Status of Agricultural Meteorology

Strength, Weakness, Opportunity and Threat (SWOT)

by

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FOREWORD

Teaching, Research and Extension activities in the field of Agricultural Meteorology have been strengthened since inception of the Kerala Agricultural University in 1972 though teaching at B.Sc (Ag) level commenced much before. Two Agricultural Meteorology Units were established initially in the University, one at the College of Horticulture in 1977 and later at the Regional Agricultural Research Station, Pilicode in 1982 under the National Agricultural Research Project (NARP). The status of research in Agricultural Meteorology in the University revolves around the activities taken up by the above two Units. Based on the recommendations of the National Commission on Agriculture, the Agricultural Meteorology Unit at the College of Horticulture was elevated to the statutory Department of Agricultural Meteorology in 1988. It is the unique department in humid tropics within the country, started M.Sc (Ag) in Agricultural Meteorology in 1994-95 with intake capacity of two seats. During the same period, the Indian Council of Agricultural Research, Government of India, New Delhi recognised the department as a Co-ordinated Centre under AICRP on Agrometeorology extending financial support for agrometeorology research. Concurrently, four Agrometeorological Field Units (AMFUs) were also established in different agroclimatic zones of the State to disseminate weekly advisory based on Medium Range Weather Forecast with the financial support of the National Centre for Medium Range Weather Forecasting (NCMRWF), DST, Government of India for the benefit of the farmers on farm decision making. Probably, this is the one department for which two-third or more of its funding requirement is met from the Externally Aided Projects.

Within a short span of time, the Department of Agricultural Meteorology could establish a sound linkage with allied institutions at the state/national and international level. The syllabus prepared by the department for B.Sc (Ag) in Agricultural Meteorology is the one approved by the ICAR and followed in many State Agricultural Universities. In tune to the syllabus, a textbook is proposed by the ICAR in which a considerable portion is contributed from the faculty members of this department. The department is proud that one of the faculty members is on deputation to CRIDA (ICAR), Hyderabad for development of agromet databank at national level. It is also understood that the faculty members serve in various selection committees and take up consultancy in the field of agrometeorology of plantation crops.

I hope the SWOT analysis prepared by the department will be a broad-based model to others too. The meteorological data, instructions to Meteorological Observers, glossary of commonly used meteorological words and the Syllabus approved by the ICAR for M.Sc (Ag) in Agricultural Meteorology provided in this publication will be a ready-reckoner not only to the department but also to the teachers, researchers, extension workers and students who use meteorological data. I hope that the department will grow further with leaps and bounds under the dynamic leadership of the present head of the department. I wish the department a good success.

K.V. Peter
Vice-Chancellor
Kerala Agricultural University

Vellanikkara
20-11-2002

PREFACE

The Department of Agricultural Meteorology was established at the College of Horticulture, Vellanikkara in 1988 to strengthen teaching, research and extension activities in the field of agricultural meteorology in tune with the recommendations of the National Commission on Agriculture, Government of India. It is the unique department in southern Agricultural Universities where M.Sc (Ag) in Agricultural Meteorology is offered. Five students have come out successful and two are on rolls at present. All the five students from the department also passed the National Eligibility Test (NET) conducted by the ASRB, ICAR, Government of India, New Delhi. In this connection I would like to mention that the Kerala Agricultural University stood first during the year 2001-'02 based on performance of our students in the exams conducted by the ICAR at the national level.

In recognition of the research work carried out under AICRP on Agrometeorology, the Indian Council of Agricultural Research, Government of India, New Delhi extended the project during the X Plan (2002-'03 to 2006-'07). An Agrometeorological Field Unit (AMFUs) was also established in the department to disseminate weekly advisory based on Medium Range Weather Forecast with the financial support of the National Centre for Medium Range Weather Forecasting (NCMRWF), DST, Government of India for the benefit of the farmers on farm decision making of this part of Kerala. This is one of the Field Units in addition to other three Units,viz. RARS, Ambalavayal, RARS, Pilicode and NARP (SZ), Vellayani.

The college, in principle, decided to document various activities taken up in detail by the departments separately and update the same at least once in five years similar to Accreditation Report of the college.

This publication deals with the Strength, Weakness, Opportunity and Threat (SWOT) analysis of the department of agricultural meteorology. The common words used in meteorology are included under the glossary in one of the appendices. The course schedule for B.Sc (Ag) in Agricultural Meteorology, the Syllabus approved for M.Sc (Ag) in agricultural meteorology approved by the ICAR and the syllabus for the National Eligibility Test (NET) in agricultural meteorology conducted by the ASRB, ICAR are also appended with the SWOT.

The monthly meteorological data recorded at Vellanikkara from 1980 to 2001 and the guidelines for Meteorological Observers included in the publication is an asset to the users who involved in installation of weather equipment, maintenance of observatories, weather records and databank and. analysis of climatological data. I am sure that the publication will serve as a good reference material to the students, scientists, teachers and extension workers who are interested in the field of agroclimatology and allied disciplines. I hope the other departments in the college are expected to take up the similar job in due course of time.

A. Sukumara Varma
Associate Dean
College of Horticulture
Kerala Agricultural University

Vellanikkara
19-11-2002

ACKNOWLEDGEMENTS

The Department of Agricultural Meteorology, College of Horticulture, Kerala Agricultural University was a small unit when the present head of the department joined as Assistant Professor of Agricultural Meteorology on 01-12-1980. It was elevated to a statutory department in 1988 in tune with the recommendations of the National Commission on Agriculture, Government of India. Due to shortage of technical hands in the field of agricultural meteorology, it was decided to start M.Sc (Ag) in Agricultural Meteorology. It is the unique department among southern agricultural universities where P.G. programme is offered in Agricultural Meteorology. Thanks should go to the efforts made by my predecessor Dr. P.Balakrisna Pillai, Professor of Agronomy who headed the department and retired as the Dean i/c, college of Agriculture, Vellayani in April 1999. When I assumed charge as the head of the department it is felt that there is a need to highlight the departmental activities in an abridged form. The SWOT analysis of the department is just an outcome of the various activities related to academic, research and extension in the field of agricultural meteorology. The faculty of the department is indebted to Dr. K.N. Syamasundaran Nair, Former Vice-Chancellor, Kerala Agricultural University who mooted the idea on SWOT analysis. Thanks are also due to him for his decentralisation concept and delegation of powers to the head of the departments. This is the one department in the college, which got the vantage instantaneously.

The service rendered by the faculty and technical staff of the department in bringing out the publication is highly acknowledged. The timely printing of this publication by Mr. K.Rajappan, Press Manager, KAU and his staff is placed on record. The services rendered by Mr. Jagadeesh Kayali in typing manuscript and climatological data are appreciated.

The services of Mr. M.V. Sudheesh, Assistant Professor of Agronomy, joined in the department just a few days before this publication is ready for release, are also acknowledged.

The faculty of the department is grateful to the NCMRWF, DST, Government of India for holding XI Annual Review Meeting of the DST Project at KAU Campus, Vellanikkara from 28-11-2002 to 30-11-2002, which only inspired to bring out the publication in this form. Thanks are also due to DST and ICAR for funding Research Projects in the field of Agricultural Meteorology.

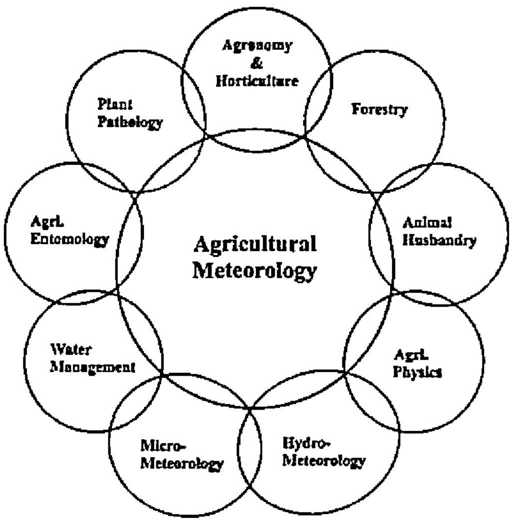
G.S.L.H.V. Prasada Rao
Professor and Head
Department of Agricultural Meteorology
College of Horticulture

Vellanikkara
25-11-2002

CONTENTS

I. INTRODUCTION

Climate decides crop selection while weather decides crop production and productivity. Crop production depends on the chain of factors, *viz.* genotype, soil, weather, technology and the farmer. Any weak link in the chain of factors will decide the final crop output. Indian agriculture mainly depends on the vagaries of monsoon and weather aberrations. Despite several technologies evolved, the Indian *kharif* foodgrains production is still controlled by the timely onset of monsoon and its behaviour during the crop season. It is also true in paddy production of Kerala during *kharif (Virippu)* as pre-monsoon showers in April and May and monsoon behaviour from June to September influence final paddy output. In humid tropics like Kerala, where the plantation crops are predominant, weather aberrations not only affect the crop production in the same year but also in the subsequent years depending upon the type of crop. The rainfall distribution from November to May play a major role in deciding plantation crop production. The aim of agricultural meteorology is to understand crop weather interactions and mitigate ill effects of adverse weather on crop husbandry through better crop management practices to increase crop productivity in quantity as well as quality. Considering its importance and relevance in the field of agriculture, the National Commission on Agriculture recommended to start a separate department of Agricultural Meteorology in all the State Agricultural Universities. With this in view, a "Unit of Agricultural Meteorology" was established in 1977 at the College of Horticulture, Kerala Agricultural University, Vellanikkara,Trichur. Later on, it was elevated to a statutory department as per the notification No.GA/E3/27238/86 dt.10-5-1988 of the Government of Kerala. The department aims at multidisciplinary approach and undertakes various activities in the field of agricultural meteorology. This is the first department among southern State Agricultural Universities, where M.Sc (Ag) in Agricultural Meteorology is being offered. Besides, Agrometeorological Field Units were established across Kerala at four different agroclimatic zones, *viz.* NARP Southern Zone (Vellayani), Central zone (Vellanikkara), RARS High Ranges (Ambalavayal) and RARS Northern Zone (Pilicode) to carry out research investigations in the field of agricultural meteorology in addition to dissemination of weekly agromet advisory based on Medium Range Weather Forecast for the benefit of the farming community. The agromet unit under the National Agricultural Research Project at the Regional Agricultural Research Station, Pilicode did a commendable work in the field of agrometeorology of plantation crops.



Agricultural Meteorology - a multidisciplinary science

2. MANDATE

To teach agricultural meteorology at the Under Graduate level
To undertake Post Graduate Programme in agricultural meteorology
To initiate and update agromet database
To carry out research on basic and applied aspects of agroclimatology
To study the influence of weather on insect pest and diseases of major crops
To disseminate weekly agro-advisory based on Medium Range Weather Forecast
To provide short term training in basic meteorological observations and applied meteorological aspects to agricultural service personnel and farmers

3. MANPOWER

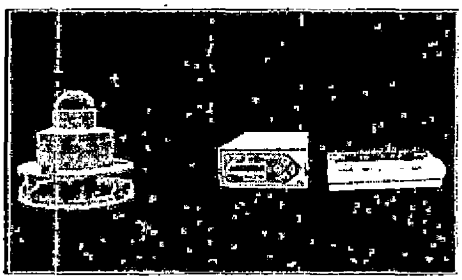
i) Technical

Category	Sanctioned	Position	Vacant	Total	Remarks
Professor and Head	1	1	Nil	1	–
Associate Professor	2	1	1	2	1 – KAU 1- AICRP
Assistant Professor	6	4	2	6	AAS – 4 KAU– 2
Total	9	6	3	9	
ii. Para - technical					
Farm Supervisor Gr. I	1	1	Nil	1	KAU
Farm Supervisor Gr. II	1	1	Nil	1	AICRP
Lab Asst. Gr. III	1	--	1	1	AICRP
Senior Observer	1	1	Nil	1	IMD
Total	4	3	1	4	

4. EQUIPMENT

The department possesses few sophisticated and ordinary meteorological equipments. They are as follows:

UV-Biometer, Tube solarimeters and quantum sensors, Automatic weather station
Psychron, Psychrometer and Leaf wetness recorder
Infrared thermometer
Barometer, Sunshine recorder, Wind vane and Anemometer
Open pan evaporimeter
Single Stevenson screen with maximum, minimum, dry and wetbulb thermometers
Grass-minimum thermometer and soil thermometers



UV-Biometer

5. ACADEMIC PROGRAMMES

The department offers sixteen courses, having a total of 38 credits for the *B.Sc.(Ag.), B.Sc. (Forestry), MSc.(Ag.) in Agricultural Meteorology,* and *Ph. D* programmes of allied departments. The details of courses offered by the department are given below:

5.1. Under Graduate Courses

B.Sc.(Ag.)

1.	Agmt 101	Agricultural Meteorology	1+1
2.	W.E. Agmt.101	Applications of Agricultural Meteorology	0+1
		Total	1+2=3

B.Sc.(Forestry)

1.	Metg 101	Agricultural Meteorology	I+1
2.	Metg 302	Photo-interpretation and Remote Sensing	1+1
		Total	2+2=4

5.2. Post-Graduate Courses

M.Sc.(Ag.) in Agronomy

1.	Agron. 602	Weather and Agriculture	1+1
		Total	1+1=2

5.3. Courses offered for M.Sc.(Ag.) in Agricultural Meteorology

1.	Agromet 603	Agricultural Meteorology-I	2+ 1
2.	Agromet 604	Agricultural Meteorology-II	2+ 1
3.	Agromet 605	Climatology	2+ 1
4.	Agromet 606	Weather and Agriculture	1+1
5.	Agromet 607	Micrometeorology	2+ 1
6.	Agromet 608	Drought Climatology	2+ 1
7.	Agromet 609	Hydrometeorology	2+ 1
8.	Agromet 611	Agrometeorological Instrumentation	0+2
9.	Agromet 612	Crop Weather Models	2+ 1
		Total	15+10=25

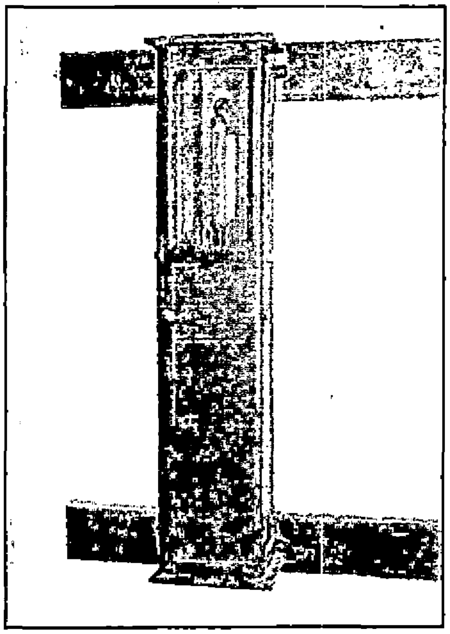
5.4. Ph.D (Ag. /Hort.)

1.	Agron. 702	Advances in Agroclimatology	2+0
2.	Agromet 702	Advances in Agroclimatology	2+0
		Total	4+0=4
		Grand total	3+4+2+25+4 = 38

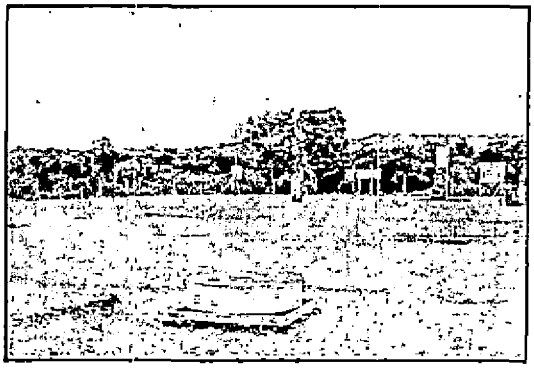
5.5 **Semester-wise break up of courses offered from the department during an academic year (2 semester)**

Degree programme	No. of credits offered in each semester		
	I	II	Total
B.Sc.(Ag.)	3	–	3
B.Sc. (Forestry)	2	2	4
M.Sc.(Ag.)Ag. Met.	13	12	25
M.Sc.(Ag.)Agron.	2	–	2
Ph.D.(Ag.)Agron.	2	–	2
Ph.D(Ag./Hort.)	2	–	2
Total	24	14	38

In addition to the above, a few classes (both theory and practical) are being handled in Climatology for the B.V.Sc&A.H graduates at the College of Veterinary and Animal Sciences, Mannuthy.



Barometer



Principal Agricultural Meteorological Station

5.6. M.Sc (Ag) in Agricultural Meteorology

The department offers the Postgraduate Programme in Agricultural Meteorology. This is the only University among the southern State Agricultural Universities where M.Sc.(Ag.) in Agricultural Meteorology is offered. Four batches have come out successfully. Five students have been obtained their M.Sc.(Ag.) in Agricultural Meteorology and two are on rolls.

The research projects handled by them were as follows:

Sl. No.	Name of the Student with admission no.	Thesis submitted for award of M.Sc (Ag) in Agrl.Meteorology	Year of pass	Name of the adviser
1.	Ms. P. Lincy Davis (94-11-60)	Crop weather relationships of bittergourd (*Momordica charantia* L.)	1996	Dr. P.Balakrishna Pillai
2.	Mr. K. Ajith (95-11-43)	Agroclimatology in crop planning for central zone of Kerala	1999	Dr. A.V.R. Kesava Rao
3.	Mr. B. Ajith Kumar (96-11-38)	Crop weather relationships of tomato(*Lycopersicon esculentum* Mill.)	1999	Dr. E.K. Lalitha Bai
4.	Mr. K.M. Sunil (97-11-24)	Crop weather relationship of rice(*Oryza sativa* L.)	2000	Dr. A.V.R. Kesava Rao
5.	Ms. S.Kavitha (97-11-29)	Crop weather relationships of okra (*Abelmoschus esculentus (L.)* Moench.	2000	Dr. A.V.R. Kesava Rao
6.	Mr. P.Shajeesh Jan (2001-11-50)	Leaf and spadix phenology of coconut (*Cocos nucifera* L.)	Likely in 2003	Dr. GSLHV Prasada Rao
7.	Mr. N.Manikandan (2001-11-61)	Climate variability and small cardamom (*Elettaria cardamomum* Maton) production across the Western Ghats	Likely in 2003	Dr. GSLHV Prasada Rao

5.7. Intake of PG students

The intake of PG students for Agricultural Meteorology since the inception of the course in the department is given below:

Academic year	Sanctioned no. of seats	No. admitted	No. completed	Remarks
1994-'95	2	1	–	PG programme commenced
1995-'96	2	1	1	
1996-'97	2	1	0	
1997-'98	2	2	0	
1998-'99	2	0	2	
1999-2000	2	0	2	
2000-'01	2	1	0	Discontinued
2001-'02	2	2	0	On rolls
2002-'03	2	0	–	

6. RESEARCH PROGRAMMES

The department has undertaken a number of research projects, which are both basic and applied in nature. The total number of research projects in agrometeorology successfully completed at the main campus as well as at other research stations under the KAU are 19 as listed below:

a) Agrometeorology of rice: 4

1. Influence of crop geometry on the growth and yield of rice var *Jaya*
2. Influence of weather parameters on growth and yield of rice variety *Jaya*
3. Crop weather relationship of paddy (KAU)
4. Crop growth simulation models in rice (DST)

b) Agrometeorology of coconut: 1

Agrometeorology of coconut and coconut based farming systems in Kerala (DST)

c) Agrometeorology of cashew: 2

1. Crop weather models for cashew (ICAR)
2. Influence of weather and soil factors on cashew yield and its quality across the west and east coasts of India (ICAR)

d) Agrometeorology of banana: 2

1. Crop weather relationship in rainfed banana under different time of planting
2. Effect of soil moisture status on growth and yield of banana cv. *Nendran*

e) Agrometeorology of vegetables: 6

1. Effect of date of sowing and levels of irrigation on the growth and yield of bitter gourd variety *-Priya*
2. Effect of time of sowing and levels of irrigation on the growth and yield of snake gourd
3. Influence of date of sowing and levels of irrigation on the growth and yield of watermelon (*Citrullus lanatus)* grown in rice fallow.
4. Crop weather relationship studies in bitter gourd var MC-84
5. Agrometeorological investigations in summer vegetables (DST)
6. Crop weather relationship in tomato *(Lycopersicon esculentum)*

f) Agroclimatic classification: 4

1. Prediction of water availability periods for crop management in Kerala
2. Prediction of water availability periods for crop planning in Kerala
3. Climate and rice in the Onattukara region
4. Agroclimatology of crop planning in central zone of Kerala

g) Plan schemes -2

1. Strengthening Dept. of Ag.Met (206-21-2248)
2. Agrometeorology research on drought management (343-31-2291)

h) Externally Aided Projects Completed – 5

Sl. No.	Title of the project	Duration of the project and location	Funding Agency	Budget allocation (lakh Rs.)	Name of the Principal Investigator
1.	Agrometeorology of coconut and coconut based farming systems in Kerala	1987-1992 RARS, Pilicode	DST, Govt. of India, New Delhi	14.28	GSLHV Prasada Rao
2.	Crop growth simulation models in rice	1990-1992 RARS, Pilicode	DST, Govt. of India, New Delhi	2.72	GSLHV Prasada Rao
3.	Crop weather models for cashew	1992-1995 RARS, Pilicode	ICAR, Govt. of India, New Delhi	4.68	GSLHV Prasada Rao
4.	Influence of weather and soil factors on cashew yield and its quality across the west and east coasts of India	1995-1999 RARS, Pilicode	ICAR, Govt. of India, New Delhi	4.60	GSLHV Prasada Rao
5.	Agrometeorological investigations in summer vegetables	1995-1999 CoH, Vellanikkara	DST, Govt. of India, New Delhi	7.30	P. Balakrishna Pillai
6.	Crop weather interaction studies on sole crops and intercrops in coconut based cropping system	2002-2005 CoA, Vellayani	DST, Govt. of India, New Delhi	15.20	L. Girija Devi
7.	Influence of microclimate on the productivity of a coconut based cropping system	2002-2005 CoA, Vellayani	STED, Govt. of Kerala	2.35	L. Girija Devi

i) Ongoing Externally Aided Projects - 6

1. AICRP on Agrometeorology (ICAR)
2. Agrometeorological Advisory Services (DST)
3. Climate and coconut (Marico Industries (Pvt.) Ltd. Bombay)
4. Influence of microclimate on the productivity of a coconut based cropping system (STED)
5. Crop weather studies of sole crops and intercrops in coconut based cropping system (DST)
6. Forecasting tea mosquito bug in cashew in collaboration with (BCCP) - Sanction letter from ICAR is expected during 2002-03 (ICAR Project)

7. ACHIEVEMENTS

7.1 Academic

The M.Sc. (Ag.) programme in Agricultural Meteorology was started in academic year 1994-'95 with an intake capacity of two students. Four batches comprising of five students have successfully completed the course. All the five students were awarded M.Sc. (Ag.) in Agricultural Meteorology by the University.

7.2 Research

7.2.1 Agrometeorology of coconut

Irrigation requirement of coconut palm has been worked out based on reference evapotranspiration, crop co-efficient and area of coconut root zone. CROPWAT is used for reference evapotranspiration.

The adverse effect of drought on coconut yield was seen in the succeeding year starting from eighth month to twentieth month after the drought period was over. The peak decline in monthly coconut yield was seen in the twelfth/thirteenth month after cessation of the drought.

Nearly fifty per cent of the variability in coconut yield could be explained by severity of soil moisture stress during the preceding summer.

The effect of drought on low yielders was low when compared to that of high yielders. However, the number of nuts produced by high yielders was much better even in drought situation when compared to that of low yielders under rainfed conditions.

A regression model was developed for forecasting coconut production of Kerala seven months ahead based on agroclimatic variables.

7.2.2 Agrometeorology of cashew

The law stated by Hopkins holds good in biotic events of cashew under better crop management in rainfed situations of tropical monsoon climates, provided the genotype and rain distribution of rainfall are uniform. However, there was a difference in number of days delayed in cashew flowering at each degree of North latitude while the effect of altitude on time of cashew flowering is similar as stated by Hopkins (1938). In humid tropic monsoon climates, as you move north there appeared to be a delay of six days in cashew flowering at every one degree change of North latitude and for every 100m of altitude, the delay in cashew flowering is three days.

The flowering of cashew may require relatively dry atmosphere with mild winter for better flowering. If that is not the case, it may be detrimental for cashew production since the number of bisexual flowers may be less. The mild winter may be defined as "low minimum surface air temperature ranging between 15 and 20°C coupled with more dew nights having moderate dew" in humid climates. Better availability of soil moisture during flowering period (December and January) may not influence the flowering in cashew.

A cashew plant, undergoing a first dry spell may have to wait for the second dry spell to occur for bud break. It appears that both the dry spells at the time of bud break and thirty days prior to bud break along with bright sunshine hours are critical for bud break in cashew. Soil moisture stress has no relevance in bud break of cashew as it commences much before soil moisture stress starts across the west coast. However, the influence of dry spell and bright sunshine on bud break of cashew is yet to be understood.

Cashew is enamoured with dry spell/drought during its reproductive phase and yields relatively better. However, the abnormal drought situation affects the cashew yield very much under rainfed conditions.

Cashew productivity can be increased towards north across the west and east coasts of India up to a certain limit while it may decrease towards inland plateau of Peninsular India.

Hot spots of tea mosquito across cashew growing areas have been identified based on critical weather "Night temperature".

Based on the work done in the Kerala Agricultural University, a technical bulletin entitled "Climate and Cashew" was published. Copies are available in the department of Agricultural Meteorology, College of Horticulture, Vellanikkara on payment of Rs. 100/- per copy. It is the first of its kind.

7.2.3. Agrometeorology of rice

The rainfall during kharif accounted for 37 per cent variability in rice productivity of Kerala.

Crop growth simulation models have been tested in rice varieties Jaya, Jyothi and Triveni. CERES-Rice model was found to be suitable for assessing potential grain yields during *kharif*, while it requires validation for use with *rabi* crop.

Incidence of gall midge in rice is expected if the pre- monsoon showers were noticed in April and May. A continuous rainfall with high intensity is the most significant factor, which hinders the symptom development of leaf blast even though the night temperature and relative humidity are congenial.

A prediction equation was developed based on weather variables for forecasting leaf blast severity in rice.

Local cultivar "Allikkannan" yields better if transplanted during the first fortnight of June in high rainfall zones of Kannur and Kasaragod districts of Kerala. There was a drastic decline in crop duration and grain yield when the date of planting is delayed.

7.2.4 Agrometeorology of black pepper

The weekly incidence of a *Phytophthora* foot rot was found positively correlated with relative humidity, rainfall and the number of rainy days. A regression model was developed to estimate the number of vines affected due to *Phytophthora* based on weather variables.

7.2.5 Agrometeorology of vegetables

In bitter gourd the temperature range during 45 to 65 days after sowing (DAS) and sunshine hours during 45-55 DAS were positively correlated with both total fruit yield and the number of female flowers per plant while it was negatively correlated with minimum temperature and relative humidity. A regression equation ($R^2 = 0.92$) was worked out for estimating yield in bitter gourd based on surface air temperature, sunshine and relative humidity.

Tomato could be successfully grown if the seedlings are transplanted in the middle of December under Vellanikkara conditions.

Growing Degree Days influenced crop duration of okra and fruit yield positively under Vellanikkara conditions.

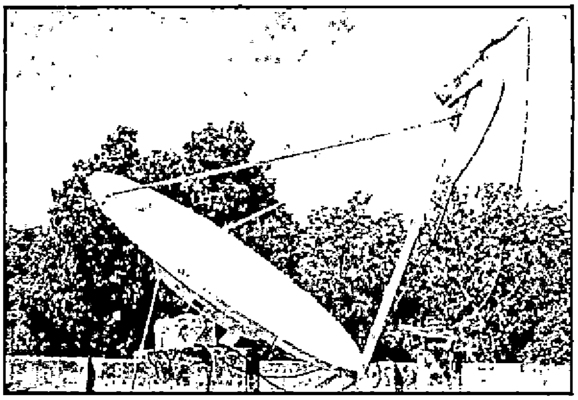
7.2.6 Agroclimatology/Climatology

There was a decrease of 131mm in monsoon rainfall of Kerala over a period of 131 years (1870-2000), indicating a decline of 6.8 per cent over the normal rainfall of 1933 mm. The monsoon rainfall is likely to be below normal if the onset of monsoon is early (before 25th May). This was true in 2001 when the onset of monsoon was on 23rd May.

The onset of monsoon over Kerala is stable and varies mostly between 25th May and 8th June. The normal onset of monsoon over Kerala is first June with a standard deviation of seven days.

The State of Kerala has been divided into 20 agroclimatic zones based on rainfall, soil type and cropping pattern.

In the central zone of Kerala, the annual rainfall and its probability at 75 per cent increase from east to west. The maximum number of moist days was recorded at Piravom(203), followed by Aluva and Perumbavoor (188). The minimum number of moist days was observed at Parambikulam (82). The number of moist days was high towards south while low in the southeast of the central zone.



VSAT under NCMRWF Project

Considerable variation in the annual rainfall was noticed in the various taluks of Onattukara region viz, Mavelikkara recording 3112 mm, Haripad 2981mm Karunagappally and Kayamkulam with 2400 mm. Mavelikara has a high rainfall regime as compared to the other taluks of the Onattukara region.

8. EXTENSION ACTIVITIES

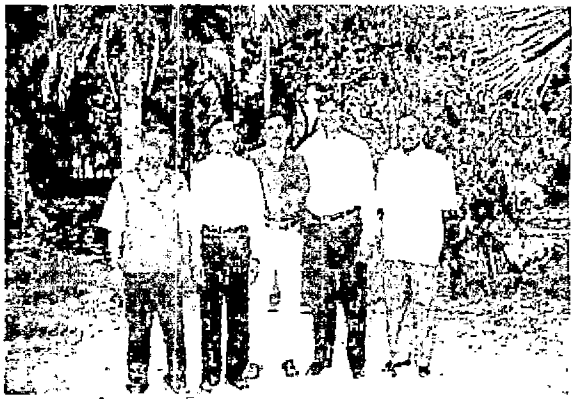
In addition to teaching and research, the department is involved in extension programmes by giving training to field staff and officers working in the KAU as well the Department of Agriculture, Govt. of Kerala. Training is being given on recording and analysis of agrometeorological data and maintenance of meteorological instruments. Training is also given to the Officers of the Soil Survey Department, Government of Kerala on the analysis of meteorological data for the preparation of agroclimatological maps.

There is a full-fledged Principal Agricultural Meteorological Station functioning in main campus at Vellanikkara. This is the only station in the KAU, which is enlisted as a co-operating station with the IMD for weather forecasting work. Observations are taken four times a day and weather telegrams are sent twice daily to IMD, Trivandrum, for use in weather forecasting. The Agrometeorological data collected from various research stations are processed in the department for building up a data archive. The data are supplied to scientists and research students of KAU and other research institutions in Kerala. Recently, an *Automatic Weather Station* for continuous monitoring of weather parameters was also installed.

Demonstration of Leaf Wetness Recorder

8.1. Training programmes

Several training programmes were conducted to train the Farm Assistants/Lab Assistants of the University for recording and maintenance of meteorological data. Three days training on " Agrometeorology of plantation crops" was also organized at RARS, Pilicode to Deputy Directors/ Assistant Directors of the Department of Agriculture, Government of Kerala.



Meteorological Observers from the Department in a Training Programme at IMD, Pune

Sl. No.	Title	Period	No. of participants
1	Training to the farm assistants/ lab assistants (recording of weather data)	14-3-1983 – 18-3-1983	6
2	Recording of meteorological data from the agrometeorological observatory	12-10-1991 – 26-10-1991	1
3	Recording of meteorological data from the agrometeorological observatory	16-6-1994 – 18-6-1994	1
4	Training programme of agro-meteorology of plantation crops	26-12-1994 – 28-12-1994	5
5	Agromet training	14-7-1997 – 16-7-1997	1
6	Agromet training	3-11-1997 – 7-11-1997	1
7	Training for meteorological observers	5-8-1999 – 7-8-1999	4

8.2. Agrometeorological Advisory Service

The Agrometerological Field Unit (AMFU), Department of Agricultural Meteorology, College of Horticulture, Trichur is one of the initial five centres in the country started by the National Centre for Medium Range Weather Forecasting (NCMRWF), Department of Science and Technology (DST), Government of India, New Delhi during the year 1991. Later on, three more AMFUs have been sanctioned by the DST and attached to different agroclimatic zones of the State of Kerala, viz. NARP Southern Zone, Vellayani; NARP Northern Zone,RARS, Pilicode and High Range Zone,RARS, Ambalavayal. The aim of the project is to disseminate Agrometeorological Advisory Services to the farming community based on Medium Range Weather Forecast for farm decision - making.

The weekly Agrometeorological Advisory Bulletins (AABs) consisting of weather summary for the past week, weather forecast for the next 3 to 4 days, stage and state of important crops of the region and agroadvisory for the coming week along with the control measures for the important pests and diseases of major crops are prepared and disseminated on every Tuesday through print and e-media. A copy of the same is directly handed over to nearby research stations and to selected farmers of the region on Tuesday afternoon or Wednesday forenoon so as to enable them to make use of the agro-advisory on farm decision making. The economic impact of weather forecasting is yet to be quantified for which steps have been initiated based on the feedback from the farmers.

8.3. Organisational Capabilities

A National Seminar on Agrometeorology of plantation crops was organised at RARS, Pilicode from 12-13 March 1987. About 60 delegates from different parts of the country attended the seminar.

Faculty member of the department accompanied the College students on All India study tour

An International Seminar on Agrometeorology was hosted at Kochi from 28-30 March 1988.

More than 100 delegates participated in the deliberations.

III Project Advisory and Monitoring Committee Meeting of the DST Project on Agrometeorology was hosted at RARS, Pilicode on 15-10-1990. 40 members were present.

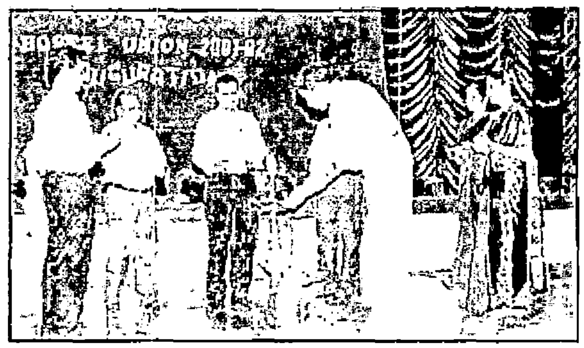
XI Annual Review Meeting of the DST Project entitled "Medium Range Weather Forecasting and Experimental Agrometeorological Advisory Services" was hosted at KAU headquarters from 28-11-2002 to 30-11-2002. About 150 delegates participated in the deliberations.

8.4. Books/Chapters/Reports (Published/Edited)

1. Prasada Rao, G.S.L.H.V. and Nair, R.R.(eds) 1988. Proccedings of the National Seminar on Agrometeorology of plantation crops. Kerala Agricultural University. Trichur, Kerala, India.187p
2. Prasada Rao, G.S.L.H.V. 1989. Climate of Kerala(1.4 – 16-27pp). NARP Status report. Vol.I Kerala Agricultural University. Trichur, Kerala, India.
3. Prasada Rao, G.S.L.H.V. 1993. Rice and weather (36-46pp). Sustaining rice productivity through integrated nutrient management (Compiled by Padmaja, P., Menon, P.K.G, Prasada Rao, G.S.L.H.V., Chinnamma, N.P., Geethakumari, V.L., George, K.C. and Sushma Kumari). Kerala Agricultural University. Trichur, Kerala, India. 79p
4. Prasada Rao, G. S. L. H. V. 1988. Agrometeorology of coconut (81-93pp). Six Decades of Coconut Research. (Eds. Aravindakshan, M, Mair, R.R. and Wahid, P.A). Kerala Agricultural University. Trichur, Kerala, India.
5. Prasada Rao, G.S.L.H.V. 2000. Guidelines for Agromet database. KAU Manual. Kerala Agricultural University. Trichur, Kerala, India.
6. Prasada Rao, G. S. L. H. V. 2002. Climate and Cahew. Kerala Agricultural University. Trichur, Kerala, India. 100p
7. Prasada Rao, G.S.L.H.V. 2001. A Chapter on Weather Forecasting. Included in the proposed text book on Agricultural Meteorology. ICAR Publication(In Press)
8. Prasada Rao, G.S.L.H.V., Krishna Kumar, K.N.,Xavier Tony and Lalitha Bai, E.K. 2002. Status of Agrometeorology (SWOT). Kerala Agricultural University. Trichur, Kerala, India. 72 p
9. Prasada Rao, G.S.L.H.V.(2002).Climate variability and coconut production in humid tropics. Kerala Agricultural University. Trichur, Kerala, India. 38 p
10. Varshneya, M.C. and Pillai, P.B(eds). 2001. A text book on Agricultural Meteorology. ICAR Publication (In Press)
11. Vinayak, P.V.S.S.K and Kesava Rao, A.V.R. 2002. District-wise Agroclimatic Atlas of Kerala. A publication of CESS and AICRP on Agrometeorology, 62p
12. For B.Sc(Ag) students - *Agricultural Meteorology Practical Manual for B.Sc.(Ag.) students*

8.5. Co-curricular activities

The faculty members from the department shared the college activities as NSS Co-ordinator and Asst. Warden of Pamba Men's Hostel. Participate in RAWE programmes and study tours.



Head of the Dept. as Asst. Warden

8.6. Research Publications

Appendix VII

8.7. Linkages

The faculty members of the department are in close association with the following international/national /state institutes:

International Research Institute for Climate Prediction, New York, USA
Queensland Centre for Climate Applications, Queensland, Australia
International Crops Research Institute for Semi Arid Tropics, Hyderabad
AICRP on Agrometeorology, CRIDA, ICAR, Hyderabad
National Centre for Medium Range Weather Forecasting, DST, New Delhi
Indian Climate Research Programme, DST, New Delhi
All the departments/divisions of Agricultural Meteorology in SAUs/ICAR institutes
Division of Agricultural Meteorology, IMD, Pune
Indian Institute of Tropical Meteorology, Pune
Department of Meteorology and Oceanography, Andhra University, Waltair
Division of Atmospheric Sciences, CUSAT, Kochi
Water Management (Ag) Division, CWRDM, Kozhikode
Centre for Earth Science Studies, Regional Centre, Kochi
Kerala Forest Research Institute, Peechi

9. SWOT (Strength, Weakness, Opportunity and Threat)

"SWOT as an acronym stands for strength, weakness, opportunity and threat of an organization. These four attributes are also called SWOT parameters. Strength is the basic asset of the organization that would provide competitive advantage for its growth and development. Weakness is the liability of an organization that can create a state of time and situation-specific disadvantage for its growth and development. Opportunity is the ability of the organization to grow and achieve its specific objectives in a given situation. Threat is a situation that blocks the abilities of the organization to grow and develop for meeting its ultimate goal"(extract from SWOT analysis of NARP-authors: K.Venkateswarlu and Jagdeesh C.Kalla (1996). Delta Publishing House, New Delhi. 225p

9.1 Strength

9.1.1 Research

Interdisciplinary approach
Agrometeorology of plantation crops
Crop weather relationships and modelling
Agromet Advisory Services based on Medium Range Weather Forecast (DST Project)
AICRP on Agrometeorology (ICAR)
Climate and coconut (M/s Marico Industries (Pvt.) Ltd. – Private Industry Participation)

9.1.2 Academic

Introduced M.Sc.(Ag.) in Agricultural Meteorology. KAU is the first University in southern Agricultural Universities where M.Sc (Ag) in Agricultural Meteorology is awarded.

Syllabus introduced at U.G level in agricultural meteorology (Metg .101 - (1+1); W.E.Metg.101-(0+1) is accepted at national level by the ICAR and the same is introduced in all the Agricultural Universities.

Lecture notes have been prepared at the U. G. level in the field of Agricultural Meteorology since it is very difficult to collect the course material by the students as no textbook is available to suit the syllabus. With this in view, ICAR is likely to publish a textbook on Agricultural Meteorology. Teachers from this department contributed several chapters and edited the above proposed textbook.

Services from allied departments are being utilized for handling teaching as well as research programmes in agricultural meteorology.

All the five students produced from the department could pass NET being conducted by ASRB, ICAR, Government of India, New Delhi.

9.1.3 Advisory

Initiated weather based weekly agro-advisory based on Medium Range Weather Forecast across the Kerala State for the benefit of the farmers.

9.1.4 Consultancy

Optimum climatic requirements of various crops

Hon'ble Vice-Chancellor looking at the Data logger insatalled in the field

9.1.5 Database

Sound in meteorological observational network.

9.2 Weakness

9.2.1 Research

Lack of professional scientists in the department due to no recruitment.

Lack of multidisciplinary approach in the field of agricultural meteorology.

9.2.2 Academic

Syllabus at P. G level should be strengthened/modified

No Ph.D. programme in Agricultural Meteorology

Inadequate infrastructure facilities.

9.2.3 Advisory

Weak in physical strength (Manpower as well as in infrastructure)

9.2.4 Consultancy

More and more research programmes in crop weather relationships of major crops are to be taken up in different agroclimatic zones for working out optimum climatic requirements of various 8 crops.

9.2.5 Database

Weak in agromet database management.

9.3 Opportunity

9.3.1 Research, Academic and Extension

Students from the department can appear for ARS since Agrometeorology is one of the identified areas in ICAR.

Openings outside the country are good as there is a dearth of qualified hands even in developed countries like USA and UK.

Openings in KAU as well as in other SAUs are expected as there is a dearth in professional agrometeorologists.

Professional Manpower in the field of agricultural meteorology.

Project formulation in agrometeorology of plantation crops.

9.3.2 Advisory

Agromet advisory services

9.3.3 Consultancy

Agromet Advisory services in the field of plantation crops in humid tropics

9.3.4 Database

Agromet database

9.4 Threat

The department loses its identity if professionalism is not seen in research, academic and extension activities.

9.5 Suggestions

Elevate the department to a Centre of Excellence

Project oriented budgeting

Initiate short-term training/certificate courses in agrometeorology and remote sensing

Observational network and agromet database should be strengthened

Sanctioned posts in Agricultural Meteorology should be filled with professional hands

A multidisciplinary team is to be identified for taking up crop growth simulation modelling and remote sensing related to plantation crops

Patronage and support for the development of the Department of Agricultural Meteorology.

10. VISION

10.1 Academic

Enhance number of seats from two to four for M.Sc. (Ag.) in Agricultural Meteorology

Ph.D. programme in Agricultural Meteorology

Publications in the field of agrometeorology of plantation crops on crop wise in line with "Climate and Cashew" already published, based on original work

International collaboration in the field of Agricultural Meteorology

Develop sound database in the field of Agricultural Meteorology.

10.2 Research

10.2.1. Observational network and agromet database

a) Network of Agromet stations in KAU

At different research stations, agromet observatories are manned without technical support. This leads to errors in data collection. This situation can be avoided if the stations are regularly monitored. Also wherever the Agrometeorological observatory is required, services will be rendered from the department. The weather data collected will be centrally computerised and supplied to the users on payment basis. Under this, agromet observations are to be collected from all the 32 research stations/Colleges of the University. Where Agromet station is not available, at least raingauges and thermometers are to be installed for recording daily rainfall as well as the maximum and minimum temperatures, as per IMD specifications.

b) Agromet Advisory Services (AAS)

The department of agricultural meteorology and other zonal centres of KAU disseminate AAS in collaboration with the NCMRWF, DST, Govt. of India on experimental basis. From the feedback obtained from the farmers/users, it is understood that the AAS is quite useful and informative for timely reaction based on medium range weather forecast. It is felt that the university should step up the AAS on its own across Kerala with a good network of telecommunication system and infrastructure facilities. This programme can be linked with the Directorate of Extension.

10.2.2. Crop growth simulation modelling

The IBSNAT and PLANTGRO models are used universally for simulating crop growth and yield. In India, ICRISAT is the first institute started working in simulation modelling of millets and dry land crops. IARI also took up some studies in the above crops as well in wheat and rice. The KAU is the first one, which tested the CERES -Rice model with the experimental data collected on three test varieties viz. Jaya, Jyothi and Thriveni at the RARS, Pilicode. The utility of the model is also being demonstrated. However, the revalidation work could not be taken up due to technical incompetence. Hence it is requested to form a multi-disciplinary group comprising of agrometeorology, plant physiology, agronomy, soil science and computer scientists, to take up the work on simulation modelling. The same group may be sent abroad for a six months training where competency is available in the field.

10.2.3. Drought and scarce water resources management in plantation crops

All the plantation crops in the northern region suffer due to severe soil moisture stress from December to May if pre-monsoon showers fail. The occurrence of drought during summer is also not uncommon in this part of Kerala. As a result, crop production is adversely affected. The decline in yield in plantation crops is expected to be 30-50 per cent due to drought in summer. Irrigating the crop during summer by way of lift irrigation from surface wells and ponds is the usual practice. Initial results indicate that providing irrigation during summer till water is available is beneficial to coconut. The drought and scarce water resources study aims at the following:

i) To study the effect of water stress on different plantation crops; ii) To study the efficiency of different irrigation system /methods in plantation crops; iii) To study effect of limited irrigation on plantation crops during summer till water is available; iv) To investigate suitable agronomic practices to mitigate the effect of drought under rainfed conditions and v) To test and validate soil moisture simulation models like SPAW, CROPWAT and WATBAL in plantation crops.

10.2.4 Centre for advanced studies in Agrometeorology of plantation crops for humid tropics

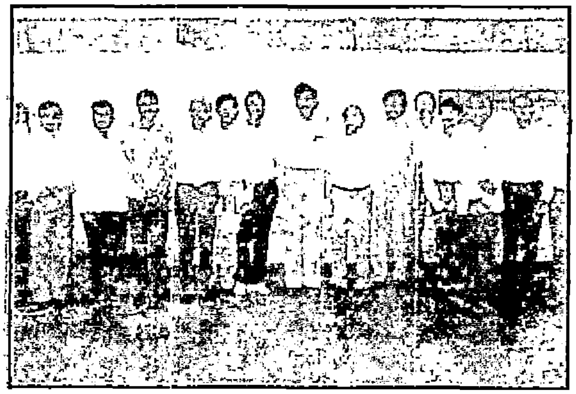
Plantation crops dominate in Kerala, which is classified under tropical monsoon climates. The behaviour of the plantation crops in the above climates is totally different to that of the other environments where plantation crops are grown. Keeping this in view, several crop weather relationship studies were undertaken in a few plantation crops. Several crops like arecanut, black pepper, coffee, tea, cocoa and cardamom are yet to be included in crop weather studies. The crop weather studies initiated in coconut and cashew will be strengthened further.

10.2.5 Application of Remote sensing in agriculture

Remote sensing techniques can be applied for acreage identification and yield estimation in important plantation crops. Visual and digital image processing techniques will be used based on the remote sensing data collected from IRS-1A/1B/1C, LANDSAT and NOAA for drought monitoring and identification of pest and disease affected areas of major crops.

10.2.6 Training personnel and documentation

Short term training programmes on advanced aspects of Agricultural Meteorology and short term/certificate courses in remote sensing applications will be organised. Awareness on weather service to farmers will be popularised. The research/teaching material produced from the department will also be documented.



One of the faculty members of the Dept. at IIT, Mumbai in connection with the training on digital image processing (Remote Sensing)

Staff and students - Department of Agricultural Meteorology

Appendix I

GLOSSARY

Annual mean temperature	Average of twelve monthly mean temperature
Annual temperature range	Difference between the warmest and the coldest monthly mean temperatures
Anticyclone	A high pressure area with dry air, resulting no clouds and rains.
Climate	The mean state of weather over a period of 30 years. Rainfall is a weather variable while mean rainfall climate variable. If the mean of a weather variable is over a period of 30 years, it is known as climatic normal of that particular weather variable.
Crop calendar	It provides information from tillage to harvest with various operations in different crop growing seasons for each crop of a region in years of normal weather.
Crop weather calendar	It is a pictorial form of providing information on different biotic events of a crop along with climatic normals under which it is grown in a particular season and the need of weather forecast on meteorological variables during different crop growth stages. It is handy to weather forecaster and farmers.
Cyclone	A low pressure area with high wind speed and moist air. It gives heavy rains if formed along the coast, leading to floods. It is known in different forms in different regions as Willy-willies and Typhoons.
Daily mean temperature	Average of maximum and minimum temperatures of a day
Daily temperature range	Difference between the maximum and minimum temperatures of a day
Definition of drought	There is no universally accepted definition of drought. However, it is broadly perceived in three different ways.
Meteorological drought	It is defined when the rainfall of a place receives less by 25% or more when compared to normal
Hydrological drought	Meteorological drought, if prolonged, results in hydrological drought with marked depletion of surface water and consequent drying up of reservoirs, lakes, streams and rivers, cessation of spring flows and fall in ground water levels.

Agricultural drought	It occurs when rainfall and soil moisture are inadequate during the growing season to support healthy crop growth in maturity and causes extreme stress and wilting. Permanent droughts, seasonal droughts and terminal droughts come under the category of agricultural drought.
Diurnal temperature	Hourly temperatures of a day
El Nino	Warm sea surface temperature over Peru coast, leading to unusual warming of eastern equatorial Pacific Ocean. This may lead to bad monsoon over India.
ENSO	Combination of El Nino and Southern Oscillation

Excess and deficit rainfall as per IMD classification

Excess	+ 20% of normal or more
Normal	+ 19 % to – 19 % of normal
Deficient	-20 % to – 59 % of normal
Scanty	- 60 % of normal or less

IITM	Indian Institute of Tropical Meteorology
IMD	India Meteorological Department
Indian drought	When the rainfall deficiency for the country as a whole is more than 10% of normal and more than 20% of the country's area is affected by drought conditions, the situation is defined as an all-India drought year. Hence, 2002 was declared as Indian drought year. Such drought last seen was 1987. In Kerala, the rainfall during monsoon was less by 35% in 2002, probably one of the lowest rainfall years. The water level in major reservoirs was below normal during the above year.
Isobar	A line drawn on a map connecting places of equal pressure
Isohyet	A line drawn on a map connecting places of equal amount of rainfall
Isotach	A line drawn on a map connecting places of equal wind speed
Isotherm	A line drawn on a map connecting places of equal temperature
ITCZ	Inter Tropical Convergence Zone. It is the zone where moist Southeast trade winds meet the Northeast trade winds of the northern hemisphere. The shift of ITCZ also influences Indian monsoon.
La Nina	Opposite to El Nino
Monsoon	It refers to season. Two distinct seasonal winds are blown over India for a period of six months in one direction (Southwest) and other half in another direction (Northeast). Rains are received across India during southwest monsoon due to moist winds carried from Indian Ocean between June and September. Poor rains are noticed during northeast monsoon from mid-October to December except in Tamil Nadu and Jammu & Kashmir, where significant rains are noticed.

NCMRWF	National Centre for Medium Range Weather Forecasting
Pressure unit	It is measured in hectoPascals (hPa)
Rain shadow area	A dry area on the leeward side of a mountain range.
Rainfall unit	It is measured in millimetres (mm)
Rainy day	A day with a total rainfall of more than or equal to 2.5mm.
Seasons in India based on rainfall and temperature	
	June –September – Southwest monsoon
	October-November – Post monsoon
	December-February- Winter
	March-May – Summer
Southern Oscillation	Referred to changes in surface atmospheric pressure between the eastern equatorial Pacific and the Indonesian regions. It also influences Indian monsoon.
SST	Sea Surface Temperature
Standard Meteorological Week	It starts with 1st January and ends with 31st December, having 52 weeks. See Appendix VI
Temperature unit	It is measured in degree Celsius (^{O}C)
Troposphere	The atmospheric layer over the Earth's surface, extending up to 20km height over the equator and 08-10km over the poles in which weather is produced. Troposphere is known as weather making layer.
Weather	The physical state of atmosphere at a given time. It is measured in terms of atmospheric pressure, wind, temperature and rainfall. Likewise, it can be measured in many forms. They are known as weather variables or meteorological variables.
Weather Forecasting	Predicting the future state of atmosphere. It is of four types, viz. Nowcasting (less than few hours), Short Range Weather Forecasting (less than three days), Medium Range Weather Forecasting (three to ten days) and Long Range Weather Forecasting (for a season normally, otherwise any forecast for more than ten days)
Wind unit	It is measured in kilometres per hour (km/h)
WMO	World Meteorological Organization. The WMO day falls on 23rd March

Appendix II

a) Syllabus and class schedules for B.Sc (Ag)/B.Sc. (Forestry)

Agmt. 101 Agricultural Meteorology (1+1)

i) Theory:

1. Introduction to Meteorology - Definition of Agricultural Meteorology - Branches of Meteorology, Physical, dynamic, statistical and synoptic meteorology.
2. Importance and scope of Agricultural Meteorology
3. Concept of weather and climate, macro, meso, micro and phytoclimate
4. Laws of Radiation - Solar constant - Short wave and Long wave radiation - Composition of the atmosphere: Absorption by carbon dioxide, water vapour and ozone.
5. Stratification of atmosphere - Troposphere, stratosphere, mesosphere and thermosphere. Temperature inversion, effects on air pollution, Ionosphere and homosphere.
6. Meteorological elements - Temperature, Factors affecting temperature at a place- latitude, altitude, nearness to sea, prevailing winds, ocean currents , topography, condition of atmosphere. Isothermal charts. Diurnal variation of air and soil temperature, Cardinal temperatures.
7. Atmospheric pressure, units, variations with height, Isobars, Pressure gradient and Coriolis force, Geostrophic wind, General circulation, Trade and antitrade winds, Cyclones and anticyclones, Beaufort's Scale.
8. Humidity, Saturated and actual vapour pressure, Absolute specific and Relative humidity, Psychrometry, Diurnal variation of humidity.
9. Stability and instability conditions, Condensation, Atmospheric nuclie, Precipitation processes, Forms of precipitation - rainfall, frost, snow, fog, isohytes, thunderstorms, Classification of clouds, cloud seeding for agriculture.
10. Spectral distribution of solar radiation, Radiation balance - Albedo , Radiation distribution in plant canopy - Net radiation, Radiation instruments, Sensible heat flux and air temperature, Leaf temperature, Thermoperiodism, Growing Degree Days.
11. Influence of weather elements on crop growth and distribution
12. Effect of weather elements on the incidence of pest and diseases
13. Moisture factor in plant growth-plant growth under moisture stress-Drought, Evapotranspiration -Measurement and computation
14. Onset and withdrawal of southwest and northeast monsoon, Onset of effective rains, Dry and wet spells, Hydrological cycle with reference to agriculture - Thornthwaite's water balance method

15. Weather forecasting for agriculture - Use of radiosonde, RADAR and satellites, Synoptic chart, Weather services to farme Crop weather calendar and crop weather diagram, Weather abnormalities and their control - Weather and climate modification, Agricultural seasons

17. Climatic and Agroclimatic classification - Koppen and Thornthwaite's methods, Agroclimatic classification of Kerala

18. Introduction to Crop weather studies and modelling - Role of remote sensing in agriculture– Indian Remote Sensing Programme

ii) Practical:

1. Agromet Observatory - Choice of site and layout
2. Installation of Stevenson screen and thermometers and soil thermometers
3. Installation of Windvane and anemometer
4. Installation of raingauges and sunshine recorder
5. Installation of evaporimeter and dew gauge
6. Recording and tabulation of the observations
7. Measurement of air temperature - Stevenson screen, Dry bulb, wet bulb, maximum and minimum thermometers
8. Measurement of soil temperature - soil thermometers
9. Measurement of wind speed - Cup anemometer
10. Measurement of wind direction - Windvane
11. Rainfall measurement - FRP raingauge
12. Rainfall measurement - Self recording raingauge
13. Measurement of evaporation - Open pan evaporimeter
14. Measurement of duration of sunshine - Sunshine recorder
15. Measurement of humidity and vapour pressure using psychrometer
16. Measurement of dew - Duvdevani dew gauge
17. Thermograph
18. Hygrograph

iii) W.E. (Agmet 101) Application of Agricultural Meteorology (0+1)

1. Recording and tabulation of agromet observations; air and soil temperature and rainfall.
2. Recording and tabulation of agromet observations: Wind speed and direction.
3. Recording and tabulation of agromet observations: Evaporation, sunshine hours and dew.

4. Maintenance of agromet observatory instruments: Thermometers windvane and anemometer
5. Maintenance of agromet instruments: Raingauges, evaporimeter, sunshine recorder
6. Maintenance of agromet instruments: Dew gauge, thermograph and hygrograph
7. Recording of synoptic observations
8. Preparation of weather telegram
9. Assessment of crop condition and preparation of agroadvisory bulletin based on IMD weather forecast
10. Computation of PET and water balance of a station using Thornthwaite's method
11. Analysis of climatic droughts using aridity index
12. Study on the effect of weather on the incidence of pests and diseases on rice
13. Study on the effect of weather on the incidence of pests and diseases on vegetables and other crops
14. Measurement of temperature and humidity in greenhouse to study microclimate
15. Rainfall studies of a station - Computation of mean, SD,CV and 75% probability rainfall
16. Preparation of crop weather diagram
17. Recording data automatic weather station
18. Demonstration of rice model and image processing of satellite imageries in the computer

vi) Agmet. 402 Photo interpretation & Remote sensing (1+1)

a. Theory

1. Introduction to aerial photography - types of aerial photographs
2. Aerial Photographs vs Maps - Aerial sensors - Cameras, films and filters.
3. Aerial Photography planning - season and time - scale for forest photography - direction of flight - tilt, crab and drift - procurement of aerial photography.
4. Photogrammetry - definition- Stereoscopy - mapping instruments- measurement of height of tree, slope etc.
5. Aerial photo interpretation- measurement of tree crown diameter, crown closure, tree count, tree and stand volume etc.
6. Aerial photographs in forest management - forest cover types, insect and disease surveys, silvi-cultural surveys, timber sale and recreation and wild life management.
7. Introduction to remote sensing - history - Remote sensing as a tool for resources survey.

8. Active and passive types of remote sensing - energy sources and radiation principles
9. Interaction of electro-magnetic radiation with atmosphere - atmospheric windows - scattering etc.
10. Interaction of electro-magnetic radiation with earth surface features.
11. Spectral reflectance characteristics of vegetation, soil and water.
12. Satellite remote sensing - introduction - spectral bands
13. Remote sensing in thermal IR region - radiation laws, thermal sensors, scanners
14. Satellite systems - LANDSAT, NOAA, SPOT - Indian remote sensing programme.
15. Visual image processing - interpretation techniques, spectral pattern recognition.
16. Introduction to digital image processing - image enhancement - supervised and unsupervised classification.
17. Use of satellite imageries in forestry - forest cover mapping and damage assessment.
18. Introduction to microwave remote sensing - surface roughness, wavelength, polarization, synthetic aperture radar.

b. Practicals

1. Stereo test and study of laboratory instruments for interpretation and mapping.
2. Aerial photography equipment - pocket stereoscope.
3. Aerial photography equipment - mirror stereoscope.
4. Estimation of instrument base using mirror stereoscope.
5. Orientation of stereo model under mirror stereoscope.
6. Tracing of details from stereo pair.
7. Determination of photo scale.
8. Determination of heights and slopes.
9. Estimation of tree height using mirror stereoscope.
10. Preparation of base map using survey of India map
11. Preparation of thematic map from aerial photograph.
12. Computation of energy at different wavelength for the Sun and earth.
13. Study of different types of satellite data products.
14. Visual interpretation of a satellite imagery.
15. Study of multi spectral data using additive color viewer.
16. Demonstration of digital image processing - image enhancement.
17. Demonstration of digital image processing - preparation of FCC and NDVI map.
18. Demonstration of digital image processing - supervised and unsupervised classification.

Suggested references;

1. Bhatt, A. B. 1994. **Aerial photography and remote sensing (an introduction)** Bishen singh mehendra pal singh, 23-a, New Connaught place, Dehra Dun - 248 001 p164.

2. ISRO 1993. Technical report ISRO- NNRMS -TR- 98-93 **Remote Sensing - special reference to Indian scenario.** Indian space research organisation, Bangalore p34.

3. Sharma, A. K. 1986. **Remote sensing and forest** surveys International book distributors, Dehra Dun p210.

4. Tomar, M.S. and Maslekar, A.R. 1974. **Aerial photographs in land use and forest surveys** Jugal Kishore & Co. Dehra Dun p210.

b) Postgraduate courses:

i) M.Sc. (Ag.) in Agronomy

Agron.602 Weather and Agriculture (1+1)

Theory

Climate and crop production. Weather factors affecting plant growth. Effect of weather elements on crop production. Sunshine, temperature, rainfall, pressure, humidity and wind. Measurement of weather parameters. Weather and incidence of pests and diseases. Crop weather studies. Crop weather, pest and cultivation calendar. Review of crop weather studies in India. Weather analysis and forecasting. Study of meteorological instruments. Effect of soil air, soil temperature and soil water interface. Temperature on crop growth and production.

Agricultural seasons and their significances on crop production. Important crops of each season. Weather and crop outlook. Weather abnormalities, their effects and methods of overcoming.

Practical

Measurement of weather elements such as atmospheric temperature, pressure, wind, humidity, sunshine, rainfall using non-recording and recording instruments. Observations of evaporation using US open pan evaporimeter -computation of potential evapotranspiration using formulae - field studies on the incidence of pests and diseases in relation to weather change - Measurement of soil temperature at different depths- studying the rainfall pattern of Kerala.

c) Ph.D (Ag/Hort.)

Agron.702 | Advances in Agro-climatology | (2+0)

Weather and climate. Macro, micro, meso and ecoclimate. Field scale modification of micro- climate. Concepts of climatology -Energy balance -Radiation measurements.

Climatic classification of the world. Climatic factors of tropical farming. Agroclimatic regions of India and Kerala. Important crops of each region.

Weather elements and their studies. Solar radiation. Temperature, pressure, wind. Rainfall, cloud seeding and artificial rain. Analysis of rainfall data, relative humidity. Composition and vertical structure of the atmosphere. Heat distribution. Lapse rate. Atmospheric circulation. Precipitation. Frost, mist, fog, hail storms. Cyclones, Anticyclones, Effect of adverse climatic factors on growth and yield of crop. Weather modifications. Forecasting, crop weather outlook -weather and pest & disease incidence.

Appendix III

CURRICULA AND SYLLABUS FOR MASTER'S DEGREE PROGRAMMES

AGRICULTURAL METEOROLOGY

(Publication No: ICAR/ED (A) /Pub-9/5-2000)

A. Major

A. 1 Core Courses	**12 credits**	
1. Fundamentals of meteorology		2+1
2. Fundamentals of climatology		3+0
3. Micrometeorology		2+1
4. Agrometeorological Instrumentation		1+2
Seminar		**0+1 credit**
A. 2 Optional Courses		**8 credits**
1. Evapotranspiration		2+1
2. Agroclimatic analysis		2+2
3. Crop weather models		1+2
4. Water budgeting and drought meteorology		2+1
5. Applied agrometeorology		3+0
6. Weather and agriculture		2+1
7. Hydrometeorology		2+1
8. Weather modification		2+0
9. Principles of Remote Sensing and its applications in agriculture		2+1
B. Supporting courses		**14 credits**

To be decided by the Student's Advisory Committee

TA.1 Core Courses

1. Fundamentals of meteorology (2+1)

Solar radiation and laws of radiation, green house effect, albedo, heat balance of the earth and atmosphere, variation of pressure and temperature with height, potential temperature, pressure gradient, cyclonic and anticyclonic motions. geostrophic and gradient winds, equations of motion, general circulation, turbulence, vorticity atmospheric waves.

Gas laws, laws of thermodynamics and their application to atmosphere; water vapour in the atmosphere, various humidity parameters and their interrelationships, vapour pressure, psychrometric equation, saturation deficit, stability and instability conditions in the atmosphere. Lapse rates- ascent of dry and moist air, condensation, clouds and their classification, evaporation and rainfall; the hydrological cycle, precipitation processes, artificial rainmaking, thunderstorms and dust storm, haze, mist, fog, and dew; air masses and fronts; tropical and extra-tropical cyclones. Effect of earth's rotation on zonal distribution of radiation, rainfall, temperature, and wind. The trade Winds, equatorial trough and its movement; The SE Asia monsoon. Weather charts, forecasting methods- short, medium and long range forecasting techniques, numerical weather prediction. EL Nino and Southern oscillations. Instruments for measurement of meteorological elements. Agromet observatory.

Practical

Agromet observatory- different classes of observatories (A,B,C). Site selection and installation procedures for meteorological instruments, Measurement of weather parameters, Reading and recording, Calculation of daily, weekly, monthly means/totals of weather data, climatic normals, weather chart preparation and identification of low pressure systems and ridges.

Suggested readings

Byers, H.R. 1959. General Meteorology. McGraw Hill, Inc., New York.

Ghadekar, A.E. 1991. Meteorology. Agromet Publishers, Nagpur.

Petterson, S. 1958. Introduction to Meteorology. McGraw Hill, Inc., New York. Trewartha Glenn T. 1954. An Introduction to Climate, McGraw Hill, Inc., New York, pp.395.

2. Fundamentals of climatology (3+0)

Weather and climate: Climatological elements and their seasonal distribution over latitudes. Climatic classificatioin: Koppen, Thornthwaite, Hargreaves and Troll's systems, humid and dry climates. Continental, monsoonal, maritime and desert climates. Agroclimatic indices, agroclimatic zones; different agroecological zones for India. Climatology of India: Monsoons, length of day, temperature, rainfall and its variability, atmospheric and soil drought. Arid and semi-arid regions. Frequencies of disastrous weather events in the different regions, Climatological factors and their effect on crop growth and yield. Climatic change and its causes, global warming, Bioclimatology: Heat balance of animals, body temperature inputs.

Suggested readings

Haurwitz, B. and Austin, J.M. 1944. Climatology. McGraw Hill, Inc., New York, pp.410.

ICRISAT Climatic classification -A consultants meeting. 1980. ICRISAT- Hyderabad, India, p.153.

Lal, D.S., 1989. Climatology. Chaitanya Publishing Home, Allahabad, p.420.

Petterson, S., 1958. Introduction to meteorology. McGraw Hill. Inc. New York, pp.327.

Trewartha, Glenn T. 1954. An Introduction of Climate. McGraw Hill, New York, pp.395.

3. Micrometeorology (2+1)

Properties of atmosphere near the earth's surface. Molecular and eddy transport of heat, water vapour and momentum, frictional effects, eddy diffusion, mixing. Temperature instability, air pollution. Microclimate near the bare ground, unstable and inversion layers, variations in microclimate under irrigated and rainfed conditions, soil moisture and temperature variation with depth. Micrometeorology of plant canopies: Distribution of temperature, humidity, vapour pressure, wind and carbon dioxide. Modification of microclimate due to cultural practices, intercropping. Radiation distribution and utilization by plant communities-leaf temperature and its biological effects. Heat transfer near and within the ground. Influence of topography on microclimate. Shelter belts and wind breaks, micro climate in low plant area of meadows and grain fields, microclimate within forests, glass house and plastic house climates. Instruments and measuring techniques in micrometeorology. Effects of ambient weather conditions on growth, development and yield of crops. Crop-weather relations, statistical regression equations and crop growth models.

Practical

Measurement of global radiation and diffuse radiation; Measurement of albedo over natural surfaces and cropped surfaces; Net radiation measurement at different levels; PAR distribution in plant canopies and interception; Wind, temperature and humid- ity profiles in (a) short crops and (b) tall crops; Energy balance over crops and LAI and biomass estimation.

Suggested readings

Chang, J.H. 1968. Climate and Agriculture, Aldine Publishing Co.,Chicago.

Evans, L.T. 1963. Environmental Control and Plant Growth, Academic Press, New York.

Gates, D.M. 1968, Energy Exchange in the Biosphere, UNESCO, Paris.

Grace, John 1983. Plant Atmospheric Relationships: Outline studies in Ecology, Chapman & Hall, New York, pp92.

Munn, R.E, 1970. Biometeorological Methods, Academic Press, New York.

Rose, C. W. 1996. Agricultural Physics, Pergamon, London

Sellers, W. 1967. Physical Climatology. The University of Chicago Press, Chicago.

4. Agrometeorological instrumentation (I +2)

Fundamentals of measurement techniques, theory and working principles of barometers, thermometers, thermographs, psychrometers, hair hygrometer, thermohygrograph, rainguage, self recording rain gauge, duvdevani dew gauges, lysimeters, open pan evaporimeters, anemometer, windvane, anemograph, soil thermometers, soil heat flux plates, instruments for measuring soil moisture, sunshine recorder, albedometer; photometer, spectro-radiometer, quantum radiation sensors, pressure bomb apparatus, porometer, photosynthesis system, infra-red thermometer.

Practical

Working with the above instruments in the meteorological observatory, taking observations of relevant parameters, computation interpretation of the data.

Suggested readings

Byers, H.R. 1959.General Meteorology. McGrow Hill Book Co. Inc., New York.

Middleton. W.E. and Spilhaws. A.F. 1962. Meteorological Department. Univ. of Toronto. Press. Canada.

Tanner, C.B. 1973. Basic Instrumentation and Measurements for Plant Environment and Micrometeology. Univ. of Wisconzin, Madisan, Wisconsin, USA.

NCERT. 1985.Agrometeorology- A Practice Manual, NCERT Pub.

A. 2 Optional courses

1. Evapotranspiration (2+1)

Basic laws of radiation, Radiation interaction with plant environment, Energy balance in atmosphere, crop canopy. The atmosphere near the ground. Laminar and turbulent flows. Wind profile near the ground, Theories of evapotranspiration and their comparison. Aerodynamic, eddy correlation, energy balance, water balance and other methods Application under different agroclimatic conditions. Concepts of Potential, Reference and Actual evapotranspiration-modified techniques. Influence of microclimatic, plant, soil and cultural factors. Techniques of lysimetry in measuring actual evapotranspiration. Yield functions, water use efficiency and scheduling of irrigation based on evapotranspiration. Radiation instruments. Advanced techniques for measurement of radiation and energy balance. Computation of Kc values and their use.

Practical

Measurement and evaluation of radiation components, Computation and comparison of evapotranspiration by different methods; Energy balance method; Aerodynamic method; Penman method; Remote sensing and other methods and Measurement of wind and temperature profiles near the ground.

Suggested readings

Chang, J .H. 1968. Climate and Agriculture, Aldine Pub. Chicago

Evans, L. T. 1963. Environmental Control and Plant Growth. Academic Press, New York.

Grace, John.1983, Plant Atmospheric Relationships: Outline studies in Ecology, Chapman & Hall, New York, pp92.

Rose, C. W. 1966. Agricultural Physics, Pugaman London

Sellers, W. 1967. Physical Climatology. The University of Chicago Press, Chicago.

2. Agroclimatic analysis (2+2)

Review of Agroclimatic methods, characteristics of agroclimatic elements; Sampling of atmosphere: temporal and spatial considerations: micro-meso- and macro climates. Network spacing. Numerical characterization of climatic features. Crop response to climate, time lags, time and distance constants, hysteresis effect; influence of climate on stress-response relations. Thermal time approach in agroclimatology: heat unit system, thermal time, heat and radiation use efficiency in crop plants: applications to insect-pest development and prediction, comfort indices for human and animals.

Instrumentation and sampling problems design of agrometeorological experiments. Data processing techniques in agroclimatology-synoptic, numerical and graphical techniques, spatial analysis of weather systems and charts.

Modelling techniques of crop weather relations. Methods of forecasting crop yields, pests and disease development, using climatic inputs.

Practical

Calculation of Continentality factors, PET by Thornthwaite method; Computation of Climatic Water balance and its components. Climatic indices and climograms; Degree days, Photothermal, Phenthermal and other indices, heat units; Heat use efficiency of crops, Biomass, crop growth rates; Analysis of Thermogram, Hygrogram, Hyetogram, sunshine cards etc; Preparation and analysis of isobar chart, isothermal and isohyetal charts. Stream lines and wind roses and Statistical analysis of climatic data.

Suggested readings

Conrad, V. and L. W. Pollak. 1950. Methods in Climatology, Harvard University Press.

IMD/WHO. 1998. Users Requirements for Agrometeorological Services, IMD pp.336.

Munn, R.E. 1970. Biometeorological Methods. Academic Press. New York and London.

Thom,H.C.S. 1971. Some Methods of Climatological Analysis. W.M.O. Technical Note No. 81, W.M.O.Geneva.

3. Crop weather models (1+2)

Principles of crop production, Evaluation of crop responses to weather elements, Impact of natural and induced variability of climate on crop production. Empirical and statistical crop weather models their application with examples, Regression models incorporating weather, soil, plant and other environmental related parameters and Remote sensing inputs. Growth and yield prediction models. Crop simulation models, forecasting of pests and diseases.

Practical

Working with statistical and simulation models, Plantgro, Ceres models, Brassica, Rescap etc

Suggested readings

DeWit, C.T.,Brouwer, R. and de Vries, F.W.T.P.1970. The simulation of photosynthetic systems. pp. 7- 70. In. Prediction: and measurement of photosynthetic activity. Proc. Int. Biological Programe Plant Physiology Tech. Meeting Trebon.PUDOC, Wageningen, The Netherlands.

Duncan, W.G. 1973. SIMAI- A model simulating growth and yield in corn. In. the application of systems methods to crop production (Ed. D.N. Baker). Mississippi State Univ. Mississipi.

Frere, M. and Popav, G. 1979. Agrometeorological Crop Monitoring and Forecasting. F.A.O. Rome.

Hankes, R.J. 1974. Mode for Predicting Plant Yield as Influenced by Water Use. Agron. J. 66: 660-665.

Keulen, H. Van. And Seligman, N.G. 1986. Simulation of Water Use, Nitrogen Nutrition and Growth of a Spring Wheat Crop. Simulation monographs. PUDOC Wageningen.

4. Water budgeting and drought meteorology (2+1)

Water budgeting in climatic studies, Soil moisture budget models of Thornthwaite and Mather, and Baier. Linear models, log and exponential models of soil moisture decay. Water and yield relationships, consumptive use and water use, dry matter production and water use efficiency. Concept of drought and its meaning, types and kinds of drought, permanent, seasonal droughts and contingent droughts, Atmospheric, agricultural and hydrological drought, use of rainfall analysis in drought. Water balance concept in drought studies, frequency and intensity droughts, mild, moderate and severe droughts. Spread of drought, MAI and its probability. Drought prediction and Remote sensing in drought monitoring.

Impact of climatic water budgeting parameters on crop planning and agricultural products.

Practical

Drought classification using seasonal and annual rainfall, Monthly and weekly water balance, Aridity and Humidity indices, drought classification by water deficiency and Aridity index, MAI and its probability, Short term droughts, Duration and intensity of dry spells, evaluation of different kinds of drought.

Agricultural drought, categorization of agricultural droughts, Principles and practices for agricultural drought management- short term and long term approaches.

Suggested Readings

Baier, W. and Robertson, G. W. 1966. A new versatile soil moisture budget., Can. J. Plant Sci. 46: 299-315.

Palmer, W.C., 1964. Meteorological Drought, Res. Paper No.45. Weather Bureau.

Palmer, W.C. 1968. Keeping track of crop moisture conditions Nationwide: the new crop moisture index. Weatherwise 21, 156-161.

Subrahmanyam, V.P. 1967. Incidence and spread of continental drought. WMD/IHD Rept. No.2. World Meteorol Organization, Geneva.

Thornthwaite, C. W. and Mather, J .R. 1955. The Water Balance, Publications in Climatology. Laboratory of Climatology, Centerton (NJ) Vol.8, No.1.

5. Applied agrometeorology (3+0)

Phenology and seasonal changes of weather conditions. Thermoperiodism, photoperiodism, heat unit concept and its applications. Climatic water budgeting technique and its application in evaluation of moisture availability periods within crop growing season, planning of multiple cropping pattern for different soil-climatic zones of India based on above techniques. Influence of agrometeorological factors on incidence of pests and diseases- effects on timing and effectiveness of control measure on herbicides, nematode population, seed rate. Weather forecasting for agriculture. General forecasting medium range, short range and seasonal forecasting for agricultural purposes. Special weather forecasts for frosts, hail, insects, pests and diseases, droughts, high winds, heat waves etc. Crop protection from weather hazards. Protection from frost, forest fire, drought and floods, wind breaks and shelter belts.

Suggested readings

Gadvian J. 1977. Crop Micro Meteorology and Simulation Study, PUDOC. Wagenedigan, pp.249.

Grace, J. 1977. Plant Atmospheric Relationships: Outline studies in ecology, chapman and Hall New York.

Mavi, H.S. 1986. Introduction to Agrometeorology. Oxford IBH, Publishing Co. New Delhi.

Jhon Grace 1983. Plant atmospheric relationship.Chepmanand Hall, New York.

Munn, R.E., 1970. Biometeorological Methods. Meteorological services of Canada Toronto, Canada.

6. Weather and agriculture (2+1)

Climate and crop production, weather factors affecting plant growth. Cardinal weather parameters for different crops Effect of weather elements on crop production, Measurement of weather parameters. weather and crop growth relations, weather and incidence of pests and diseases. Crop weather calenders. Use of weather forecasting in agriculture. Weather based Agro advisories.

Agricultural seasons and their significance on crop production. Important crops of each season - specific to region. Weather abnormalities and weather hazards their effects and methods of overcoming.

Practical

Preparation of crop weather calendars; Weather and pest relations in different cropping system; Computation of parameters for weather forecasting; Agroadvisories.

Suggested Readings

Chang Jen Hn. 1968. Climate and Agriculture Aldine Publishing Co., Chicago. Critchfield, H.J. 1975. General climatology, Prentice Hall, London.

Geiger, R. 1966. The Climate Near the Ground. Horwend University Press, Cambridge.

Mavi, H.S. 1986. Introduction to Agrometeorology. Oxford IBH Publishing Company, New Delhi.

Sellers, W. 1965.Physical Climatology, University of Chicago Press, Chicago.

7. Hydrometeorology (2+1)

Hydrologic cycle and its modifications. Rainfall and its interception by plants and crops. Measurement of runoff, infiltration, moisture retention of soil, percolation, evaporation, evapotranspiration and its importance to agriculturists, irrigation engineers and flood forecasting personnel. Water holding capacity of soils, available water, cultural practices on soil moisture in relation to different phases of crop growth Evaporation from snow, lakes, reservoirs and crops. Drought and its effect on water balance. Climatic water budgeting and its applications.

Practical

Compilation of water balance for selected stations; Estimation of water surplus runoff; Visit to Dam areas and assessing hydrometeorological problems.

8. Weather modification (2+0)

Historical review of weather modification, evolution of atmospheric composition green house effect; present status of weather modification for agriculture, theories of weather modification, scientific advances in cloud seeding for rainfall, hail suppression, dissipation of fog and stratus clouds, modification of severe storms and electrical behaviour of clouds, modification of frost intensity, shelter belts and wind breaks, mulches and antitranspirants, protection of plants against climatic hazards air and water pollution. Field trips to sites where weather modification has been introduced

Suggested Readings

Critchfield, M.j. 1975. General Climatology, Prentice Hall, London.

Riehl, H. 1978. Introduction to the Atmosphere. Mc Graw Hill, New York.

Sutchffe, R.C. 1966. Weather and Climate, Weidanfeed and Nicolson.

9. Principles of remote sensing and its applications in agriculture (2+1)

Basic components of remote sensing: signals, sensors and sensing systems; active and passive remote sensing; characteristics of electromagnetic radiation and its interaction with matter; spectral features of earth's surface features; remote sensors in visible, infrared and microwave regions; imaging and non imaging systems; framing and scanning systems; resolution of sensors; sensors platforms, their launching and maintenance; data acquisition system, data pre-processing, storage and dissemination; digital image processing and information extraction; microwave remote sensing visual and digital image interpretation; introduction to GIS and GPS.

Digital techniques for crop discrimination and identification; crop stress detection soil moisture assessment, inventory of ground water & satellite measurement of surface soil moisture and temperature; drought monitoring, monitoring of crop disease and pest infestation; soil resource inventory; land use/land cover mapping and planning; Integrated watershed development; crop yield modelling and crop production forecasting.

Practical

Acquisition of maps; field data collection; map and imagery scales; S/W and H/W requirements and specifications for remote sensing; data products, their specifications, media types, data inputs, transformation, display types, image enhancement; image classification methods; evaluation of classification errors; crop discrimination and acreage estimations; differentiation of different degraded soils; time domain reflectometry; use of spectrometer and computation of vegetation indices; demonstrations of case studies; hands on training.

Suggested readings

Colwell, R.N.(editor). Manual of Remote Sensing -Vol. I& II, Am Soc. Photogrammetty, Virginia.

Curan, P.J. Principles of Remote Sensing, ELBS/Longman.

Jain, A.K. 1989. Fundamentals of Digital Image Processing, Prentice Hall of India, Saddle river, NJ.

Kamat, D.S and Sinha, S.K (eds) 1984. Proceedings of the Seminar on Crop Growth Condition and Remote Sensing, June 22-23, ICAR & ISRO.

Lillesand T.M and Kiffer, R. W. Remote Sensing and image interpretation, John Wiley & son., Inc, New York.

Majumdar, K.L et.al, 1983. Selection of spectral bands and their widths for the Indian Remote Sensing satellite (IRS). RSP-LP/TN03/83, Space Applications Centre, Ahmedabad-380 053.

Schowengerdt, R.A. 1997. Remote Sensing, Models and Methods for Image Processing, 2nd edn. Academic Press, London.

Appendix IV

AGRICULTURAL SCIENTISTS RECRUITMENT BOARD, PUSA, NEW DELHI-110 012

SYLLABUS FOR NET IN AGRICULTURAL METEOROLOGY

Section 1: General Meteorology

Sun,earth and seasons. Laws of radiation; Planck's, Stephan-Boltzman, Wein's displacement Law, Kirchoff's Law, Beer's Law and Lamberts Cosine Law. Solar constant, length of day. Atmospheric and astronomical factors effecting depletion of solar radiation received on earth. Selective absorption by constituents of atmosphere. Raleigh and Mie scattering. Direct and diffuse radiation. Heat transfer-convection, conduction and radiation. Concepts of latent and sensible heat. Radiant flux and flux density. Atmospheric motion under balanced forces. Gas laws, pressure gradiant; isobars, hydrostatic equation and its application. Coriolis force. Geostrophic, gradient and cyclostrophic winds. Pressure systems, cyclones and anti-cyclonic motions, trough, ridge cot. Thermal wind. Contour charts. Concepts of specific heat at constant volume and pressure, first and second laws of thermodynamics. Vapour pressure, specific humidity, relative humidity, humidity mixing ratio, absolute humidity and dew point. Wet bulb temperature. Vapour pressure deficit. Psychrometric equation, entropy. T-phi gram. Vertical stability of atmosphere, virtual temperature and potential temperature. Moist and dry adiabatic processes. Clouds, their description and classification. Condensation process- artificial rain making, Bergeron-Findeison theory,' Dew, frost, fog, mist, haze, thunderstorm and hail. Air masses and fronts. Extra tropical cyclones. Land and sea breeze. Mountain and valley winds. Fohn and Chinook winds. Tropical cyclones and their structures.

Section 2: General Climatology

Weather and climate. Climatological elements. Seasonal distribution of radiation, rainfall, temperature, sunshine, wind, pressure over India. Climatic classification -Koppen and Thornthwaite. Gaussen and Emberger systems. Climatology of India: principal weather phenomena occurring in four main seasons of India, mechanism of Indian monsoons, role of physiography and rainfall distribution. Cyclones and cyclonic tracks over the Indian region; North-western and western disturbances; and monsoon breaks. Drought climatology: rainfall and its variability; atmospheric and soil drought; arid and semi-arid climate, aridity and moisture indices. Moisture availability indices. Heat and cold waves. Continental, maritime and monsoon climates.

Section 3: Agricultural Climatology

Meaning and scope. Effects of thermal environment on growth and yield of crops. Cardinal temperatures, thermoperiodism, photo-nycto temperatures. Vont Hoff's Law. Phenology of crops. Heat unit concept and related parameters. Meteorological factors associated with incidence and development of crop pests and diseases such as rust diseases. potato blight. apple scab, groundnut red hairy caterpillar, etc. Locust meteorology. Thermal and moisture balance of animals. Climatic aspects of animal production and nutrition. Comfort zones for different species and breeds of animals. Adaptation and acclimatization of animals of new environment. Protection of animals from adverse weather and immunity against animal diseases and parasitic afflictions.

Section 4: Micrometeorology

Concept of micro-, meso- and macro-meteorology. Micrometerological processes near bare ground and crop surfaces. Shearing stress, molecular and eddy diffusion, forced and free convection. Boundary layer, frictional velocity, roughness length, and zeroplane displacement. Temperature, wind and CO_2 profiles in crop canopies. Richardson number, Reyionds analogy, exchange coefficients, fluxes of momentum, water vapours, CO_2 and heat. Inversion and its effect on smoke plume distribution. Windbreaks and shelterbelts. and their effect on modification of microclimate. Frost protection. Spectral properties of vegetation, light interception by crop canopies as influenced by leaf area index, leaf arrangement and leaf transmissibility; extinction coefficient.

Section 5: Evapotranspiration

Hydrologic cycle and concept of water balance. Energy balance equation and significance of the components and their estimation. Angstroms formula and estimation of radiation parameters. Concepts of evaporation. evapotranspiration, potential and actual evapotranspiration. Aerodynamic. eddy correlation, and combination approaches. Bowen ratio method and empirical methods-Oalton's approach, consumptive use, andThomthwaite's climatic water balance method. Advantages and limitation of different methods. Water use, water use efficiency, dry matter production and crop yields. Yield functions. Advection and its effect on water use by crops and yield. Irrigation scheduling based on evapotranspiration. Lysimetry-types and principles. Heat conduction and thermal diffusivity in soils. Soil heat flux and soil temperature.

Section 6: Crop-Weather Modelling

Concepts of mechanistic and deterministic models. General features of dynamical and statistical modelling techniques. Weather data-based and physiology-based approaches to modelling of crop growth and yield. Advantages and limitations of modelling. Climatic change, greenhouse effect, CO increase. global warming, and their impact on agriculture.

Section 7: Weather Forecasting for Agriculture

Crop weather calendars. Short, medium and long range weather forecasting. Monsoon onset and rainfall forecasts. Weather forecasting and agro-advisories. Use of satellite cloud imageries in weather forecasting. . Synoptic charts and synoptic approach to weather forecasting.

Section 8: Agrometeorological instruments

Principles, exposure conditions and operation of meteorological equipment in agrometeorological observatory Principles and working of instruments for measurement of solar radiat.ion; direct, diffuse and photosynthetically active radiation; soil heat flux; soil temperature; wind speed and direction; humidity and precipitation; evaporation, sunshine and dew. Automatic weather station, infra red thermometer, spectral radiometer and net radiometer.

Section 9: Supporting Disciplines and Topics

C.G.S. and S.I. systems of units and their conversion. Units for measurement of momentum, force, work, power, surface tension, pressure, temperature, thermal conductivity and diffusivity, resistance, radiation, light intensity and water vapour. Concepts of texture, structure, bulk density and moisture characteristics of soil. Available soil water, soil water potential infiltration and hydraulic conductivity.

Photosynthesis, respiration, net assimilation, solar energy conversion efficiency and relative water content. Light intensity, water and CO_2 in relation to photosynthetic rates and efficiency. Physiological stress in crops. Remote sensing: spectral indices, canopy temperature technique of estimation of evapotranspiration, crop water stress index and crop stress detection.

Section 10: Statistical Techniques in Agroclimatology

Frequency distribution, measures of cental tendency, correlation, variability. Assured rainfall probability analysis using normal, binomial and incomplete gamma distributions. Markov-chain probability and its application. Orthogonal polynomial techniques for crop yield estimation.

Appendix V

CLIMATOLOGICAL DATA AT VELLANIKKARA FROM 1980 TO 2001

Monthly rainfall (mm) from 1980 to 2001

Year	Jan	Feb	Mar	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1980	0.0	0.0	0.0	10.0	139.8	893.8	1217.0	939.4	123.8	390.5	180.1	0.0	3894.0
1981	0.0	0.0	2.0	16.0	225.8	1125.0	512.9	407.9	528.8	136.7	80.2	0.0	3035.0
1982	0.0	0.0	0.0	61.4	173.1	715.0	600.9	566.4	67.4	277.8	98.4	5.2	2565.6
1983	0.0	0.0	0.0	0.0	37.4	387.2	580.6	754.7	494.6	149.8	60.2	24.4	2488.9
1984	0.0	27.0	18.9	109.2	39.4	853.1	730.4	260.2	158.6	323.7	7.8	16.4	2544.7
1985	14.7	0.0	2.0	20.3	216.4	947.1	532.3	374.6	59.3	377.1	14.4	58.8	2617.0
1986	1.2	1.9	8.4	23.2	118.6	669.9	381.4	358.7	296.3	421.3	176.2	10.8	2467.9
1987	0.0	0.0	0.0	13.3	95.0	837.7	336.5	388.4	174.0	280.4	224.4	64.6	2414.3
1988	0.0	7.8	37.9	145.4	242.6	632.1	545.0	507.8	700.0	116.6	11.0	14.9	2961.1
1989	0.0	0.0	31.3	52.6	115.8	784.6	562.0	319.9	180.1	351.3	8.1	0.0	2405.7
1990	3.5	0.0	4.4	38.8	583.9	477.3	759.3	356.4	87.5	313.3	69.8	1.8	2696.0
1991	3.9	0.0	1.8	83.8	56.1	993.1	975.6	533.3	61.5	281.7	191.3	0.2	3182.3
1992	0.0	0.0	0.0	48.6	90.6	979.8	874.5	563.9	302.9	386.7	377.5	2.0	3626.5
1993	0.0	6.6	0.0	32.1	131.1	700.3	661.6	287.7	85.3	519.0	74.6	18.0	2516.3
1994	19.4	1.7	21.0	165.2	124.2	955.1	1002.1	509.2	240.5	358.2	125.3	0.0	3521.9
1995	0.0	0.5	2.8	118.7	370.5	500.4	884.7	448.7	282.5	110.4	88.4	0.0	2807.6
1996	0.0	0.0	0.0	152.0	95.6	400.3	588.7	310.0	391.6	219.3	23.1	60.8	2241.4
1997	0.0	0.0	0.0	8.2	63.0	720.5	979.2	636.8	164.0	194.7	211.3	66.7	3044.4
1998	0.0	0.0	11.0	61.4	203.0	809.3	752.9	433.6	571.3	452.8	109.4	33.0	3437.7
1999	0.0	22.8	0.0	39.0	430.5	500.2	823.3	260.1	28.4	506.2	9.1	0.0	2619.6
2000	0.0	4.6	0.0	67.9	117.2	622.6	332.9	518.8	198.1	262.2	41.3	13.4	2179.0
2001	0.0	12.2	4.4	243.1	192.6	676.2	477.7	256.2	206.1	215.8	115.8	0.0	2400.1
Mean	1.9	3.9	6.6	68.6	175.6	735.5	686.9	454.2	245.6	302.1	104.4	17.8	2803.1

Number of rainy days from 1980 to 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	0	0	0	4	9	23	30	23	9	13	6	0	117
1981	0	0	0	1	8	25	20	17	19	9	3	0	102
1982	0	0	0	4	7	23	26	24	5	12	6	1	108
1983	0	0	0	0	3	19	21	26	24	7	3	3	106
1984	0	3	2	9	6	28	24	21	7	12	1	1	114
1985	2	0	0	2	10	28	25	21	6	16	2	2	114
1986	0	0	1	3	7	20	16	12	10	11	9	1	90
1987	0	0	0	1	3	21	17	22	8	16	6	6	100
1988	0	1	2	9	6	25	26	25	24	9	1	2	130
1989	0	0	2	4	7	27	17	19	15	16	2	0	109
1990	0	0	1	2	18	25	28	22	8	12	3	0	119
1991	1	0	0	4	5	28	27	24	7	14	9	0	119
1992	0	0	0	3	6	22	26	25	17	14	12	0	125
1993	0	2	0	2	6	22	29	20	9	16	4	2	112
1994	1	0	1	10	7	27	29	20	8	20	5	0	128
1995	0	0	0	5	13	19	26	22	13	8	5	0	111
1996	0	0	0	7	4	16	25	20	17	12	2	2	105
1997	0	0	0	1	4	18	28	23	13	12	7	2	108
1998	0	0	1	4	9	24	28	18	24	18	9	4	139
1999	0	1	0	4	18	23	28	12	3	15	1	0	105
2000	0	1	0	3	8	21	15	19	10	10	5	2	94
2001	0	1	0	8	14	23	19	21	6	8	6	0	106
Mean	0	0	0	4	8	23	24	21	12	13	5	1	111

Monthly pan evaporation (mm) from 1984 to 2001

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1984	219.3	210.6	199.1	159.5	214.9	85.0	90.3	125.2	137.7	118.9	160.2	201.7	1922.4
1985	241.8	178.9	224.3	196.2	177.3	83.1	95.2	91.8	114.5	103.9	125.0	216.9	1848.9
1986	230.8	191.5	226.0	211.0	167.0	101.6	104.8	128.5	118.2	120.6	141.8	223.4	1965.2
1987	266.8	230.0	257.6	214.9	218.6	106.5	117.4	100.0	120.0	118.2	103.8	143.3	1997.1
1988	217.4	191.2	202.5	172.9	144.9	86.3	78.7	97.6	87.5	113.7	116.7	206.3	1715.7
1989	253.8	227.7	218.6	179.2	152.0	83.0	98.1	110.0	97.8	112.4	141.3	204.7	1878.6
1990	222.0	210.6	213.7	189.8	109.5	84.3	79.1	90.4	101.0	109.9	101.7	184.5	1696.5
1991	198.6	211.7	195.6	170.6	149.3	66.8	74.9	78.2	110.2	78.7	120.7	190.1	1645.4
1992	129.6	150.4	206.7	174.1	160.1	88.6	68.7	83.4	93.8	80.5	98.9	206.3	1541.1
1993	216.0	197.5	213.3	180.3	158.1	104.5	90.5	117.9	110.1	89.6	122.0	194.0	1793.8
1994	220.0	169.2	209.2	144.7	137.0	84.2	86.1	91.4	113.9	97.1	137.9	169.6	1660.3
1995	178.5	172.2	190.2	164.3	129.3	103.7	88.5	96.4	97.7	113.8	89.1	195.9	1619.6
1996	208.6	200.9	219.2	157.1	135.0	103.4	88.9	100.1	94.9	92.8	119.0	133.4	1653.3
1997	174.8	158.7	203.0	190.2	157.1	128.2	91.7	109.4	111.6	125.3	90.2	135.3	1675.5
1998	168.0	167.4	189.8	241.7	120.9	86.6	87.1	88.3	86.0	88.9	91.8	127.3	1543.8
1999	174.3	175.5	167.1	133.9	99.5	90.0	73.3	96.1	105.5	87.2	115.5	177.7	1495.6
2000	203.4	147.4	180.9	128.4	152.2	91.8	104.3	95.9	101.1	101.1	123.4	161.5	1591.4
2001	199.3	142.0	171.0	128.2	121.7	87.8	83.5	96.7	124.0	105.9	122.2	181.7	1564.0
Mean	206.8	185.2	204.9	174.3	150.2	92.5	89.0	99.9	107.0	103.3	117.8	180.8	1711.6

Monthly mean bright sunshine hours (h/day) from 1982 to 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1982	9	9.5	9.2	8.7	6.7	0.6	2.9	3.8	6.9	6.6	6.4	8	6.5
1983	9.2	9.5	9.8	9	7.8	3.8	2.9	2	3.6	3.7	8.2	7	6.4
1984	8.2	8.2	7.7	7.3	8.0	1.4	2.5	5.0	6.5	6.0	7.3	9.0	6.4
1985	9.0	8.9	9.0	8.2	6.8	2.2	2.7	2.9	5.7	6.5	7.1	9.0	6.5
1986	7.7	8.9	8.5	8.4	6.7	3.7	4.8	5.5	5.7	6.4	7.4	9.3	6.9
1987	9.6	10.1	10.2	7.8	9.0	4.2	5.7	3.7	7.4	6.2	6.7	8.1	7.4
1988	10.4	10.0	9.1	8.8	6.2	4.2	3.0	3.7	5.1	7.1	7.9	9.0	7.0
1989	8.1	9.8	9.5	8.3	7.0	3.2	4.2	5.4	5.5	6.2	8.5	9.7	7.1
1990	9.0	10.0	9.7	8.3	4.5	3.4	2.4	3.5	6.2	6.5	6.0	10.2	6.6
1991	8.9	10.1	8.7	8.9	7.5	4.8	2.5	2.8	7.3	4.3	7.1	8.6	6.8
1992	9.0	9.2	9.2	8.8	7.4	3.3	2.1	2.7	4.1	4.6	5.5	8.9	6.2
1993	8.1	9.4	9.0	9.1	6.5	3.3	2.4	4.8	6.4	4.8	5.8	7.5	6.4
1994	9.1	8.7	9.3	8.0	8.0	2.1	1.4	3.0	7.3	6.7	8.1	10.6	6.9
1995	9.6	10.0	9.3	9.1	6.5	3.7	2.1	3.7	6.1	8.3	6.5	10.3	7.1
1996	9.4	9.9	9.3	8.3	7.7	4.7	2.7	3.7	4.3	6.0	7.1	6.8	6.7
1997	9.6	9.3	9.6	9.4	6.7	5.9	1.9	3.4	6.8	7.3	5.3	7.5	6.9
1998	9.3	9.6	10.0	9.0	7.6	3.4	3.3	3.6	4.1	4.8	7.2	6.6	6.5
1999	9.3	9.1	8.8	10.3	4.9	5.0	2.4	5.5	7.1	4.8	8.2	8.8	7.0
2000	9.2	8.6	9.7	7.2	8.5	3.3	4.8	3.1	5.9	5.6	6.7	7.9	6.7
2001	8.0	8.0	8.2	6.5	6.4	1.9	2.4	3.6	5.3	4.7	6.2	8.1	5.8
Mean	9.0	9.3	9.2	8.5	7.0	3.4	3.0	3.8	5.9	5.9	7.0	8.5	6.7

Monthly mean maximum temperature °C (°C) from 1980 to 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1980	33.4	35.2	36.3	35.6	34.6	30.1	29.5	29.6	31.2	32.3	32.3	33.6	32.8
1981	32.7	36.9	36.3	36.2	33.1	28.8	29.2	29.4	29	29.6	31.2	31.2	32.0
1982	32.5	34.5	35.4	37.7	33.8	30.6	29.1	28.9	31	32	31.4	31.9	32.4
1983	33.3	34.3	36.2	36.2	35.1	35.9	29.7	29.1	29.5	31.2	31.8	31.2	32.8
1984	32.4	34.3	35.2	34.5	34.5	29.0	28.6	29.3	30.4	29.9	32.6	31.9	31.9
1985	32.6	34.7	36.1	34.5	34.1	28.3	28.5	28.8	30.5	31.1	31.8	32.2	31.9
1986	32.5	34.2	36.2	36.0	34.2	30.0	29.5	29.4	30.5	31.8	31.2	32.5	32.3
1987	33.2	35.0	36.4	36.2	36.1	30.7	30.3	29.6	31.5	31.9	31.6	31.6	32.8
1988	32.4	35.8	35.7	35.1	33.7	30.0	29.0	29.2	29.9	31.7	32.6	32.6	32.3
1989	33.4	36.3	36.5	35.3	33.7	29.4	29.1	29.5	29.9	31.0	32.5	32.7	32.4
1990	33.5	34.9	36.0	35.8	31.5	29.7	28.4	29.0	30.7	31.9	31.2	32.3	32.1
1991	33.6	35.9	36.4	35.6	35.1	29.7	29.1	29.0	31.5	30.9	31.5	31.9	32.5
1992	32.6	34.5	36.9	36.3	33.8	30.1	28.8	28.9	30.1	30.7	31.0	31.1	32.1
1993	32.6	34.1	35.4	34.5	34.4	30.1	28.5	29.6	30.6	30.7	31.5	31.6	32.0
1994	32.9	34.8	36.2	34.9	33.6	28.9	28.6	30.0	31.8	32.3	31.8	32.2	32.3
1995	32.9	35.4	37.6	36.6	33.5	31.6	29.9	30.6	30.1	33.2	31.3	32.5	32.9
1996	33.1	34.7	36.4	34.6	32.8	30.5	28.8	29.1	29.2	30.1	31.5	30.5	31.8
1997	32.0	33.9	35.7	35.2	34.4	31.2	28.6	29.0	30.6	32.2	31.6	31.7	32.2
1998	33.1	34.4	36.2	36.5	34.1	30.2	29.2	29.8	30.2	28.0	31.5	30.1	31.9
1999	32.4	34.5	35.5	33.4	30.7	29.4	28.4	29.8	31.6	30.5	31.4	30.7	31.5
2000	32.9	33.3	35.6	34.0	33.7	29.6	28.8	29.1	30.7	30.7	33.3	30.4	31.8
2001	32.6	34.5	34.9	34.2	32.3	28.4	29.0	27.5	30.8	30.7	31.6	31.3	31.3
Mean	32.8	34.8	36.1	35.4	33.8	30.1	29.0	29.3	30.5	31.1	31.7	31.7	32.2

Monthly mean minimum temperature (°C) from 1980 to 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	21.8	22.3	24.1	24.5	24.8	23.4	23.0	22.7	22.7	22.1	21.6	22.1	22.9
1981	23.1	22.8	24.1	25.6	24.7	21.8	22.0	21.4	22.3	22.8	22.0	21.6	22.9
1982	21.5	21.3	23.2	25.4	24.5	23.1	22.9	24.3	24.0	23.1	23.9	23.2	23.4
1983	21.6	22.7	23.8	25.8	25.5	24.5	23.7	23.8	23.4	23.1	22.3	23.9	23.7
1984	23.3	24.2	24.3	26.9	25.8	22.7	22.9	22.2	23.2	22.1	23.1	20.8	23.3
1985	22.6	22.8	24.6	25.1	25.3	22.8	22.7	22.7	23.0	22.5	22.3	22.9	23.3
1986	22.4	22.1	24.3	25.2	24.7	23.1	23.2	22.7	22.7	22.9	22.0	23.5	23.2
1987	22.7	22.4	22.2	25.3	24.3	23.7	23.5	23.5	23.9	23.9	22.8	23.3	23.5
1988	22.0	23.1	24.7	24.3	25.4	23.7	23.2	24.3	23.2	23.3	22.9	22.3	23.5
1989	22.2	21.2	23.3	25.1	24.5	22.7	23.3	23.1	23.1	23.0	22.7	23.2	23.1
1990	20.8	21.9	23.8	25.4	24.1	23.3	22.5	23.0	23.4	23.2	22.6	23.1	23.1
1991	22.2	21.7	24.9	24.5	25.5	23.8	22.8	22.7	23.6	23.2	23.0	21.7	23.3
1992	20.9	21.8	22.8	24.4	24.8	23.7	22.7	23.3	23.1	22.9	23.1	22.3	23.0
1993	20.7	22.0	23.7	25.0	24.8	23.9	22.9	23.4	23.1	23.4	23.6	23.1	23.3
1994	22.6	23.1	23.7	24.4	24.7	22.9	22.4	22.8	23.2	22.7	23.3	22.2	23.2
1995	22.4	23.4	23.8	24.9	23.9	23.1	23.2	23.7	23.5	23.2	22.5	21.3	23.2
1996	22.4	23.4	24.3	25.0	25.2	23.8	23.1	23.6	23.7	22.9	23.6	21.8	23.6
1997	22.9	21.8	24.0	24.5	24.5	23.0	21.8	22.8	23.4	23.6	23.2	23.8	23.3
1998	22.8	23.6	23.6	25.6	25.2	23.3	23.6	23.9	23.3	22.8	23.1	22.9	23.6
1999	21.5	23.3	24.5	25.6	24.7	23.0	23.0	22.9	23.4	23.2	22.7	22.7	23.4
2000	23.2	22.8	23.9	24.6	24.4	22.8	21.9	22.6	23.0	22.7	23.1	22.0	23.1
2001	23.2	22.9	24.0	24.7	24.5	23.1	22.7	23.1	23.2	23.0	23.1	22.2	23.3
Mean	22.2	22.6	23.9	25.1	24.8	23.2	22.9	23.1	23.2	23.0	22.8	22.5	23.3

Monthly mean temperature (°C) from 1980 to 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1980	27.6	28.8	30.2	30.1	29.7	26.8	26.3	26.2	27.0	27.2	27.0	27.9	27.9
1981	27.9	29.0	30.2	30.9	28.9	25.3	25.6	25.4	25.7	26.2	26.7	26.4	27.4
1982	27.0	29.1	29.3	31.6	29.2	26.9	26.0	26.6	27.5	27.6	27.7	27.6	28.0
1983	27.5	28.6	30.0	31.0	30.3	30.2	26.7	26.5	26.5	27.2	27.1	27.6	28.3
1984	27.9	29.3	29.8	29.7	30.2	25.9	25.8	25.8	26.8	26.0	27.9	26.4	27.6
1985	27.6	28.8	30.4	29.8	29.7	25.6	25.6	25.8	26.8	26.8	27.1	27.6	27.6
1986	27.5	28.2	30.3	30.6	29.5	26.6	26.4	26.1	26.6	27.4	26.6	28.0	27.8
1987	28.0	28.7	29.3	30.8	30.2	27.2	26.9	26.6	27.7	27.9	27.2	27.5	28.2
1988	27.2	29.5	30.2	29.7	29.6	26.9	26.1	26.8	26.6	27.5	27.8	27.5	27.9
1989	27.8	28.8	29.9	30.2	29.1	26.1	26.2	26.3	26.5	27.0	27.6	28.0	27.8
1990	27.2	28.4	29.9	30.6	27.8	26.5	25.5	26.0	27.1	27.6	26.9	27.7	27.6
1991	27.9	28.8	30.7	30.1	30.3	26.8	26.0	25.9	27.6	27.1	27.3	26.8	27.9
1992	26.8	28.2	29.9	30.4	29.3	26.9	25.8	26.1	26.6	26.8	27.1	26.7	27.6
1993	26.7	28.1	29.6	29.8	29.6	27.0	25.7	26.5	26.9	27.1	27.6	27.4	27.7
1994	27.8	29.0	30.0	29.7	29.2	25.9	25.5	26.4	27.5	27.5	27.6	27.2	27.8
1995	27.7	29.4	30.7	30.8	28.7	27.4	26.6	27.2	26.8	28.2	26.9	26.9	28.1
1996	27.8	29.1	30.4	29.8	29.0	27.2	26.0	26.4	26.5	26.5	27.6	26.2	27.7
1997	27.5	27.9	29.9	29.9	29.5	27.1	25.2	25.9	27.0	27.9	27.4	27.8	27.8
1998	28.0	29.0	29.9	31.1	29.7	26.8	26.4	26.9	26.8	25.4	27.3	26.5	27.8
1999	27.0	28.9	30.0	29.5	27.7	26.2	25.7	26.4	27.5	26.9	27.1	26.7	27.5
2000	28.1	28.1	29.8	29.3	29.1	26.2	25.4	25.9	26.9	26.7	28.2	26.2	27.5
2001	27.5	28.7	29.5	29.5	28.4	25.8	25.9	25.3	27.0	26.9	27.4	26.8	27.3
Mean	27.5	28.7	30.0	30.2	29.3	26.7	26.0	26.2	26.9	27.1	27.3	27.2	27.8

Monthly mean morning relative humidity (%) from 1982 to 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1982	75	80	85	83	85	94	93	92	90	88	79	69	84
1983	67	81	85	82	84	90	94	94	93	90	84	71	85
1984	71	72	83	87	86	93	94	94	91	90	79	71	84
1985	81	77	82	81	85	94	94	93	91	88	81	77	85
1986	70	76	79	82	86	91	93	92	93	93	82	72	84
1987	68	70	76	80	79	92	94	95	91	89	89	80	84
1988	70	77	86	85	89	93	94	94	93	91	80	73	85
1989	69	68	79	86	87	94	94	94	92	91	74	72	83
1990	65	80	81	83	92	93	94	94	91	92	87	72	85
1991	74	74	84	83	85	94	94	95	91	90	87	78	86
1992	69	87	84	82	85	92	95	94	91	92	86	72	86
1993	71	78	81	83	86	94	93	95	93	91	82	76	85
1994	74	79	79	88	88	96	96	95	92	92	77	71	86
1995	76	79	83	87	91	94	96	94	94	91	91	71	87
1996	71	72	82	87	91	94	96	95	94	93	84	80	87
1997	78	82	82	83	87	93	95	95	93	88	88	83	87
1998	78	77	86	86	90	94	96	95	96	94	92	79	89
1999	76	77	88	88	92	94	96	94	89	94	81	72	87
2000	76	85	87	89	88	94	93	94	91	91	77	70	86
2001	71	86	84	88	89	94	93	97	91	91	83	72	87
Mean	73	78	83	85	87	93	94	94	92	91	83	74	86

Monthly mean evening relative humidity (%) from 1982 to 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1982	46	33	45	74	68	83	78	79	67	65	61	48	62
1983	36	47	45	50	54	69	79	80	75	64	58	55	59
1984	45	40	51	58	55	80	78	74	68	68	54	46	60
1985	52	40	45	53	60	84	77	79	69	66	54	46	60
1986	45	40	42	53	58	77	75	75	69	68	61	48	59
1987	37	34	34	48	53	75	74	79	68	69	65	59	58
1988	42	36	48	55	63	80	82	77	77	67	55	42	60
1989	39	21	37	52	62	79	77	73	72	70	74	47	59
1990	34	36	46	53	72	76	82	75	67	69	62	45	60
1991	41	28	47	53	55	82	79	78	64	74	63	49	59
1992	36	42	38	48	61	77	80	81	73	72	68	49	60
1993	35	42	44	55	61	77	80	78	68	74	64	55	61
1994	42	38	38	59	61	83	85	75	64	68	58	45	60
1995	41	41	37	55	65	77	81	78	70	65	69	43	60
1996	35	34	37	59	63	75	83	78	74	70	59	55	60
1997	45	39	37	50	57	71	84	78	71	65	67	61	60
1998	49	51	47	50	63	79	80	77	78	76	64	58	64
1999	40	35	48	58	72	75	82	73	63	75	57	48	61
2000	43	52	46	59	56	77	70	79	70	68	54	48	60
2001	41	48	54	63	73	79	77	76	67	71	60	48	63
Mean	41	39	43	55	62	78	79	77	70	69	61	50	60

Monthly mean relative humidity (%) from 1982 to 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1982	61	57	65	79	77	89	86	86	79	77	70	59	74
1983	52	64	65	66	69	80	87	87	84	77	71	63	72
1984	58	56	67	73	71	87	86	84	80	79	67	59	72
1985	67	59	64	67	73	89	86	86	80	77	68	62	73
1986	58	58	61	68	72	84	84	84	81	81	72	60	72
1987	53	52	55	64	66	84	84	87	80	79	77	70	71
1988	56	57	67	70	76	87	88	86	85	79	68	58	73
1989	54	45	58	69	75	87	86	84	82	81	74	60	71
1990	50	58	64	68	82	85	88	85	79	81	75	59	73
1991	58	51	66	68	70	88	87	87	78	82	75	64	73
1992	53	65	61	65	73	85	88	88	82	82	77	61	73
1993	53	60	63	69	74	86	87	87	81	83	73	66	73
1994	58	59	59	74	75	90	91	85	78	80	68	58	73
1995	59	60	60	71	78	86	89	86	82	78	80	57	74
1996	53	53	60	73	77	85	90	87	84	82	72	68	74
1997	62	61	60	67	72	82	90	87	82	77	78	72	74
1998	64	64	67	68	77	87	88	86	87	85	78	69	77
1999	58	56	68	73	82	85	89	84	76	85	69	60	74
2000	60	69	67	74	72	86	82	87	81	80	66	59	73
2001	56	67	69	76	81	87	85	87	79	81	72	60	75
Mean	57	58	63	70	75	86	87	86	81	80	72	62	73

Monthly mean wind speed (km/hr) 1983 to 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1983	10.2	4.5	4.6	4.5	4.8	4.6	1.9	2.4	2.4	5.5	5.8	8.6	5
1984	12.2	12.0	7.6	5.9	6.3	5.1	5.6	5.7	4.8	4.9	6.9	8.7	7.1
1985	12.6	7.1	6.6	5.9	5.6	4.8	4.6	4.6	4.2	4.1	6.4	8.4	6.2
1986	12.2	8.7	7.8	5.9	5.9	5.7	5.7	6.6	5.0	3.8	7.3	14.2	7.4
1987	14.1	9.5	7.1	5.5	5.6	5.0	4.3	3.8	7.2	4.2	4.4	9.1	6.7
1988	11.7	6.9	5.1	5.2	4.7	5.2	4.0	4.1	4.1	3.4	5.9	10.4	5.9
1989	10.9	7.1	5.8	5.5	5.2	4.5	5.3	4.7	4.1	3.7	7.9	11.4	6.3
1990	10.0	8.4	5.4	5.2	4.4	4.4	3.9	3.8	2.8	2.4	4.2	9.5	5.4
1991	4.5	4.5	4.9	4.7	4.5	4.8	4.6	3.6	4.2	3.7	6.1	9.8	5.0
1992	11.7	5.0	5.0	4.8	4.4	5.3	4.3	4.3	3.8	3.2	5.8	13.7	5.9
1993	10.0	7.8	6.0	5.0	5.0	4.5	4.6	4.5	3.8	3.6	7.4	10.5	6.1
1994	10.5	6.3	5.6	4.3	4.5	4.2	5.0	2.1	3.5	3.4	7.9	10.1	5.6
1995	9.0	6.7	4.5	4.1	3.7	3.6	1.7	1.9	2.1	1.8	1.0	6.6	3.9
1996	7.1	5.9	3.6	3.0	2.4	3.0	2.7	3.0	2.7	2.0	3.7	6.4	3.8
1997	6.9	3.9	4.0	3.3	3.3	2.7	4.6	2.8	2.5	2.6	2.9	5.9	3.8
1998	6.6	5.2	3.4	3.1	2.6	2.7	2.8	2.5	2.0	2.1	1.7	5.7	3.4
1999	6.5	5.1	3.0	3.3	3.0	2.5	2.5	2.3	2.1	1.6	3.6	6.6	3.5
2000	7.1	3.7	3.2	2.6	2.9	3.1	3.8	3.4	3.2	2.7	5.7	7.8	4.1
2001	8.5	4.2	4.1	3.5	3.3	3.4	3.5	3.6	3.2	3.1	4.9	10.0	4.6
Mean	9.6	6.4	5.1	4.5	4.3	4.2	4.0	3.7	3.6	3.3	5.2	9.1	5.2

Reference Evapotranspiration ETo according to Penman-Monteith using CROPWAT

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1984	5.79	6.40	5.46	5.12	5.26	2.59	2.88	3.59	4.12	3.77	4.53	5.05	4.55
1985	5.44	5.52	5.84	5.51	4.77	2.68	2.89	3.00	3.89	3.97	4.31	4.09	4.33
1986	5.66	5.75	5.98	5.59	4.78	3.28	3.53	3.75	3.89	3.92	4.27	5.89	4.69
1987	6.67	6.50	6.29	5.52	5.62	3.43	3.76	3.22	4.55	4.00	3.80	4.58	4.83
1988	6.09	5.90	5.53	5.43	4.43	3.32	2.94	3.25	3.05	3.27	3.67	5.14	4.34
1989	5.81	6.20	5.96	5.42	4.66	3.01	3.30	3.70	3.76	3.82	4.60	5.73	4.66
1990	5.88	5.98	5.75	5.48	3.65	3.13	2.75	3.16	3.97	3.89	3.64	5.52	4.40
1991	4.62	5.46	5.50	5.58	4.98	3.42	2.87	2.94	3.58	3.34	4.07	4.97	4.28
1992	6.00	5.04	5.69	5.59	4.75	3.17	2.71	2.92	3.41	3.37	3.63	5.63	4.33
1993	5.55	5.61	5.67	5.49	4.60	3.12	2.80	3.47	4.03	3.44	4.02	4.82	4.39
1994	5.68	5.36	5.84	5.04	4.86	2.65	2.45	3.05	4.35	4.01	4.72	5.67	4.47
1995	5.49	5.70	5.73	5.52	4.32	3.41	2.69	3.24	3.85	4.36	3.48	5.07	4.41
1996	5.32	5.68	5.43	5.01	4.56	3.46	2.80	3.18	3.36	3.62	3.92	3.97	4.19
1997	5.13	4.89	5.57	5.41	4.50	3.79	2.58	3.07	4.08	4.25	3.36	4.04	4.22
1998	4.92	5.25	5.54	5.43	4.63	3.07	3.01	3.12	3.29	3.20	3.69	3.84	4.08
1999	4.95	5.26	5.14	5.52	3.66	3.44	2.72	3.67	4.23	3.32	4.14	4.64	4.22
2000	5.09	4.63	5.39	4.60	4.87	3.03	3.43	3.01	3.88	3.60	4.33	4.66	4.21
2001	5.25	4.66	5.05	4.50	4.17	2.64	2.83	3.08	3.77	3.40	3.85	4.92	4.01
Mean	5.52	5.54	5.63	5.32	4.62	3.15	2.94	3.25	3.84	3.70	4.00	4.90	4.37

Appendix - VI

GUIDELINES FOR AGROMET DATABASE

Data on primary weather variables become necessary in meteorology and its applications in the field of agriculture. The daily meteorological variables are to be recorded from Agrometeorological Stations where weather instruments are installed. The selection of site, installation and maintenance of instruments and observational timings are to be uniform wherever the Agrometeorological Stations are in function. To achieve the above, the guidelines are provided here. It is felt that the material may be useful even for non-technical personnel who are interested to develop database in meteorology.

I. Choice of site for Agromet Station

To record weather variables, an open site is required. The soil type as well as location chosen for agromet site should be well representative of the cropped area of that location/station. It should be a rectangular site with 25 m (North-South) x 15 m (East-West) or 55 mm (North-South) x 36 m (East-West). The choice of the size of the site is left to the station based on type of instruments and space availability (Annexure I). However, the size of agromet observatory preferred is 55 x 36 m2 if there is enough area to accommodate. The site should be well leveled. The ground should be maintained with grass to avoid radiation cooling/heating.

The classification of agromet station where weather instruments are installed and crops are maintained should be uniform based on the type meteorological instruments and the technical know how available at the station.

Classification

According to WMO technical regulations, each agricultural meteorological station belongs to one of the following categories:

a) <u>A principal agricultural meteorological station</u> is a station which provides detailed simultaneous meteorological and biological information and where research in agricultural meteorology is carried out. The instrumental facilities, range and frequency of observations in both meteorological and biological fields, and the professional personnel are such that fundamental investigations into agricultural meteorological questions of interest to the countries or regions concerned can be carried out.

b) <u>An ordinary agricultural meteorological station</u> is a station which provides, on a routine basis, simultaneous meteorological and biological information and may be equipped to assist in research into specific problems. In general, the programme of biological or phenological observations for research will be related to the local climatic region of the station.

c) **An auxiliary agricultural meteorological station** is a station which provides meteorological and biological information. The meteorological information may include such items as soil temperature, soil moisture, potential evapotranspiration, duration of vegetative wetting, detailed measurements in the very lowest layer of atmosphere, the biological information may cover phenology, onset and spread of plant diseases etc.

d) **An agricultural meteorological station** for specific purposes is a station setup temporarily or permanently for the observation of one or several elements and/or of specified phenomenon.

Station corresponding to (a) are not common because of their requirements for trained professionals/technical personnel and equipment. In most countries the majority of agricultural meteorological stations belong to categories (b), (c) and (d).

To maintain uniformity, categorise the agromet stations in KAU under (d) and name them as "Agricultural Meteorological Stations" except the stations where technical personnel are available for agromet research. The India Meteorological Department, Govt. of India has given the classification of Meteorological Observatories as class A, B and C. The purpose of those observatories is recording surface and upper air data for weather forecasting. This classification may not be necessarily followed in the case of agromet stations, which are established at agricultural research stations.

Co-ordinates of the locations should be noted down. This means that the latitude, longitude and altitude of the station are to be mentioned while reporting data.

Setting up of "Agrometeorological Stations" require top most care in its installation as meteorological parameters are to be recorded from there for long and any slight deviation in the accuracy of installation of any instrument will affect the recordings and ultimately leads to wrong results.

The site should be free from tall buildings, trees, main irrigation channels, waterlogging etc. The precaution should be taken not only at the time of installation but also in future too. This means master plan of the campus/station should be well defined. Once the master plan is prepared, it should be permanent. The distance of the site for agromet station from the tall buildings should at least twice the height of the tall building in the case of raingauge while it is ten times the height of tall buildings in the case of other instruments.

The agromet station should be fenced to protect from grazing animals and tresspasses. The height of fencing should be 4" (1.2 m) from the ground level.

II. Instruments

1. Basic form of the instruments

The agromet instruments may be divided into two basic forms:

(a) Direct-reading instruments; and (b) Self-recording instruments

Of these, direct-reading instruments are more accurate, accuracy of self-recording instruments is maintained by regular calibration and comparison readings with those of direct reading.

2. General characteristics of self-recording instruments

Most of the recording instruments use some arrangement of levers which magnify the property to be observed of some material (used as sensor) and move a pen on a chart located on a clock driven drum. These recorders should be made as and when required, checking for which should be made daily. Ideal trace should be as thin as possible without scratching the paper or leaving gaps for which the pen position should be proper and pen be cleaned regularly.

3. Type of instruments

Single Stevenson Screen : It is a wooden box specifically designed for housing four thermometers which record the surface air temperature in °C. They are maximum, minimum, dry and wet bulb thermometers. The box has a provision inside to place the thermometers separately such that each thermometer has its own position in the screen. The bottom of the screen is placed at four feet height from the surface. It has uniform design of double louvered from all the four sides. This provision admits uniform flow of air to the thermometer bulbs. The box is white painted and also having double roof. The air space between the double roof and white painting prevent direct heating from the intensity of sunlight. It has four wooden legs to support the box. The legs are fixed in the soil such that the concrete material used for fixing legs should not be exposed and seen from outside.

Maximum thermometer: The maximum thermometer is a mercury-in-glass thermometer which has a constriction (small bend) just below the lower graduation. It is placed on the upper platform of the screen horizontally which is earmarked for the maximum thermometer. It should be rested at an angle of 2° having the bulb to the lower side. Once the mercury in thermometer reaches to its maximum with increase in air temperature, the mercury does not come back due to the constriction when surface air temperature starts coming down. The purpose of the constriction is to allow mercury from the bulb when temperature rises and does not allow mercury down to bulb when temperature decreases. After taking the reading the thermometer should be shaken gently till it reaches to the reading level of dry bulb thermometer by positioning it vertically in the right hand. That is why the maximum thermometer gives the maximum temperature recorded during the last 24 hours. The maximum temperature is generally obtained between 1300 and 1500 hours depending upon season.

Minimum thermometer: The minimum thermometer is placed on the lower platform of the screen just below the maximum thermometer. It should be rested at an angle of 2° having the bulb to the lower side as in the case of maximum thermometer. The main difference between the maximum and minimum thermometers is that in former, mercury is used and in the latter alcohol. It is a thermometer with the light weight movable index in its capillary tube. When temperature rises the alcohol in capillary tube alone expands leaving the movable index/blue glass pin. While the alcohol pushes the index back towards the bulb due to its surface tension when temperature decreases. The right side of the position of the glass index is the reading of the minimum thermometer. After taking the reading of the minimum thermometer, the minimum thermometer should be tilted towards right side such that the glass pin touches the surface of the alcohol column. After adjustments, the minimum thermometer reading and the dry bulb thermometer reading should be the same with within the accuracy of ± 0.5°C. The minimum thermometer gives the minimum temperature recorded during the last 24 hours in °C. It generally occurs just before sunrise.

Dry bulb thermometer: The dry bulb thermometer consists of a bulb at one end and is connected with a tube in which the mercury is filled. It is placed in the Stevenson Screen vertically towards left, inside the box. It gives instantaneous air temperature in °C.

Wet bulb thermometer: The dry bulb thermometer together with wet bulb thermometer is known as the station hygrometer. This is the best instrument to measure relative humidity. The construction of wet bulb thermometer is same as that of dry bulb thermometer except that the bulb of the thermometer is wrapped with a muslin cloth using cotton thread. The other end of the strings of the cotton thread is dipped in a small and narrow mouth glass bottle having distilled water. This facility is provided to see that the bulb of the wet bulb thermometer is always wet through capillary action of the cotton thread dipped in water. It is also placed on vertical platform seen on the right, inside the box.

The dry bulb and the wet bulb readings are noted down to obtain relative humidity directly using hygrometric table. The relative humidity is recorded in percentage.

Double Stevenson Screen: The design of the Double Stevenson Screen is exactly same as Single Stevenson Screen except that it has double length as compared to the Single Stevenson Screen. Self recording instruments like thermograph, hygrograph, thermohygrograph and barograph are placed inside the box to record temperature, relative humidity, temperature and relative humidity and atmospheric pressure respectively. The equipment give continuous record for 24 hours if it is daily, for a weekly if it is week and for a month if it is monthly.

Thermograph: This instrument is used for recording continuous air temperature of 24 hours. It consists of air temperature sensitive element called Helix which is a bimetallic spring which deforms in proportion to temperature changes and amplified by mechanical levers. A pen attached to them record temperature variations on a mechanical clock drum which makes a complete circle within 24 hours. The diameter of drum is 93.3 mm. The chart has reading of hours on x-axis and of temperature in °C vertically (y-axis).

Hygrograph: It is a self-recording instrument in which the relative humidity of the air is continuously traced on a chart fixed to a rotating drum and diameter of the drum is 93.3 mm. The hygrograph depends upon the contraction and expansion of human hair with variation in relative humidity. A pen transfers these changes on the chart. It is not an accurate instrument but is useful for recording the sudden changes in amount of moisture in the atmosphere. The length of hair increases by about 2-2.5 % as the relative humidity changes from 0 to 100 percentage. The rotating drum with the chart makes a complete circle within 24 hours and the chart has a range of relative humidity from 0-100 % vertically with each division equal to 2 % and the number of used chart is 398.

Assman Psychrometer: It is a portable instrument housing dry and wet bulb thermometers and small clock-work ventilating fan. Thermometers are protected from direct radiation by suitable covering with highly polished material. It is used to obtain vertical temperature and humidity profiles (called micrometeorological observations). The levels of measurement are at surface 1, 2, 4, 8 and 12 feet from ground. A micrometeorological tower is provided for this purpose.

Soil Thermometers: Soil thermometer is mercury in glass thermometer. There is a bend of 120° just above the bulb, rest of the stem being straight, so that when the bulb rests horizontally on the soil at the correct depth, the stem is inclined at 120° from the ground to facilitate the recording on the scale. The graduation begins at a distance of 6.5, 17.5 and 35 cm from the bulb in the 5/7.5 cm, 10/ 15 cm and 20/ 30 cm depth of the soil thermometers respectively. These soil depths are known as standard soil depths, which are within the plant root zone with considerable temperature variations. Iron stands are used as platform for soil thermometer. The thermometers used beyond 30 cm depth are known as earth thermometers. They are used for specific purpose. The temperature can be read with an accuracy of 0.1°C with eye estimation.

Grass minimum thermometer: This is known as terrestrial radiation minimum thermometer. This is kept on a grass surface which is very close to the ground (2.5 cm height of the grass tips from the surface is regularly maintained). Two such grass plots are maintained. In the centre of the grass plot, V-shaped wooden platforms having height of 2.5 cm from the surface are erected to place the grass minimum thermometer. The principle of grass minimum thermometer is similar to that of the minimum thermometer placed inside the Stevenson Screen. It is kept after sunset for observation and readings are recorded just before sunrise. It provides the lowest temperature attained at the ground surface by the exposed vegetation surface. It is used from October to March period only when frost occurrence liability is expected.

Ordinary Raingauge: It consists of a base and outer drum with a funnel. The funnel is placed on the base. There is a plastic jar inside the base in which rainwater is collected through the funnel. The rainwater is measured at 0830 hrs daily with the help of a graduated cylinder. The diameter of the funnel is 5 inches and the height of the gauge is 12 inches above the ground level. It gives the total amount of rainfall during the last 24 hours in millimeter. It is better to maintain a wooden platform very nearby the raingauge to place the measuring jar. This avoids error in taking readings.

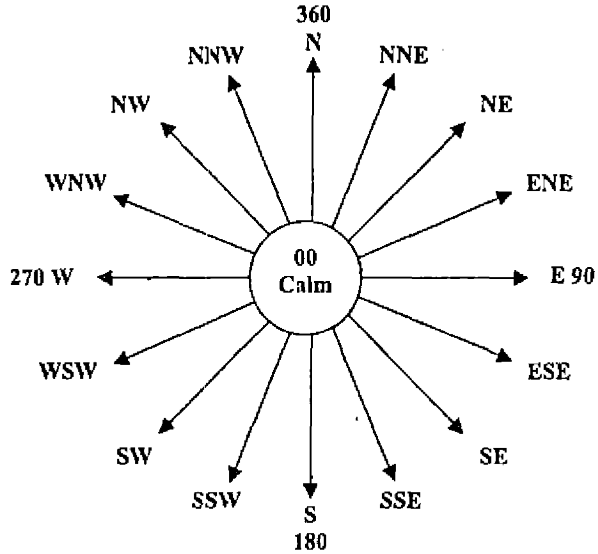
Self-Recording Raingauge: It gives continuous rainfall for 24 hours on all events. They are as follows : Onset and cessation of rainfall; duration of rainfall; intensity of rainfall and the total amount of rainfall in mm.

Wind vane: It is a horizontal metallic vane suspended on a frictionless vertical axis to show the direction from which the wind is coming. It is installed 10' above the ground level. The mean direction in 16 pints of the compass from which the wind comes as indicated in by arrowhead of wind vane should be recorded.

The vane consists of two flat plates joined together at an angle. The rotating arm is mounted by means of ball bearing and brass sleeve on wind vane stand. The brass sleeve is fixed by means of two screws on iron rod of the stand.

Below the rotating arm, eight fixed direction arms are fixed to a brass bar for indicating main and intermediate directions.

Wind direction is expressed in degrees measured clockwise from the North. For reports purpose, however, it is expressed on the compass scale from 0 to 360 degrees and the total direction as well as code numbers in different directions are indicated in figure.



Anemometer: The Robinson cup anemometer consists of a wheel with three semi-conical cups. The cups are attached to a central spider by means of three arms made of brass. The spider is provided to a vertical steel spindle and the top of the spindle moves on small ball bearing while the bottom rests on a thrust bearing. The lower tip of spindle is enclosed in a bushing which allows free rotation of the spindle. The rotation of the upright spindle is transferred by means of a wheel and gear to a counter having bold figures with a range from 00000 to 99999. The four white figures to the left give whole number in kilometers and the last figure in red gives tenths of a kilometer.

The reading of cup anemometer is taken at 0725 hours and 1425 hours daily. For finding the mean wind speed, the difference of two readings is taken for three minutes and worked out per hour. The wind speed is calculated in km/hour generally. To work out wind speed, an example is given below:

Initial reading of anemometer on standard time (0725/1425 hrs)	= 7966.4 km
Final reading of anemometer after three minutes	= 7966.6 km
Difference in three minutes	= 0.2 km
Wind speed in km/hr	$= 0.2 \times 60 / 3 = 4$km
Wind speed on standard time	= 4 km/hr

Open Pan Evaporimeter: The evaporimeter consists of a pan of 122 cm diameter and 25.5 cm depth is placed on well leveled wooden board having a height of 12.5 cm on the hard soil. A still well having 27.5 cm height and 8.5 cm diameter is kept in the evaporimeter to make the water free from any movement and inside it there is a pointed rod fixed. Intially water is filled in the pan upto the tip of the reference point (pointer). The purpose of the fixed rod inside the still well is to maintain the water level always constant at the time of observation. It acts as a reference point for constant water level. The quantity of water added by using the evaporation measuring bucket provided along with the instrument to bring the water level to the fixed point inside the still well is nothing but evaporation since last observation. It is measured in millimeter.

Sunshine Recorder: The bright sunshine hours are recorded with the help of Campbell stokes sunshine recorder. The cards fit into the grooves and three types of cards for use at different periods of the year. For example, straight cards are used between 1st March to 11th April and 3rd September to 14th October, long cards between 12th April to 2nd September and short cards between 15th October to 28th February or 29th February. The burning trace on the cards gives the number of bright sunshine hours. The unit is hours/day.

Duvdevani Dewgauge: This instrument is consists of rectangular wooden blocks of 32 x 5 x 2.5 cm3 in dimension coated with a special red paint. The size, form and distribution of dew drops on the surface of the dewgauge are compared with a series of standard full-scale photographs (dew album) each with a dew scale number, given based on the amount of dew present on the surface, in the morning. The reading of dew gauge should be taken before the sunrise. The wooden blocks are kept at standard heights of 05, 25, 50 and 100 cm from the ground after sunset and the dew amount is recorded for the above heights before sunrise.

Dew scale and amount

Dew scale	*Amount of dew (mm)*
0	No dew
1a, 1b	0.02
2a, 2b	0.045
3a, 3b	0.075
4a, 4b	0.11
5a, 5b	0.16
6a, 6	0.21
7a, 7b	0.27
8	0.35
9	No dew but rain

A list of firms supplying meteorological instruments is given below :

III. Precaution in installation

1. Observatory instrument should be robust, durable and simple for operation.
2. While installing the Single Stevenson Screen, care should be taken that the door of the screen should face towards North so as to prevent the direct sunshine falling on the screen during the observation time.

3. Tall instruments should be installed towards the North of the agromet station so that they may not shade the other meteorological instruments.

4. All the tall instruments viz., wind vane, anemometer and sunshine recorder should be fixed at 10' height in the North of agromet station.

5. While installing the instruments, care must be taken to ensure that the height, orientation and exposure are strictly followed. Foundation is location specific and depends on the strength of the underlying soil. Some specifications have been mentioned against installation of each instrument. This need not be strictly adhered to. Only thing to remember is the foundation of the instrument is strong against the adverse weather.

6. All the instruments should be painted with good quality white paint except the top portion of the wind vane and ordinary raingauge which are painted with black colour. The barbed wire and gate should be painted with silver paint. The fencing poles, base of the self-recording raingauge, wind vane and anemometer should be given white wash once in a year.

IV. Instructions for meteorological observers

1. Punctuality is a matter of great importance in making meteorological observations. Strictly adhere to the observational timings. No alternative option as they are not reproducible.
2. Each observation must be written down immediately after it is read. The instrument should be read once, twice and thrice before noting down the reading to avoid observational error.
3. The reading should be written down directly into pocket register with sharp pencil. Wherever pocket registers are not available, use loose slips for noting down data. Do not carry previous readings while going for recording weather observations. Note down neatly and legibly immediately after the observations are taken.
4. Copy the observations after applying correction factor, if any, in daily records immediately after returning from the agromet station.
5. Observation should be made in following order: wind, precipitation, temperature (including soil temperature at different depths), evaporation, cloud observation are taken between the two readings of the anemometer or before commencing other instrumental observations. The observation must be checked to ensure accuracy. Direct reading instruments may be read before the recording instruments. All work including changing of charts must be completed before 0845 hours for the morning and before 1445 hours for afternoon observations.
6. The reading of rainfall from ordinary raingauge should be taken daily at 0830 am immediately after that the chart of the self-recording raingauge has to be replaced. If rain is anticipated at the time of observation, wait till that spell is over or take the observation before the spell.
7. Open pan evaporation has to be recorded at 0830 hours.

8. The door of the Stevenson Screen should be opened/closed with least disturbance to the instruments installed inside.

9. Any defect in the instrument should be reported immediately to the concerned authorities. For example, break in mercury column, glass pin away from alcohol in the case of minimum thermometer, reading not seen in the case of anemometer, wind vane not moving, burning trace on sunshine card not seen, dry and wet bulb readings showing same etc should be brought to notice of the technical personnel immediately.

10. The observation should not be taken before ten minutes of the standard time and always preferred to complete the observation on standard time.

11. Examine the previous reading of anemometer before recording the current reading.

12. When wind instrument indicate calm, observe the movement of shrubs or crops growing nearby to confirm the same.

13. The reading of wet bulb thermometer has to be lower or at the most equal to the dry bulb thermometer. When humidity is higher, the difference is narrower between dry and wet bulb thermometer readings and vice versa. Use only distilled water in the water bottle of the wet bulb thermometer.

14. The dry bulb and maximum thermometer readings are quite close, even if both the thermometers are not same.

15. Avoid parallax error while reading.

16. Minimum temperature recorded in the morning has to be lower than that of evening except in the exceptional cases.

17. Remove dust deposits on sunshine recorder (Glass Sphere) once in fifteen days with soft cloth to avoid irregular burning trace.

18. Make sure about the compatibility of the rain measuring glass with the installed raingauge. While purchasing the new one, inform the collector area of the raingauge.

19. Do not cast shadow on the soil thermometers while recording readings.

20. In the case of open pan evaporimeter, observe minutely the movement of a bubble at the time when the water level is approaching towards the set level. Check the level of water frequently especially during the rainy season. Clean the open pan once in fifteen days and refill with fresh water. Store water separately for daily use for evaporimeter purpose. Do not use tap water.

21. Recheck the observations while recording.

V. Observational timings

The standard timings of recording weather data are 0700 and 1400 hours Local Mean Time (LMT). The corresponding IST timings over Kerala are 0725 am and 0225 pm. However, rainfall and pan evaporation are recorded at 0830 and 1425 IST. The following formula may be used for obtaining observational time based on longitude of the station over Kerala. An example is also given for Thrissur.

IST = LMT – 4 x (Longitude of the station – 82°30') minutes

Longitude of Thrissur station	= 76°13'
IST for Thrissur at 0700 LMT	= 0700 – 4 x (76°13' – 82°30') minutes
	= 0700 – 4 x (- 6°17') minutes
	= 0700 + 25 minutes 8 seconds
	= 0725 hrs
IST for Thrissur at 1400 LMT	= 1425 hrs

The observational timings of different weather variables and units of each weather variable are tabulated.

Meteorological instruments and their observational timings (Agrometeorological observatory)

	Parameters	Instruments	Observational frequency
1.	Rainfall (mm)	Ordinary Raingauge	Twice daily 0830 hrs & 1425 hrs
		Self-recording	Continuous (The time of placing or removing chart – 0830 hrs)
2.	Air temperature (°C)	Dry and wet bulb thermometer	Twice daily 0725 hrs & 1425 hrs
		Minimum and maximum thermometer	Twice daily 0725 hrs & 1425 hrs
		Thermograph	Continuous (The time of placing or removing chart – +0830 hrs)
3.	Sunshine (h/day)	Sunshine recorder	Continuous, the time of placing the chart is after sunset and before sunrise during rainy season
4.	Evaporation (mm)	US Class A Open Pan Evaporimeter	Twice daily 0830 hrs & 1425 hrs
5.	Relative humidity (%)	Assman Psychrometer	Twice daily 0725 hrs & 1425 hrs
		Hygrograph	Continuous (The time of placing or removing chart – 0830 hrs)
6.	Soil temperature (°C)	Soil thermometers	Twice daily 0725 hrs & 1425 hrs
7.	Wind speed (km/h)	Cup anemometer	Twice daily 0725 hrs & 1425 hrs
8.	Wind direction (0-360°)	Wind vane	Twice daily 0725 hrs & 1425 hrs
9.	Dew (mm)	Dew gauge	Place after sunset and remove before sunrise (1st November to 30th April)

VI. Inspection

Observatory must be inspected at least once in each year with objectives to ensure that

a) the siting and exposure of instruments are satisfactory;
b) instruments are of approved type, in good working condition and verified against necessary standards;
c) there is uniformity in the methods of observation and in the procedures of calculating derived quantities from the observation and
d) the observers are competent to carry out their duties

VII. Maintenance of crop weather data

All the aspects relating the agrometeorolgical data, viz., observation, transmission, storage and analysis are important for their fruitful utilisation in operational and R & D work. For the above purpose, the following registers should be maintained.

Daily Register: Only the final observations arrived at from raw (or observed) data after applying required corrections are recorded in the register. This should be done soon after the observations have been completed. It is a permanent record. In this register, the month and year are mentioned in the top of each page. First column is for dates and subsequent columns are meant for the observations pertaining to different observed parameters. The observations which are recorded twice are maintained as morning and evening observations. Daily register may be maintained in duplicate, one for observer and the other for users to maintain the register in good condition for longer duration.

The daily data recorded may also be posted in the following format supplied by the agromet division, IMD, Pune wherever the agromet stations are registered with the IMD.

Crop weather stations (CWS) 1 form: This form is of the daily register and is filled everyday. This needs to be sent every month to the IMD, Pune, if the observatory is registered with them. This contains daily information of 4 to 5 meteorological weeks. The morning and evening observations are recorded separately under the first hour (I) and second hour (II), respectively. Wherever the observations are taken only in the morning, then it is recorded only under the first hour (I). In CWS I form, the observations are recorded as they are required to be reported., e.g., the maximum temperature is read twice a day but reported for only first hour (I) and hence there is a place for only first hour in the form. Meteorological week-wise totals and means are worked out and written at appropriate places.

CWS 2 form: This is used for reporting the microclimatic observations. These observations are recorded at the micro-climatic post, wherever it is available in the agromet station. The dry and wet bulb temperatures for first and second hour recorded separately. The observations on vapour pressure and relative humidity derived from the dry bulb and wet bulb temperatures are also recorded for first and second hour. However, it is not mandatory for all the observations.

Weekly register: There are 52 standard meteorological weeks in a year commencing from 1st January. Duration of 9th week in leap year and 52nd week is of 8 days each.

Monthly register: This is to be maintained to refer monthly averages/totals of data. As soon as month is over, the daily data of particular parameter are added together and divided by number of days in the month. This work should be completed within 2 to 5 days after completion of the month.

Annual register: This is to be maintained to refer the annual averages/totals of different weather variables.

Climatological data: Long term (at least of 30 years as per WMO) average of weather parameter for a location together constitute the climatology of that location. Obtain the past data from various sources. Enter it in registers or, if available, feed in computer. These average values are called the normals. By knowing climatology of a place, planning of various human activities, including agricultural operations, can easily be done. The climatology of different agroclimatic zones of Kerala also can be studied and updated using the database.

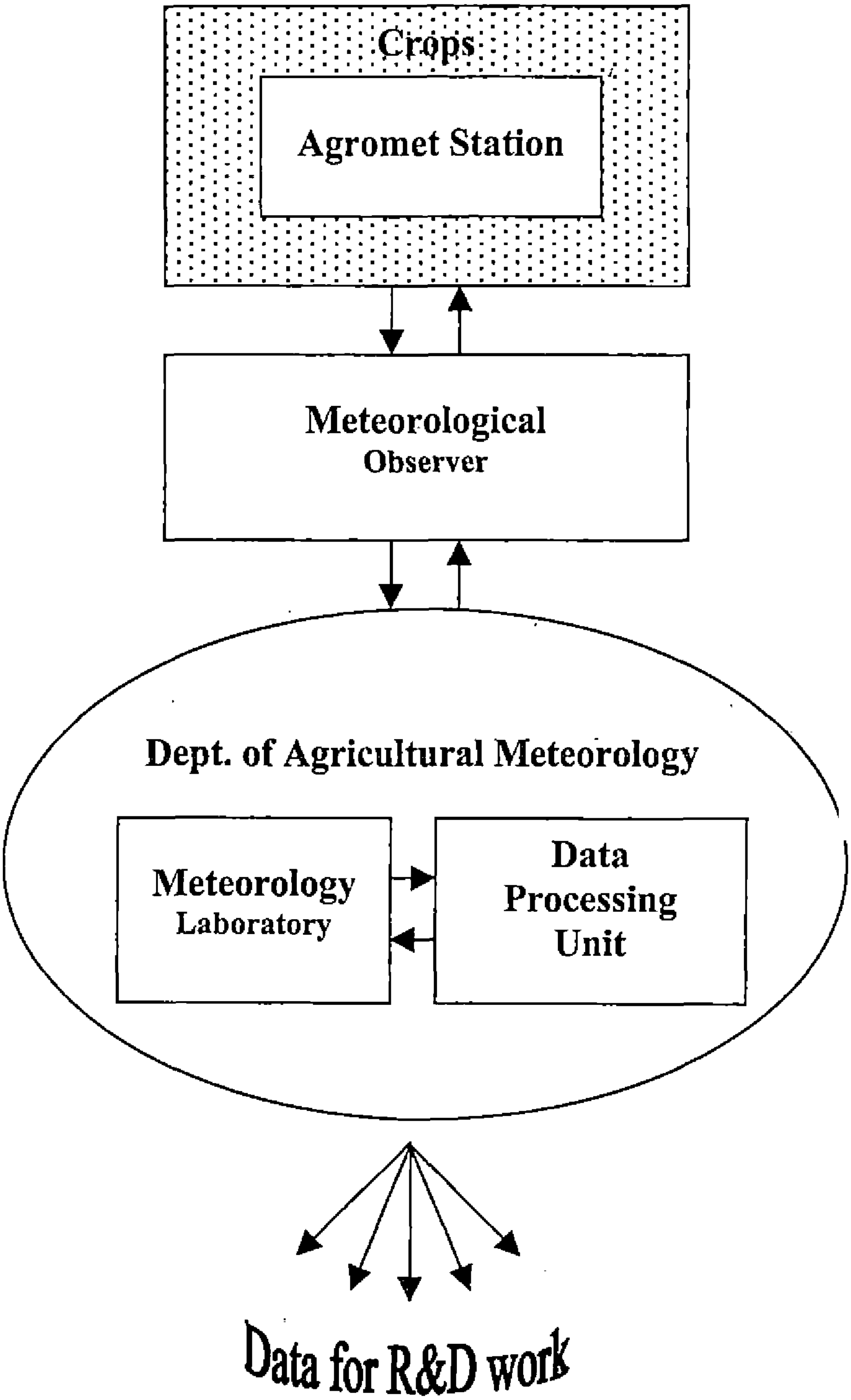
Biological data: The agromet station surrounded by open space can be used for cultivating seasonal crops. From these crop fields, chronological, morphological and phenological data can be generated. This data together with weather information become a key in understanding crop weather interactions. Crop yields also may be recorded experiment-wise along with the bulk yields, wherever it is possible.

VIII. Communication of data

Agromet database is a well-defined collection of record that contains weather observations and biological information related to major crops. Every agromet station should maintain database using any of the available database packages. The database packages commonly used are Dbase, FoxPRo, Access, MS-Excel. The database helps in storing and retrieval of long term data. Many statistical manipulations like calculations and analysis can be carried out using database packages. For example, weekly, monthly and yearly means can be easily generated based on daily files.

Each agromet station should communicate the database in a floppy along with hard copy to the Department of Agricultural Meteorology. For this purpose, weather data recorded daily may be communicated once in a month in the given format. It becomes easy for data storage and retrieval. Wherever facilities are available, the data may be stored in computer along with basic registers viz., daily, weekly, monthly and yearly. Every agromet station in KAU should maintain agromet database in the given format. This network of database system enables the university to provide crop weather information for the State of Kerala on demand. A model of agromet database is schematically presented below.

A model for agromet database



List of IMD approved firms supplying meteorological instruments

Sl. No.	Source of availability	Instruments
1	2	3
1	The Managing Director, National Instruments Ltd, 1/1 Raja Subodh Chandra Mallick Rd. Jadavpur, Calcutta- 700 032	Thermometers, Sunshine recorders, Radiation instruments
2	A. Paul Instruments Co., JIND, Haryana	Soil Thermometers, other meteorological thermometers
3	M/s Electronic Equipment, Block No. 22, Electronic Co-op. Estate Ltd., Pune Satara Road, Pune-411 009 Tel: 449327	Meteorological instruments of different types: Cup counter anemometer, wind vane, hygrograph, thermograph, self and non-recording raingauge, clock drum, barographs
4	M/s Hindusthan Clock Works, 246/2, Shaniwar Peth, Pune 411 030, Tel: 441223	Self-recording raingauge, Clock drum for recording instruments, thermograph, hair hygrograph
5	Premier Instruments & Controls Ltd., P.B. No. 4209, Perianaickenpalayam, Coimbatore-641 020	Cup counter anemoemter
6	National Industrial Designers, 2 Union Co-op. Industrial Estate, Rakhial, Ahmedabad-380 023	Self-recording raingauge, sunshine recorders, cup counter anemometer
7	Borosil Glass Works Ltd., Khanna Construction House, 44 Maulana Abdul Gaffar Road, Mumbai- 400 018	Measuring glasses for use with non-recording raingauge and snow-gauge
8	M/s Adept Recording Instruments Pvt. Ltd., Plot No. 4, Survey No. 17/1-B, Kothrud Industrial Estate, Kothrud, Pune- 411 029, Tel: 340640, 340480, 341124	Recorders
9	Recordwell, D-290/B, Street No. 11, Laxmi Nagar, Vikas Marg, New Delhi- 110 092	Charts for recording instruments
10	M/s Kedar Enterprises, Krupashree, 1084 Shukrawar Peth, Pune-411 002	Charts for recording instruments and recording inks
11	M/s Chenna Corporation, A-6, Naraina Industrial area, Phase-II, New Delhi. Tel: 588328/560898	Charts for recording instruments
12	M/s Technograph Corporation, Rara ramdwara, Pahargang, New Delhi. Tel: 5833777/589915	Charts for recording instruments and recording inks, sunshine cards
13	M/s Computech India, 403, Brookefield, Lokhandwala Complex, Off four Bungalows, Andheri West, Mumbai – 400 058. Tel: 577352	Charts for recording instruments

1	2	3
14	M/s Hydromet Instruments, 1 , Gujarati House, Opp. Victoria Garden, Bhadra, Ahmedabad-380 001	FRP non-recording raingauge, sunshine recorders, open pan evaporimeter, mechanical wind vane, stevenson screen
15	M/s Ramkala, 387, Sadasiva (Navi) Peth, Pune- 411 030. Tel: 436010	FRP non-recording raingauge, open pan evaporimeter, mechanical wind vane, stevenson screen, cup counter anemometer
16	M/s Utile Equipment, 13 Jal-Tarang, Prabhath Road, Lane No. 1, Pune-411 004, Tel: 348652	Thermometers, sunshine recorders, radiation instruments
17	M/s Lawrence & Mayo (I) Ltd., 3 Dr. Ambedkar Road, Opp. Nehru Memorial Hall, Pune-411 011 Tel. 631882, 634717	Meteorological instruments of different types (non-recording raingauge, SRRG, Whirling psychrometer, sunshine recorders, electrical anemometers, wind vanes etc.)
18	M/s Dynalab, G-2 Bldg, C3 Bramha Memories, Bhosale nagar, Pune-411 007	Weather monitors, electrical wind equipment, digital hand held anemometer, cup counter anemometer, evaporimeter etc.

Standard meteorological periods and weeks

Period No.	Week No.	Dates
1	2	3
I	1 January	1-7
	2	8-14
	3	15-21
	4	22-28
	5	29-4 February
II	6 February	5-11
	7	12-18
	8	19-25
	9	26-4 March
III	10 March*	5-11
	11	12-18
	12	19-25
	13	26-1 April
IV	14 April	2-8
	15	9-15
	16	16-22
	17	23-29
	18	30-6 May

1	2	3
V	19 May	7-13
	20	14-20
	21	21-27
	22	28-3 June
VI	23 June	4-10
	24	11-17
	25	18-24
	26	25-1 July
VII	27 July	2-8
	28	9-15
	29	16-22
	30	23-29
	31	30-5 August
VIII	32 August	6-12
	33	13-19
	34	20-26
	35	27-2 September
IX	36 September	3-9
	37	10-16
	38	17-23
	39	24-30
X	40 October	1-7
	41	8-14
	42	15-21
	43	22-28
	44	29-4 November
XI	45 November	5-11
	46	12-18
	47	19-25
	48	26-2 December
XII	49 December	3-9
	50	10-16
	51	17-23
	52	24-31**

* In leap years the last week of period II have 8 days
** Last of period XII have 8 days

Appendix VII

RESEARCH AND POPULAR ARTICLES

I. Number of Research and Popular articles: 94

i) Agrometeorology of coconut : 26

Balakrishnan,P.C., Rao, G.S.L.H.V.P. and Nair, R.R. 1988. Heat unit requirement for germination of coconut cultivar West Coast Tall - A preliminary study. *Agrometeorology of plantation crops (eds.Rao, G.S.L.H.V.P. and Nair, R.R..).* Proceedings of the National Seminar on Agrometeorology of plantation crops, March 12-13, 1987, Kerala Agricultural University, Trichur, pp. 79-80

Nambiar, P.K.N and Rao, G.S.L.H.V.P. 1991. Varietal and seasonal variation in the oil content of coconut. *Coconut Breeding and Management* (eds. Silas, E.G., Aravindakshan, M. and Jose, A.I.). Proceedings of the National Symposium on coconut breeding and management, 1988. Kerala Agricultural University, Trichur, pp. 283-286

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Rao, G.S.L.H.V.P. 1986. Effect of drought on coconut production. *Indian Cocon. J.* 17(8):11-12

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Rao, G.S.L.H.V.P. and Nair, R.R. 1986. Impact of drought on coconut production – A review. Workshop on Impact of drought and plantation crops, Central Plantation Crops Research Institute, Kasaragod, pp.16-18

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Rao, G.S.L.H.V.P and Nair, R.R. 1988. Vertical profiles of air temperature and vapour pressure in coconut gardens and open space.Agrometerology of plantation crop(eds.Rao,G.S.L.H.V.P.and Nair,R.R.).Proceedings of the National Seminar on Agrometeorology of plantation crops,March 12-13,1987.Kerala Agricultural University, Trichur, pp. 63-69

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Rao, G.S.L.H.V.P. 1991. Performance of T x D coconut hybrids in drought years under irrigated conditions in red sandy loam.*Coconut Breeding and Management* (eds.Silas,E.G., Aravindakshan,M.and Jose,A.I.).Proceedings of the National Symposium on coconut breeding and management,1988. Kerala Agricultural University, Trichur ,pp.150-155

Rao, G.S.L.H.V.P. 1991. Agricultural droughts with reference to coconut. *J. Plantation Crops*. 18 (supplement):166-170

Rao, G.S.L.H.V.P. 1991. Agrometeorological aspects in relation to coconut production. *J. Plantation Crops*. 19(2):120-126

Rao, G.S.L.H.V.P. 1993. Water management in coconut. Proceedings of the National Seminar on water management for plantation crops, Centre for Water Resources Development and Management,Kozhikode.pp. 65-70

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ii) Agrometeorology of cashew : 09

Naik, B.J., Gopakumar, C.S., Subash, N and Rao, G.S.L.H.V.P. 1997. Anther and anther dehiscence in cashew *(Anacardium occidentale* L.*).* Proceedings of the Tenth Kerala Science Congress, January 1-3, 1998. Kozhikode, pp. 193-195

Rao, G.S.L.H.V.P. and Gopakumar,C.S. 1995. Climate and Cashew. *The Cashew.* 8(4):3-9

Rao, G.S.L.H.V.P. and Gopakumar, C.S. 1999. Latitudinal and altitudinal influence on cashew flowering over Kerala. Proceedings of XI Kerala Science Congress, February 27-March 1, 1999, Central Plantation Crops Research Institute, Kasaragod, pp. 242-246

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Rao, G.S.L.H.V.P., Krishnakumar, K.N. and Tony, X. 2001. Agroclimatic zones for cashew across India. Proceedings of TROPMET 2000, February 1-4, 2000. Cochin, pp. 556-559

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Rajagopalan, A., Rao, G.S.L.H.V. P. and Devi, T.S. 1992. Leaf area index - A measure of vigour in softwood grafts of cashew. *The Cashew.* 6(1) : 10

iii) Agrometeorology of plantation crops : 05

Pillai, P.B. Climatic requirements for plantation crops in Kerala – A review. *Indian Farmers Digest.* 12:11-12

Rao, G.S.L.H.V.P. 1993. Influence of weather in plantation crop production. Proceedings of the National Seminar on water management for plantation crops, Centre for Water Resources Development and Management, Kozhikode, pp. 11-16

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iv) Agrometeorology of rice: 13

Pillai, P.B. and Sreelatha. 1997. Differential response of two medium duration rice varieties to time of planting and graded doses of nitrogen. *Proceedings of the International Symposium on Rainfed Rice Production Strategy*, November 11-13, 1997. Assam Agricultural University, Jorhat

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Rao, G.S.L.H.V.P. 1994. Effect of date of planting on the duration and grain yield of rice cultivar Allikkannan. *J. Tropical Agric.* 32 : 96-97

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