parameters of the network and the optimum level was found to be the current one reported above.

The Fig 14 to 16 depicts the simulated and observed evaporation for years 1991 to 1993 using the ANN model. These were simulated after training the network with the data for 1990. The figures illustrated that the model could simulate evaporation to a good degree of accuracy. However, it can be observed that the model performance to simulate extreme values was not to the mark.

Chapter 5

Development of Irrigation Schedules using CROPWAT

5.1 General

CROPWAT is a computer program to calculate crop water requirements and irrigation requirements from climatic and crop data. Furthermore, the program allows the development of irrigation schedules for different management conditions and the calculates scheme water supply for varying cropping patterns. The program will run on any IBM-PC type of computer with a minimum of 360 Kb.

Procedures for calculation of the crop water requirements and irrigation requirements are mainly based on methodologies presented in FAO Irrigation and Drainage Papers No.24 "Crop water requirements" and No.33 "Yield response to water".

The program is meant as a practical tool to help both the Irrigation Engineer and Irrigation Agronomist to carry out standard calculations for design and management of irrigation schemes. It will further help in the development of recommendations for improved irrigation practices and the planning of irrigation schedules under varying water supply conditions.

The CROPWAT version 7.0 (prototype) has been used to develop the water requirements of paddy in the present study. The CROPWAT has been employed to develop schedules based on the observed climatic data which considers all the climatic parameters such as temperature, humidity, sunshine hours, and wind velocity. The program has been used to develop the schedules based on the simulated evaporation data and compared with the results from the previous run.

5.2 Rice Water Requirements

The calculation of the irrigation requirements of wetland rice is different from other field crops. The calculation procedure is illustrated in the Fig 17, graphically. Extra irrigation water is required not only to cover evaporation losses but also to compensate for the percolation losses in the inundated fields. Furthermore, prior to transplanting, substantial irrigation water is required for the land preparation and the nursery. Input and calculation procedures will therefore differ from those of other crops for which a separate program is included in the CROPWAT. This module is called up automatically whenever the crop name Rice or paddy is given.

5.3 Input of Rice Data

Data input required for rice include the following.

- length of crop growth stages
- crop factors
- nursery area
- land preparation depth
- percolation rate.

The details of input data are discussed below. The input data used for the present study are depicted in Table 3

5.3.1 Length of growth stages

Normally upland crops will have 4 growth stages. In wetland rice this is extended to 6 stages to include the nursery and land preparation periods.

The length of different stages is defined as follows:

> Length of nursery period: number of nursery days starting from land preparation nursery area to transplanting of rice.
>
> Length of land preparation: number of days required to carry out land preparation and inundation prior to transplantation for given irrigation unit. Normally land preparation will fall within the nursery period.
>
> Lengths of initial period (A), development stage (B), mid-season (C) and late season (D) are defined similarly to those for field crops.

Table 3 Input data for paddy to CROPWAT.

Growth Period	Length stage	Crop coefficient
Nursery	30 days	1.20
Land preparation	20 days	-
Initial stage (A)	20 days	1.00
Development Stage	30 days	-
Mid Season (C)	40 days	1.05
Late Season (D)	30 days	0.80
TOTAL	150 days	
Nursery Area	10 %	
Land Preparation	180 mm	
Percolation rate	1.5 mm/day	

5.3.2 Crop factors (K_c)

Each of the 6 growth stages will be allocated a crop factor, which converts the reference crop evapotranspiration to actual crop evaporation. As rice is permanently inundated, the crop factor, represents values for the combined effect of crop transpiration and open water evaporation. Values will vary from 1.0 to 1.2 . In late season a lower value (0.9) can be taken to account for the drying out of the soil profile.

5.3.3 Nursery area

The area covered by the rice nurseries will occupy only a fraction of the total area. Crop water requirements will be proportionally reduced. An input is therefore required of the area covered by the nursery area as a percentage of total cultivated area.

5.3.4 Land preparation depth

For land preparation and inundation a considerable amount of irrigation water is normally required, normally given in two irrigation. A first application to bring the soil to saturation (±100 to 150 mm), after which puddling and land cultivation are carried out. Prior to transplanting, a second irrigation for inundation of a water layer to 100 mm is effected.

The total irrigation requirements for land preparation amount to 200-300 mm. This high momentary irrigation requirement for inundation and land preparation for a given rice area is spread over the land preparation period by rotating irrigation supply over the fields. A longer land preparation will result therefore in lower daily irrigation requirements.

5.3.5 Percolation rate

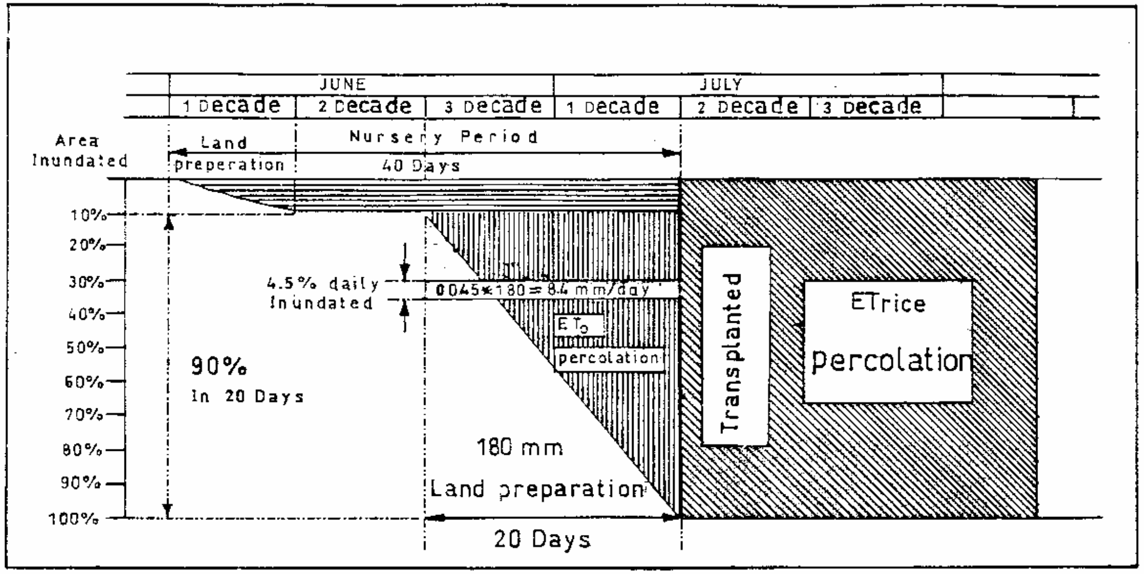
Depending on soil type and groundwater levels, the inundated rice fields will have a continuos water percolation to the deeper layers. This percolation process is favorable for plant growth as the water movement will keep oxygen content within the soil at a reasonable level. Normal percolation rates are 1-3 mm/day (Martin, 1992), but rice fields on light soils and slopes may have as much as 10-20 mm/day.

5.4 Rice Irrigation Calculations

Rice irrigation requirements include the combined effect of the evapotranspiration and percolation and the requirements for land preparation and nursery before transplanting.

Evapotranspiration and percolation occur as soon as the fields are inundated. During the nursery period ET_0 and percolation are accounted for only that area covered by the nursery. During the land preparation this area increases daily with more land being inundated until the area is fully covered at transplanting. The area factor in the results shows the average area coverage over the 10 day period.

Figure 17 illustrates the calculation procedures for rice irrigation requirements during nursery and land preparation periods and after transplanting.



Water requirements of rice

Fig 17 Calculation Procedure for Rice Irrigation requirements

5.5 Results and Discussion

The crop water requirement and the irrigation schedule for paddy crop grown in the study area has been developed using the CROPWAT, as detailed above. The climatic data for years from 1990 to 1993 has been employed in developing the schedule and the results are discussed in this chapter. Initially the schedules are developed using the actual observed data. In the second run, the input data has been changed to evaporation values simulated from the ANN model, described in the previous chapter, for the study area. The results from both the runs are compared.

The CROPWAT produces scientific irrigation scheduling which results in saving of water. The Table 4 represents the output from the CROPWAT for the year 1990. The results are obtained from giving actual climatic data as input to the model.

Irrigation requirement computed from the actual and simulated data are illustrated in Figures 18 to 25. It can be observed from the figures that the irrigation requirement is varying corresponding to the effective rainfall, while in actual practice in the area the irrigation supply is continuos and is not reduced during rainy days. During the initial periods of the season, the amount of irrigation required is more compared to the final stages. During both these stages, though the rainfall is almost nil, the high amount of requirement in the early stages corresponds to the nursery and land preparation.

Table 4 Output from CROPWAT for the year 1990 (July Crop) from actual climatic data

Month	Deciday	Refernce ET (mm)	Crop coefficient (mm)	ET_{crop} (mm)	Percolation (mm)	Land preparation (mm)	Effective rainfall (mm)	Irrigation requiremnt (mm)
Jun	2	0.33	1.2	0.40	0.1	1.1	1.1	8.5
Jun	3	0.87	1.17	1.02	0.3	5.6	5.8	63.6
Jul	1	2.32	1.09	2.53	0.9	8.1	18.9	96.5
Jul	2	3.40	1.02	3.47	1.4	3.2	29.8	51.0
Jul	3	3.80	1.00	3.80	1.5		37.7	24.1
Aug	1	3.94	1.01	3.88	1.5		37.0	16.8
Aug	2	3.92	1.02	4.00	1.5		39.1	15.9
Aug	3	3.92	1.04	4.08	1.5		39.1	25.8
Sep	1	3.93	1.05	4.13	1.5		30.8	25.5
Sep	2	3.95	1.05	4.15	1.5		27.5	29.0
Sep	3	3.69	1.05	3.87	1.5		27.4	26.3
Oct	1	3.35	1.05	3.52	1.5		29.7	20.5
Oct	2	3.04	1.02	3.10	1.3		30.3	13.7
Oct	3	3.15	0.94	2.96	0.9		23.2	21.6
Nov	1	3.29	0.85	2.80	0.5		8.2	24.7
Nov	2	3.35	0.77	2.58	0.0		0.0	2.6
Total				**489**	**178**	**176**	**385**	**466**

Climatic Station : SAMALKOT Crop : Paddy Transplanting Date : 15 July,1990

The computed irrigation requirement from both data sets is presented in Table 5(a) and 5(b). It can be concluded from the table that the total irrigation requirement is within the

Table 5(a) Total irrigation requirement for the season during first crop

Year	Total irrigation Requirements	
	From Actual data	From Simulated data
1990	466.00	441.90
1991	438.20	419.80
1992	393.20	336.50
1993	462.90	425.20

Table 5(b) Total irrigation requirements during second crop

Year	Total irrigation Requirement	
	From Actual data	From Simulated data
1990	466.00	441.90
1991	438.20	419.80
1992	393.20	336.50
1993	462.90	425.20

Table 5(c) Total crop water requirement for the season during first crop

Year	Crop Water Requirements	
	From Actual data	From Simulated data
1990	489	465
1991	467	448
1992	490	429
1993	504	465

Table 5(d) Total crop water requirement for the season during second crop

Year	Crop Water Requirements	
	From Actual data	From Simulated data
1990	551	468
1991	573	494
1992	544	486
1993	574	560

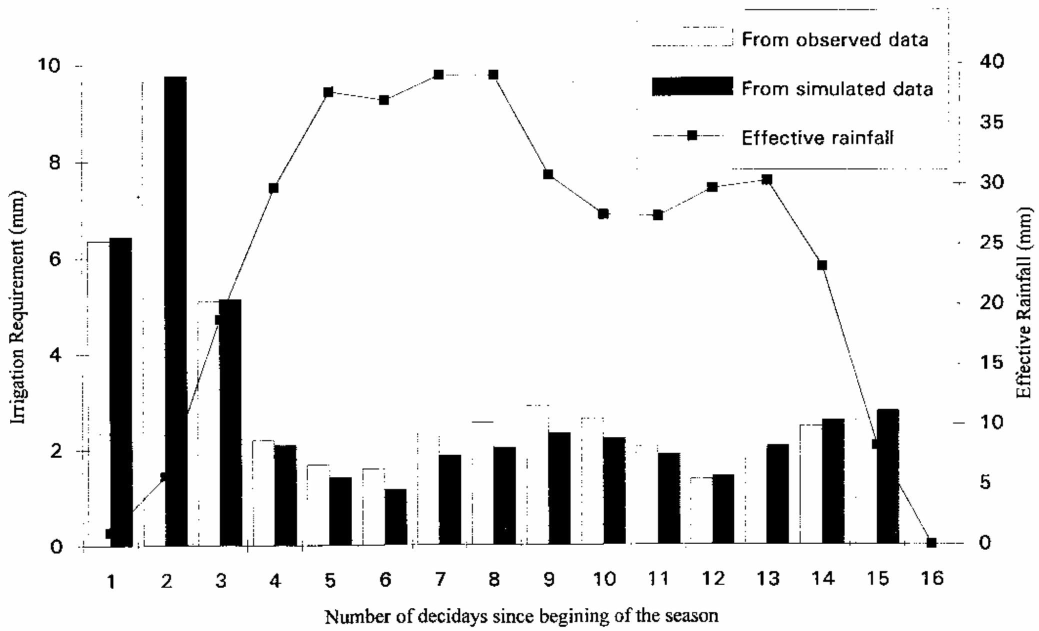


Fig. 18 Irrigation requirement computed from actual and simulated data (July crop) for the year 1990

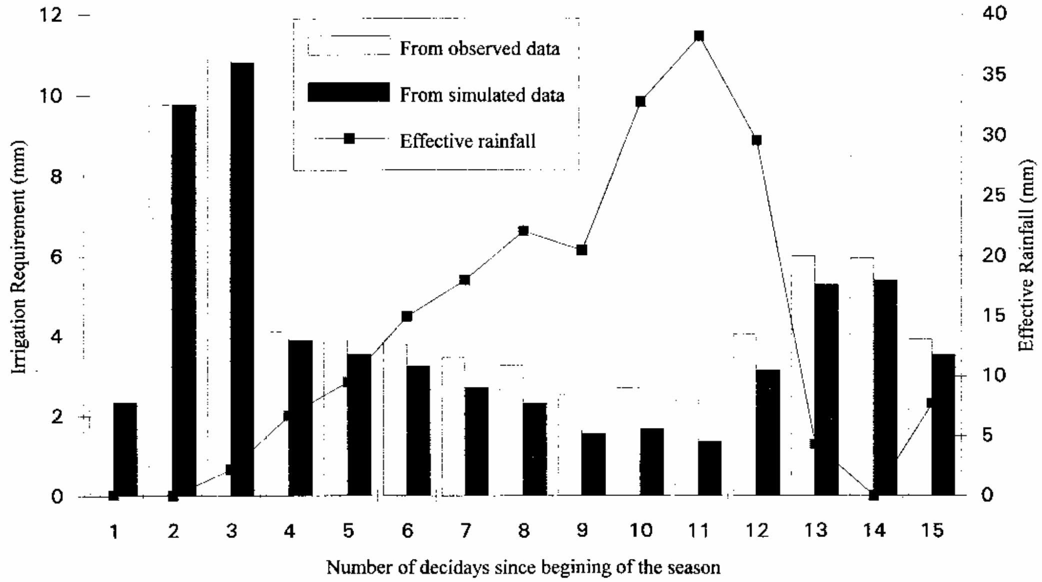


Fig. 19 Irrigation requirement computed from actual and simulated data (Decemeber crop) for the year 1990

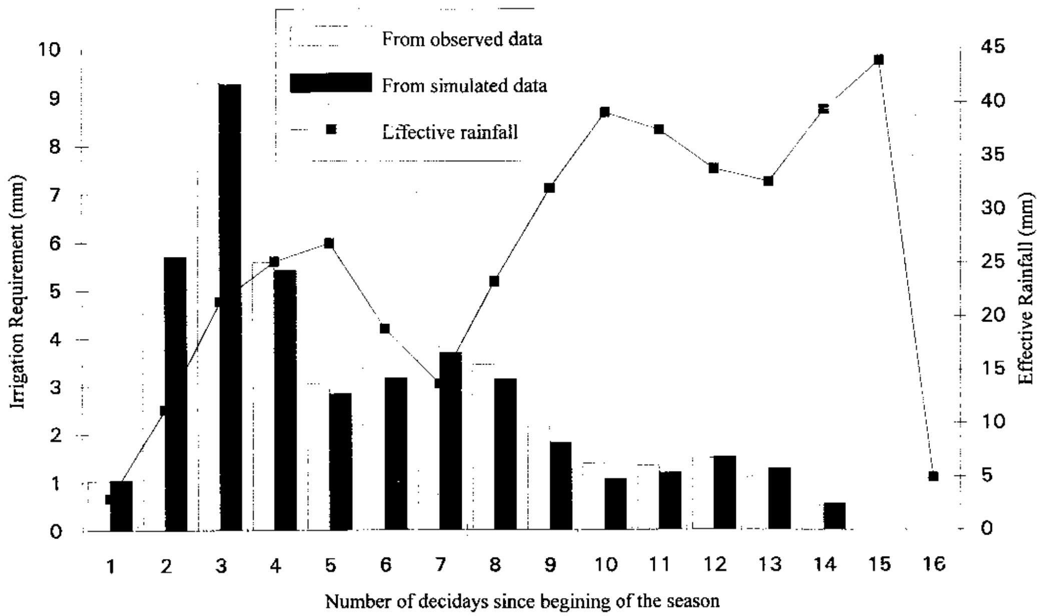


Fig. 20 Irrigation requirement computed from actual and simulated data (July crop) for the year 1991

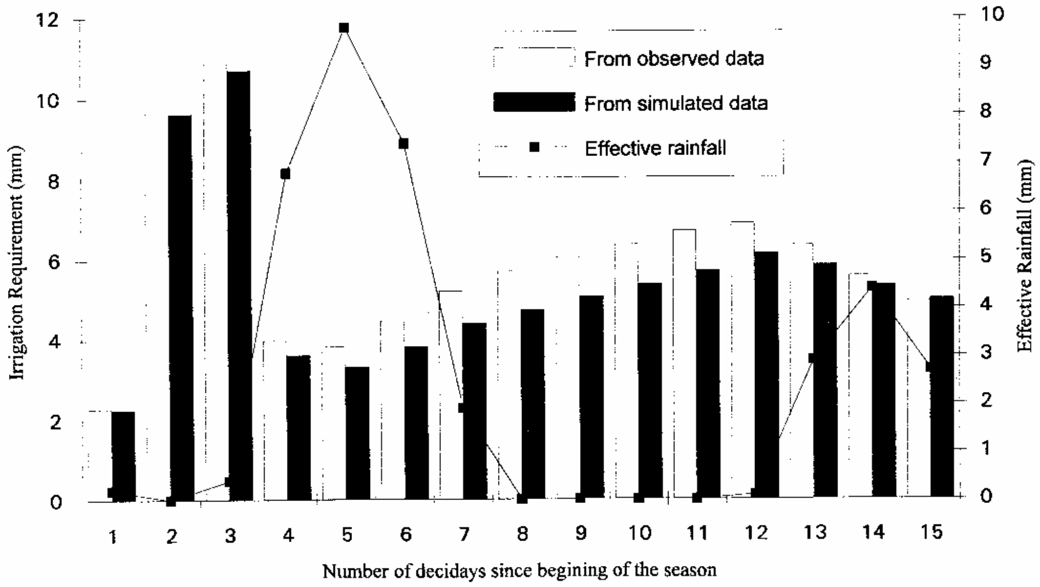


Fig. 21 Irrigation requirement computed from actual and simulated data (December crop) for the year 1991

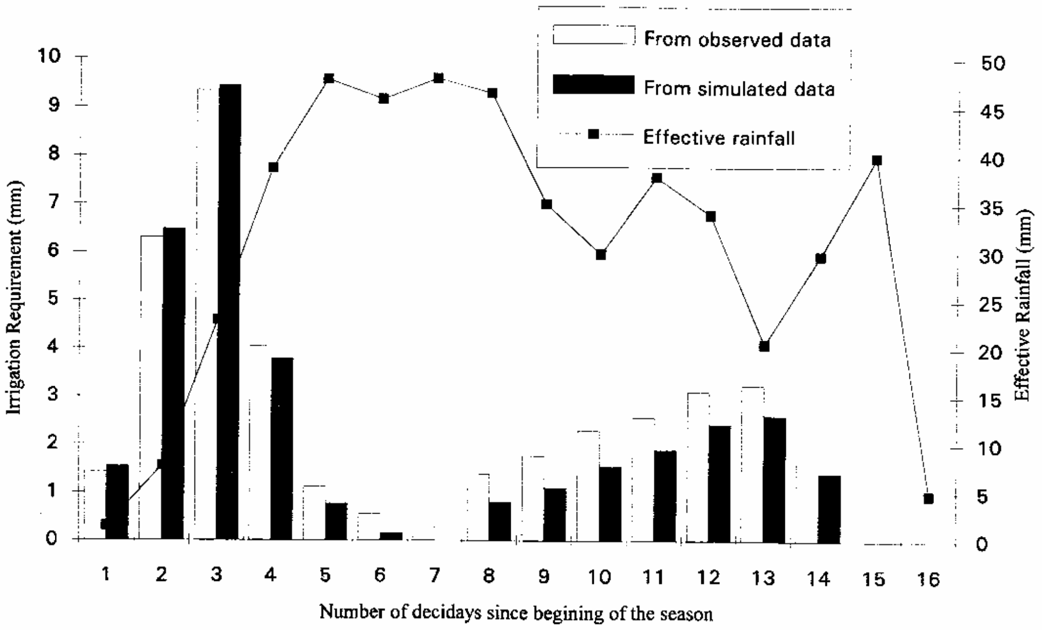


Fig. 22 Irrigation requirement computed from actual and simulated data (July crop) for the year 1992

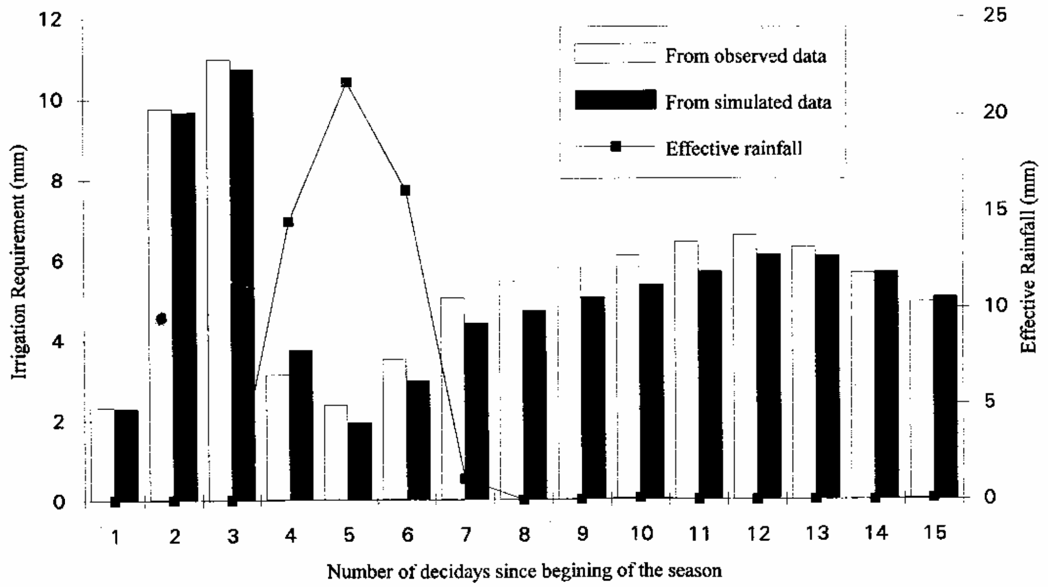


Fig. 23 Irrigation requirement computed from actual and simulated data (Decemeber crop) for the year 1992

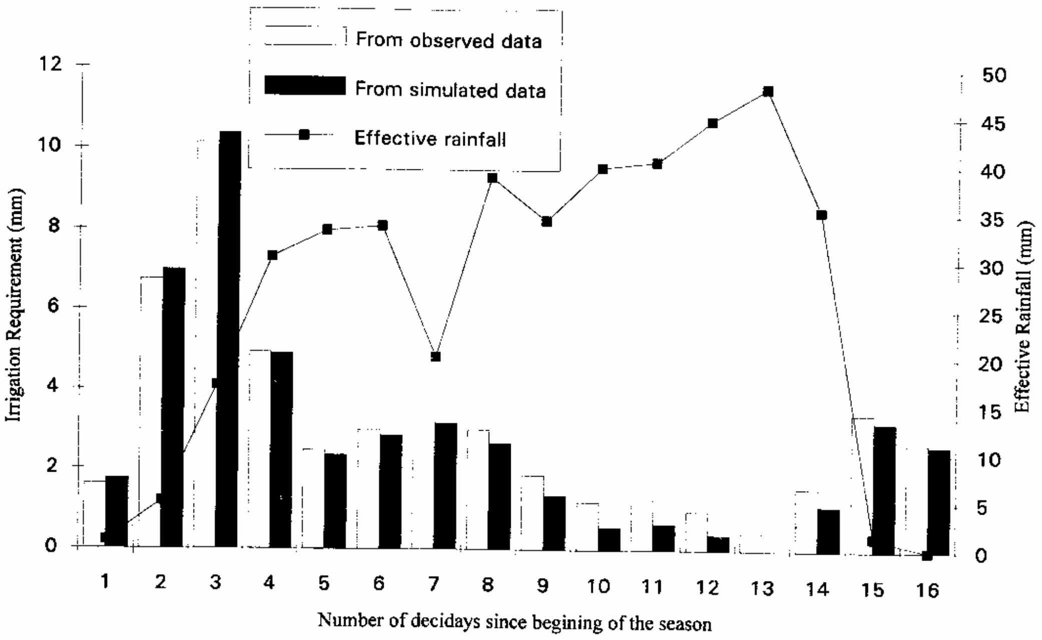


Fig. 24 Irrigation requirement computed from actual and simulated data (July crop) for the year 1993

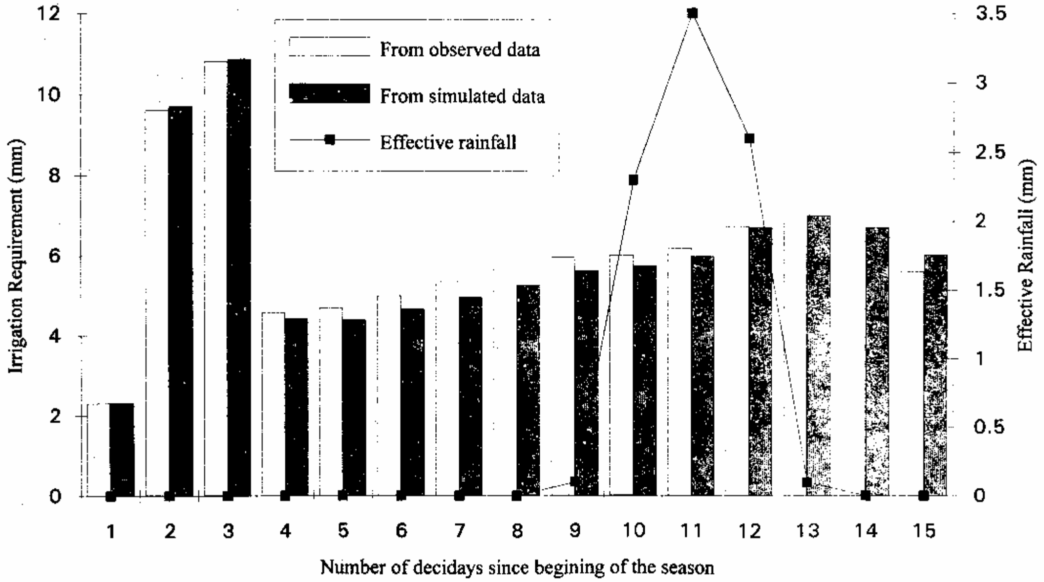


Fig. 25 Irrigation requirement computed from actual and simulated data (December crop) for the year 1993

range of 400 to 600 mm, which is the range specified for paddy by researchers (Handbook of Agriculture, ICAR). Since the study area is relatively hot, the evaporation requirement for the paddy field is high and hence the irrigation requirement are on the higher side of the range. Table 5(c) and Table 5(d) depicts the crop water requirement for paddy computed from both the data sets for the years 1990 to 1993. From the table it is obvious that the simulated data sets are performing to satisfactory level. Further, it can be observed from the Tables 5(a) to 5(d), that while computing irrigation requirement effective rainfall has been taken into account and hence resulting supplemental irrigation only which will be less than actually being applied.

After analysing the results it can be concluded that the predicted evaporation from the ANN model can very well be used in preparing irrigation schedule for the season. This is important in the case of areas where data availability on climatic parameters are limited. In such areas a trained ANN network can be used to predict evaporation from minimum climatic parameters which are easily available and the resulted evaporation can be used for planning irrigation programs.

Chapter 7

Summary and Conclusions

An artificial neural network (ANN) model has been developed for simulating the evaporation in the eastern godavari delta of Andhra Pradesh. The results of the model was found to be satisfactory (correlation coefficient = 0.9). The technique was employed so as to help the irrigation mangers to plan the irrigation schedules when the climatic data are not available. The results from this model has been given as input the CROPWAT (developed by FAO, Italy) to develop the irrigation schedules for the season.

The schedules for the irrigation has been developed by using the actual climatic data so as to compare the results with simulated data set. The schedules computed from actual and simulated data set were compared and is found to perform satisfactory.

The specific conclusions arrived at from the study are briefed as follows.

- An ANN model can very well predict the evaporation from a field.
- In areas where climatic data availability is limited, the ANN model can be used to simulate the data requirements for developing irrigation schedule.

CROPWAT develops the irrigation schedule for any crop management practice and cropping pattern in scientific manner thus saving water.

References

Blaney, H. F. and Criddle, W. D. 1950. *Determining Water Requiremens in Irrigated Areas from Climatological and Irrigation Data.* USDA Soil Conservation Service, Technical Paper 96.

David Seckler. 1997. New era of water management and information technique. *Information technique for irrigation systems,* 3(1):1-3.

Doorenbos, J. and Pruitt, W. O. 1977. *Crop water requirements.* FAO Irrigation and Drainage Paper No. 24, FAO, Rome, Itali.

Eagleson, P. S. 1978. Climate, Soil and vegetation : 3. A Simplified Model for Soil moisture movement in the liquid phase. *Water Resources Research,* 14(5) : 722-730.

Gandhi, P. R. 1981. *History and Practices of irrigation Waters in Maharashtra.* Publication No. 1, Water and Land Management Institute, Aurangabad, Maharastra, India.

Hargreaves, G. H. and Samani, Z. 1985. Reference Crop Evapotranspiration from Temperatutre. *Applied Engineering in Agriculture,* ASAE, 1(2):96-99.

Hoshin, V. G., Kuo-lin Hsu, and Soroosh, S. 1997. Superior Training of Artificial Neural Networks using Weight Space Partitioning. *Proceedigns of the ASCE Water Resources Planning land Management Division Confeence,* April 7-10, Huston, Texas, USA.

Jishu, H., Anders, K., and Richard, G. P. 1993. *Introduction to the theory of neural computation.* Addison-Wesley Publishing Company, New York.

Judith, E. D. 1990. *Neural Network Architectures.* Van Nostard Reinhold, New York.

Kuo-lin Hsu, Hoshin, V. G., and Soroosh, S. 1997. Application of Reccurrant Neural Networks to rainfall Runoff Modelling. *Proceedigns of the ASCE Water Resources Planning and Management Division Confeence,* April 7-10, Huston, Texas, USA.

Martin, S. 1992. *CROPWAT: A Computer Program for Irrigation Planning and Management.* FAO Irrigation and Drainagae Paper No. 46, FAO, Rome, Itali.

Michael, A. M. 1978. *Irrigation Theory and practice.* Vikas Publishing House Private Limited., New Delhi, 801pp.

Penman, H. L. 1948. Natural Evaporation from Open Water, bare soil and Grass. *Proceedings of Royal Society of London (Series A),* 193: 120-145.

Thornthwaite, C. W. 1948. An Approach Towards a Rational Classification of Climate. *Geographic Review,* 38 : 55-94.

WALMI. 1992. *Crop Water Requirements.* publication No. 30, Water and Land Management Institute, Aurangabad, Maharashtra, India.

DIRECTOR : Dr. S. M. Seth

Co-ordinator : Dr. K. S. Ramasastri

Head : Mr. S. V. N. Rao

STUDY GROUP

K. P. SUDHEER, Scientist 'B'
T. Thomas, Senior Research Assistant
S. M. Saheb, Senior Research Assistant
D. Mohana Rangan, Technician Gr. III