CHAPTER II

REVIEW OF LITERATURE

2.1 Introduction

A review of studies related to the subject of research is of immense use for designing concepts, objectives, hypothesis, identifying the tools of analysis and confirming the model. It also sheds light on the various dimensions of the problem studied and enables the determination of simulated data from the source data. It comprises of literature sought to identify the topic and the method chosen to precipitate the model from the data. The presentation of all the materials right from the basics of the topic till the conclusion of the related studies is listed in this chapter.

2.2 Atmospheric Boundary Layer (ABL)

Molders and Raabe (1997) analyzed the results of 24-h simulations with and without a two way coupling of the models substantiate that even on a short time scale surface run off and lateral water flows affect soil wetness, soil temperature, cloudiness and the thermal regime of the Atmospheric boundary layer within the catchments.

Sen Gupta and Radhika (1998) suggested that the region close to the earth is a part of Atmospheric boundary layer (ABL) in which we live and interface that moderates biosphere- atmosphere exchange process.

Edward et.al. (2001) analysed the result that, ABL processes are of importance in both environmental quality and regional to global atmospheric chemistry as vegetation emits a wide variety of reactive gases into the ABL.
2.3 Soil-air interface

Land surface processes strongly influence the dynamics of the atmosphere over a wide range of space and time scales through exchange of momentum, moisture and energy. Soil surface temperature and moisture are parameters of the energy balance between the land and atmosphere. Reliable modelling of surface temperature and soil moisture is crucial to simulate land surface interactions (Yuei-An Liou and England, 1996).

Giorgi (1997) discussed a series of sensitivity experiments aimed at testing the surface heterogeneity representation. The temperature heterogeneity representation mostly affects the process of snow formation and therefore during winter and spring, energy and water are heterogeneous however, for land surface atmospheric modelling purpose, it is considered homogeneous.

Land-surface interaction is greatly improved by the re analysis of the previous model studied by Betts et.al. (1998). Land-surface heterogeneity affects surface energy (Song et.al., 1997). An analytic approach is presented to study the effects of spatial heterogeneity of land-surface parameters in climate models (Zhenglin Hu and Islam, 1998). Land atmosphere interactions are examined for three different synoptic situations during a 21 day period in the course of the first ISLSCP (International Satellite Land Surface Climatology Project). The objective is to understand the relationship between biophysical feedback processes (Wai and Smith, 1998). Land-surface parameters such as soil wetness, roughness length, leaf area index that are mainly playing a role in land surface interactive models are studied by Rodriguez-Camino and Avissar (1998).
An air-soil layer coupled scheme is used to compute surface fluxes of sensible heat and latent heat developed by Xu et.al. (1999). Bao et.al. (2002) pointed that the surface sensible and latent heat fluxes under a few roughness length schemes have been developed to fit observations under conditions of maximum surface wind speed.

2.4 Soil moisture

The most important characteristic of the soil is the soil moisture which regulates the strength of the heat flux between atmosphere and ground. The presence of adding water to soil and at the point of contact between particles not only improves thermal contacts but also replaces the air in the soil space with water. According to Baver et.al. (1972), the greatest rate of increase in conductivity occurs at low moisture content. A linear relation between heat capacity and soil water was found and verified it experimentally on Jobner sand and Udaipur clay was derived theoretically by Yadav and Saxena (1973).

Tripathi and Ghildyal (1974) observed that heat capacities of the soil increased linearly with moisture upto 85% of saturation. The air content of soil is important since air is a poor conductor and has a low heat capacity. Thus, the surface layer of a dry soil is warmer during the day and cooler during the night than that of wet soil of the same type. Also the ground that is covered by vegetation is protected from direct solar rays and therefore has a low daily range of temperature.

Hunt (1985) linked soil hydrology to climate modelling and promoted the inclusion of soil hydrology in the numerical model of climate. The prediction of the
onset of monsoon through the interaction of boundary layer with soil moisture was studied by Kandal Goanker and Manohar (1993).

Soil temperatures are not only influenced by air temperature but also by the presence or absence of an insulating layer of snow on the surface (Sturm et al., 1997).

Samui et al. (2002) in a comparative study of radiation and balance components on soyabean crop and bare soil found that net and reflected radiation and albedo over canopy were higher by 7, 26 and 25% respectively than bare soil. The net short wave radiation and net long wave radiation evaluation over the canopy were less than those over bare soil by 5 and 20% respectively.

### 2.5 Soil temperature

Chowdhury et al. (1991) has analysed that the thermal wave penetrates the sub soil layers consequent to the surface solar heating and the amplitude of the wave decreases.

Krishnan and Kushwaha (1972) and Liakatas (1994) have predicted accurate estimation of soil temperature using harmonic analysis.

Campbell (1977), Parton (1984) and Noble & Geller (1987) point out that the theory based models at small scales may not be practical for the estimation of soil temperature at continental and global scales. Many analyses show that the soil temperatures are based on the theories of heat flow and energy balance.

Retnakumari et al. (1995) have studied that the intense solar radiations is observed by the soil during daytime and it warms the ground surface more than the
layers beneath, resulting in a temperature gradient between the surface and the sub-soil on one hand, surface and air layers on the ground on the other hand. This causes heat to flow downward within the soil as thermal wave.

Li et.al. (1999) calculated the soil heat exchange and developed an integral method to calculate the heat flux at different layers by using soil temperature profile data. Heat flux estimates are based on the phase delay of soil temperature with increasing depth or the decay of its amplitude with increasing depth.

Abraham Thambi Raja et.al. (2001) observed that the temperature at the bottom of the sub-soil stratum is maximum and hence declining temperature thereafter at the depth reverses the direction of flow of heat upwards across the stratum and this is due to the diurnal variation of the soil temperature along the soil depth.

Manjusha and Shekh (2001) reported that during warm season, soil temperature decreases with depth and the associated heat flux builds up the soil’s heat store and during the cold season gradient is reversed and the heat store is gradually depleted. The soil temperature gradient reverses the sign at the transitional periods spring and autumn.

Borken et.al. (2003), Christopher Harper et.al. (2005) and Sponseller (2007) found that the soil temperature and moisture sensitivities of soil CO₂ efflux were strongly confounded by the change in soil temperature and moisture. The temperature and moisture are most crucial because both can account for global warming.
Sascha Reth et al. (2005) measured by a model that allows estimation of soil CO$_2$ efflux on bare soils, meadow soils as well as forest soils. The study confirmed that the soil temperature and soil water content as the most important factors influencing soil CO$_2$ emission. In addition, soil pH and relative root mass are found as important factors to describe spatial variation of soil CO$_2$ emission due to vegetation productivity and microbial activity spans.

Silva (2007) established that soil temperature was a fenologic parameter that is significantly influenced by climate variations and is an indicator of plants hydrous state and therefore its estimation has a large utility to survey that need to assure the observation of hydrous culture demand, contributing in a significant way to irrigation programs.

Jackson et al. (2008) reported that soil temperature is an important parameter in different areas of research such as hydrology, soil science, geo-technology, ecology, meteorology, agronomy and environmental studies.

Chako Tessy and Renuka (2008) reported that soil temperature varies among different soil types due to the soil texture and at a given location through the solar energy that received in the earth’s surface. The surface of earth gets heated up during the day and gets cooled during night causing significant diurnal changes in the top layers of the soil and the heat flows downwards as a thermal wave in the soil.

Pious and Abraham Thambi Raja (2009) have pointed out that diurnal and annual variation of soil temperature influences local climate and the behaviour of annual variation of soil temperature which is the cumulative effect of seasonal variation of soil temperatures. Loss or gain of heat either in cold or hot weather is
totally location based and the velocity of seasonal variation of soil temperature during
cold weather is lower than hot weather in the presence of soil moisture.

Samara Salamene et.al. (2010) investigated by the atmospheric physical factors (air temperature, precipitation, solar radiation, air moisture and wind) contribute to soil temperature in Keller Peninsula, King George Island, Antarctica. The air temperature was the factor that mostly influences the soil temperature. The air humidity and wind affects respectively the first 5 to 20 cm of soil. These results demonstrated the importance of monitoring the soil temperature as an indicator of climate change.

Hongxing Zhang et.al. (2011) studied that the soil temperature and moisture sensitivities of soil CO$_2$ before and after tillage and revealed that soil was the largest carbon pool in terrestrial ecosystems and the release of CO$_2$ from crop land soils to the atmosphere plays an important role in global carbon cycling. The relatively higher soil temperature and moisture accompanied by enhanced temperature and moisture sensitivities would release more CO$_2$ from soils after the tillage, intensify the global warming.

**2.6 Air temperature**

Ronald and Jill (1978) conducted a study on atmospheric temperature and precipitation and found that over most areas, summer temperature and precipitation were negatively correlated.

Anders Lindroth et.al. (1998) presented two years net ecosystem flux measurements above a boreal forest in central Sweden. Fluxes were measured with an
eddy correlation system based on a sonic anemometer and a closed path CO$_2$ and H$_2$O gas analyser. The measurements show that the forest acted as a source during this period, and that the annual balance is highly sensitive to changes in temperature. Although annual mean temperature remained close to normal, the results by higher than normal respiration, due to abnormal temperature distribution and reduced soil moisture during one growing season.

Sergio Caltagirone (2001) measured by evolutionary neural networks have been applied successfully in the past to many prediction problems. This attempts to describe an evolutionary neural network, to predict the maximum air temperature during the day and month of the year.

Devendra Singh (2010) estimated the surface vapour pressure deficits using satellite derived land surface temperature data and pointed out that the vapour pressure deficit which was the difference between saturated vapour pressure at air temperature and actual vapour pressure which indicates the climatic variables used in ecosystem models to simulate fluxes.

2.7 Soil-air temperature

Marshall and Holmes (1979) have studied the tendency towards extreme temperatures in the soil surface which leads to some top consequences in the lowest layers of atmosphere in the bio-zone and extremely high soil temperatures have a harmful effect on roots and cause destructive lesion on the stems of plants.

Dwyer et al. (1990) have predicted the soil temperature from air temperature and pointed out that the predicted soil temperature can be used in the calculation of
thermal units and identified the significant changes in the response of emergence rates to temperature and could be useful in the selection and modification of crop and soil management.

Pathak et al. (1993) revealed the basic link between energy budget of the land-surface and hydrological cycle as the moisture content of the soil and also during the heat exchange between earth’s surface and the atmosphere, the surface temperature plays a natural and crucial role.

Daolan Zheng et al. (1993) studied the daily soil temperature based on air temperature and shows that annual soil respiration can be estimated from the predicted soil temperature with reasonable accuracy and daily soil temperature may be predicted from daily air temperature. Air temperature correlates well with the soil temperature because both are determined by the energy balance at the ground surface.

Paul Schwarz et al. (1997) analysed the seasonal air and soil temperature effects on photosynthesis and found out that soil temperature tracked changes in air temperature but the day to day fluctuation in the soil temperature measured within the rooting zone (at a depth of 0.1 m) was less than the fluctuation at the soil surface (at a depth of 0.01 m). Although, warmer air and soil may delay the onset of winter that hardens and hastens spring time recovery.

Best (1998) designed a model to predict the surface temperature of a variety of surfaces and the model solved the surface energy balance equation using meteorological data. The simulations by atmospheric general circulation models showed similar results for surface temperature and total net radiation when compared with observations.
Abraham Thambi Raja and Renuka (2002) studied the effect of sub surface heat in microclimate at Thiruvananthapuram and reported that the microclimate of the atmosphere was influenced by the diurnal variations of the heat at the earth’s surface and beneath. The result of this study reveals that the thermal waves were the first step to interpret such changes in terms of local climatic change.

Oliver and Isaac (2002) have found that the thermodynamic action of the latent transport depends primarily on the total latent heat transport and on the difference between the surface temperature and the effective temperatures of latent heat release.

Fahim Ahmad *et.al.* (2008) have predicted soil temperature by air temperature and illustrated that soil temperature plays an important role in the decomposition of the soil. The soil-air temperature predictions indicated by the global and regional circulation on climate models can be used to check the validity of models to describe the surface and atmospheric energy interaction.

The response of soil temperature to the changes in air temperature strongly depends on the temporal distribution, depth and density of the snowpack during the winter (Lawrence and Slater, 2010).

Sousa Neto *et.al.* (2011) have studied the soil atmosphere and exchange of CO$_2$ in tropical forests which are important to the global budgets of green house gases. In addition, climate change associated with increasing temperature may result in increased microbial activity with a consequent increases in soil CO$_2$ emissions.
2.8 Rainfall

Hasting (1965) suggested that the coefficient of variation giving real degree of meaning in terms of precipitation probabilities of seasonal precipitation in arid and semi-arid regions of Baja California, U.S.A.

Raman (1974) has adopted the inter-spell duration to evaluate agricultural drought over Maharashtra.

Sikka and Gadgil (1980) have shown that cloudiness over an extensive zone in the Asian summer monsoon domain shows a periodic oscillation in the time scale of 30-50 days. It has been claimed that this mode is capable of explaining the major active-break cycle in monsoon rainfall.

Ramana Murthy et.al. (1987) studied about a detailed hydro meteorological study of the catchment upto the Karanja dam site has been made to design storm depths of different return periods and the probable maximum rainfall likely to be experienced by the catchment using rainfall data of the period 1891-1984. It has been found that the catchment experienced minimum rainfall of 193, 258 and 312 mm during the last 94 years of record.

Sivaramakrishnan (1987) studied the statistical aspects of rain spells for Mohanbari considering four years data. Weeks and Boughton (1987) reviewed applications of time series models to hydrology and showed that a number of well known hydrologic model are special cases of the ARIMA models.

Rupakumar et.al. (1992) furthered the analysis of long term rainfall data over different locations of India and concluded that the monsoon rainfall is trendless.
Sharon Nicholson (1993) analysed five sub-Saharan regions of Africa that experienced one of the intense drought throughout West Africa and moderately dry conditions in most of Southern Africa and the continent except for the equatorial latitudes.

Jeffery (1995) has developed Acoustical Rainfall Analysis Algorithm (ARA) and tested it for several dozen rainfall events and found to provide excellent estimates of rainfall rate, rainfall accumulation, and rainfall reflectivity. High temporal resolutions in drop size distribution within the rain can be studied using ARA.

Roy Abraham et.al. (1996) have observed the simulations of monsoon circulations and cyclone with different type of orography. The study aimed to know and gain insight into analysis of variability and mean monthly rainfall amounts during the period.

Sontakke and Singh (1996) presented a time series of rainfall dividing India in six homogeneous zones but within the zones there are number of incoherent catchment of high variability of rainfall due to regional and local complexities; viz., geography, topography and diverse atmospheric processes.

Kripalani and Kulkarni (1997) found that there was no one-to-one correspondence between monsoon rainfall and El Nino because peak of El Nino/La Nina phases do not coincide with monsoonal peak.

Bhatti et.al. (2000) have been exhibiting scale invariance behaviour over a range of space and time scale. Although various approaches have been taken to
investigate and model the various scaling aspects of rainfall and floods, theoretical work has been done on the relation between the scaling of rainfall and flood.

Siva Kumar (2001) studied the behaviour of rainfall dynamics at different temporal scales identified the type of approach most suitable for transformation of rainfall data from one scale to another. The correlation dimension method is employed to identify the behaviour of rainfall dynamics. A possible implication of this might be that rainfall processes at these scales are related through a chaotic (scale-invariant) behaviour. However, a comparison of the correlation dimension and coefficient of variation of each of the time series reveals an inverse relationship between the two.

Franks (2002) showed that in the case of the Australian climate, previous studies on the climate conditions of the Indian and pacific oceans has indicated marked multi-decadal variability in both mean sea surface temperatures and typical circulations patterns. In this light, data from 40 stream gauges around New South Wales were examined to determine whether flood frequently data were indeed independent and distributed identically, gives a correlation in flood records between gauges.

Mehfoozali et.al. (2005) studied the onset, withdrawal dates and rainfall of southwest monsoon corresponding to east and west Rajasthan sub-divisions examined statistically for the past 63 years (1941-2003) to bring out some major aspects of their variability and trend to predict these parameters of southwest monsoon over Rajasthan. Various correlation coefficients have been worked out. Study reveals shift
in monsoon activity, enhancement of monsoon duration, early onset and late withdrawal and seasonal rainfall over Rajasthan.

The study conducted by Agashe and Padgalwar (2005) on some characteristic features of daily rainfall over Madhya Maharashtra deals with some of the characteristic features of daily rainfall at nine selected stations in Madhya Maharashtra. The study is based on daily rainfall data of June to September months for 10 years (1991-2000).

Guhathakurta and Rajeevan (2006) analysed the monthly, seasonal and annual rainfall time series. Trend analysis was carried out to examine the long term trends in rainfall over different divisions. It has been found that the contribution of June, July and September rainfall to annual rainfall is decreasing and contribution of August rainfall is increasing in few subdivisions.

Kalsi et al. (2006) studied that the features of monsoon such as onset, progress, stagnation, different synoptic and semi-permanent features and characteristics of rainfall of southwest monsoon in 2002 over India have been discussed. A comparison of these features with those in the earlier drought years has been made. Results show that many abnormal and unique features during 2002 have resulted in a drought all over India.

Bhargava et al. (2010) has been analysed for the probability and variability to evolve rainfall based cropping system. The mean rainfall, standard deviation and coefficient of variation for annual and seasonal rainfall can be computed. The study
revealed that July month is regarded suitable for transplanting of rice crop in Roorke region.

Mohita Anand Sharma and Jai Bhagwan Singh (2010) studied the use of Probability Distribution in Rainfall Analysis. The daily rainfall data of 37 years were collected from the IMD approved Meteorological Observatory situated at GB Pant University of Agriculture and Technology, Pantnagar, India. The data were then processed to identify the maximum rainfall received on any one day (24hrs duration), in any week (7 days), in a month (4 weeks), in a monsoon season (4months) and in a year (365 days period).

Metri and Khushvir Singh (2010) studied that rainfall features over Goa state during South west monsoon season. The rainfall features at different rain gauge stations of Goa state have been studied for the period of 30 years. The statistical parameters such as mean monthly rainfall, standard deviation and coefficient of variation have been computed for each rain gauge station of Goa. Studies revealed that most of heavy rainfall events caused due to active off-shore trough and low pressure systems formed over southeast Arabian Sea. It has also came out from the study that the orography of Goa plays an important role in rainfall distribution. Valpoi receives maximum rainfall due to its orographic effect.

Vivekanandan (2011) studied by involving the use of Artificial Neural Network (ANN) and Regression (REG) approaches for prediction of runoff for Betwa and Chambal regions. Model performance indicators such as model efficiency, correlation coefficient, root mean square error and root mean absolute error are used to evaluate the performance of ANN and REG for runoff prediction. Statistical
parameters are employed to find the accuracy in prediction by ANN and REG for the data under study. The study presents that ANN approach is found to be suitable for prediction of runoff for Betwa and Chambal regions.

Dash *et.al.* (2011) studied that changes in the long and short spells of different rain intensities are statistically analysed using daily gridded rainfall data prepared by the IMD for the period 1951–2008. In order to study regional changes, analyses have been conducted over nine selected agro-meteorological (agro-met) divisions, five homogeneous zones, and also over the whole of India. Rain events of different intensities with continuous rainfall of more than or equal to 4 days are classified here as long spells. Results further show that the contributions of long spell moderate and short spell low-intensity rain events to the total rainfall have decreased whereas the contributions of short spell heavy and moderate-intensity rain events to the total seasonal rainfall have increased.

Geetha and Selvaraj Samuel (2011) performed by the new approach using an Artificial Neural Network technique to improve rainfall forecast performance. A real world case study was observed in Chennai for 32 years of monthly mean data with meteorological parameters such as wind speed, mean temperature, relative humidity, aerosol values (RSPM) in the area were used to develop the ANN model. In order to forecast rainfall, Back Propagation Neural Networks (BPNNs), a data driven technique based on the working principle of biological neurons are applied in this study. The model can perform well both in training and independent periods.

Suman Jangra and Mohan Singh (2011) studied that Kulluvalley is famous for tourism and agricultural activities but recently it has assumed importance for studies
on climatic variability. There is an increasing trend in minimum and maximum temperatures but no trend in annual rainfall. The maximum temperature was more during summer month and the minimum temperature during winter month.

Sharad Jain and Vijay Kumar (2012) analysed the rainfall and temperature data over India. In the basin-wise trend analysis, most of the basins showed the same directions of trend in rainfall and rainy days at the annual and seasonal scale. The study revealed that the mean maximum temperature series occurs on a rising trend at most of the stations.

Arti Naik and Pathan (2012) presented by the application of artificial neural networks in weather classification and prediction, some existing weather forecasting models have limitations and also benefits of neural network are discussed in this study. Since there is non-linearity in weather data, the study focuses on potential method of weather prediction using artificial neural networks and training this network by back propagation algorithm.

Sandip Nemade et.al. (2012) developed by the Artificial Neural Network (ANN) models to predict rainfall and rainfall rate in the one of the major city of India i.e., Indore. Also compared the actual rainfall in 2012 and predicted model of rainfall on the basis of last five years (2007-2011). A new method is presented for calculating daily rainfall amounts from ground based radar. The results of estimation show that the neural network can be successfully applied and this method is in good compromise between competing demands of accuracy and generalization.

Stephen (2012) analysed the natural disaster in India. The mean annual precipitation totals have remained steady due to the declining frequency of weather
system that generates moderate amounts of rain. This review elucidates the natural disaster of Tamil Nadu and its possible cause as well as the preventive measures.

Stella Maragatham (2012) has studied by comparing the different time series analysis to compare the actual performance and the cause of variation of rainfall series. The series may be increasing or decreasing at various rate. The secular changes in the annual rainfall of 1476 rain gauge stations to detect the best suitable trend for the rainfall time series.

Naik and Pathan (2013) studied about a model for rainfall classification and prediction using an artificial neural network and various tests were performed with the model to test its ability to predict for rainfall as well as to classify it. The study proposes a new modified BP algorithm which is more robust than that of a simple BP algorithm.

Deepak Ranjan Nayak et.al. (2013) developed by a survey of available literature of some methodologies employed by different researchers to utilize ANN for rainfall prediction. The survey also reports that rainfall prediction using ANN technique is more suitable than traditional statistical and numerical methods.

Ganesh Gaikwad and Nikam (2013) studied the different rainfall prediction models like Weather research and forecasting, Seasonal climate forecasting, Global data forecasting and general data mining rainfall prediction model.

Yaakov Aviad et.al. (2013) studied that the Environmental (ecological, geomorphological and hydrological) processes are controlled by rainfall, particularly in the Mediterranean, semi-arid and arid regions. Rainfall was analysed using the concept of rain-spells i.e., a period of successive rain days proceeded and followed by
at least one day without rainfall. Daily data from 13 stations along a climatic transect extending from the Judean Mountains with a Mediterranean climate to the Dead Sea arid region in Israel.

Indrabayu et al. (2013) studied that this study proposed a new approach for rainfall prediction method, which combines the Support Vector Machine (SVM) and Fuzzy Logic methods. The performance of the proposed method is compared to the Neural Network (NN)–Fuzzy. The results confirm that the SVM Fuzzy achieves higher accuracy than NN-Fuzzy.

Priya et al. (2014) conducted a study for prediction of Indian rainfall. The purpose of this study is to evaluate the applicability of ANN. In this study, the performance of different networks have been evaluated and tested. The multilayered ANN with learning by back propagation algorithm is used. It implements weather prediction by building training and testing data sets and finding the number of hidden neurons in these layers for the best performance. The proposed model has been able to predict values with suitable results.

2.9 Rainfall and soil temperature

Retnakumari et al. (1994) reported a realization of 20°C and 0.07°C respectively as maximum and minimum values at the depth of 0.05 m during pre-monsoon 2001 and at the depth of 0.5 m during winter 1994 and on comparing the ranges at all the depths during the years 1994 and 2001, the range of temperatures during 2001 were either two times or more than that during all the seasons. It may happen due to the drying up of the soil equally at the depths, due to more sunshine or due to less rainfall or natural dry up due to global warming.
Joseph et. al. (2001) studied the soil temperature at the various stations of south Kerala. The century mean rainfall over the 20th century was discussed in connection with the annual soil temperature at different depths and on comparing them with north Kerala. It was inferred that the annual thermal wave supported the decreasing trend of century mean of rainfall in south Kerala.

Jeslin Sunitha et. al. (2014) studied the impact of meteorological parameters rainfall and soil temperature influences the environment. Time series analysis is applied to analyse the cause of variation. The results obtained from this study are positive trend occurrence of soil temperature and negative trend occurrence of rainfall, and reveals that the soil temperature is out of proportionate of rainfall. This indicates the warming nature of soil.

2.10 Artificial Neural Network

Said (1992) and Imran et. al. (2002) studied the application of neural networks for the prediction of hourly mean surface temperatures in Saudi Arabia and proved that a multilayer perception with a single hidden layer including a sufficient number of neurons could approximate any function with the desired accuracy.

Neural Ware (1993), Haykin (1994) and Yang et. al. (1996) have pointed out that ANNs have helped to solve many problems and to develop new techniques in many scientific and engineering fields. This model has been used to predict soil moisture and ANN have the capability for the simulation and real-time control of water table management systems under subsurface drainage and sub-irrigation.
Zurada (1992) has reported that with ANNs there exists the capability to extract the relationship between the inputs and outputs of a process, without the physics being explicitly provided.

Shukla et.al. (1996) have found that ANNs require fewer input variables than conceptual models and they can run in a short time when they are trained. This becomes critical when the simulation is for a large scale environment, long term predictions or real-time control to respond to rapid changes in inputs.

Usowicz et.al. (1996) studied the spatial variability of soil thermal properties in cultivated fields by determining mass and energy exchange processes taking place in the soil-plant-atmosphere system and concluded that the spatial variability of soil thermal properties over cultivated fields was mainly due to soil water content and bulk density values which were modified by meteorological conditions.

Yang et.al. (1997) studied the application of ANN for the simulation of soil temperature and described its importance to develop a model capable of assisting agricultural processes when that soil temperature estimation in distinct depth was complex due to its large number of involved variables.

Chun-Chieh Yang et.al. (1997) estimated the soil temperature using ANN for transient simulation of soil temperature at different depths by considering readily available meteorological parameters and investigated that the estimated values were found to be close to the measured values and concluded that ANN models could be used to estimate soil temperature by considering routinely measured meteorological parameters.
The ANN technique has been widely applied to solve many meteorological problems such as predicting tornadoes, damaging winds, thunderstorms, quantitative precipitation, typhoon intensity, long range monsoon precipitation and even precipitation of surface ozone was studied by Marzban and Stumpf (1996) and Guha Thakutra (1999).

Costa and Pasero (2001) have found that ANN system is used to forecast weather variables such as temperature, humidity, wind speed and wind direction along a mountain highway.

Raju George (2001) measured by the neural networks algorithms to predict the soil temperature and consider a single layer neural network having McCulloch-Pitts type neurons and uses the generalised Widrow-Hoff algorithm to train the network. The fixed point theorem was used to prove the convergence. Also considering multi-layer neural networks for the prediction where back-propagation algorithm with momentum for training the networks is used.

Muller and Fill (2003) have illustrated how ANNs are organised and interconnected the processing units whose operation is an analogue to a neural structure of intelligence organisms.

Li and Wei (2004) have found that ANNs are one of the artificial intelligence methods and they have been developed as generalizations of mathematical models of biological nervous systems and the processing of ANNs are branch marked form natural neurons and organized as the same to make a learning process.
Imran Maqsood et.al. (2004) presented that the applicability of an ensemble of neural networks for weather forecasting and proposed that ensemble method for weather forecasting had advantage over other techniques and in comparison, the ensemble of neural networks produced the most accurate forecasts.

Weiyu Yi (2005) proved that ANNs provided a general practical method for real-valued, discrete valued and vector valued functions and used gradient descent to tune network parameters to best fit a training set of input-output pairs.

Mohsen Hayati and Zahra Mohebi (2007) investigated by Multi Layer Perceptron (MLP) was trained and tested using ten years (1996-2006) meteorological data. The results show that MLP network has the minimum forecasting error and can be considered as a good method to model the STTF systems.

Soo-See Chai et. al. (2008) carried out the back propagation neural network for soil moisture and observed that the back propagation artificial neural network was a well-known and widely applied mathematical model for remote sensing applications for pattern recognition, approximation and mapping of non-linear functions and time-series predictions.

Roy Bhowmik et.al. (2009) have shown that efforts are made by researches to develop statistical technique of multiple linear regression analysis for predicting maximum and minimum temperature of a situation using other meteorological parameters as predictors.

Chadin Chuachin da kate (2009) has applied ANN to predict the hourly suspended sediment concentration by relating rainfall, temperature, water discharge
and demonstrated that ANN is capable of modeling the hourly suspended sediment concentration with good accuracy with proper input variables.

Jaswal and Prakasa Roa (2010) have studied the recent trends in meteorological parameters and expressed that the global average surface temperature has increased by about 0.6°C and this increase has not been uniformly distributed over time and temperature. Differential changes in daily maximum and minimum temperature results in narrowing of the diurnal temperature range all over the globe.

Bilgili and Mehmet (2010) studied that the monthly soil temperature was modeled by linear regression (LR), nonlinear regression (NLR) and artificial neural network (ANN) methods. The soil temperature was measured at depths of 0.05, 0.1, 0.2, 0.5 and 1 m below the ground level. A three layer feed-forward ANN structure was constructed and a back propagation algorithm was used for the training of ANNs. The independent variables were LR and NLR models. The ANN method was found to provide better performance than the LR and NLR methods.

Veronez and Wittmann et.al. (2010) estimated surface temperature using ANN and observed that it was an alternative method to the extrapolation of land surface temperature using positional variables such as temperature and air relative humidity. The average error provided by this model for surface temperature measurement was 2.2°C and through executed statistical tests it was possible to verify that non existing variation between average surface temperature values accepted as true and the values obtained by the neural model with a significance level of 5%.
Manjusha Kulshrestha *et al.* (2010) have predicted the soil temperature at three depths namely 0.05, 0.1 and 0.2 m for morning and afternoon hours by using ANNs algorithm and harmonic analysis techniques and they have found out all the predictions by ANN were significant to actual soil temperature.

Ogolo (2010) evaluated the performance of global solar radiation across varying climatic conditions and pointed out that solar radiation was the ultimate control of weather and climate. The sun through the emission of solar radiation provides about 99.97% of the heat energy required for physical processes.

ANN and multivariate linear regression methods for the estimation of daily soil temperature in an arid region were studied by Hossien Tabari *et al.* (2011) and revealed that ANN could be a useful tool in the estimation of daily soil temperature.

Shahlla *et al.* (2011) measured by the ANNs are interconnected collections of processing units which have been used in different applications. The objective of this study is to develop an ANN model to estimate soil temperature for any day by using various previous day meteorological variables. For this purpose, average temperature of air, sunshine, radiation and soil temperature for meteorological data between the years of 1980 and 1984 at Nineveh/Iraq Meteorological Station were used. The soil temperature at different depths of 0.05, 0.1, 0.2, 0.5 and 1m within the time 9, 12 and 15 respectively are measured. Results showed that the Nonlinear Autoregressive ANN approach is the best model for forecasting the soil temperature of the day.

Jeslin Sunitha Bai *et al.* (2012) studied about the weekly soil temperature. Data were collected from the experimental site for a period of eleven successive years (1993-2007) and these data were fed separately as input to ANN and soil temperature
for the year 2007 was predicted in each case. The predicted result is accurate for the annual wave of soil temperature.

Jebamalar et.al. (2012) studied that the back propagation algorithm, an ANN training algorithm is a widely applied mathematical implementation for spatial monitoring tool and is used for the analysis and prediction of soil temperature. The predicted values were compared with observed values and statistically validated. The characteristics of predicted annual and seasonal wave were also compared with observed values.

Alexis Kemajou et.al. (2012) studied the application of ANN for predicting the indoor air temperature in modern buildings in humid region and found that ANN could be a valuable tool for air temperature prediction and the ANN models were strongly correlated with the experimental data. The results testified that ANN model could be a valuable tool for air temperature prediction.

Parag Kadu et.al. (2012) developed neural-networks based ensemble models and applied for hourly temperature forecasting. The experimental results show that the ensemble networks can be trained effectively without excessively compromising the performance.

2.11 Thermal parameters and wave characteristics

The flux of heat into and out of the soil is a significant component of the surface energy budget, which should enter into calculations of evaporation using methods such as that of Penman (1948), particularly in temperate climates where there is seasonal storage of heat in the soil profile (Edwards and Rodda, 1972).
Van Wijk and De Vries (1963) have suggested that damping depth is a depth at which the amplitude of the sinusoidal temperature wave is equal to the reciprocal of the base of natural logarithms, e times the amplitude of the corresponding wave at the soil surface, increases with increasing mineral particle size, with increasing moisture content and with decreasing matter content.

Sugawa and Akira (1966) have determined thermal diffusivity of soil using amplitude and time lag methods. The methods have some assumptions which did not agree with actual state of soil. Then a new method was introduced to avoid the unsuitable assumptions in the amplitude and time lag methods. The result derived from the method was compared with the value obtained from the amplitude and time lag methods and it was found that the values from the amplitude and time lag methods were very different from the value by the new method.

Stearns Charles (1969) analysed by the diurnal variation of heat budget constituents and related measurements in an absolutely dry climate and thus to increase the available surface heat budget data in a meteorologically neglected by interesting area.

Bhumralkar (1975) carried out numerical experiments on the computation of ground temperature in an atmospheric general circulation model which revealed that soil heat flux exponentially decayed with increasing soil depth. Due to solar heating the top-soil usually experienced dramatic diurnal changes in soil temperature and heat flux.
Singh and Sinha (1977) suggested that a near accurate approximation of boundary condition was essential for a reliable variation of thermal diffusivity using heat conduction equation.

Soil with high diffusivity allows penetration of surface temperature changes. By the day, the surface heating is used to warm a thick layer of soil and at night the surface cooling can be partially offset by heat from a similar thick stratum. Soil with poor diffusivity consequently experiences relatively extreme diurnal temperature fluctuations. Therefore, a wet day is conservative, whereas an almost dry peat is its thermal climate (Oke, 1978) and suggested that the extinction coefficient is computed from the thermal diffusivity of the soil at different depths.

Kevin Gilman (1980) has estimated the soil temperature in an upland drainage basin and found that the surface soil heat flux is a small but possibly significant component of the energy budget. The actual measurement of surface flux is difficult and requires more instrumental sophistication.

Hortan et.al. (1983) estimated soil thermal conductivity, thermal diffusivity and heat flux in the near surface layer from soil temperature. They compared several methods and concluded that numerical and harmonic methods had a better model.

Ridder (1986) has suggested that the extinction coefficient is a soil characteristic and can either be derived from experimental data or from a detailed model of soil evaporation.

Massman et.al. (1990) discussed an error which can arise when measuring soil heat flux by the combination approach and outlined a method to correct it. Also, they
verified the eddy correlation measurements using the study of the energy balance components.

Maximum temperatures within 0.01 m of the soil are attained in the afternoon and at deeper layers it is at midnight (Chowdhaury et.al. 1991). Retnakumari et.al. (1994) have found that the range in soil temperature and soil heat flux computed show higher values during winter than that during north east monsoon period. Heating and cooling of the soil is attained by the daily cycle of solar heating.

Steven Evett (1994) has pointed out that soil thermal properties are important inputs for models of soil heat and water flux which are very difficult to calculate due to complex effects of soil particle size, shape and packing on thermal diffusivity and conductivity. Harmonic analysis of diurnal soil surface and subsurface temperatures has been used to find the apparent soil thermal diffusivity in the field.

Fan and Tang (1994) and Gao et.al. (2003) undertook a study on conductive and convective soil heat flux and presented new ideas to take both conduction and convention processes into the calculation of soil heat flux. This shows that vertically homogeneous soil possessed constant thermal conductivity or diffusivity and assumed that the soil temperature in each layer followed a sine-curve diurnal variation and then derived soil temperature in each layer followed a sine-curve diurnal variation and then derived soil parameters with temperature phase and amplitude observations.

Kenneth and Williams (1994) suggested that the temperature in the soil profile was modelled by calculating the damping depth as a function of soil moisture content.
Budyko (1995) has formulated a complete heat budget for the earth-atmosphere interface, thereby establishing the magnitude of the sensible heat flux from the earth to the atmosphere.

Banta and Gannon (1995) has found that the soil thermal conductivity is greater in moist soil and the higher thermal conductivity allows warmer soil temperatures to diffuse upward to the soil surface and prevents the surface temperature from becoming as cold in the moisture run as in the dry run.

Narasimha and Vasudevamurthy (1995) found that high thermal conductivity of soil was one of the reasons for the occurrence of Ramdas layer during calm and clear nights and an attempt was taken to find out the thermal conductivity of the soil of the experimental site.

Noborio et.al. (1996) studied the two-dimensional model for heat transport in soil and highlighted that the knowledge of basic soil thermal properties was required to predict the heat transfer in the soil under the conditions of steady and non-steady heat flow.

The temperature rise within the top layers of the soil depends on the soil. Lower is the thermal conductivity of the soil shallower is the depth through which heat penetration occurs. Time lag of the thermal wave which was lagging in maximum temperature of the succeeding level, i.e., 0.05 m depth (Padmanabhamurthy et.al., 1998) was used to work out thermal diffusivity of the soil. The computed values of thermal conductivity from observed data during the occurrence of Ramdas layer for winter 1994 and pre-monsoon 2001 were respectively found as $0.845 \times 10^{-6} \text{m}^2 \text{s}^{-1}$ & $0.59 \times 10^{-6} \text{m}^2 \text{s}^{-1}$ and $2.5 \text{Wm}^{-1} \text{K}^{-1}$ & $1.05 \text{Wm}^{-1} \text{K}^{-1}$. 
Thermal conductivity during winter 1994 is as 2.2 Wm\(^{-1}\)K\(^{-1}\) quoted by Oke (1978) against sandy soil (40% pore space-saturated). It is realized that high thermal conductivity of soil causes occurrence of the Ramdas layer.

Peters-Lidard et al. (1998) using Soil Vegetation Atmosphere Transfer demonstrated the sensitivity of sensible and latent heat fluxes and surface temperatures to the soil thermal conductivity.

Tarnawski and Leong (2000) studied the thermal conductivity of soils at very low moisture content and moderate temperatures revealed that soil thermal conductivity varied insignificantly at very low moisture contents and started to increase from a certain critical volumetric moisture content whose value tended to be dependent on clay mass fraction.

Trabea et al. (2000) measured by the Global solar radiation on a horizontal surface, mean daily maximum temperature, mean daily relative humidity, mean daily sea level pressure, mean daily vapor pressure and hours of bright sunshine. The locations chosen represent the different weather conditions of Egypt. The correlation between the measurements of global solar radiation and the meteorological parameters were given for the locations. The values of correlation coefficients vary from 89% to 99% and the errors of estimation are between 0.01 and 0.04.

Abraham Thambi Raja et al. (2001) studied soil heat flux during the occurrence of Ramdas layer and confirmed that the soil heat flux or subsoil layer had close links with Ramdas layer.
Gordon McIntosh *et.al.* (2001) have studied heat flow and thermal properties of various materials and highlighted that air and soil temperatures generally exhibit a diurnal cycle. Moreover, if the thermal characteristics of the soil are considered constant with depth and time of day and soil temperature is modelled as a sine wave solution to the heat equation, the amplitude of the diurnal soil temperature wave is expected to decrease exponentially with increasing depth in the soil.

Tyson *et.al.* (2001) studied the soil thermal properties and revealed that soil temperature and consequently their thermal properties governed the exchange of energy and mass between the soil and the atmosphere.

Anandakumar *et.al.* (2001) computed soil thermal diffusivity using subsurface temperature at two locations in Kalpakkam. Borgaonkar and Pant (2001) pointed out that the knowledge of climate variability over the period of instrumental records and beyond on different temporal and spatial scales was important to understand the nature of the different climate systems and on their impact on the environment and society.

Jegede (2002) found that the variation of the surface energy balance with the amount of cloudiness appeared most dominant.

Jan Hopmans *et.al.* (2002) estimated the soil thermal properties and reported that soil conductivity, volumetric heat capacity and soil thermal diffusivity have advanced the development of the heat pulse technique for the estimation of soil thermal properties. To characterize soil physical properties, knowledge of the soil thermal properties was required for accurate prediction of soil temperature.
Tessy Chacko and Renuka (2002) have computed thermal diffusivity from combined effects of the first and second harmonics amplitude and phase angles that showed consistency with that calculated from time lag and range methods.

Joseph et.al. (2003) studied that the diurnal behavior of heat flux as a function of net radiation is examined for sparse cover and bare soil conditions, focusing on patterns of diurnal variation as well as on the effects of soil moisture and soil type. The result shows that a relatively simple function can be used to capture the first-order diurnal co variation between heat flux and net radiation.

Heusinkveld et.al. (2004) studied that the role of soil heat flux and the surface energy balance closure in an arid region and observed that soil heat flux can sparse cover and bare soil conditions focusing on patterns of diurnal variations as well as on the effects of soil moisture and soil type. This method provides improvement over other semi empirical treatments for soil heat flux for which diurnal energy balance closure is required.

Kakane (2004) found out the net radiations relations for surfaces reported that the net radiation and the soil heat flux, measured to determine latent heat fluxes and sensible heat fluxes and found out that the soil heat flux at the dry location was less than half the value at the wet location, in spite of warmer surface temperatures.

Diandong Ren and Ming Xue (2004) determined damping depth by the amplitude-phase method. Zhang et.al. (2004) studied the calculation of soil heat conduction and proved that the co-efficient between soil heat flux and net radiation relationships could be spatially dependent and the estimate had errors in the phase of soil heat fluxes.
Barclay Shoemaker et al. (2005) developed a new method to estimate change in stored heat energy that overcomes an important data limitation namely the limited spatial and temporal availability of water temperature measurements. The magnitude of changes in stored heat energy approached the magnitude of net radiation more often during the winter dry season than during the summer wet season.

Marin et al. (2006) have undertaken a study on the thermal wave of the soil and observed that the conduction of heat in soils excited by a natural periodically time dependent source, namely the daily periodical oscillations in the earth’s temperature, which can be denoted as thermal waves. The changes in the temperature depend on the nature of the soil and described a laboratory experiment based on the phenomenon of thermal wave propagation for the measurement of the key parameters governing in soil such as thermal diffusivity.

Yang Kun and Wangjie Min (2008) carried cut a study on a temperature prediction correction method for estimating surface soil heat flux from soil temperature and moisture and developed a new simple method to estimate soil heat flux from soil temperature and moisture observation and the soil heat flux were obtained through integrating the soil temperature profile. Also the heat flux measured with a heat plate could be quite erroneous in magnitude, though its phase was accurate.

Evan Weller et al. (2008) estimated a surface heat budget of the Great Barrier Reef and Coral Sea has been developed for understanding the trends of sea surface temperature and the surface balance.
Pious et.al. (2009) studied the sub surface thermal mapping during contrast seasons over central Kerala and the characteristics such as soil temperature, time lag, range of temperature, soil heat flux and speed of the seasonal variation of annual soil temperature are determined. It is seen that lower annual rainfall at Chinnar WLS influenced temperature range and time lag at different soil depths, and the loss or gain of heat either in cold or hot weather periods were totally location based.

Cheng et.al. (2009) suggested that soil heat flux is one of the important components of surface energy balance. In this study, long term estimation of soil heat flux from single layer soil temperature which was carried out by the traditional sinusoidal analytical method and the half order time derivative method of Wang and Bras. Good agreement was found between soil heat flux measurement and predictions made by the half-order time derivative method.

Xingang Fan (2009) studied the impacts of surface changes to the surface heating condition derived from soil temperature observations on regional weather simulations.

Tomasz Gnatowski (2009) evaluated different methods for the assessment of thermal conductivity of selected organic top soil layer and analysed the thermal diffusivity of soil and concluded that the thermal diffusivity was a very complex soil property. Also revealed that for the determination of thermal diffusivity, the distribution of the soil temperature at two depths was required and the thermal diffusivity value based on thermal conductivity and volumetric heat capacity could also be determined.
Heitman et al. (2010) evaluated the degree to which heat flux measurements may be affected by evaporation that occurs beneath the soil surface. Zhaoqiang Ju et al. (2010) suggested that global warming has become evident and rising temperature has greater influence in ecosystem.

Putz et al. (2011) suggested that damping depth calculation modification was required for Boreal forest condition.

Upadhyay et al. (2011) investigated by a neural network approach for short term wind speed forecasting. A multi-layered feed-forward ANN, trained by the resilient back propagation learning algorithm has been used for hourly forecasting of wind speed in the region of Canada.

Binbin et al. (2011) studied the temperature and humidity field coupling model of conservatory soil without crop vegetation in full illumination is simplified into a one-dimensional thermal diffusion model. The heat flux of soil surface in conservatory reaches the maximum approximately at noon. The conservatory soil is in the state of heat release from 20:00 to 8:00 in the next morning which is the moment when heat flux of each layer changes in sequence and solar radiation has less influence on deep soil. The depth of 0.5 m can be considered as constant temperature strata.

Uno et al. (2012) estimated the soil heat flux from both short and long-term remotely sensed surface temperature.

Milan Protic et al. (2012) measured heat flux indirectly from known ground surface temperature time-dependent functions using previously developed fractional
diffusion equation for ground heat conduction is elaborated. Validation of results indicate the solution obtained with fractional approach closely correspond to analytical solution.

Steven Evett et.al. (2012) studied the soil profile method for soil thermal diffusivity, conductivity and heat flux revealed that soil thermal properties were important inputs for models of soil heat and water flux but thermal properties were prone to error when calculated from soil texture and bulk density data due to the complex effects of soil particle size, shape and packing.

Adeniyi et.al. (2012) computed soil thermal conductivity and diffusivity together with the damping depth of soil temperature using Amplitude decay, Phase shift, Harmonic, Arctangent, Logarithmic and conduction convection algorithms. The results were compared with de Vries model.

Muhammad Hussain et.al. (2012) measured that the coastal urban local climate has been showing changing pattern due to global climate change. This communication attempts to explore fluctuating pattern of urban average monthly wind speed during past 50 years (1961-2010). It shows peculiar results taking Karachi (24° 53’N, 67° 00’E), a coastal mega-city of Pakistan as a case study. The analysis performed reveals the effect of global warming on the local urban wind speed which appears to be temporal non-stationary.

Krakauer et.al. (2013) evaluated the impact on the modelled climate of aquifer-soil heat and water fluxes separately, as well as in combination.
Wen-Yeau Chang (2013) studied about a method to accurately and reliably forecast the wind power of a WECS (Wind energy conversion system). To verify the effectiveness of the proposed technique, the historical power generation data of a practical WECS during typical winter days are used. The numerical results show that the proposed back propagation neural network based wind power forecasting method can forecast the wind power accurately and reliably.

Shaminder Singh and Jasmeen Gill (2014) developed weather forecasting in the application of science and technology to predict the state of the atmosphere for a given location. The dependence of humidity on a particular data series a humidity prediction model using integrated back propagation with genetic algorithm technique is proposed. This could be further extended to include more weather parameters such as sunshine, wind speed and evaporation.

2.12 Model validation

Chen and Adams (2006) studied the integration of ANNs with conceptual models and expressed that the performance of ANN and regression models could be analysed using model performance indicators such as model efficiency, correlation co-efficient and root mean square error.

Allan Marcus and Robert Elias (1998) studied the useful statistical methods for model validation and discussed the application of a statistical procedure of measurement error correction that allows essential adjustment to empirical comparisons between observed and predicted data. The measurement of error correction removes some of the biases associated with these empirical comparisons.
Carroll et al. (1998) observed the measurement error, biases and the validation of complex models to illustrate conclusively how measurement error could distort the apparent relation between exposure and biologic response and would very probably bias the test statistics in the direction of attenuating the apparent predictiveness of the model.

Sarangi et al. (2005) developed by the ANN and regression models were using watershed-scale geomorphologic parameters to predict surface runoff and sediment losses of the St. Esprit watershed, Quebec, Canada. Regression models were developed using the curve-fitting toolbox of MATLAB software and compared with the results obtained from ANN models. The coefficient of determination and model efficiency factor were estimated to ascertain the model performance.

Literature survey was conducted and the amount of work done by researchers regarding the soil temperature, variation of soil temperature, prediction of soil temperature using ANN with the data of soil temperature and meteorological parameters, prediction of air temperature, validation of predicted values using different statistical parameters have been presented. Determination of thermal characteristics of soil and thermal wave characteristics in the past is also elaborated.

The next chapter explains the data and methodology adopted in the present work.