DSS (DECISION SUPPORT SYSTEM) FOR URBAN WATER MANAGEMENT WITH CLIMATE CONSIDERATION

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

WATER RESOURCES DEVELOPMENT

By

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MAY, 2013

CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "Decision support system for urban water management including climate considerations", in partial fulfillment of the requirements for the award of degree of Master of Technology in Water Resource Development in Water Resources and Management Department of Indian Institute of Technology, Roorkee is an authentic record of my own work carried out under the supervision of Prof. Deepak Khare , WRD&M.

The matter in this report has not submitted for award of any other degree of this you or any other institution.

(Praveen Kumar)

Enrollment No.-10548017

This is to certify that the statement made by the candidate is correct and true to the best of my knowledge.

(Prof. Deepak Khare)

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ACKNOWLEDGEMENTS

This thesis entitled as, "Decision support system for urban water management including climate considerations" concludes my work carried out at the Department of Water Resources Development and Management, Indian Institute of Technology Roorkee. The result of work carried out during the fourth semester of my curriculum whereby I have been accompanied and supported by many people. It is pleasant aspect that I have now the opportunity to express my gratitude for all of them.

First of all, I would like to express my gratitude to my supervisor Prof. Deepak Khare, under whose inspiration, encouragement and guidance I have completed my thesis work.

I would like to express my thanks to Professor (Dr.) Deepak Khare, Head, WRD&M, Associate Professor S.K. Mishra and Assistant Professor Dr. Ashish Pandey for his time to time suggestion and providing all the facilities in the department during the thesis work.

I am also thankful to all the faculty and staff members of WRD&M for providing me all the facilities required for the completion of this work. It has a pleasure working at Indian Institute of Technology, Roorkee and this is mostly due to the wonderful people who have sojourned there over the past years.

Most importantly, I would like to give God the glory for all the efforts I have put into this work.

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ABSTRACT

To find out the water demand and problems in supplying that in the near future is a big problem, as in the urban areas like Dehradun, which is a decade old state capital, the change in Landuse/ Landcover pattern has been very rapid. The built up area is increasing day by day which is effecting the hydrological cycle of the district. Change in climate is also becoming a major factor to effect the hydrological cycle of the district. In the present study a scientific approach is used to propose the coming problems regarding water in the city and probable places where it will most likely to happen in the city. Different thematic layers required to study the city and nearby area of the city, such as landuse/ landcover, past and present population density, have been prepared in a Geographic Information System enviroment using high resolution digital data of LANDSAT satellite amalgamated with field data. By studying these maps one can propose the high water demand area in the near future by considering some factors, such as distance from the city, topographic slopes, landuse/lancover, present population density, existing water supply etc. Population of the city is also forecasted as per last three decades census data to have an idea of the demand of water in the near future and problems which will arise to compete that challenge. In addition a trend is made using the precipitation and temperature data of 1901 to 2002 years data from Indian Meteorological Department(IMD). Auto Regressive Integrated Moving Average(ARIMA) model is used to predict a trend between precipitation and temperature with graphical approach and analytical approach both. To assemble all the data at one place and to make it easy to use, Visual Basic 6.0 is used to make a model which is an user friendly platform. Analytical data, graphical data of precipitation and temperature, thematic maps, forecasted population and demand data is placed in the model so that one can see all the things at one place to make out decision regarding the future water problems.

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Chapter 1: **INTRODUCTION**

1.1 GENERAL

Population increase can affect the Landuse/ Landcover of a place especially the places which has a lot of scope to for expansion. Same is the case with the newly made capital of the state, Dehradun. The population has increased rapidly in the last two decades especially in the last one. In result the Landuse/ Landcover of the area in the city and nearby also. The increase of built up area cause disturbance in the hydrologiacal cycle and even on climate. More runoff, less infiltration to recharge the ground water, increase in temperature in result more runoff etc area the major effects of Landuse/ Landcover and climate change.

Now the problem will arise to mitigate the water demand as the demographic data is increasing so is the demand of water in the study area. Increasing trend of industries in the suburbs of the city and nearby places will also add up in the water demand. Increasing trend of rise in annual average temperature will also end up to increase the water demand.

Now the problem is known but one will need a scientific approach to predict how much the problem can rise and so can plan to mitigate the problem of water demand. In the study a model is made to help in assessing the present and past data to thoroughly and predicting the data of the future hence finding out the problem.

1.2 OBJECTIVE OF THESIS

Main aim of the thesis is to assess the available data of the population, precipitation, temperature and LANDSAT sattelite data to predict the near coming problems and probable effect of the problems. Last three decade's(1990, 2000, 2010) census data is used to predict the future population and so the demand of water, Indian Metereological Department(IMD) precipitation and temperature data from 1901 to 2002 is used to find out the probabale temperature and precipitation data for the future. LANDSAT sattletite data is used to find out the Landuse/ Landcover change to assess the probable places where further increase in population will be seen. And finally effect of Landuse/ Landcover and temperature is seen on the future water problems and demand. This study can help a lot to assess the upcoming conditions in the near future and to plan for the same accordingly.

1.3 ORGANIZATION OF THESIS

For better understanding of the thesis the complete thesis work is divided into six chapters. Chapter 1: This chapter, entitled as "Introduction", includes the overview of the thesis, concept of Landuse/ Landcover change effects, temperature change effects and aim of thesis is also included in the chapter.

Chapter 2: This chapter entitled as "Study Area".
Chapter 3: This chapter entitled as "Trend analysis for Precipitation and Temperature"
Chapter 4: This chapter entitled as "Land-use and Land-cover Analysis"
Chapter 5: This chapter entitled as "Deviation analysis of Climate change".
Chapter 6: This chapter, entitled as "Conclusion" mainly includes the future problems and some methods to plan for the situation.

Chapter 2: **LITERATURE REVIEW**

2.1 GENERAL

In this era, computers is involved in every area as in software field, data storage, computer system, time sharing etc. A great deal of help can be taken of computer in making decision support system to help in solving multi criteria and different objectives complexities.

2.2 APPLICATION OF DSS IN VARIOUS FIELDS

Decision Support Systems are applied in almost all the fields where decision criteria are complex. The following are some of the examples.

Environmental decision making

Environmental DSS have been developed to assess the impact of utilization of natural resources and to evaluate the impact of agricultural and industrial activities on the environment. The environmental decision support systems and provide architecture for such systems (Guariso and Werthner, 1989). Several applications of multiple criteria decision making in environmental management can be found in Paruccini, 1994. References to many systems (including environmental DSS and GIS) which were developed to solve environmental problems in Argentina, Chile, Columbia, Egypt and Poland (ERDAS, 1999).

Decision support systems for stored water quality

Environmental decision support systems (EDSS) contain three major components: a model base containing a number of numerical models, a database containing information from a large number of sites, and an interface to permit the user to access the models and data and to perform "scenario analysis" as an aid to decision making. Software decision support tools are currently promising to supple management support in a wide variety of industries. These are described here in the context of the management of stored water quality and the role of the database component of a typical EDSS is stressed (Henderson S, 1991).

Artificial Intelligence and Environmental Decision Support Systems

An effective protection of our environment is largely dependent on the quality of the available information used to make an appropriate decision. Problems arise when the quantities of available information are huge and nonuniform (i.e., coming from many different disciplines or sources) and their quality could not be stated in advance. Another associated issue is the dynamical nature of the problem. Computers are central in contemporary environmental protection in tasks such as monitoring, data analysis, communication, information storage and retrieval, so it has been natural to try to integrate and enhance all these tasks with Artificial Intelligence knowledge-based techniques.

Decision support for natural resources management: Models, GIS and expert systems - AI Applications

The specific role of integrated DSS, including models integrated with expert systems and GIS wrapped into interactive graphical user interfaces is primarily in their heuristic and didactic value. Graphical displays such as topical maps are an easy to understand form of communicating complex information. They can generate a widely accepted and familiar format for a shared information basis supporting an open debate.

A Decision Support System for sustainable maize harvesting operations scheduling

Decision Support System (DSS) developed for the scheduling of the operations of contractors who travel from farm to farm to harvest maize. Maize Manager is designed to aid the schedulers of harvesting equipment and personnel in creating or improving schedules, and enables them to use their experience and preferences.

Production management in the textile industry using the "yfadi" decision support system

The decision support system (DSS) presented here is dealing with the production planning and scheduling in the textile industry. The DSS aims at the efficient management of a mixed production system (Job-shop and flow-shop), such as that of the textile industry. Its main feature is the effective combination of a database and a model based management system in order to merge existing expert knowledge.

2.3 DEVELOPMENT IN DSS APPLICATION

Beginning in about 1980 many activities associated with building and studying DSS occurred in universities and organizations that resulted in expanding the scope of DSS applications. These actions also expanded the field of decision support systems beyond the initial business and management application domain. These diverse systems were all called Decision Support Systems. From those early days, it was recognized that DSS could be designed to support decision-makers at any level in an organization. Also, DSS could support operations decision making, financial management and strategic decision making (Power D.J., 2007). Table 2-1 shows the development taken place in DSS during the past.

Table 2-1 Development in DSS Applications

Year	Major Milestones
1945	Bush proposed Memex
1947	Simon book titled Administrative Behavior
1952	Dantzig joined RAND and continued research on linear programming
1955	Semiautomatic Ground Environment (SAGE) project at M.I.T. Lincoln Lab uses first light pen; SAGE completed 1962, first data-driven DSS
1956	Forrester started System Dynamics Group at the M.I.T. Sloan School
1960	Simon book The New Science of Management Decision; Licklider article on "Man-Computer Symbiosis"
1962	Licklider architect of Project MAC program at M.I.T.; Iverson's book A Programming Language (APL); Engelbart's paper "Augmenting Human Intellect: A Conceptual Framework"
1963	Englebart established Augmentation Research Center at SRI
1965	Stanford team led by Feigenbaum created DENDRAL expert system; Problem Statement Language/Problem Statement Analyzer (PSL/PSA) developed at Case Institute of Technology
1966	UNIVAC 494 introduced; Tymshare founded and Raymond article on computer time-sharing for business planning and budgeting
1967	Scott Morton's dissertation completed on impact of computer-driven visual display devices on management decision-making process; Turban reports national survey on use of mathematical models in plant maintenance decision making
1968	Scott Morton and McCosh article; Scott Morton and Stephens article; Englebart demonstrated hypermedia—groupware system NLS (oNLine System) at Fall Joint Computer Conference in San Francisco
1969	Ferguson and Jones article on lab study of a production scheduling computer-aided decision system running on an IBM 7094; Little and Lodish MEDIAC, media planning model; Urban new product model-based system called SPRINTER
1970	Little article on decision calculus support system; Joyner and Tunstall article on Conference Coordinator computer software; IRI Express, a multidimensional analytic tool for time-sharing systems, becomes available; Turoff conferencing system
1971	Gorry and Scott Morton SMR article first published use of term Decision Support System; Scott Morton book Management Decision Systems; Gerrity article Man-Machine decision systems; Klein and Tixier article on SCARABEE
1973	PLATO Notes, written at the Computer-based Education Research Laboratory (CERL) at the University of Illinois by David R. Woolley
1974	Davis's book Management Information Systems; Meador and Ness article DSS application to corporate planning
1975	Alter completed M.I.T. Ph.D. dissertation "A Study of Computer Aided Decision Making in Organizations"; Keen SMR article on evaluating computer-based decision aids; Boulden book on computer-assisted planning systems
1976	Sprague and Watson article "A Decision Support System for Banks"; Grace paper on Geodata Analysis and Display System
1977	Alter article "A Taxonomy of Decision Support Systems", Klein article on Finsim; Carlson and Scott Morton chair ACM SIGBDP Conference DSS Conference
1978	Development began on Management Information and Decision Support (MIDS) at Lockheed-Georgia; Keen and Scott Morton book; McCosh and Scott Morton book; Holsapple dissertation completed; Wagner founded Execucom to market IFPS; Bricklin and Frankston created Visicalc (Visible Calculator) microcomputer spreadsheet; Carlson from IBM, San Jose plenary speaker at HICSS-11; Swanson and Culnan article document-based systems for management planning

1979	Rockart HBR article on CEO data needs
1980	Sprague MISQ article on a DSS Framework; Alter book; Hackathorn founded MicroDecisionware
1981	First International Conference on DSS, Atlanta, Georgia; Bonczek, Holsapple, and Whinston book; Gray paper on SMU decision rooms and GDSS
1982	Computer named the "Man" of the Year by Time Magazine; Rockart and Treacy article "The CEO Goes On-Line" HBR; Sprague and Carlson book; Metaphor Computer Systems founded by Kimball and others from Xerox PARC; ESRI launched its first commercial GIS software called ARC/INFO; IFIP Working Group 8.3 on Decision Support Systems established
1983	Inmon Computerworld article on relational DBMS; IBM DB2 Decision Support database released; Student Guide to IFPS by Gray; Huntington established Exsys; Expert Choice software released
1984	PLEXSYS, Mindsight and SAMM GDSS; first Teradata computer with relational database management system shipped to customers Wells Fargo and AT&T; MYCIN expert system shell explained
1985	Procter & Gamble use first data mart from Metaphor to analyze data from checkout-counter scanners; Whinston founded Decision Support Systems journal; Kersten developed NEGO
1987	Houdeshel and Watson article on MIDS; DeSanctis and Gallupe article on GDSS; Frontline Systems founded by Fylstra, marketed solver add-in for Excel
1988	Turban DSS textbook; Pilot Software EIS for Balanced Scorecard deployed at Analog Devices
1989	Gartner analyst Dresner coins term business intelligence; release of Lotus Notes; International Society for Decision Support Systems (ISDSS) founded by Holsapple and Whinston
1990	Inmon book Using Oracle to Build Decision Support Systems; Eom and Lee co-citation analysis of DSS research 1971–1988
1991	Inmon books Building the Data Warehouse and Database Machines and Decision Support Systems; Berners-Lee's World Wide Web server and browser, become publicly available
1993	Codd et al. paper defines online analytical processing (OLAP)
1994	HTML 2.0 with form tags and tables; Pendse's OLAP Report project began
1995	The Data Warehousing Institute (TDWI) established; DSS journal issue on Next Generation of Decision Support; Crossland, Wynne, and Perkins article on Spatial DSS; ISWorld DSS Research pages and DSS Research Resources
1996	InterNeg negotiation software renamed Inspire; OLAPReport.com established;
1997	Wal-Mart and Teradata created then world's largest production data warehouse at 24 Terabytes (TB)
1998	ACM First International Workshop on Data Warehousing and OLAP
1999	DSSResources.com domain name registered
2000	First AIS Americas Conference mini-track on Decision Support Systems
2001	Association for Information Systems (AIS) Special Interest Group on Decision Support, Knowledge and Data Management Systems (SIG DSS) founded
2003	International Society for Decision Support Systems (ISDSS) merged with AIS SIG DSS

2.4 DEFINITION OF DECISION SUPPORT SYSTEM (DSS)

- Computer Information System to Help Decision Making.
- Interactive computer programs that utilize analytical methods, such as decision analysis, optimization algorithms, program scheduling routines, and so on, to help decision making (Adelman, 1992).
- Decision Support Systems (DSS) are defined as computer-based information systems designed to support decision makers interactively in thinking and making decisions about relatively unstructured problems (Debapriya Dutta).

2.5 ARCHITECTURE OF DECISION SUPPORT SYSTEM

The fundamental components of Decision support system architecture are :

- The database (or knowledge base)
- The module (the decision context and user criteria)
- The user interface.

Database consists of an organized collection of data for one or more multiple uses. One way of classifying databases involves the type of content, for example: bibliographic, full-text, numeric and image. Other classification methods start from examining database models or database architectures

Modules are the specific purpose sub program which accept predefined type of data and gives us output results. Modules allow feed input and extract output via a simple interface

User Interface provides access the Software or Package for user interaction like data entry, visualization of results, storing of the results, retrieval of data / results etc.

2.6 CLASSIFICATION OF DECISION SUPPORT SYSTEM

Alter concluded from his research (1980) that decision support systems could be categorized in terms of the generic operations that can be performed by such systems. These generic operations extend along a single dimension, ranging from extremely data-oriented to extremely model-oriented. Alter conducted a field study of 56 DSS that he categorized into seven distinct types of DSS. His seven types include:

- **File drawer systems** that provide access to data items.
- **Data analysis systems** that support the manipulation of data by computerized tools tailored to a specific task and setting or by more general tools and operators.
- **Analysis information systems** that provide access to a series of decision-oriented databases and small models.
- **Accounting and financial models** that calculate the consequences of possible actions.
- **Representational models** that estimate the consequences of actions on the basis of simulation models.
- **Optimization models** that provide guidelines for action by generating an optimal solution consistent with a series of constraints.
- **Suggestion models** that perform the logical processing leading to a specific suggested decision for a fairly structured or well-understood task.

A literature survey and citation studies (Alavi and Joachimsthaler, 1990, Eom and Lee, 1990a, Eom, 2002, Arnott and Pervan, 2005) suggest the major applications for DSS emphasized manipulating quantitative models, accessing and analyzing large data bases, and supporting group decision making. Much of the model-driven DSS research emphasized use of the systems by individuals, i.e., personal DSS, while data-driven DSS were usually institutional, ad hoc or organizational DSS. Group DSS research emphasized impacts on decision process structuring and especially brainstorming. Some of the Classifications as on now are as follows :

- Model-driven DSS
- Data-driven DSS
- Communications-driven DSS
- Document-driven DSS
- Knowledge-driven DSS
- Web-based DSS

2.7 CASE STUDY

Some of the Case studies are carried out to understand the developed decision support system in various fields and their behavior in carrying out decision analysis.

2.7.1 DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR JOHN DAY RESERVOIR

Scientists at the Columbia River Research Laboratory and the Upper Midwest Environmental Sciences Center are developing geographic information system (GIS) based tools to assist managers with making decisions regarding the natural resources in and around the John Day Reservoir. The reservoir, also known as Lake Umatilla, was created in 1968 when the U.S. Army Corps of Engineers constructed the John Day Dam on the Columbia River. The reservoir is 76 miles long and is bounded by John Day Dam on the western downstream end and McNary Dam on the eastern upstream end. Power generation, irrigation, navigation, angling, and windsurfing are some of society's uses of John Day reservoir. The reservoir hosts many species of fish and wildlife, including several species of threatened or endangered salmon, and is important to migratory birds that visit or nest at the Umatilla National Wildlife Refuge and other nearby wildlife areas.

More analytical tools are developed for use by scientists and other professionals. These tools, which require the user to have specialized computer software, will provide for more detailed analyses and in the planning and design of future research. These tools will help bring researchers together with managers to help make the best use of natural resources based on current scientific knowledge.

This set of tools, in conjunction with 2 dimensional hydraulic modeling, is being used to estimate the effects of reservoir level and water discharge fluctuations on aquatic and terrestrial habitats in John Day reservoir. Different scenarios being studied now range from typical reservoir levels at high and low discharges to a simulation of what things might be like if the river were to return to natural conditions.

2.7.2 WATER RESOURCES FOR AGRICULTURE IN A CHANGING CLIMATE: INTERNATIONAL CASE STUDIES

This integrated study examines the implications of changes in crop water demand and water availability for the reliability of irrigation, taking into account changes in competing municipal and industrial demands, and explores the effectiveness of adaptation options in maintaining reliability. It reports on methods of linking climate change scenarios with hydrologic, agricultural, and planning models to study water availability for agriculture under changing climate conditions, to estimate changes in ecosystem services, and to evaluate adaptation strategies for the water resources and agriculture sectors. The models are applied to major agricultural regions in Argentina, Brazil, China, Hungary, Romania, and the US, using projections of climate change, agricultural production, population, technology, and GDP growth.

For most of the relatively water-rich areas studied, there appears to be sufficient water for agriculture given the climate change scenarios tested. Northeastern China suffers from the greatest lack of water availability for agriculture and ecosystem services both in the present and in the climate change projections. Projected runoff in the Danube Basin does not change substantially, although climate change causes shifts in environmental stresses within the region. Northern Argentina's occasional problems in water supply for agriculture under the current climate may be exacerbated and may require investments to relieve future tributary stress. In Southeastern Brazil, future water supply for agriculture appears to be plentiful. Water supply in most of the US Cornbelt is projected to increase in most climate change scenarios, but there is concern for tractability in the spring and water-logging in the summer.

Adaptation tests imply that only the Brazil case study area can readily accommodate an expansion of irrigated land under climate change, while the other three areas would suffer decreases in system reliability if irrigation areas were to be expanded. Cultivars are available for agricultural adaptation to the projected changes, but their demand for water may be higher than currently adapted varieties. Thus, even in these relatively water-rich areas, changes in water demand due to climate change effects on agriculture and increased demand from urban growth will require timely improvements in crop cultivars, irrigation and drainage technology, and water management.

2.7.3 SPATIAL DECISION SUPPORT SYSTEM FOR LAND AND WATER MANAGEMENT AND ITS APPLICATION FOR WATERSHED MANAGEMENT IN BANKURA DISTRICT OF WEST BENGAL

Spatial Decision Support Systems (SDSS), which are the integration of DSS and GIS was initiated by Densham and Goodchild (1988) are emerging as efficient tools for managing natural resources like land and water. AVSWAT (Arc View SWAT), a user friendly PC based SDSS tool has been developed at the Black Land Research Center, Temple, Texas, USA integrating Soil and Water Analysis Tool (SWAT) and Arc View GIS version 3.0a software along with Spatial Analyst version 1.1 extension. SWAT is a continuous time river basin or watershed scale model operating on daily time step. In the present study, the tool was applied in digitally delineating watersheds in a block of Bankura district of West Bengal and then it was used for estimating potential water, silt and crop yield from each of them. This would be helpful in prioritizing the watersheds and presenting the results spatially for the district level decision makers.

Chapter 3: DEVELOPMENT OF DSS

3.1 GENERAL

Decision support system is made for the study area to serve the purpose as discussed in the earlier chapters. Analytical, satellite image and graphical data was used to analyze the study area and subsequently doing trend analysis for the future. For that a platform is made on which all the final data is accumulated at one place which can be accessed easily.

3.2 COMPUTER KNOWLEDGE USED

Following softwares and computer skills were used to make the DSS:-

- Visual Basic 6.0 is used as the platform for the whole DSS. Around fourty forms are connected on which the analysed data is plotted in a presentable manner. To interlink the forms and use the data easily by the user programming is done.
- ARIMA (Auto regressive integrated moving average) model is used to analyze the precipitation and temperature data in analytical manner. For this Minitab 5.0 software was used.
- Microsoft Excel 2007 was used to connect the more than 100 years data with Visual Basic 6.0 for the DSS. It was also used for plotting out the analytical data in graphical manner.
- ERDAS 9.0 and ArcGIS was used to sub setting and classifying the satellite image data of the study area.

3.3 FRAME OF THE DSS

Fig. 3.1 shows the main frame of the DSS model. It is the starting screen of the model from which one can go to different fields just by clicking on appropriate button. These different fields are :-

- Demographic Data
- Trend analysis through Analytical data
- Trend analysis through Graphical data
- Classified Satellite Data & Climate Change Effect

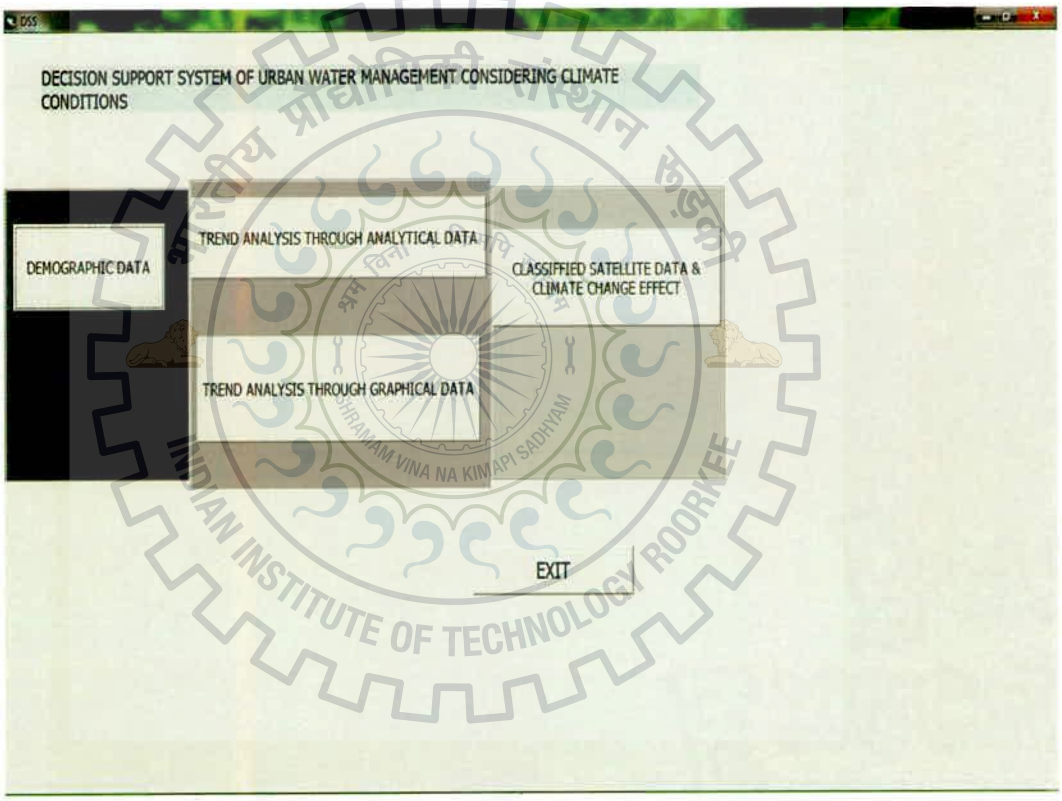


Figure 3-1 Main frame of DSS

As shown in the above figure 3-1, this is the main frame of DSS from which we can go to the subsequent frame just by clicking the subsequent button.

The frame for Demography Data is shown in figure 3-2 below.

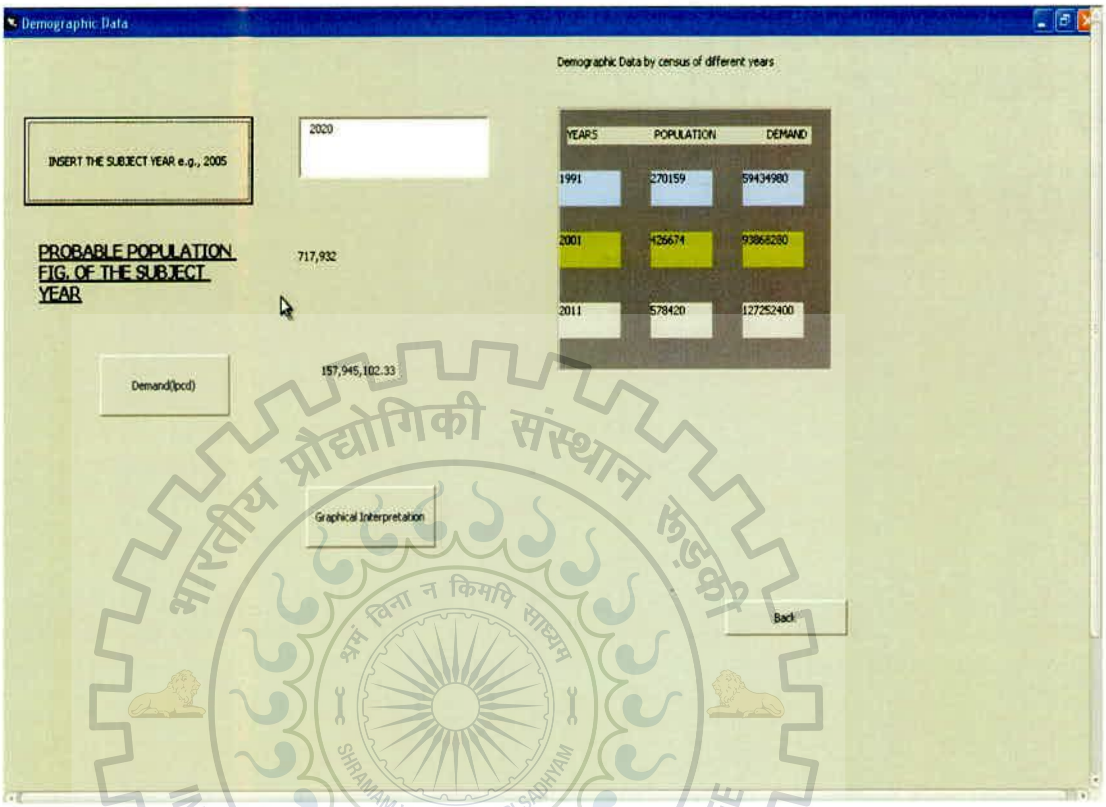


Figure 3-2 Demography frame window of DSS

The above frame is programmed as if we put an year number in the shown text box and it will show the population forecast and demand of the same year for the study area. A graphical representation button is also given for another form in which Demand and supply plotting is shown.

Similarily other forms can be opened by clicking the subsequent button for the subsequent forms as shown in the following figures.

The thorough application of the decision support system developed is demonstrated in the subsequent chapters.

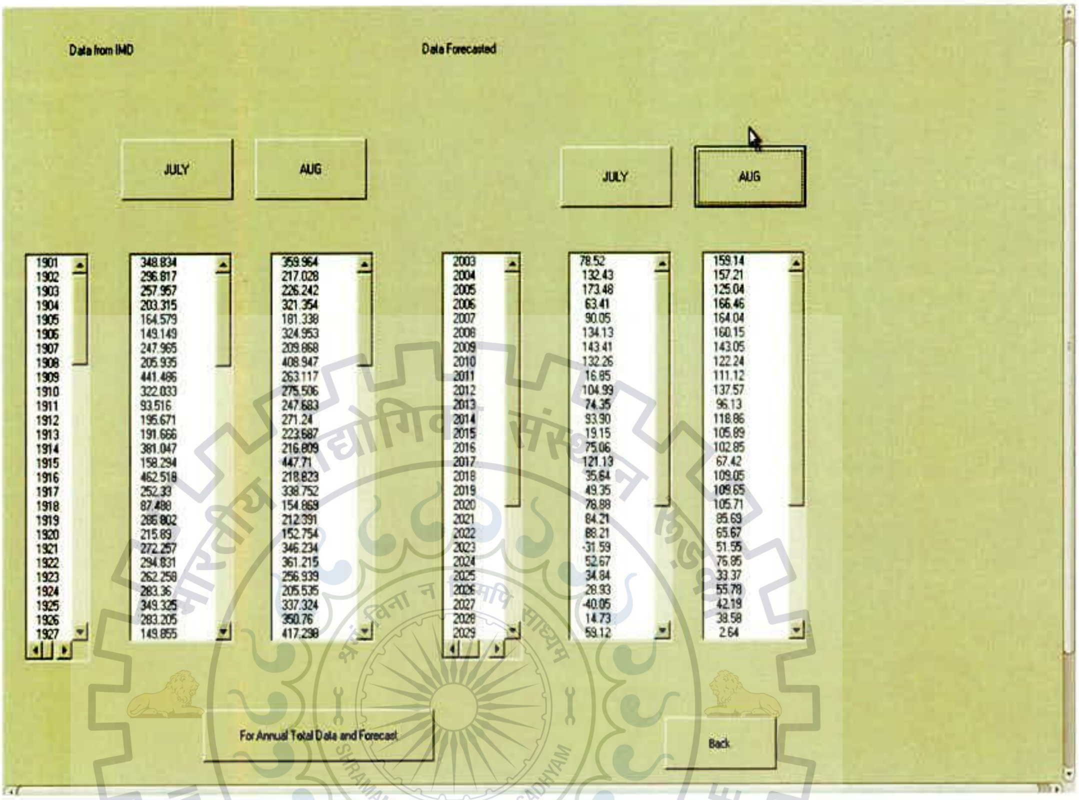


Figure 3-3 Trend analysis for analytical data frame of DSS

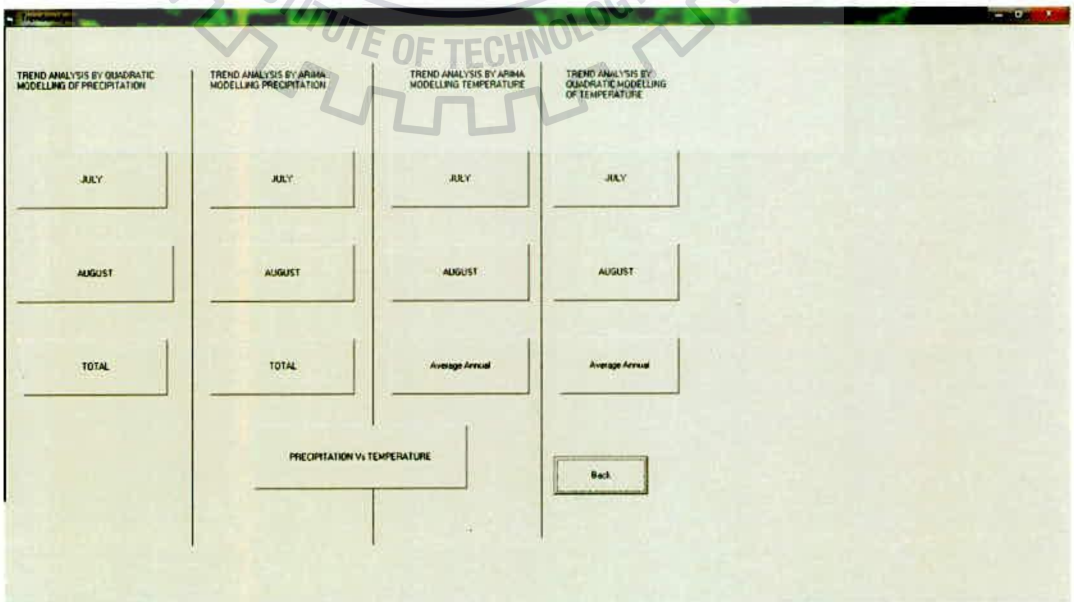


Figure 3-4 Trend analysis for graphical data frame of DSS

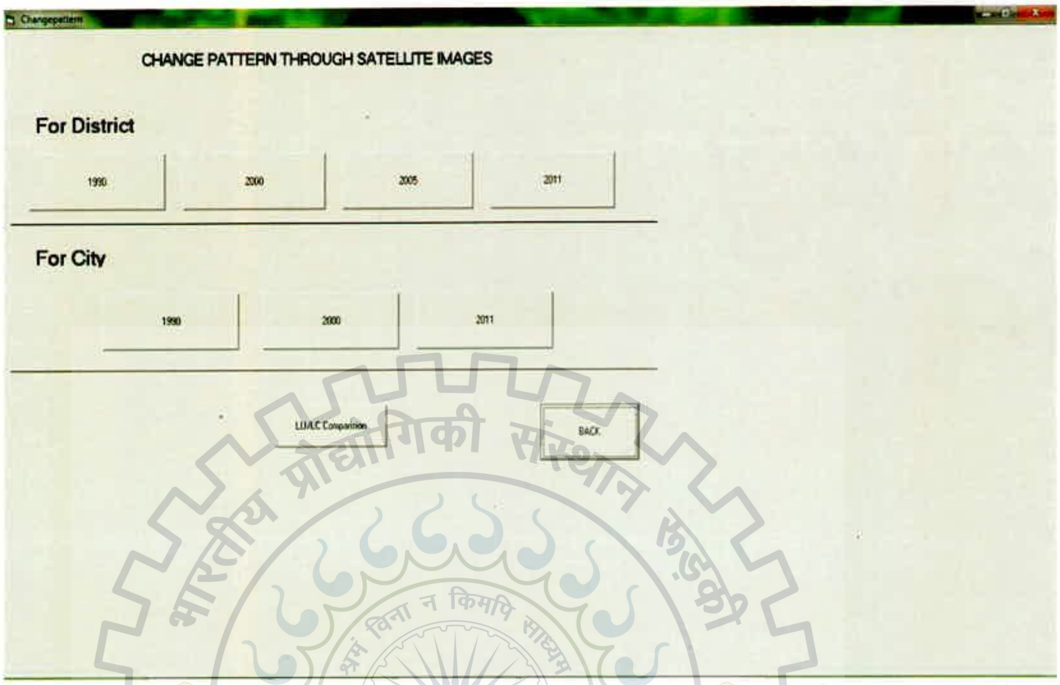


Figure 3-5 Classified Satellite image data and climate change effect

3.4 CONCLUDING REMARK

In this chapter only the interface of the DSS model is shown. Main frame, sub main frame etc. are shown and how they are connected to become a model is discussed. The application of developed decision support system is demonstrated in the following chapters.

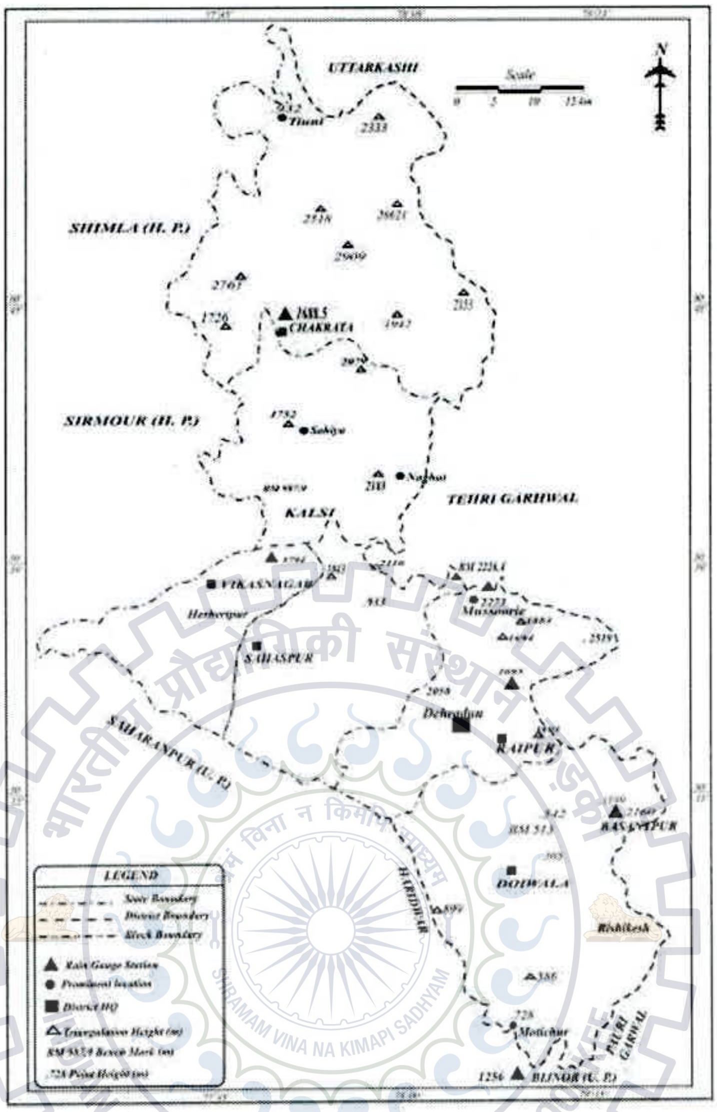
Chapter 4: **STUDY AREA**

4.1 GENERAL

In the present study, Dehradun is considered as the study area. Dehradun district is situated in NW corner of Uttrakhand state and have its area from N Latitude 29* 58' to 31* 02' and E Longitude 77*34' to 78* 18'. The total area of Dehradun district is 3088 SqKm with an average altitude of 640 m above MSL. The district comprises of six tehsils, Dehradun, Chakrata, Vikasnagar, Kalsi, Tuini, and Rishikesh. There are 17 towns and 764 villages in the district.

Capital of the state is Dehradun which has an area of 300 SqKm mostly of which comes in 500-600 m above MSL altitude region of the district. The annual average precipitation in the area is 231.5 cm. The valley has different type of forest cover due to the hydro-geological and meteorological conditions.

Dehradun district is drained by Ganga, Yamuna and their tributiaries. Song and Suswa are two main tributiaries of Ganga and Tons is the main tributiary of Yamuna. Easternly flowing river joins Ganga and Westernly flowing river joins Yamuna.



Administrative Map, District Dehradun

Figure 4-1 Administrative Map, District Dehradun

4.2 DEMOGRAPHY OF THE STUDY AREA

After becoming the capital of Uttarakhand, Dehradun demographic data increased rapidly, from 2.7 Lakhs in 1991 to 4.26 lakhs in 2001 and 5.78 lakhs in 2011 (Census Data, 2010). One can see 57.77% increase in 1991 to 2001 and 35.68% increase in 2001 to 2011. Seeking the trend future demographic data is forecasted by linear forecasting using the Visual Basic 6.0 platform as shown in Fig. 4-2

By knowing the water needed by a person in a day, one can calculate the demand of the city. The water demand in litre per capita demand (lpcd) of a day is taken as 220 lpcd (Enviromental Hygiene Committee of India). This demand is taken as considering domestic and industrial water requiremnt. With the forecasted population data, demand is also highlighted on the model as shown in the Fig. 2. The supply of the city has been always short as in the year 1991 supply was 74 Mld while the demand was 100.6, in year 2001 supply was 92.25 Mld and the demand was 129.30 Mld, and in the year 2007 supply was 127.05 Mld and demand was 154.64 Mld (K.H. Durga Rao, 2005) . Graphical representation of this is shown in the Fig. 4-3. As the demand is increasing day by day, the supply will have to meet the demands with the same pace only. Predicted demand for the years 2011, 2021, 2031 are 165.5 Mld, 211.90 Mld and 271.20 Mld respectively. To meet the demand in the year 2011, 38.45 Mld water supply is more needed, 84.85 Mld is more needed in the year 2021 and 144.15 Mld is more needed in the year 2031 as shown in Fig.4-3

4.3 CONCLUDING REMARK

By the study one can say that in the near coming future the demand of water is going to reach a level which will become very challenging to mitigate the demand with supply. Moreover as the climate is changing the challenge is going to be tougher. The supply in 2007 in the city is 127.05 Mld of which 76% comes from ground water and the rest is from surface water. So ground water is a major source which has to be restored by using different norms and methods to use it in a manageable way in the future also.

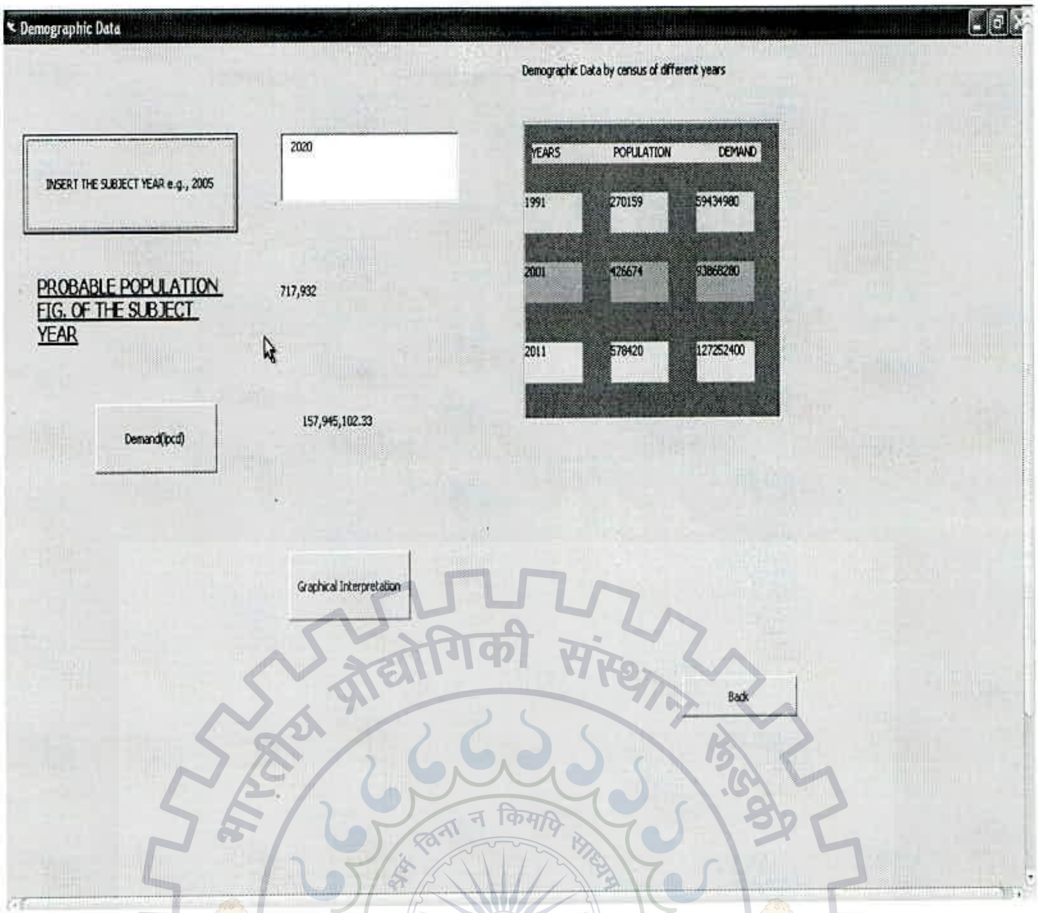


Figure 4-2 Demographic data page of model

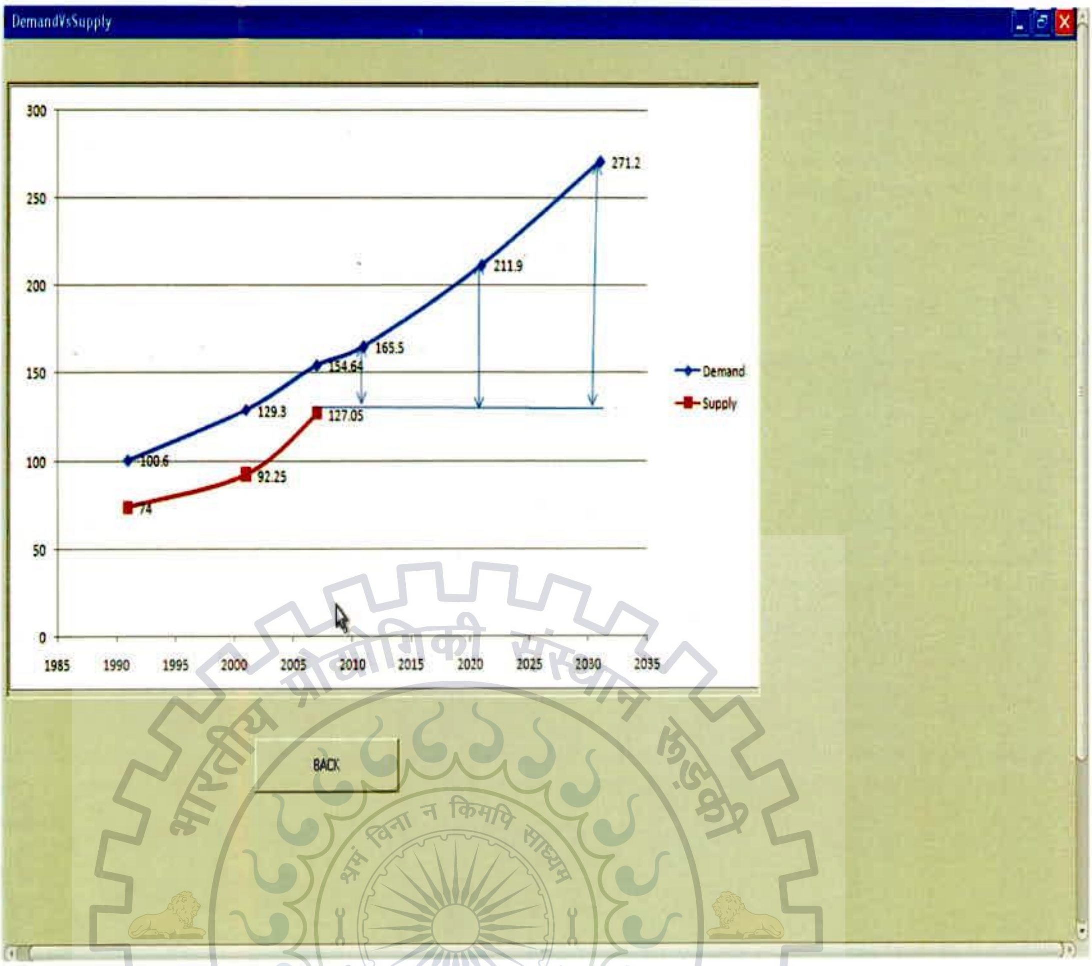


Figure 4-3 Demand Vs Supply

Chapter 5: **TREND ANALYSIS FOR PRECIPITATION AND TEMPERATURE**

5.1 GENERAL

Dehradun is normally hot in summers and cold in winters. The temperature stays in the range from freezing point in January to 36*C in May and June. Dehradun recieves an average annual rainfall of approximately 2050 mm of which 1200 mm occurs in July and August in the rainy season of the area. The average climatic data of last 25 years is shown in Table 5-1

Table 5-1 Average Climate data of last 25 years

Month	Rainfall (mm)	Relative Humidity (%)	Temperature		
			Maximum	Minimum	Average
January	46.9	91	19.3	3.6	10.9
February	54.9	83	22.4	5.6	13.3
March	52.4	69	26.2	9.1	17.5
April	21.2	53	32	13.3	22.7
May	54.2	49	35.3	16.8	25.4
June	230.2	65	34.4	29.4	27.1
July	630.7	86	30.5	22.6	25.1
August	627.4	89	29.7	22.3	25.3
September	261.4	83	29.8	19.7	24.2
October	32.0	74	28.5	13.3	20.5
November	10.9	82	24.8	7.6	15.7
December	2.8	89	21.9	4.0	12.0
Annual Average	2051.4	76	27.8	13.3	20.0

5.2 ANALYSIS FOR PRECIPITATION

Precipitation data for the last 106 years was taken from India Meteorological Department (IMD). This was average monthly data for these years which was used as the time series to forecast the precipitation of the upcoming years. Auto Regressive Integrated Moving Average (ARIMA) model is used to predict the precipitation data of the desired years. These predicted data is transferred in an excel file from where it is connected to DSS model on Visual Basic 6.0 platform. The prediction was done for the total rainfall of the year and for rainfall of July and August (these two months contributemore than 50% of the total annual rainfall). The DSS model can predict rainfall of July, August and total rainfall upto 2040 as shown in Fig. 5-1 and Fig. 5-2

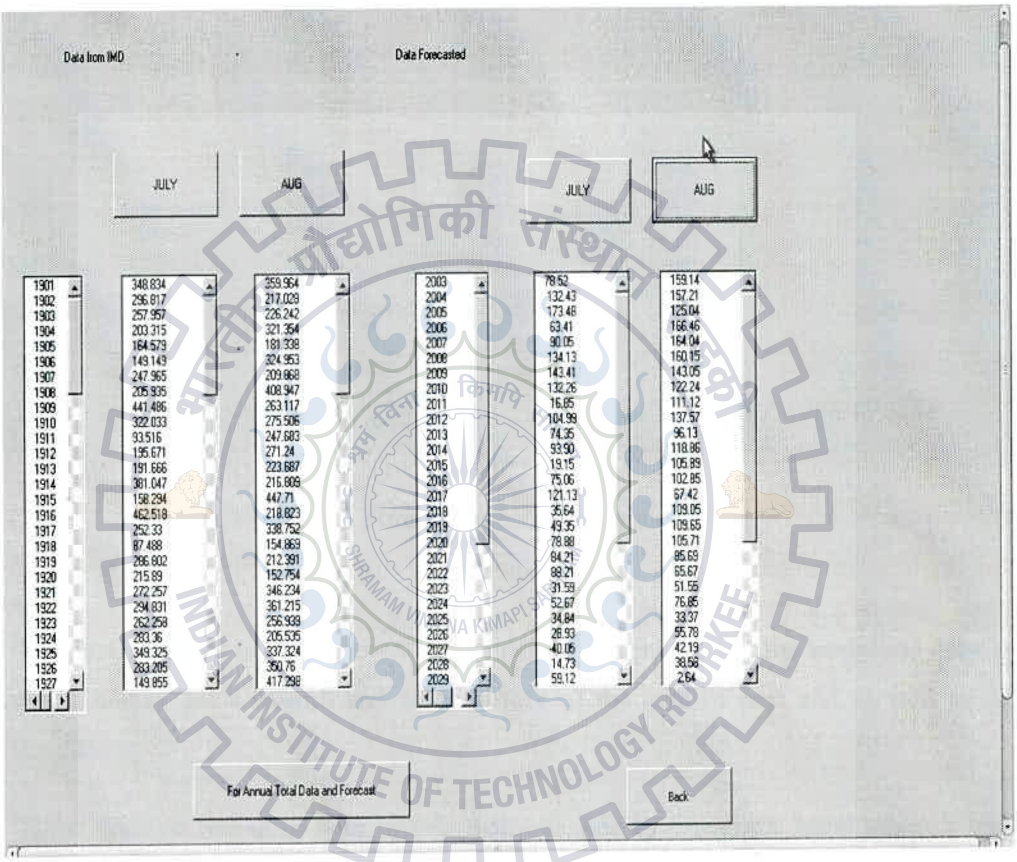


Figure 5-1 Forecast of July, August Precipitation Data

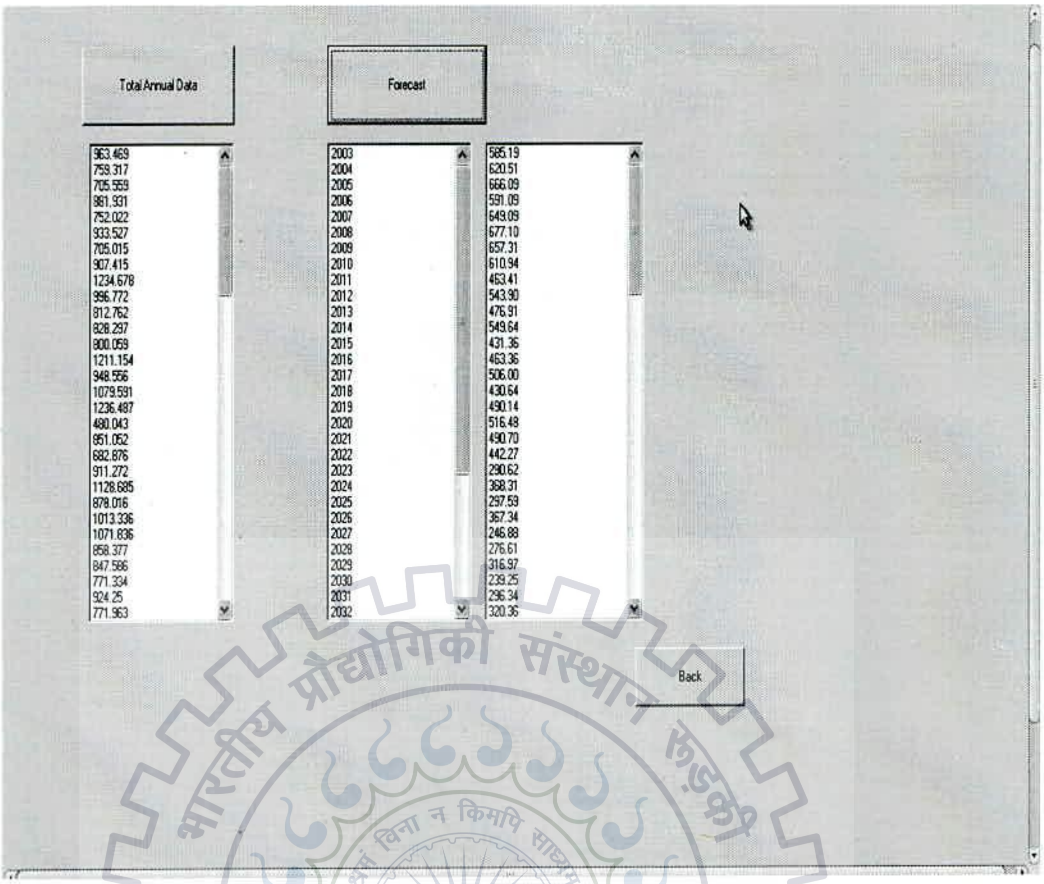


Figure 5-2 Forecast of total Precipitation

The past data was used to show the graphical representation of the analytical data in the model to get a overall and clear picture of the data of past and as well as of forecasted.

Trend analysis was done here by two methods, one by Quadratic trand analysis and other by ARIMA model trend analysis. The result of quadratic trend analysis showed a decline in the precipitation trend in the years as shown in Fig. 5-3 and 5-4. The trend equation used in the analysis is Yt = 233.3 + 1.93*t – 0.0188*t**2 of JULY and Yt = 263.5 + 0.249*t – 0.0388*t**2 for AUGUST.

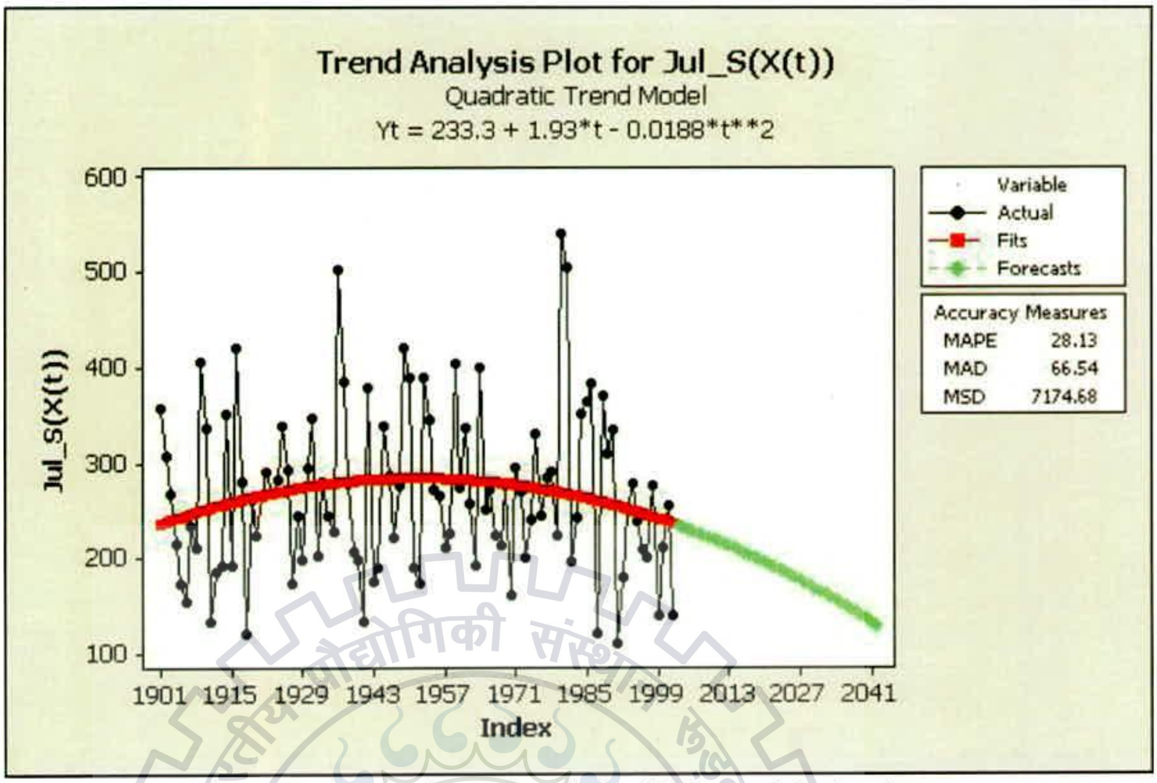


Figure 5-3 Quadratic trend analysis of July precipitation data

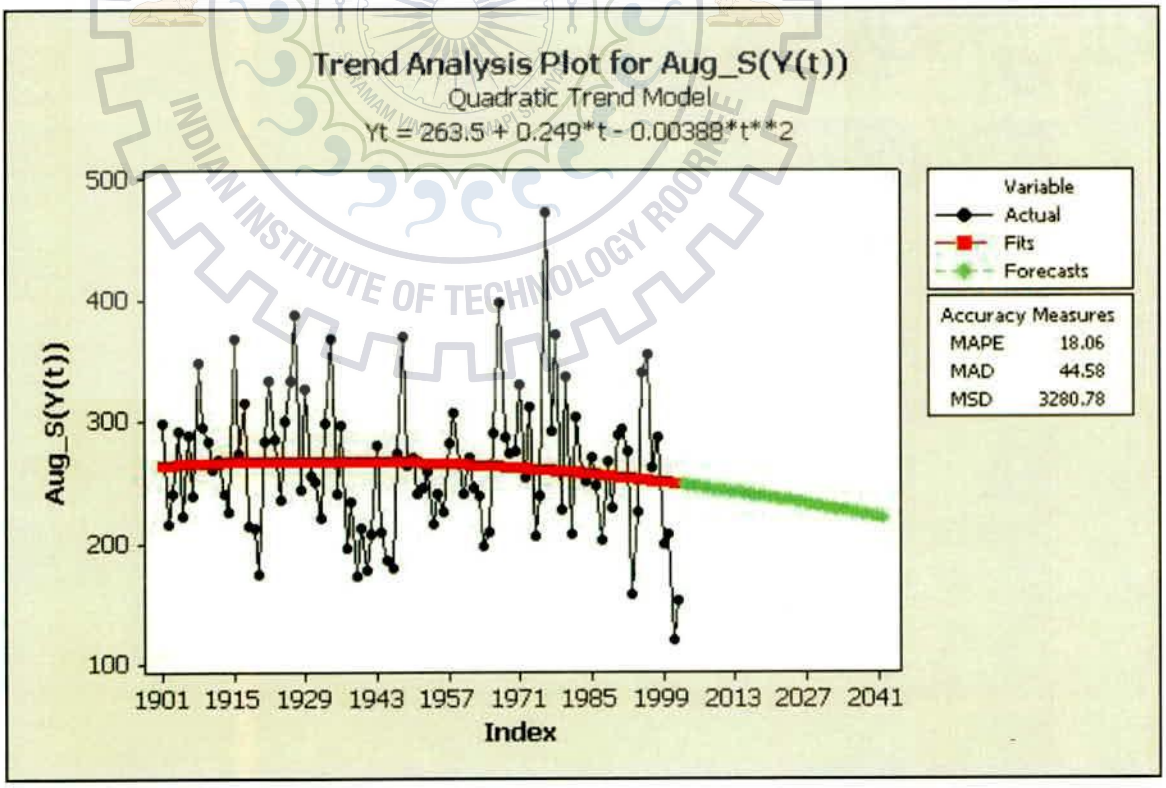


Figure 5-4 Quadratic trend analysis of August precipitation data

Quadratic trend analysis for the Total precipitation of Dehradun for these years to predict the scenario for the future years is done by the equation Yt = 861.2 + 2.36*t – 0.0251*t**2.

A decline is seen here also in the total rainfall of Dehradun over the years as shown in Fig. 5-5.

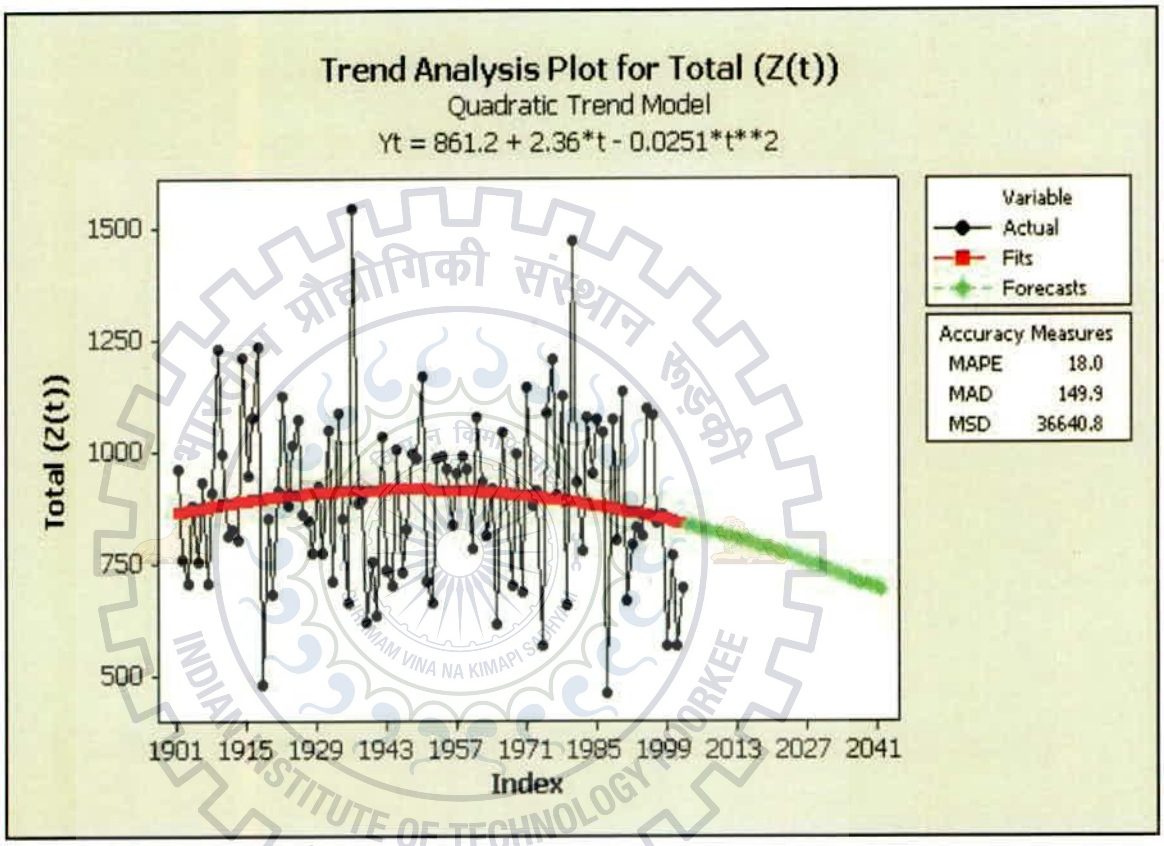


Figure 5-5 Quadratic trend analysis of total annual precipitation data

Now talking about the trend analysis done by the ARIMA model, which shows three trend lines (of 95% confidence limits) for Maximum, Minimum and Average likelyhood forecast of the difference of a data with previous data. Average forecast does not show a major decline but minute decline can be seen in July, August and Total precipitation. These are shown in the Fig. 5-6, 5-7 and 5-8.

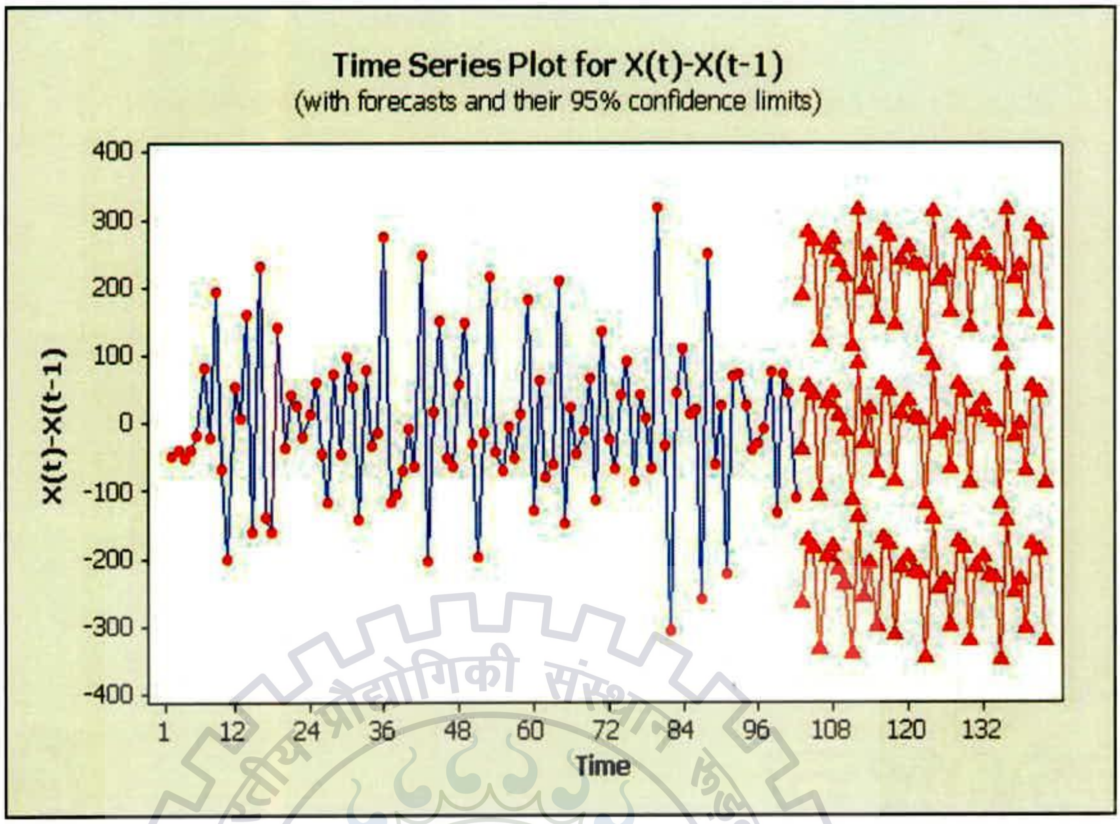


Figure 5-6 July ARIMA trend analysis

a) Coding of ARIMA for July precipitation

ARIMA Model: X(t)-X(t-1)

Final Estimates of Parameters

Type	Coef	SE Coef	T	P
SAR 12	-0.1860	0.1311	-1.42	0.160
SMA 12	0.8108	0.1162	6.98	0.000
Constant	-0.753	2.685	-0.28	0.780

Differencing: 0 regular, 1 seasonal of order 12

Number of observations: Original series 101, after differencing 89

Residuals: SS = 1153173 (backforecasts excluded)

MS = 13409 DF = 86

Modified Box-Pierce (Ljung-Box) Chi-Square statistic

Lag	12	24	36	48
Chi-Square	35.6	57.0	61.8	79.5
DF	9	21	33	45
P-Value	0.000	0.000	0.002	0.001

Forecasts from period 102

		95% Limits		
Period	**Forecast**	**Lower**	**Upper**	**Actual**
103	-39.687	-266.695	187.322	
104	53.914	-173.094	280.923	
105	41.054	-185.954	268.062	
106	-110.076	-337.084	116.933	
107	26.645	-200.363	253.653	
108	44.076	-182.932	271.084	
109	9.281	-217.727	236.289	
110	-11.154	-238.163	215.854	
111	-115.410	-342.418	111.598	
112	88.140	-138.868	315.148	
113	-30.632	-257.640	196.376	
114	19.548	-207.461	246.556	
115	-74.753	-301.762	152.256	
116	55.913	-171.097	282.922	
117	46.072	-180.937	273.082	
118	-85.489	-312.498	141.521	
119	13.703	-213.306	240.713	
120	29.535	-197.475	256.544	
121	5.327	-221.682	232.337	
122	3.999	-223.010	231.009	

123	-119.798	-346.807	107.211
124	84.263	-142.746	311.272
125	-17.829	-244.839	209.180
126	-5.915	-232.925	221.094
127	-68.983	-299.995	162.029
128	54.788	-176.224	285.800
129	44.386	-186.626	275.398
130	-90.815	-321.827	140.197
131	15.358	-215.654	246.370
132	31.486	-199.525	262.498
133	5.310	-225.702	236.322
134	0.428	-230.584	231.440
135	-119.735	-350.747	111.277
136	84.231	-146.781	315.243
137	-20.964	-251.976	210.048
138	-1.932	-232.944	229.080
139	-70.810	-304.456	162.837
140	54.244	-179.402	287.891
141	43.947	-189.700	277.593
142	-90.577	-324.224	143.069

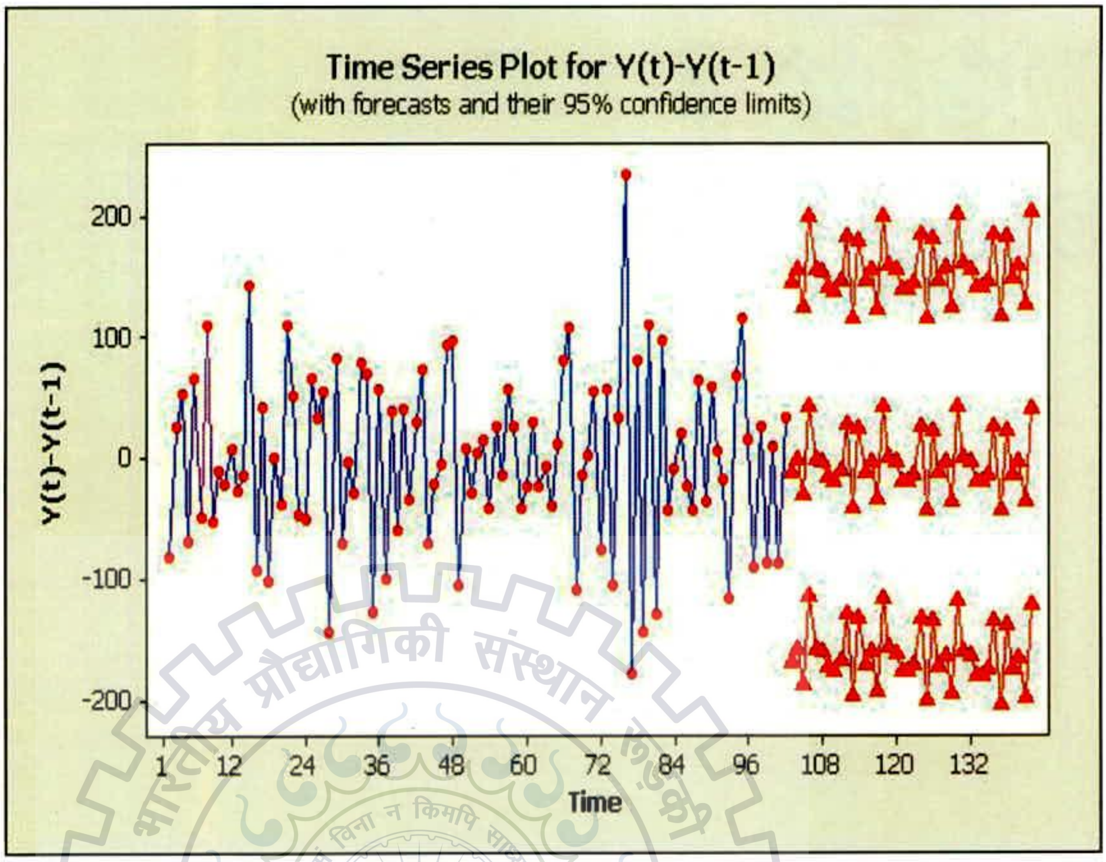


Figure 5-7 August ARIMA trend analysis

b) Coding of ARIMA Aug precipitation

ARIMA Model: Y(t)-Y(t-1)

Unable to reduce sum of squares any further

Final Estimates of Parameters

Type	Coef	SE Coef	T	P
SAR 12	-0.0309	0.1421	-0.22	0.828
SMA 12	0.8318	0.1156	7.20	0.000
Constant	-0.611	1.966	-0.31	0.757

Differencing: 0 regular, 1 seasonal of order 12

Number of observations: Original series 101, after differencing 89

Residuals: SS = 550846 (backforecasts excluded)

MS = 6405 DF = 86

Modified Box-Pierce (Ljung-Box) Chi-Square statistic

Lag	12	24	36	48
Chi-Square	46.7	64.2	80.3	113.1
DF	9	21	33	45
P-Value	0.000	0.000	0.000	0.000

Forecasts from period 102

		95% Limits		
Period	**Forecast**	**Lower**	**Upper**	**Actual**
103	-12.919	-169.814	143.976	
104	-1.935	-158.830	154.960	
105	-32.165	-189.060	124.731	
106	41.416	-115.480	198.311	
107	-2.419	-159.314	154.476	
108	-3.891	-160.786	153.004	
109	-17.093	-173.988	139.802	
110	-20.819	-177.714	136.076	
111	-11.117	-168.013	145.778	
112	26.456	-130.439	183.351	
113	-41.445	-198.340	115.450	
114	22.735	-134.160	179.630	
115	-12.978	-171.344	145.389	
116	-3.035	-161.402	155.332	
117	-35.432	-193.799	122.935	
118	41.629	-116.738	199.995	
119	0.604	-157.763	158.970	

120	-3.944	-162.311	154.423
121	-20.016	-178.383	138.350
122	-20.024	-178.391	138.343
123	-14.115	-172.482	144.252
124	25.303	-133.064	183.670
125	-43.484	-201.850	114.883
126	22.408	-135.958	180.775
127	-13.587	-174.030	146.856
128	-3.612	-164.055	156.831
129	-35.942	-196.385	124.501
130	41.011	-119.432	201.454
131	-0.101	-160.544	160.342
132	-4.554	-164.996	155.889
133	-20.537	-180.980	139.906
134	-20.660	-181.103	139.783
135	-14.633	-175.076	145.810
136	24.728	-135.715	185.170
137	-44.032	-204.474	116.411
138	21.807	-138.635	182.250
139	-14.179	-176.651	148.293
140	-4.205	-166.678	158.267
141	-36.537	-199.009	125.935
142	40.419	-122.053	202.891

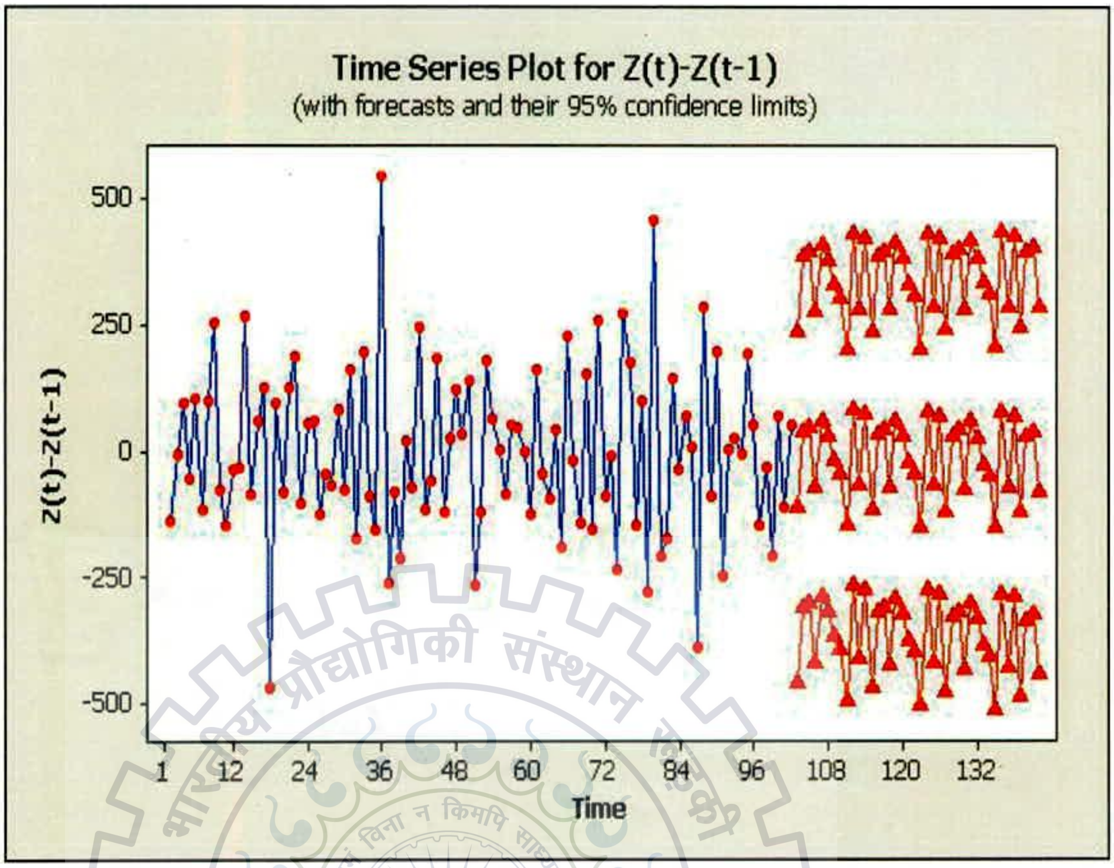


Figure 5-8 Total Precipitation ARIMA trend analysis

c) Coding of ARIMA Total precipitation

ARIMA Model: Z(t)-Z(t-1)

Final Estimates of Parameters

Type	Coef	SE Coef	T	P
SAR 12	-0.0286	0.1479	-0.19	0.847
SMA 12	0.8041	0.1310	6.14	0.000
Constant	-2.366	4.723	-0.50	0.618

Differencing: 0 regular, 1 seasonal of order 12

Number of observations: Original series 101, after differencing 89

Residuals: SS = 2707405 (backforecasts excluded)

MS = 31481 DF = 86

Modified Box-Pierce (Ljung-Box) Chi-Square statistic

Lag	12	24	36	48
Chi-Square	36.3	70.3	80.0	112.0
DF	9	21	33	45
P-Value	0.000	0.000	0.000	0.000

Forecasts from period 102

		95% Limits		
Period	**Forecast**	**Lower**	**Upper**	**Actual**
103	-111.951	-459.784	235.882	
104	35.325	-312.509	383.158	
105	45.572	-302.261	393.405	
106	-74.994	-422.827	272.840	
107	57.992	-289.841	405.825	
108	28.015	-319.818	375.848	
109	-19.793	-367.626	328.040	
110	-46.372	-394.205	301.461	
111	-147.523	-495.356	200.310	
112	80.483	-267.350	428.316	
113	-66.988	-414.821	280.845	
114	72.728	-275.105	420.561	
115	-118.280	-470.947	234.387	
116	32.004	-320.664	384.671	
117	42.640	-310.027	395.307	
118	-75.363	-428.030	277.304	
119	59.503	-293.164	412.170	
120	26.339	-326.328	379.006	

121	-25.778	-378.445	326.889
122	-48.430	-401.097	304.237
123	-151.655	-504.322	201.012
124	77.693	-274.974	430.360
125	-70.718	-423.385	281.949
126	69.750	-282.917	422.417
127	-120.465	-479.344	238.415
128	29.733	-329.147	388.612
129	40.358	-318.522	399.237
130	-77.718	-436.597	281.161
131	57.094	-301.785	415.973
132	24.021	-334.858	382.900
133	-27.973	-386.852	330.907
134	-50.737	-409.617	308.142
135	-153.902	-512.781	204.977
136	75.406	-283.473	434.286
137	-72.977	-431.856	285.902
138	67.469	-291.410	426.348
139	-122.768	-487.710	242.174
140	27.432	-337.511	392.374
141	38.057	-326.885	402.999
142	-80.017	-444.959	284.926

5.3 ANALYSIS FOR TEMPERATURE

Temperature data for the last 100 years was taken from India Meteorological Department (IMD). This was average monthly data for these years which was used as the time series to forecast the precipitation of the upcoming years. Auto Regressive Integrated Moving Average (ARIMA) model is used to predict the temperature data of the desired years. These predicted data is transferred in an excel file from where it is connected to DSS model on Visual Basic 6.0 platform. The prediction was done for the average temperature of the year and for temperature of July and August (these two months were taken in the precipitation forecasted data). The DSS model can show the graphical data to analyze the situation, which was till now and what the situation is going to be.

The past data was used to show the graphical representation of the analytical data in the model to get a overall and clear picture of the data of past and as well as of forecasted.

Here also the trend analysis was done by two methods, one by Quadratic trand analysis and other by ARIMA model trend analysis. The result of quadratic trend analysis showed a little rise in the temperature trend of July and August but a major rise is seen in the trend of Average annual temperature, in the years as shown in Fig. 5-9, 5-10 and 5-11. The trend equation used in the analysis is $Yt = 34.489 - 0.01321*t - 0.000067*t**2$ of JULY , $Yt = 263.5 + 0.249*t - 0.0388*t**2$ for AUGUST and for annual average is $Yt = 30.182 + 0.00424*t - 0.000009*t**2$.

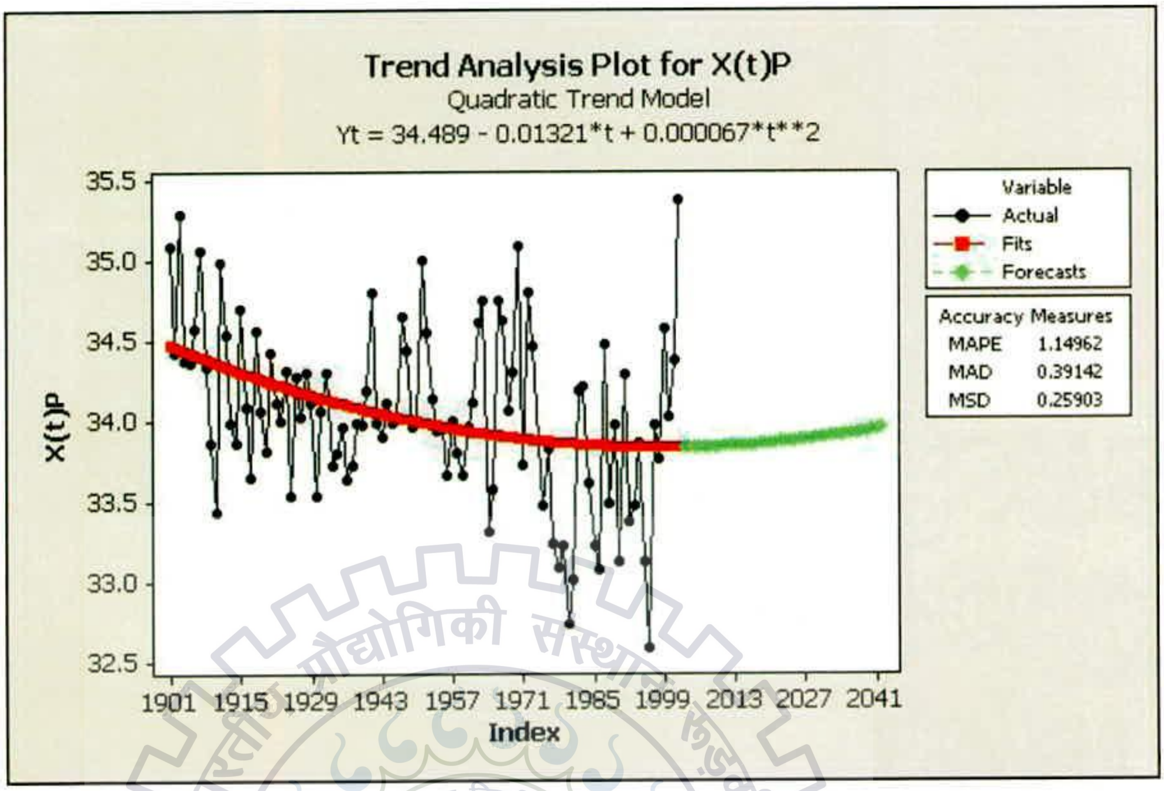


Figure 5-9 Quadratic trend analysis of July temperature data

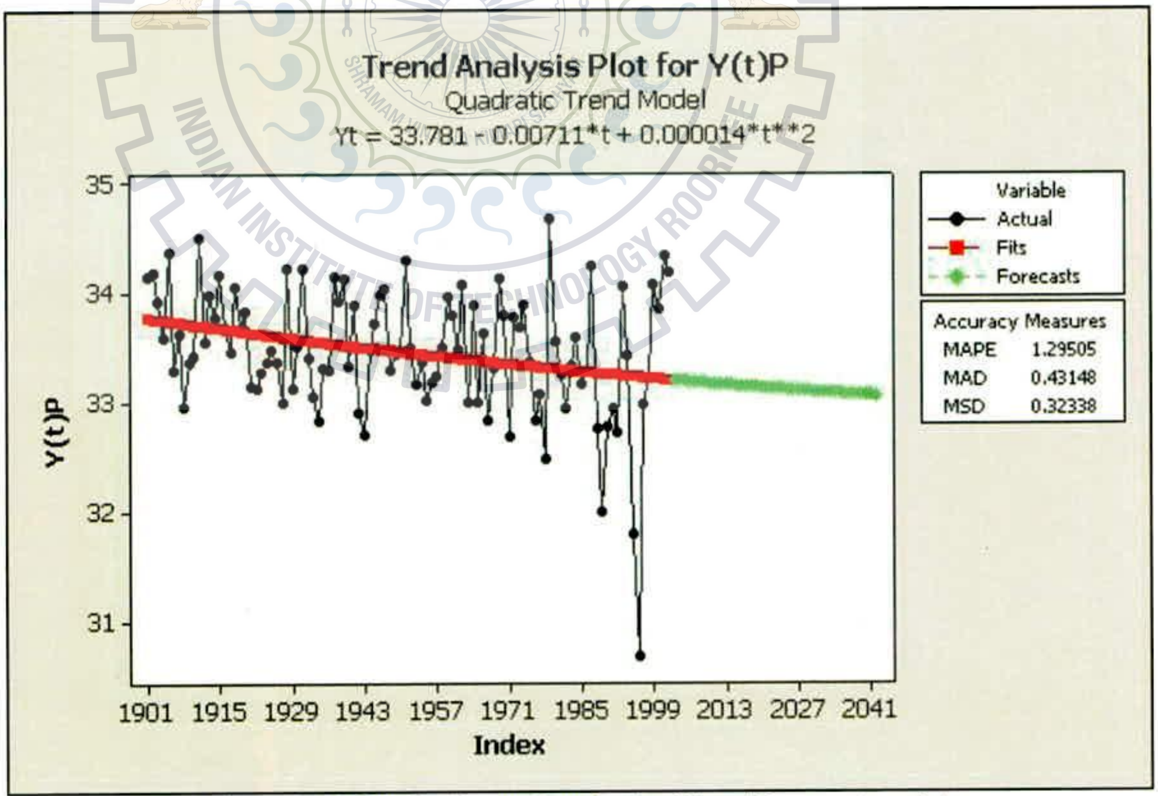


Figure 5-10 Quadratic trend analysis of Aug Temperature data

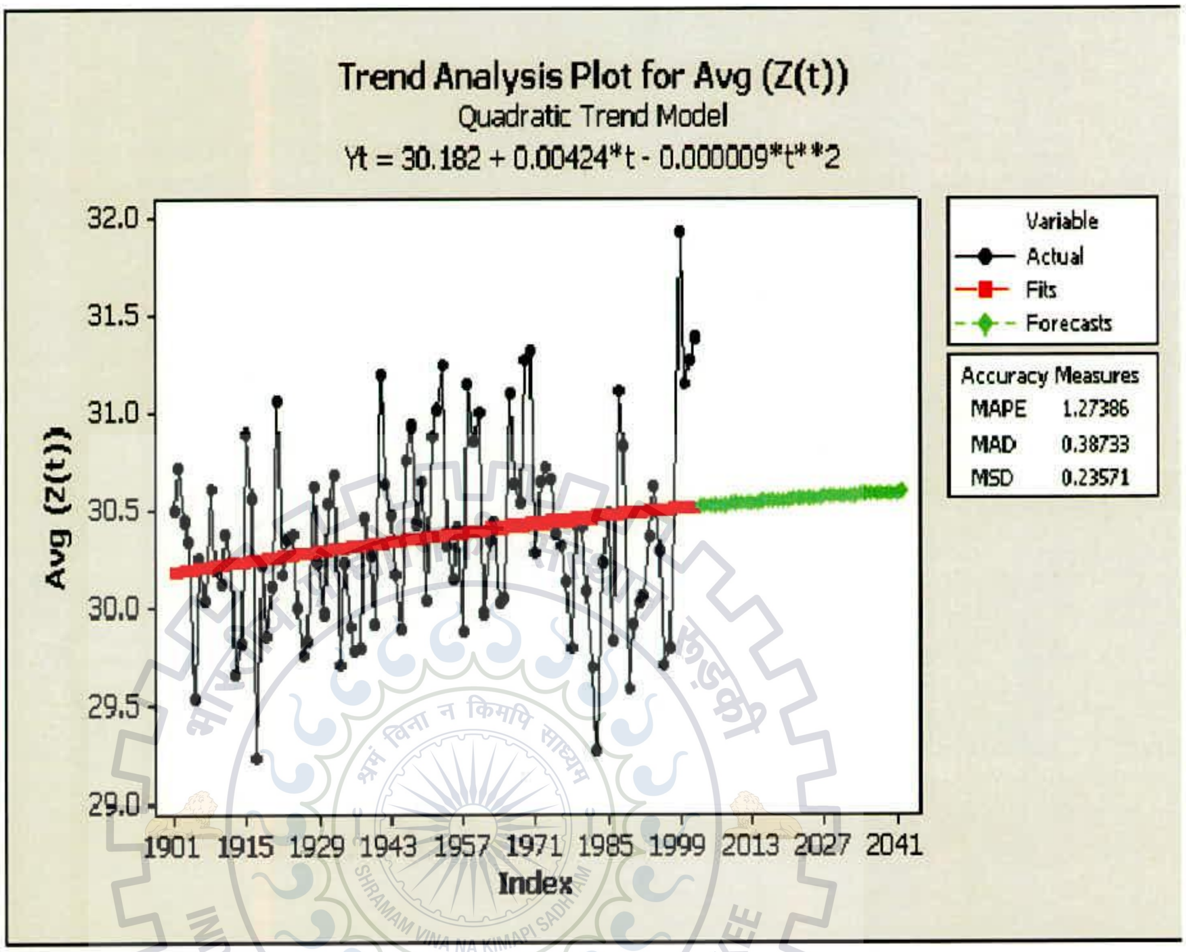


Figure 5-11 Quadratic trend analysis of annual average Temperature data

Now talking about the trend analysis done by the ARIMA model, which shows three trend lines (of 95% confidence limits) for Maximum, Minimum and Average likelyhood forecast of the difference of a data with previous data. Average forecast show a good decline but minute decline can be seen in July, August and in Average Annual temperature. These are shown in the Fig. 5-12, 5-13 and 5-14.

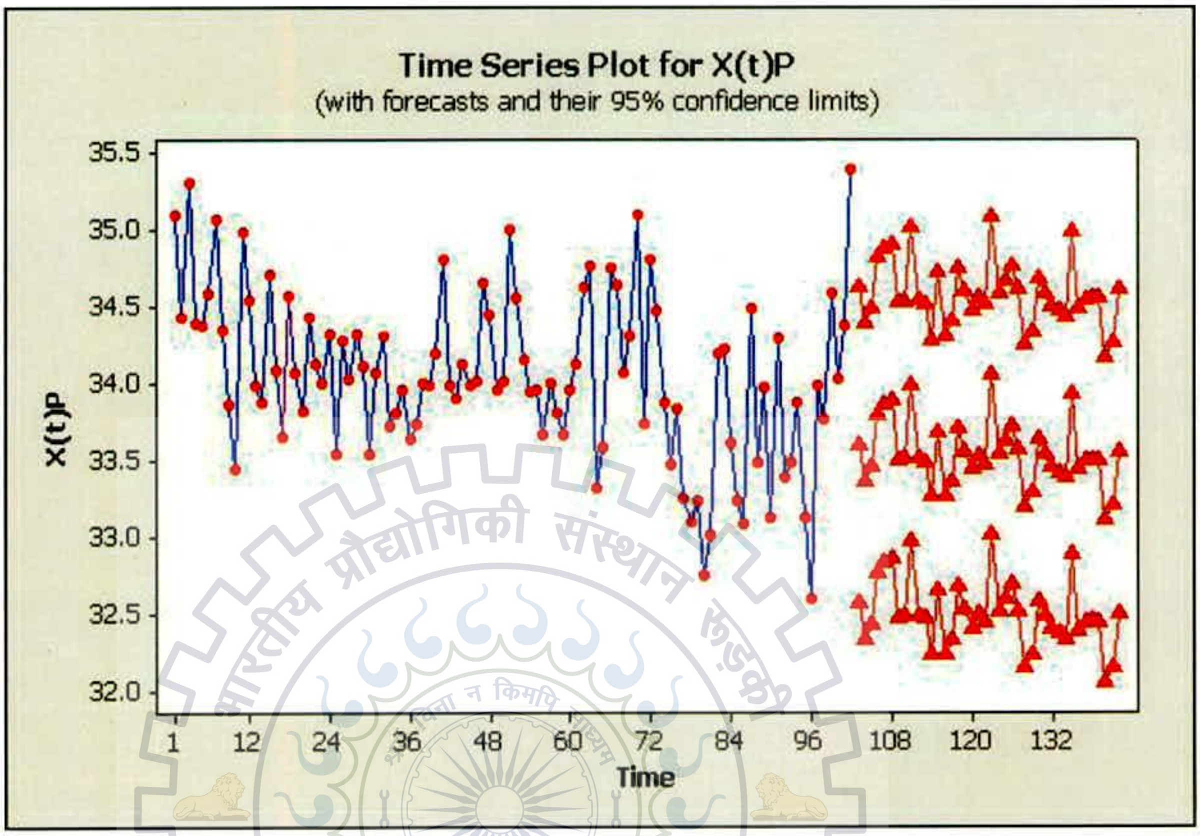


Figure 5-12 July ARIMA Temperature

a) Coding of ARIMA July Temperature

ARIMA Model: X(t)-X(t-1)

Unable to reduce sum of squares any further

Final Estimates of Parameters

Type	Coef	SE Coef	T	P
SAR 12	-0.1477	0.1334	-1.11	0.271
SMA 12	0.8452	0.1100	7.69	0.000
Constant	0.01838	0.01486	1.24	0.219

Differencing: 0 regular, 1 seasonal of order 12

Number of observations: Original series 101, after differencing 89

Residuals: SS = 32.4833 (backforecasts excluded)

MS = 0.3777 DF = 86

Modified Box-Pierce (Ljung-Box) Chi-Square statistic

Lag	12	24	36	48
Chi-Square	29.1	47.6	65.9	79.4
DF	9	21	33	45
P-Value	0.001	0.001	0.001	0.001

Forecasts from period 102

		95% Limits		
Period	**Forecast**	**Lower**	**Upper**	**Actual**
103	0.15383	-1.05099	1.35866	
104	-0.23905	-1.44388	0.96578	
105	0.16164	-1.04318	1.36647	
106	0.41261	-0.79221	1.61744	
107	0.06028	-1.14454	1.26511	
108	0.03452	-1.17030	1.23935	
109	-0.21300	-1.41783	0.99182	
110	0.05375	-1.15107	1.25858	
111	0.60203	-0.60280	1.80685	
112	-0.42263	-1.62745	0.78220	
113	0.09749	-1.10734	1.30232	
114	-0.03601	-1.24084	1.16881	
115	0.32251	-0.88235	1.52736	
116	-0.31996	-1.52482	0.88490	
117	0.17115	-1.03371	1.37601	
118	0.42698	-0.77788	1.63183	
119	-0.04079	-1.24565	1.16407	

120	-0.03035	-1.23521	1.17450
121	0.04262	-1.16224	1.24747
122	0.03203	-1.17282	1.23689
123	0.65117	-0.55368	1.85603
124	-0.42342	-1.62828	0.78144
125	0.15380	-1.05106	1.35866
126	0.13624	-1.06861	1.34110
127	0.31599	-0.90303	1.53500
128	-0.28963	-1.50864	0.92939
129	0.18813	-1.03088	1.40715
130	0.44324	-0.77577	1.66226
131	-0.00748	-1.22650	1.21153
132	-0.00239	-1.22140	1.21663
133	0.02326	-1.19576	1.24227
134	0.05363	-1.16539	1.27264
135	0.66230	-0.55671	1.88132
136	-0.40492	-1.62393	0.81409
137	0.16387	-1.05515	1.38288
138	0.12919	-1.08982	1.34821
139	0.33533	-0.89403	1.56469
140	-0.27572	-1.50508	0.95364
141	0.20401	-1.02535	1.43337
142	0.45922	-0.77014	1.68859

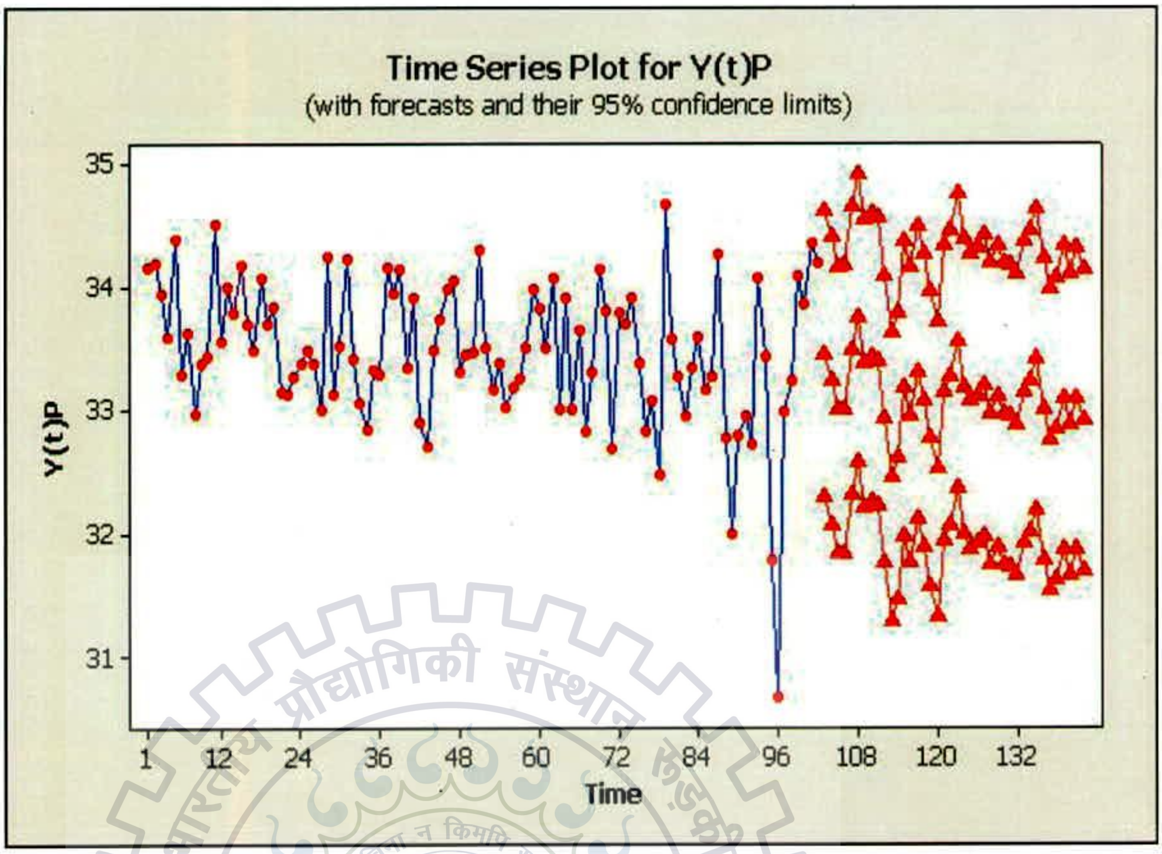


Figure 5-13 Aug ARIMA Temperature

b) Coding of ARIMA July Temperature

ARIMA Model: Y(t)-Y(T-1)

Unable to reduce sum of squares any further

Final Estimates of Parameters

Type	Coef	SE Coef	T	P
SAR 12	-0.3849	0.1280	-3.01	0.003
SMA 12	0.8227	0.1133	7.26	0.000
Constant	0.01242	0.01603	0.77	0.440

Differencing: 0 regular, 1 seasonal of order 12

Number of observations: Original series 101, after differencing 89

Residuals: SS = 45.5572 (backforecasts excluded)

MS = 0.5297 DF = 86

Modified Box-Pierce (Ljung-Box) Chi-Square statistic

Lag	12	24	36	48
Chi-Square	31.0	49.1	71.0	86.5
DF	9	21	33	45
P-Value	0.000	0.000	0.000	0.000

Forecasts from period 102

95% Limits

Period	**Forecast**	**Lower**	**Upper**	**Actual**
103	0.48901	-0.93782	1.91585	
104	-0.15368	-1.58052	1.27315	
105	-0.17712	-1.60395	1.24971	
106	0.05881	-1.36802	1.48564	
107	0.50521	-0.92162	1.93204	
108	0.31661	-1.11022	1.74344	
109	-0.37084	-1.79767	1.05600	
110	0.10999	-1.31684	1.53682	
111	-0.00526	-1.43210	1.42157	
112	-0.41366	-1.84049	1.01318	
113	-0.41660	-1.84343	1.01023	
114	0.20560	-1.22123	1.63243	
115	0.37473	-1.08252	1.83198	
116	-0.16818	-1.62542	1.28907	
117	0.42339	-1.03385	1.88064	
118	-0.20015	-1.65740	1.25710	
119	-0.30772	-1.76496	1.14953	
120	-0.22024	-1.67749	1.23701	

121	0.67250	-0.78475	2.12975
122	0.17338	-1.28387	1.63063
123	0.33569	-1.12156	1.79294
124	-0.32393	-1.78118	1.13331
125	-0.05632	-1.51357	1.40093
126	0.08045	-1.37680	1.53769
127	0.43114	-1.07162	1.93390
128	-0.15017	-1.65293	1.35258
129	0.20467	-1.29808	1.70743
130	-0.08805	-1.59081	1.41471
131	0.01761	-1.48515	1.52037
132	-0.00118	-1.50394	1.50158
133	0.28333	-1.21943	1.78609
134	0.16140	-1.34135	1.66416
135	0.21688	-1.28588	1.71963
136	-0.34605	-1.84880	1.15671
137	-0.18257	-1.68533	1.32018
138	0.14104	-1.36172	1.64380
139	0.42185	-1.08506	1.92876
140	-0.14468	-1.65159	1.36223
141	0.30128	-1.20562	1.80819
142	-0.11877	-1.62568	1.38813

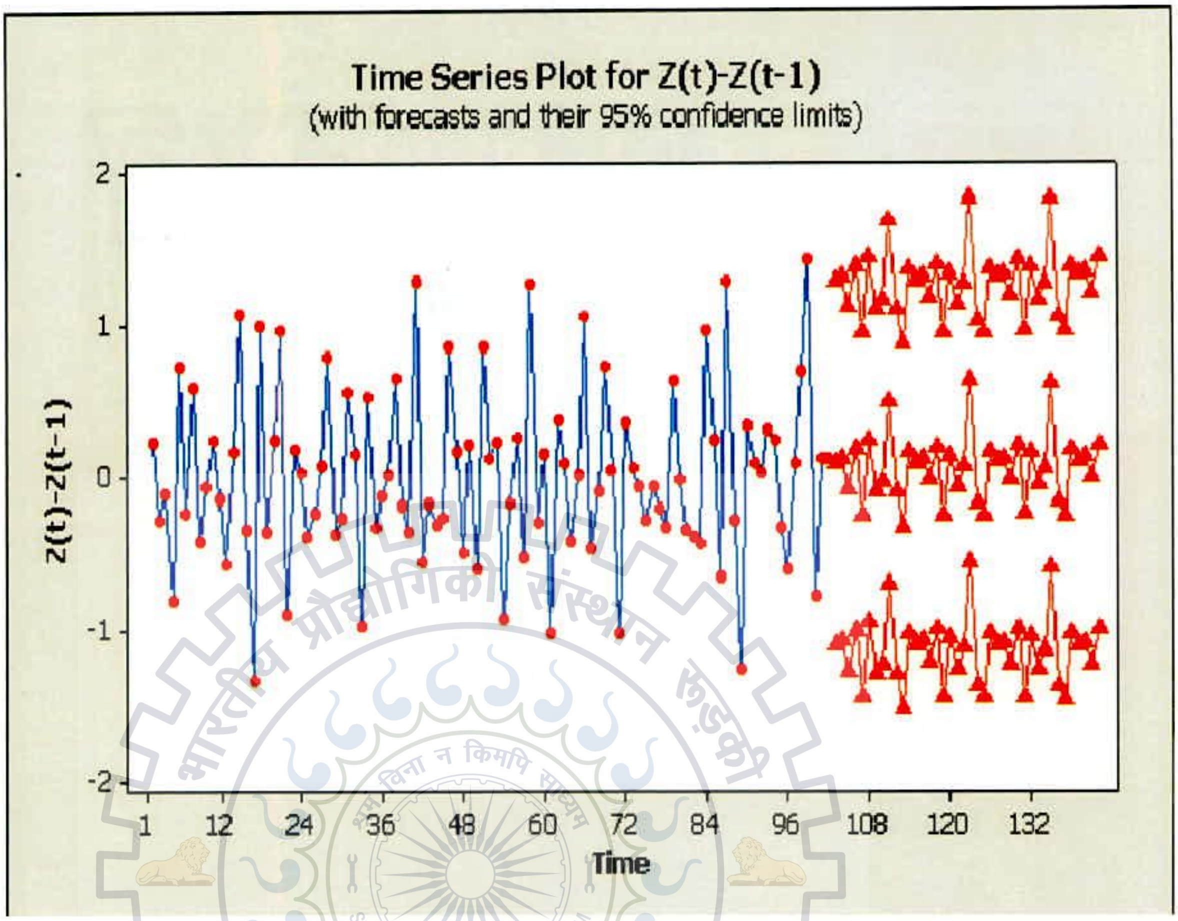


Figure 5-14 ARIMA Annual average Temperature

c) Coding of ARIMA July Temperature

ARIMA Model: Z(t)-Z(t-1)

Final Estimates of Parameters

Type	Coef	SE Coef	T	P
SAR 12	-0.1376	0.1285	-1.07	0.287
SMA 12	0.8434	0.1009	8.36	0.000
Constant	0.01001	0.01532	0.65	0.515

Differencing: 0 regular, 1 seasonal of order 12

Number of observations: Original series 101, after differencing 89

Residuals: SS = 31.9994 (backforecasts excluded)

MS = 0.3721 DF = 86

Modified Box-Pierce (Ljung-Box) Chi-Square statistic

Lag	12	24	36	48
Chi-Square	21.0	29.0	49.3	58.3
DF	9	21	33	45
P-Value	0.012	0.115	0.034	0.089

Forecasts from period 102

		95% Limits		
Period	**Forecast**	**Lower**	**Upper**	**Actual**
103	0.08851	-1.10731	1.28433	
104	0.11998	-1.07584	1.31580	
105	-0.07792	-1.27374	1.11790	
106	0.18638	-1.00944	1.38220	
107	-0.24837	-1.44419	0.94744	
108	0.25225	-0.94357	1.44807	
109	-0.09149	-1.28731	1.10433	
110	-0.03676	-1.23258	1.15906	
111	0.49699	-0.69883	1.69281	
112	-0.08947	-1.28529	1.10635	
113	-0.32259	-1.51841	0.87323	
114	0.16767	-1.02815	1.36349	
115	0.09871	-1.09733	1.29475	
116	0.11863	-1.07741	1.31466	
117	-0.01342	-1.20946	1.18261	
118	0.20580	-0.99023	1.40184	
119	-0.24887	-1.44490	0.94717	
120	0.14514	-1.05090	1.34117	

121	-0.05647	-1.25251	1.13956
122	0.07477	-1.12126	1.27081
123	0.63593	-0.56011	1.83196
124	-0.17412	-1.37016	1.02192
125	-0.25166	-1.44770	0.94437
126	0.17131	-1.02472	1.36735
127	0.10731	-1.10282	1.31745
128	0.12882	-1.08132	1.33895
129	-0.01229	-1.22243	1.19784
130	0.21314	-0.99700	1.42327
131	-0.23879	-1.44893	0.97134
132	0.16988	-1.04025	1.38002
133	-0.05128	-1.26142	1.15885
134	0.06943	-1.14070	1.27957
135	0.62682	-0.58332	1.83695
136	-0.15246	-1.36260	1.05767
137	-0.25142	-1.46155	0.95872
138	0.18082	-1.02932	1.39095
139	0.11614	-1.10479	1.33706
140	0.13742	-1.08350	1.35835
141	-0.00244	-1.22337	1.21849
142	0.22214	-0.99879	1.44306

5.4 CONCLUDING REMARKS

A plot was made between precipitation and temperature data (data = data – previous year data) as time series data of previous 100 years (1901 to 2002). From the fig. 5-15, it can be easily seen that the difference in temperature is tending positive while the difference in precipitation is tending to decrease gradually. So one can say that these two subjects are related to each other in a way that when the temperature is increasing, the precipitation is starts to decrease.

It has been seen 0.47*C increase in temperature during the 41 years period (1967-2007)(O.V. Singh, 2010). An increase of 0.12*C in temperature can be seen in every decade which is four times more than the global increase of temperature.(O.V. Singh, 2010) .

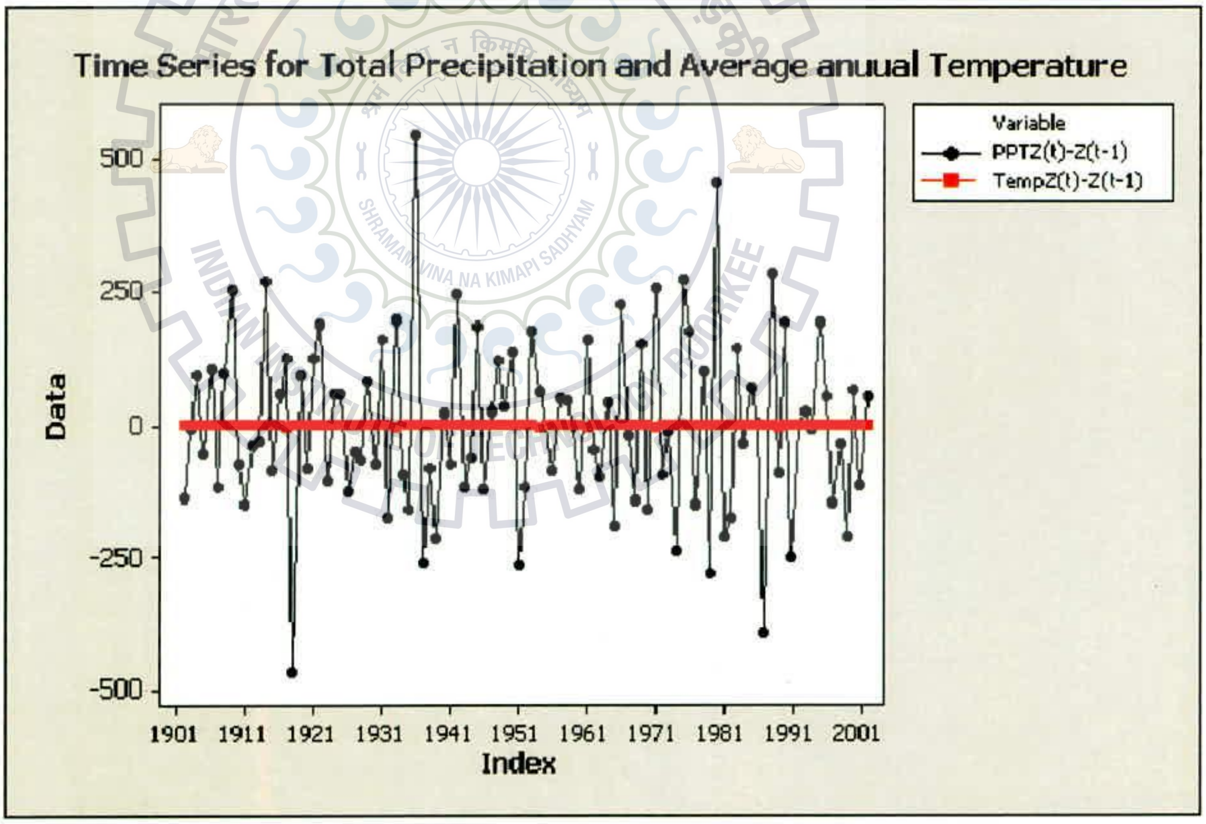


Figure 5-15 Average annual temperature Vs Total annual Precipitation

Chapter 6: **LANDUSE AND LANDCOVER ANALYSIS**

6.1 INTRODUCTION

Land use/Land cover change information has an important role to play at local and regional as well as at macro level planning. The planning and management task is hampered due to insufficient information on rates of land-cover/land-use change. The land-cover changes occur naturally in a progressive and gradual way, howeversometimes it may be rapid. The growing population and human activities are increasing the pressure on the limited land and soil resources for food, energy and several other needs. As the population increases particularly in the urban areas by attracting job opportunities and city spreads outward from its limit, encroachment on the surrounding available land starts. Due to increasing number of population, agricultural land starts converting into built up area and forest areas starts converting into agricultural land, built up etc. Thus, spatial and temporal analysis technologies are very useful in generating scientifically based statistical spatial data for understanding the land ecosystem dynamics.

So for finding out the Land-use/ Land-cover pattern, LANDSAT satellite data is taken from the www.glcf.umd.edu and this data was classified over the platform GIS to retrieve the desired data.

6.2 LANDUSE AND LANDCOVER PATTERN

The satellite LANDSAT data was taken from the www.glcf.umd.edu site for the years 1990, 2000, 2005 and 2011. The data was of the larger area in which the Dehradun district was a part of it. The desired area of interest was Dehradun district and Dhradun city. So the subset of satellite image was made with the help of ERDAS IMAGINE 9.1 for the both desired area of interest.

These subset were signatured with different attributes of Landcover to classify the different landuse pattern of the area of interest over the years. Finally the classified image was attached with the DSS model. Raw and classified image of the subsequent years are shown in the Fig. 6-1, 6-2, 6-3, 6-4 and 6-5

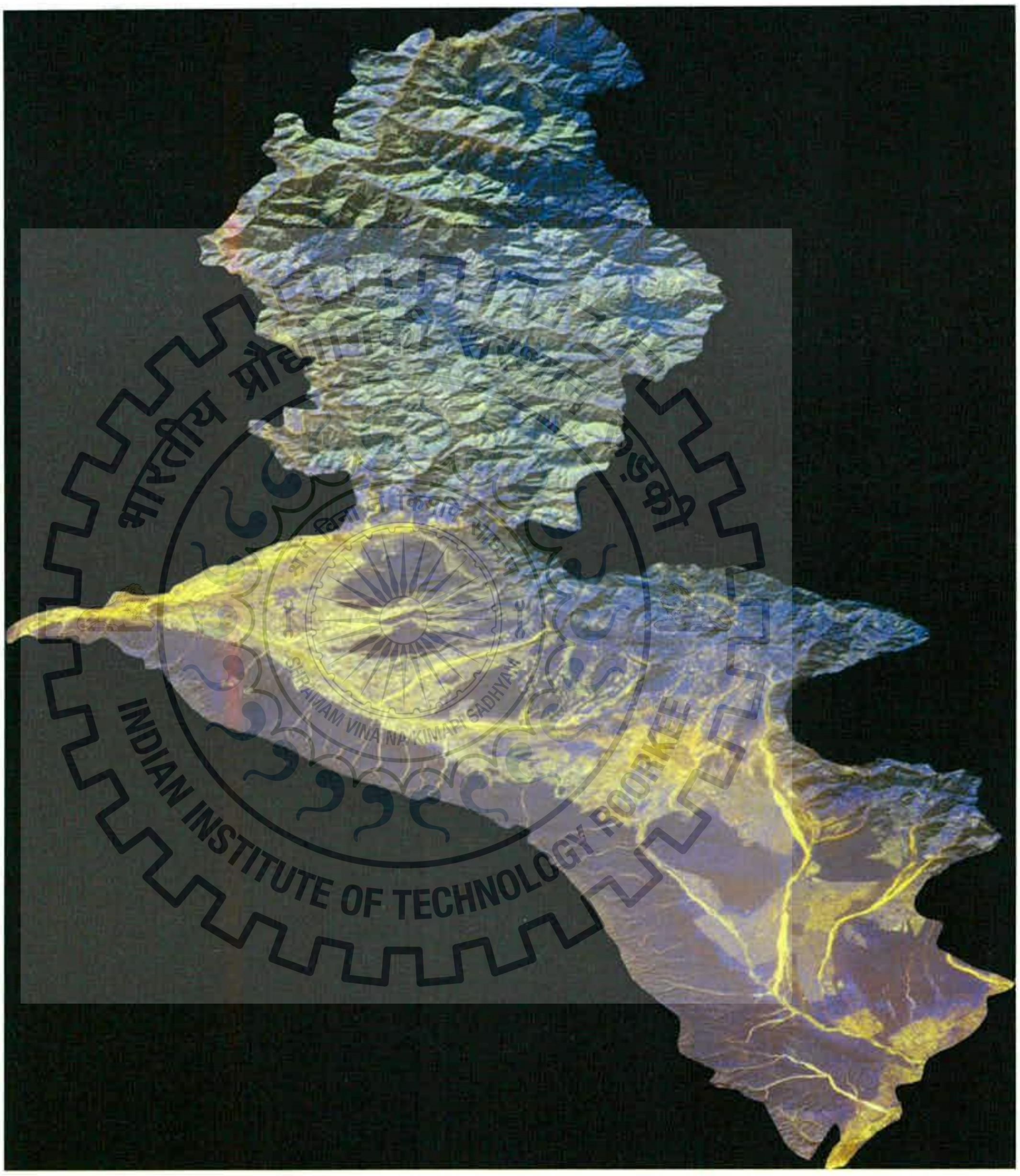


Figure 6-1 Raw image of Dehradun District subset

Figure 6-2 Classified Image of Dehradun district 1990

Bulit Up Area	Water body
Forest Land	River Bed/Barren Land
Agricultural Area	Forest Mountain

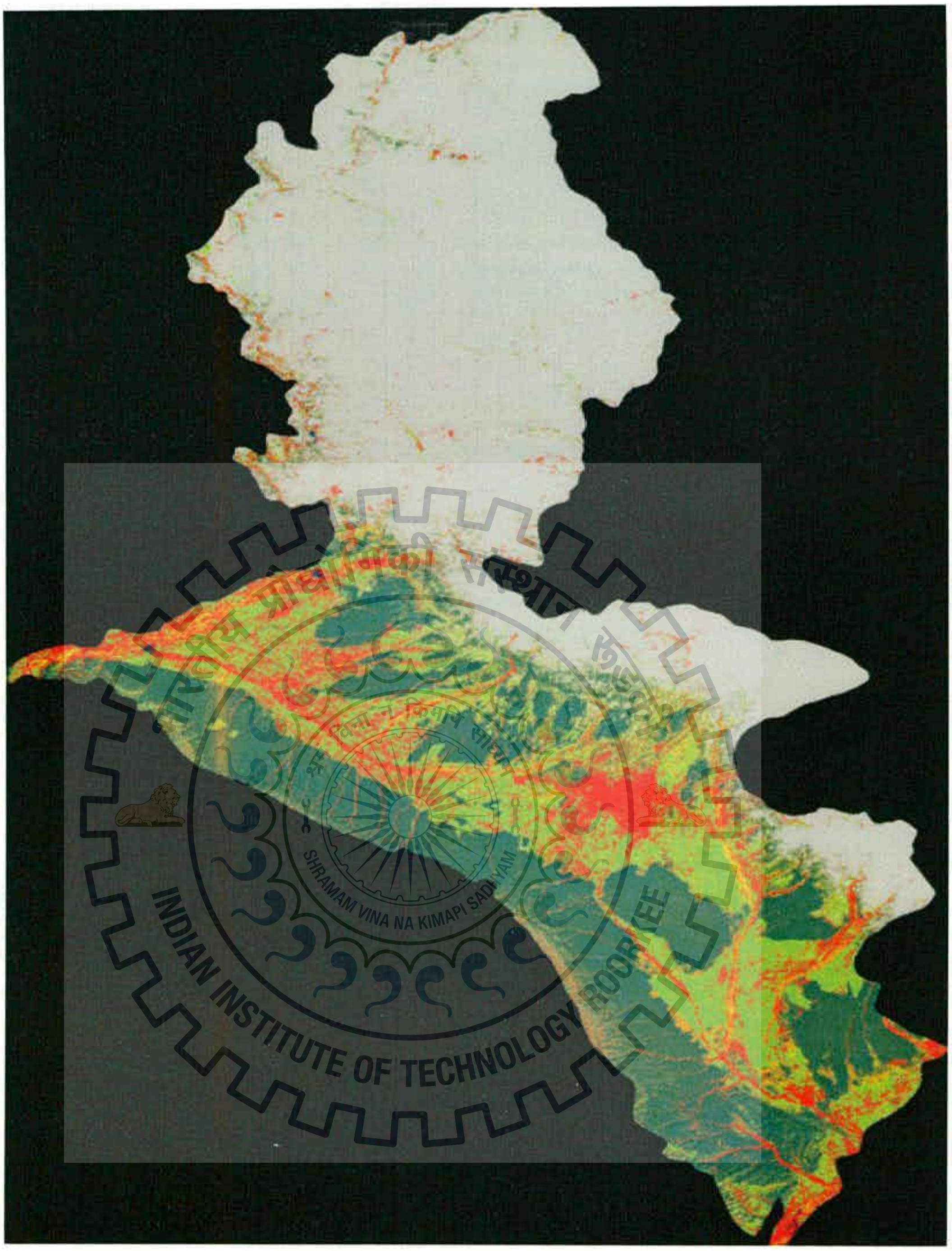


Figure 6-3 Classified Image of Dehradun district 2000

Bulit Up Area	Water body
Forest Land	River Bed/Barren Land
Agricultural Area	Forest Mountain

Figure 6-4 Classified Image of dehradun district 2005

Bulit Up Area	Water body
Forest Land	River Bed/Barren Land
Agricultural Area	Forest Mountain

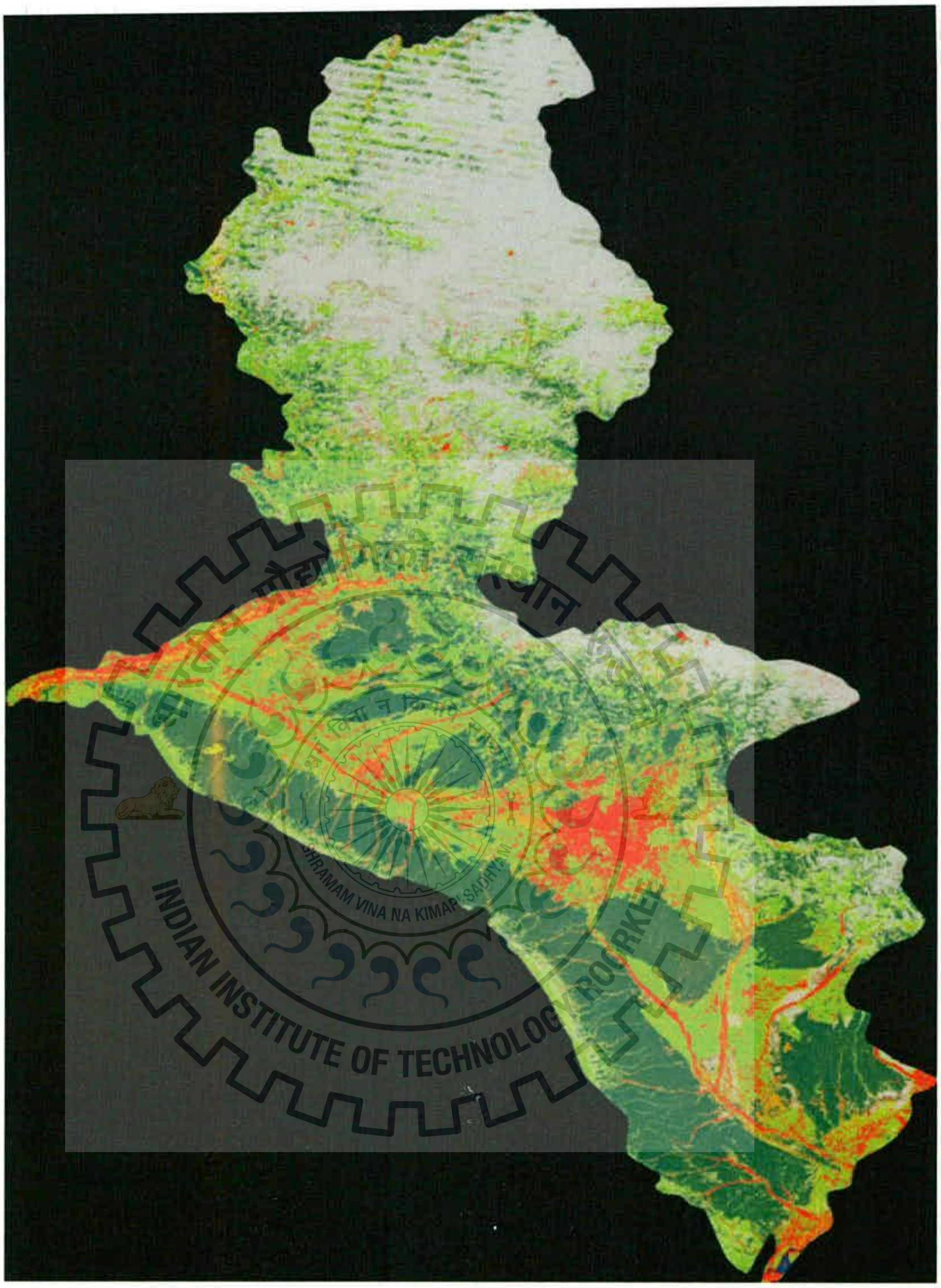


Figure 6-5 Classified Image of dehradun district 2011

Bulit Up Area

Forest Land

Agricultural Area

Water body

River Bed/Barren Land

Forest Mountain

Classified image data is made out in analytical form and shown below in tabular form in table 6-1. Built Up area in the district increased from 188.34 SqKm(6.28%) in 1990 to 205.44 SqKm (6.85%) in 2000 and reaches to 213.39 SqKm (7.11%) in 2005 which further increase upto 258.27 SqKm (8.61%) in 2011. Whereas if we see the Forest Plain, Aagricultural Land and Forest Mountain are all decreasing from 1990 to 2011.

Table 6-1 LU/LC of Dehradun district

	1990		2000		2005		2011	
LU/LC	%	Area(SqKm)	%	Area(SqKm)	%	Area(SqKm)	%	Area(SqKm)
Forest Plain	23.37	701.24	22.54	676.31	22.53	675.87	21.83	654.83
Agricultural Land	16.75	502.37	15.89	476.68	15.47	464.15	14.92	447.56
Water Body	0.42	12.60	0.44	13.20	0.41	12.30	0.44	13.20
River Bed/Barren Land	1.70	51.06	2.42	72.48	3.23	97.05	3.00	89.92
Built Up	6.28	188.34	6.85	205.44	7.11	213.39	8.61	258.27
Forest Mountain	51.48	1544.39	51.86	1555.89	51.32	1539.54	51.21	1536.22
TOTAL		3000.00		3000.00		3002.30		3000.00
Area of District(SqKm)	3000							

To analyze the data in graphical way, this data is plotted on a graph as shown in Fig. 6-6. On the ordinate axis is percentage of different landcover and on abscissa the subsequent year. Different Landcover has been given different colour to make out the difference easily. By graph we can easily make out that the light blue colour line of Built up area is increasing rapidly while forest plain, forest mountain and agricultural land, all are decreasing but gradually. Barren land increased rapidly from late 1990s to 2005 as the other landcover like agricultural land, forest land were in process to become built up area and after that is started to decrease as the land was covered by building commercial and domestic buildings.

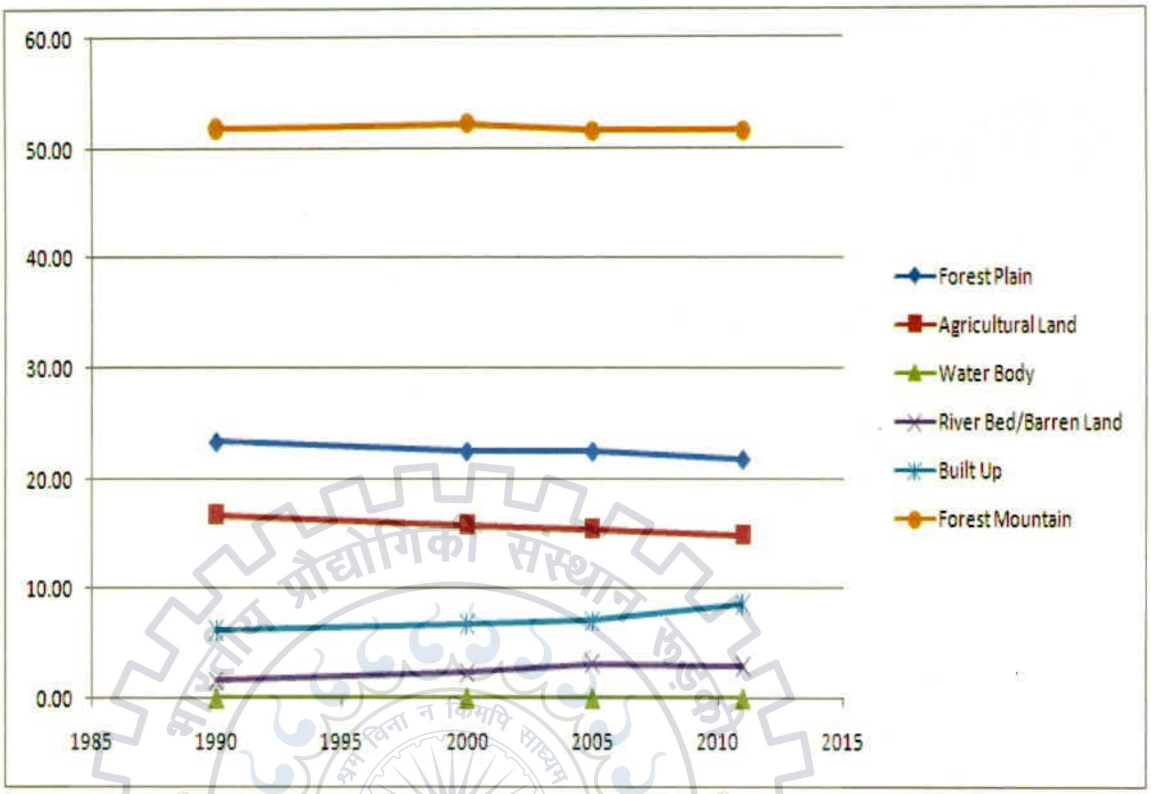


Figure 6-6 Plot between different LC percentage and time

The same procedure was followed to find out the land cover pattern of the Dehradun city, and in the same a table and a graph is made to help in understanding the situation of the study area. The image for the city is made from the subset raw image of Dehradun by cutting into desired area. Then these images were classified in different land cover pattern for the subsequent year as shown in the Fig. 6-7, 6-8 and 6-9 .

Different colours are used for different signature in the classification and the their subsequent colour details are given below of every figure as shown.

By the figures one can easily say that the land use pattern has changed drastically as Vegetation cover, Agricultural land has decreased and converted into fallow land upto year 2000 approximately and then this fallow land was used to make it into built up area of the city or near the city. Analytical data is given in the table 6-2.

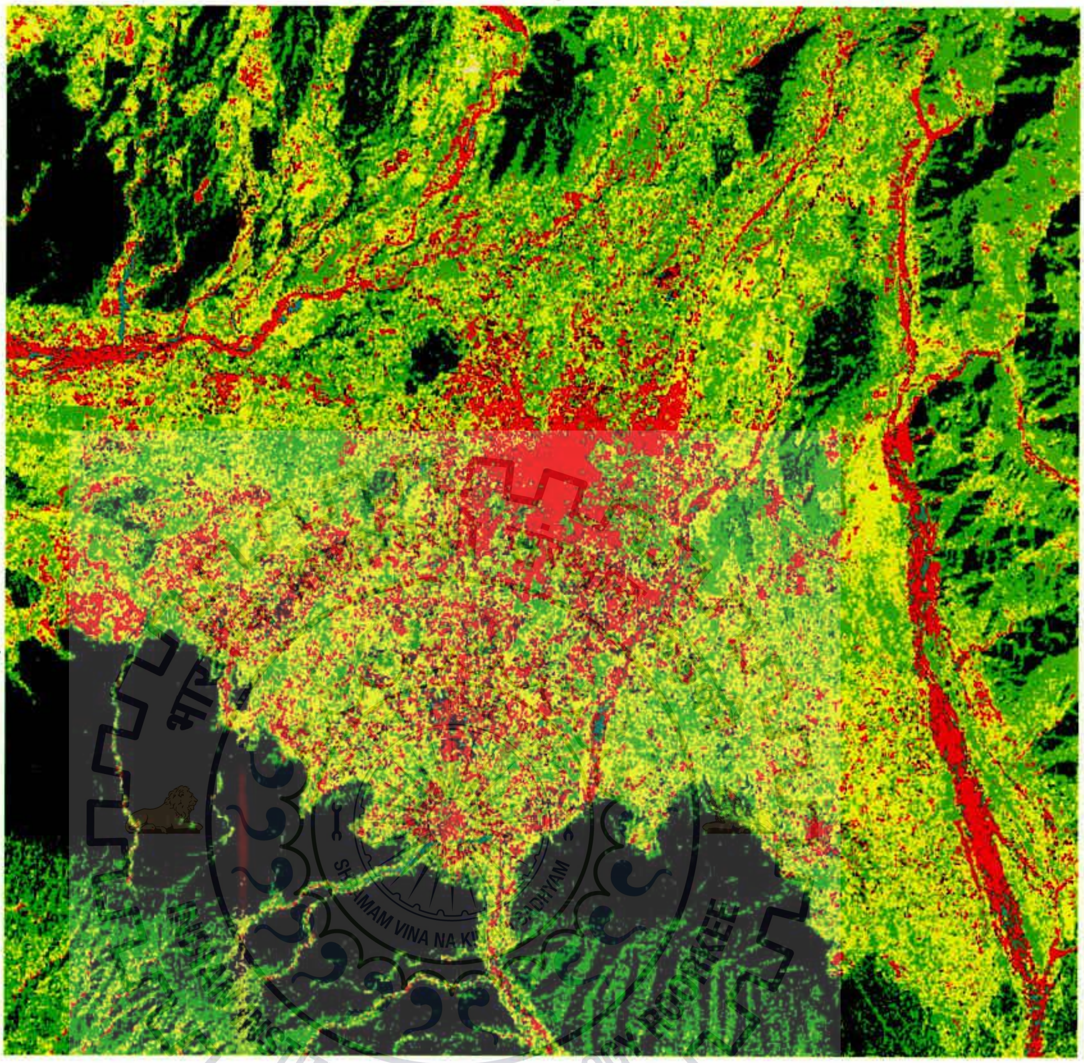


Figure 6-7 Classified image of Dehradun city 1990

- Bulit Up Area
- Dense Forest
- Agricultural Area
- Water body
- Fallow Land
- Vegetation

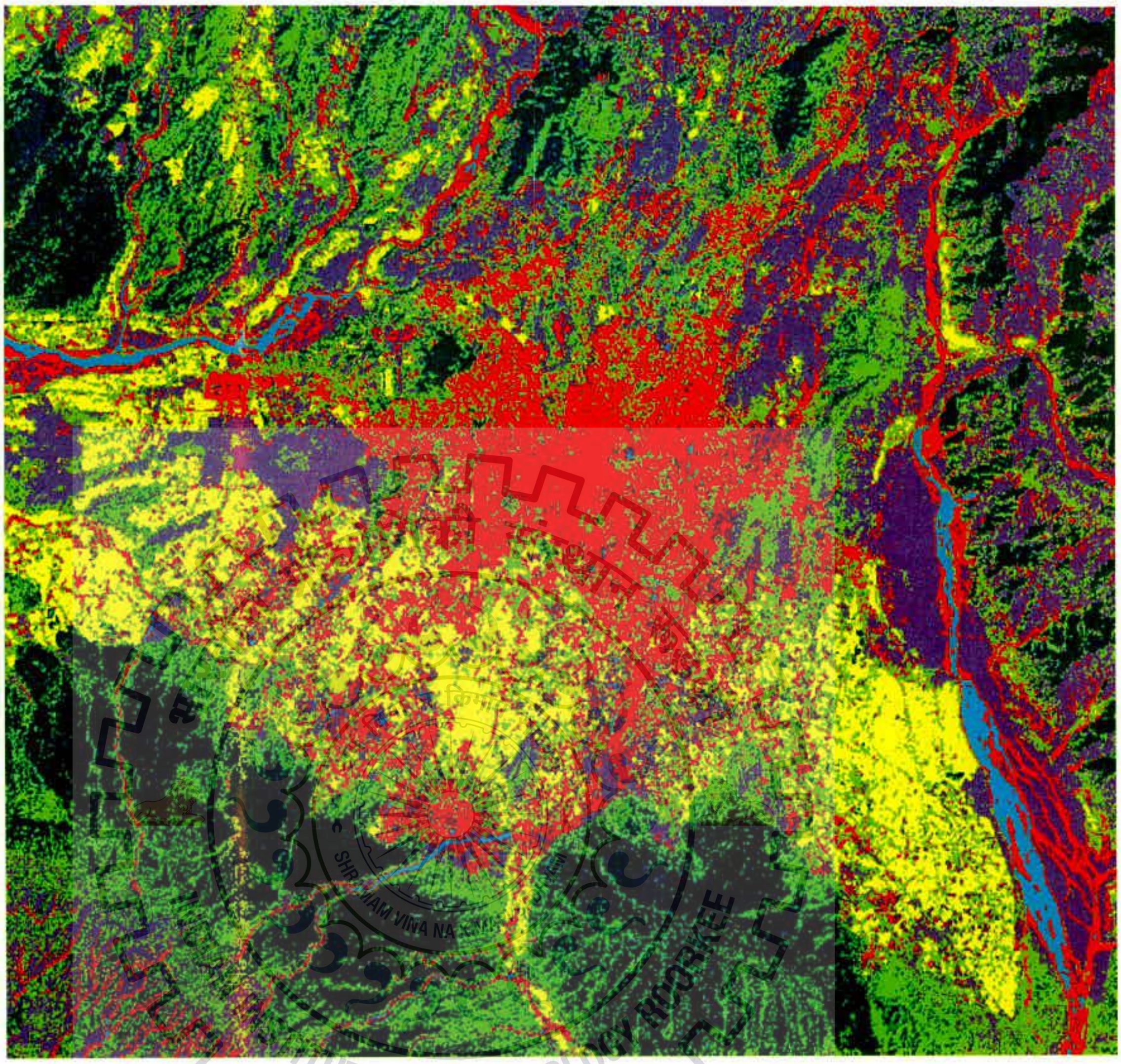


Figure 6-8 Classified image of Dehradun City 2000

Bulit Up Area

Dense Forest

Agricultural Area

Water body

Fallow Land

Vegetation

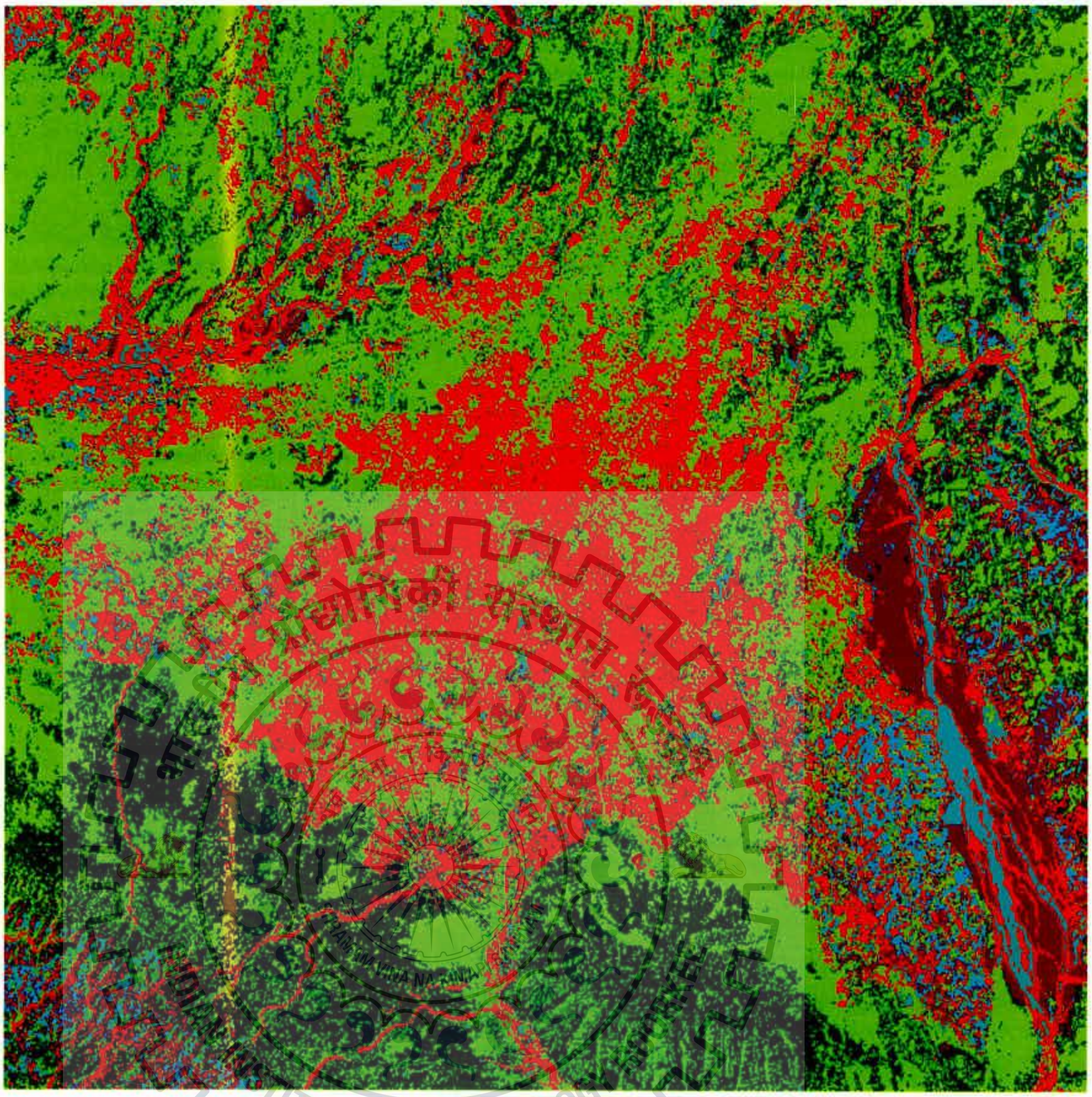


Figure 6-9 Classified image of Dehradun City 2011

Bulit Up Area

Dense Forest

Agricultural Area

Water body

Fallow Land

Vegetation

Table 6-2 LU/LC of Dehradun City

	1990		2000		2011	
LU/LC	%	Area(SqKm)	%	Area(SqKm)	%	Area(SqKm)
Dense Forest	25.31	75.92	20.38	61.14	20.12	60.35
Agricultural Land	23.78	71.35	8.68	26.04	6.81	20.43
Water Body	1.28	3.83	1.37	4.12	1.47	4.42
Fallow Land	1.90	5.71	22.35	67.05	18.20	54.60
Built Up	9.36	28.08	16.01	48.03	23.75	71.24
Vegetation	38.37	115.10	31.21	93.63	29.65	88.95
TOTAL		300.00		300.00		300.00
Area of City(SqKm)	300					

Table 6-2 shows different land cover pattern over the years of the city. Built up area as one can see has increased from 28.08 SqKm (9.36%) in 1990 to 48.03 SqKm (16.01%) in 2000 and further a rise was seen upto 71.24 SqKm (23.75%) in 2011 while the agricultural land, dense forest and vegetation shows a decline while fallow land first increased and then shows a decrease in last decade.

To show the data in a graphical way, a graph was plotted between the land cover percentage and subsequent year which is shown in the Fig. 6-10. Built up area is shown in blue colour which has grown at decent rate, agricultural land, shown in red colour, has gown down abruptly in the first decade and then decreased gradually in the next decade, vegetation (shown in orange) and dense forest (shown in dark blue) has decreased a gradual rate, fallow land (shown in violet colour) has first increased in the first decade and then decreased in the next and water body (shown in green) has remained almost constant.

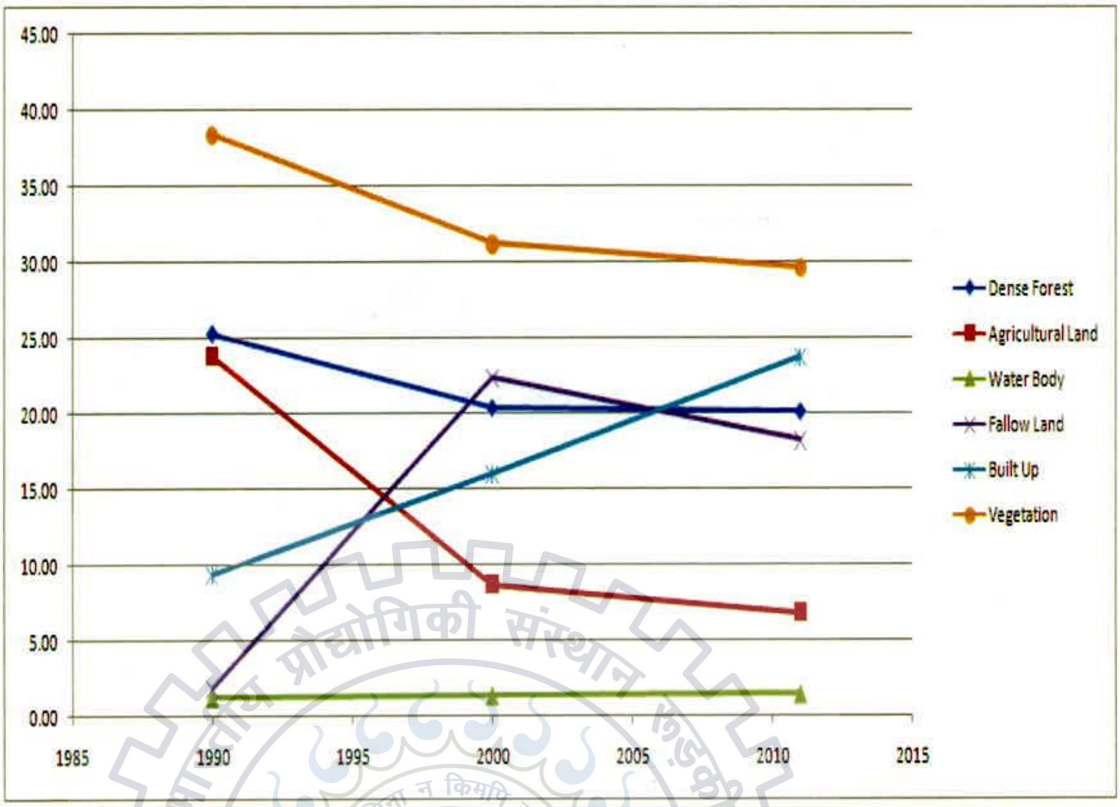


Figure 6-10 Plot between different LC percentage and time

6.3 ANALYZING RUNOFF BY THE GIVEN DATA

SCS-CN (Soil Conservation Services- Curve Number) method is used to calculate the runoff the study area. This method is based on the water balance equation

$$P = Ia + F + Q \qquad \text{.......... 6.1}$$

Where, P is Total Precipitation

Ia is Initial Abstraction

F is Cumulative infiltration excluding Ia

Q is Direct surface runoff per unit time

From above equation one can get,

$$Q = (P - zS)^2/(P + (1 - z)S) \quad \text{for } P > zS \qquad \text{.......... 6.2}$$

$$Q = 0 \quad \text{for } P \leq zS \qquad \text{.......... 6.3}$$

Where, $zS = Ia$

S = (25400/ CN) – 254 .... 6.4

The facor 'z' has a value 0.3 in Indian non black soil conditions.

The curve number CN depends upon soil type, land use/cover and antecedent moisture condition. In our case soil type is of Group-A as the soil is of low runoff potential such as gravels, drained sand and antecedent moisture conditions is AMC-II as the moisture conditions are average as the satellite data is of November month of subsequent year. So values of CN is seen for different land cover as shown in the table 6-3.

Table 6-3 CN value for Dehradun City

		1990			2000			2011		
LU/LC	CN	%	Area(SqKm)	Product(S)	%	Area(SqKm)	Product(S)	%	Area(SqKm)	Product(S)
Dense Forest	26	25.31	75.92	657.98	20.38	61.14	529.84	20.12	60.35	523.07
Agricultural Land	76	23.78	71.35	1807.57	8.68	26.04	659.59	6.81	20.43	517.64
Water Body	0	1.28	3.83	0.00	1.37	4.12	0.00	1.47	4.42	0.00
Fallow Land	71	1.90	5.71	135.16	22.35	67.05	1586.90	18.20	54.60	1292.20
Built Up	77	9.36	28.08	720.76	16.01	48.03	1232.69	23.75	71.24	1828.49
Vegetation	39	38.37	115.10	1496.31	31.21	93.63	1217.23	29.65	88.95	1156.35
TOTAL			300.00	4817.78		300.00	5226.25		300.00	5317.75
Area of District(SqKm)		300								

Table 6-4 CN value for Dehradun District

		1990			2000			2005			2011		
LU/LC	CN	%	Area(SqKm)	Product(S)	%	Area(SqKm)	Product(S)	%	Area(SqKm)	Product(S)	%	Area(SqKm)	Product(S)
Forest Plain	26	23.37	701.24	607.74	22.54	676.31	586.13	22.53	675.87	585.76	21.83	654.83	567.52
Agricultural Land	70	16.75	502.37	1172.20	15.89	476.68	1112.26	15.47	464.15	1083.01	14.92	447.56	1044.30
Water Body	0	0.42	12.60	0.00	0.44	13.20	0.00	0.41	12.30	0.00	0.44	13.20	0.00
River Bed/Barren Land	39	1.70	51.06	66.38	2.42	72.48	94.23	3.23	97.05	126.16	3.00	89.92	116.90
Built Up	77	6.28	188.34	483.41	6.85	205.44	527.29	7.11	213.39	547.70	8.61	258.27	662.90
Forest Mountain	26	51.48	1544.39	1338.47	51.86	1555.89	1348.44	51.32	1539.54	1334.27	51.21	1536.22	1331.39
TOTAL			3000.00	3060.45		3000.00	3668.35		3002.30	3676.89		3000.00	3723.00
Area of District(SqKm)		3000											

Similarily CN is calculated for Dehradun district as it was done in Dehradun city case as shown in Table 6-4. Now from the weighted CN value, S is calculated by eqn. 6.4 and with that Q (direct runoff) as the precipitation data is known already. Considering evapotranspiration losses negligible the result comes as shown in the table 6-5.

Table 6-5 Runoff table of Dehrdun District

Year	P	Q	I	Vr
1990	1134.1	601.15	532.95	1803.46
2000	766.8	375.88	390.92	1127.64
2005	2103.7	1615.04	488.66	4845.13
2011	2402.3	1913.45	488.85	5740.36

P is the total precipitation in the particular year in mm, Q is the direct runoff for the subsequent year in mm, I is the infiltration of the year in mm and Vr is the volume of runoff from the district in Mm^3. A bar chart of rainfall and infiltration is also plotted as shown in fig. 6-11.

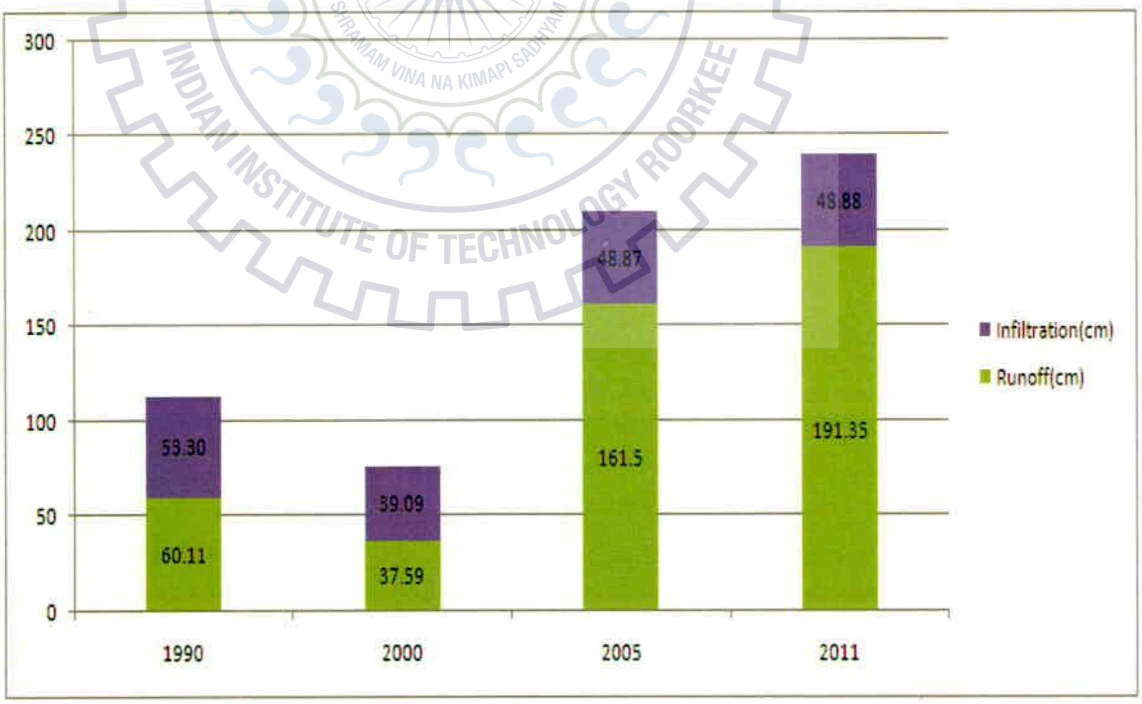


Figure 6-11 Infiltration and Runoff Bar Chart of the Dehradun District

Considering evapotranspiration losses negligible the values for runoff and infiltration comes as shown in the table 6-6.

Table 6-6 Runoff table of Dehradun City

Year	P	Q	I	Vr
1990	1134.1	835.24	298.86	2505.73
2000	766.8	523.12	243.68	1569.36
2011	2402.3	2131.11	271.19	6393.32

P is the total precipitation in the particular year in mm, Q is the direct runoff for the subsequent year in mm, I is the infiltration of the year in mm and Vr is the volume of runoff from the city in Mm^3. A bar chart of rainfall and infiltration is also plotted as shown in fig. 6-12.

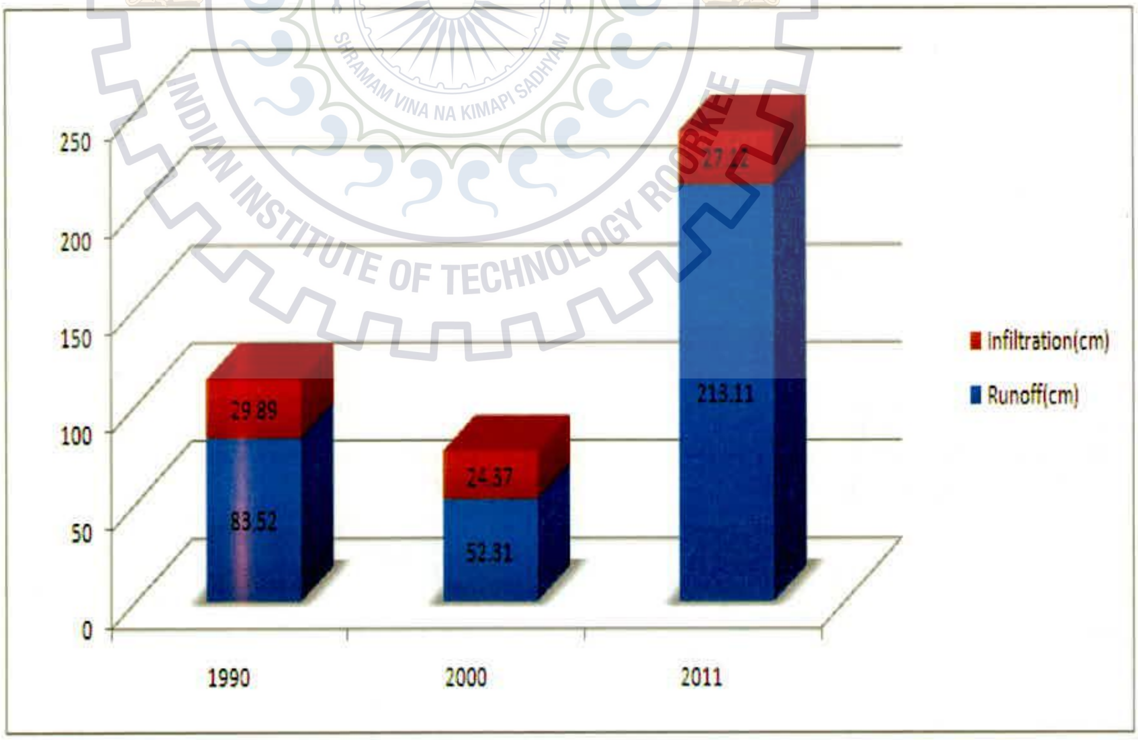


Figure 6-12 Infiltration and Runoff Bar Chart of the Dehradun City

6.4 CONCLUDING REMARKS

Land use of Dehradun district and city has changed drastically in the last two decades and so is land cover. As one can think, the built up area change is more rapid near or in the city while in other places. So the built up area percentage in Dehradun city is 23.75% in 2011 from 9.36 in 1990 while in Dehradun district is 8.61% in 2011 from 6.28% in 1990. As the built up area is going to increase in the future and to find the most probable place of that will help in planning purposes. To find the most probable places near the city, one has to check some factors which usually a person before owning place for living. These factors are distance from city, distance from main transportation road, terrain of the area, water availability, soil characteristics and the trend where the expansion is taking place. These factors with the help of last two decades classified satellite image can help in finding out the most probable places where population is going to increase.

Increasing runoff is a major issue which has to be controlled in the study area. The pattern that came out in the city as well as in the state is demoralising. Runoff percentage of the city in 1990 was 73.64% while in 2011 it was 88.71% and runoff percentage of the district in 1990 was 53.00% while in 2011 it was 79.65%. Some factors of the above data other than increase of built up area is the climate change and variation in precipitation in the study years. In 1990 the precipitation was 1134.1 mm which is below the 25 years average value of rainfall and in 2011 it was 2402.3 mm which well above the average 25 years value shown in table 6-1.

Chapter 7: DEVIATION ANALYSIS FOR CLIMATE CHANGE

7.1 GENERAL

Artificially induced climate change and global warming arising from anthropogenic- driven emissions of greenhouse gases and land-use and land-cover change have emerged as one of the most important environmental issues among researchers in the last two decades (Kadioglu 1997; Arora et al. 2005; Singh et al. 2008). The latest fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2007) has concluded that the global mean surface temperatures have risen by 0.74±0.18°C when estimated by a linear trend over the last 100 years (1906-2005). The rate of warming over the recent 50 years is almost double of that over the last 100 years (IPCC 2007), which is largely attributed to anthropogenic influences. Weather records from land stations and ships indicate that the global mean surface temperature has warmed up approximately by 0.6±0.2°C since 1850 and it is expected that, by 2100, the increase in temperature could be 1.4-5.8°C (Singh et al. 2008). Moreover, the world has witnessed change in climatic condition at the unprecedented rate in past few decades. Available records show that the 1990s have been the warmest decade of the millennium in the Northern Hemisphere and 1998 was the warmest year.

Dehradun city is surrounded by river Song on the east, river Tons on the west, Himalayan ranges on the north and Sal forests in the south. The high hills in the east and north and Siwaliks in the south offer an interesting topographical setting to the city. During the summer months, the temperature ranges between 36°C and 16.7°C while in winters the maximum and minimum temperatures touching 23.4°C and 5.2°C respectively.

7.2 TEMPERATURE AND RUNOFF ANALYSIS

The annual average temperature of the Dehradun district and city for the study years were taken from the database of temperature of Indian Meteorological Department (IMD). The data is plotted in tabular form in Table 7-1.

Table 7-1 Precipitation, Temperature and Infiltration of District

Year	Temperature	Precipitation	Runoff	Infiltration	Percentage of Infiltration
1990	23.53	1134.10	601.15	532.95	46.99
2000	24.53	766.80	375.88	390.92	50.98
2005	23.89	2103.70	1615.04	488.66	23.23
2011	23.91	2402.30	1913.45	488.85	20.35

The infiltration in the area has been decreasing since 1990 till 2011 from 46.99% to 20.35% and but as the precipitation is varying so one cannot find the role of temperature and land cover. So data is plotted again in tabular form keeping precipitation constant as 766.80 mm which is the actual total precipitation of 2000 as shown in Table 7-2.

Table 7-2 Const. Precipitation, Temperature change and Infiltration change of District

Year	Temperature	Precipitation Constant	Runoff	Infiltration	% I	Remarks
1990	23.53	766.80	301.60	465.20	60.67	ΔT=(+)1°C gives 9.69% less I
2000	24.53	766.80	375.88	390.92	50.98	ΔT=(-)0.62°C gives 0.13% less I
2005	23.89	766.80	376.85	389.95	50.85	
2011	23.91	766.80	382.03	384.77	50.18	ΔT=(-)0.02°C gives 0.67% less I

There is a increase of 1*C from the annual average temperature of 1990 to 2000 and shows a decline of 9.69% in infiltration of water to ground. As the land cover data was not changed a lot in between years, it can be said that the major difference has been made by temperature difference. After 2000 the land cover has changed very rapidly so that the contribution of temperature in infiltration change will be very small. The temperature has decreased 0.62*C from 2000 to 2005 and the infiltration decline more by 0.13% and in 2005 to 2011 the temperature increased by 0.02*C and the infiltration decrease by 0.67%.

A graph is plotted between temperature in *C and runoff in cm for the subsequent years as shown in fig. 7-1.

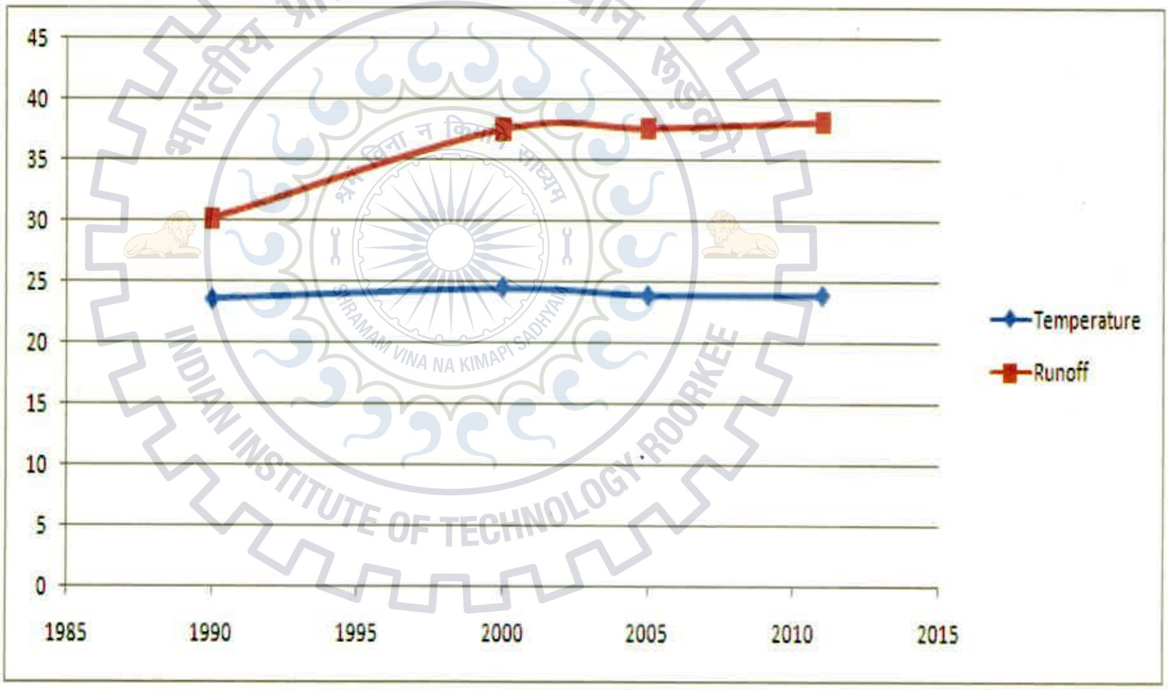


Figure 7-1 Annual average temperature Vs Runoff of District

The annual average temperature of the Dehradun city for the study years were taken from the database of temperature of Indian Meteorological Department (IMD). The data is plotted in tabular form in Table 7-3.

Table 7-3 Precipitation, Temperature and Infiltration of City

Year	Temperature	Precipitation	Runoff	Infiltration	Percentage of Infiltration
1990	23.53	1134.10	835.24	298.86	26.35
2000	24.53	766.80	523.12	243.68	31.78
2011	23.91	2402.30	2131.11	271.19	11.29

The infiltration in the area has been decreasing since 1990 till 2011 from 46.99% to 20.35% and but as the precipitation is varying so one cannot find the role of temperature and land cover. So data is plotted again in tabular form keeping precipitation constant as 766.80 mm which is the actual total precipitation of 2000 as shown in Table 7-4.

Table 7-4 Const. Precipitation, Temperature change and Infiltration change of District

Year	Temperatur	Precipitation Constant	Runoff	Infiltration	% I	Remarks
1990	23.53	766.80	489.54	277.26	36.16	ΔT=(+)1°C gives4.38% less I
2000	24.53	766.80	523.12	243.68	31.78	
2011	23.91	766.80	530.23	236.57	30.85	ΔT=(-)0.62°C gives0.93% less I (More builtup area)

There is a increase of 1*C from the annual average temperature of 1990 to 2000 and shows a decline of 4.38% in infiltration of water to ground. As the land cover data was not changed a lot in between years, it can be said that the major difference has been made by temperature difference. Again in the city also after 2000 the land cover has changed very rapidly so that the contribution of temperature in infiltration change will be very small. The temperature has decreased 0.62*C from 2000 to 2011 and the infiltration decline more by 0.93%.

A graph is plotted between temperature in *C and runoff in cm for the subsequent years as shown in fig. 7-2.

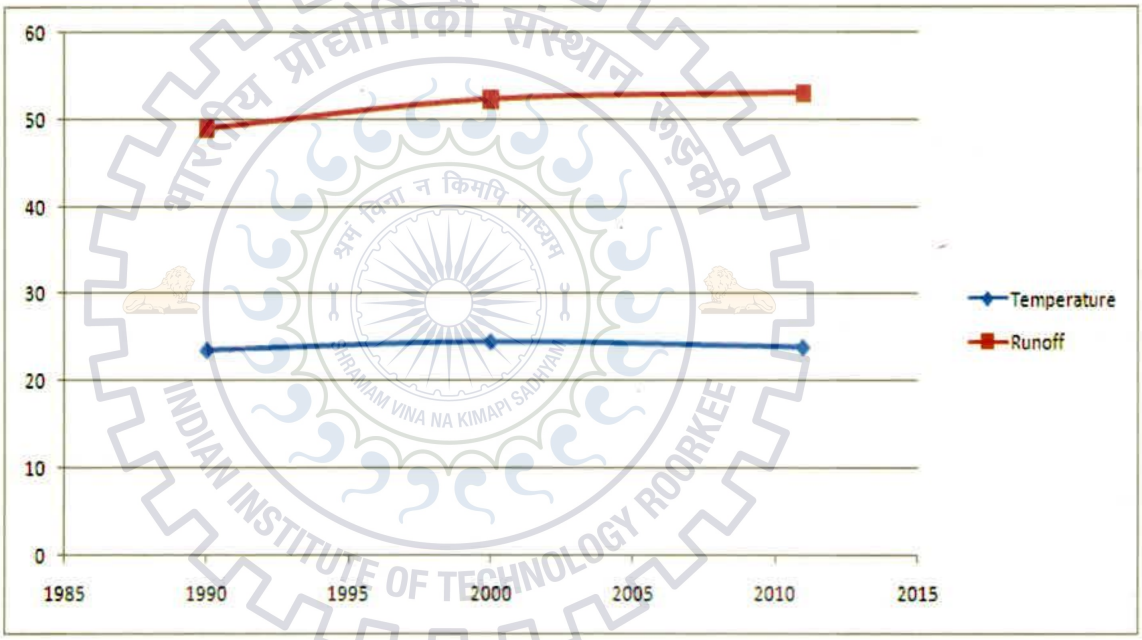


Figure 7-2 Annual average temperature Vs Runoff of City

Chapter 8: **CONCLUSION**

8.1 CONCLUSION

In the present study attempt has been made to develop a Decision Support System which can help the decision maker in Urban Water Management in changing climate. Extensive computer programming is involved as the platform taken is of Visual Basic 6.0 to develop DSS.

The DSS is capable of analysis of the following:-

I. Data Storage and data extraction including demand and supply analysis.

II. Trend analysis of precipitation and temperature.

III. Analysis of land-use and land-cover.

IV. Analysis of climate change.

Based on the study following conclusion and salient features are discussed below ;

The change in Land use and Land cover pattern has changed a lot both in city as well as in district majorly over the two decades. Built up area increased from 6.28% in 1990 to 8.61% in 2011 of dehradun district while in Dehradun city the picture is no different built up area was 9.36% in 1990 and 23.75% of the city area. This shows the area near the cities is populating very rapidly and as the population increase the problems for the management and planner of the city increase.

Variation in climate can also become a major part in the near future. The annual maximum, annual minimum and annual mean temperature at Dehradun city have positive trends of change. Overall it has warmed significantly and annual mean temperature has increased about 0.47°C during the 41 year period (1967-2007). Per decade increase in annual mean temperature was found to be 0.12°C which is about four times more than the global increase of temperature. The difference does not seem large in the last two decades. The variation in 1990 – 2000 has given an idea of runoff and temperature change relation as in 1990 – 2000 1*C rise in temperature (when land use was almost constant) give a rise of 9.69% in runoff of the district and 4.38% more runoff in the city.

Problem of demand and supply will also come into picture more, in the coming years as all the factors like land use pattern, climate change, shortage of supply in the current state will amalgamate to enhance the problem. Indirectly precipitation and runoff also get effected which is also a major issue to look into it. So for planning, one can get an idea from the study, where the population increase is going to take place in the coming years and how much the demand will be approximately after a certain time and can arrange sources to mitigate the demand.

8.2 FURTHER SCOPE OF WORK

- An optimization model should be built in the Decision Support System to provide various options of water management.
- Data used in the DSS should be more long.

References

1. Adelman, L., *Evaluating Decision Support and Expert Systems,* John Wiley and Sons, New York, 1992.
2. Applying multiple criteria aid for decision to environmental management Massimo Paruccini - 1994
3. Appraisal of city development plan, Dehradun 2007, National Institute of Urban Affairs, New Delhi
4. Appraisal of city development plan, Vol. 2, Dehradun 2007, National Institute of Urban Affairs, New Delhi.
5. Ashutosh Singh, Shalini Singh, Purushottam Kumar Garg and Kamlesh Khanduri, " Land use and Land cover change detection: A comparative approach using post classification change matrix and discriminate function change detection methodology of Allahbad City," International Press corporation, Vol.3, No.1 (March 2013).
6. David w. Watkins, Jr. and Daene C. McKinney., *Recent developments associated with decision support systems in water resources,* U.S. National Report to IUGG, 1991-1994 Rev. Geophys. Vol. 33 Suppl., © 1995 American Geophysical union
7. Determination of SCS runoff curve number and landuse changes for Hamidnagar sub-basin of Punpun Basin, Ganga Plains North Regional Centre, National Institute of Hydrology, Patna 1996-97.
8. Debapriya Dutta, *AVSWAT- a Spatial Decision Support System for Land and water management and its application for watershed management in Bankura district of West Bengal,* NRDMS Division, Department of Science and Technology, Technology Bhavan New Delhi- 110016. India.
9. G. Adamopoulos, et al., 1994. Production management in the textile industry using the "yfadi" decision support system
10. Ground Water Brouchure, District Dehradun, Uttarakhand, June 2011.
11. Guariso, G. and Werthner, H. 1989 Environmental Decision Support Systems. Ellis Horwood, Chichester, England, p. 240.

12. Henderson-Sellers, B., Future directions for water quality modeling, in *Water Quality Modeling, Volume IV: Decision Support Techniques for Lakes and Reservoirs,* CRC Press, Inc., Boca Raton, Florida, pp. 297-304, 1991.

13. India Water Portal, http://www.indiawaterportal.org.

14. K.H.V. Durga Rao, "Multi-criteria spatial decision analysis for forecasting urban water requirements : a case study of Dehradun city, India," Elsevier 2005.

15. K. Subramanya, "Engineering Hydrology" Tata Mcgraw Hill Companies Third Edition, 2008.

16. L.R Foulds and Xiao Dan Zhao, 2007, A Decision Support System for sustainable maize harvesting operations scheduling

17. Linking climate Change and water resources : Impacts and responses, www.ipcc.ch/pdf/technical-papers/ccw/chapter3.pdf

18. Monthly mean maximum and minimum temperature and total rainfall based upon 1901-2000 data, National Data Centre, Pune.

19. Omvir Singh, Poonam Arya and Bhagwan Singh Chaudhary, " On rising temperature trends at Dehradun in Doon valley of Uttarakhand, India 2010"

20. Power, D.J. 2007. A Brief History of Decision Support Systems. http://DSSResources.COM/history/dsshistory.html, version 4.0, March 10,

21. S. Nayak and M. Mandal, " Impact of land-use and Land-cover changes on temperatures trends over Western India," Current science, Vol. 102, No. 8, 25 April 2012.

22. Tiwari Kuldeep and Khanduri Kamlesh, " Land use/ land cover change detection in Doon valley (Dehradun Tehsil), Uttarakhand : using GIS & Remote Sensing Technique," Internationa journal of geomatics and geosciences Vol.2, No.1, 2011.

23. Town Report, Volume 2 of 9 , Uttaranchal Urban Development Project (UUDP), April 2007

24. USGS Web Site, http://glovis.usgs.gov/

25. Vaibhav Garg, Ampha Khwanchanok, Prasun K. Gupta, S.P. Aggarwal, Komsan Kiriwongwattana, Praveen. K. Thakur, and Bhaskar R. Nikam, " Urbanisation effect on Hydrological Response : A case study of Asan River Watershed, India," Journal of environment and earth science, vol. 2, No.9, 2012.

26. W.C. Boughton , "Effect of Data Length on Rainfall-runoff Modelling," Griffith University Brisbane, Australia.