Chapter IV

Climate and Agriculture

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CLIMATE AND AGRICULTURE

EXECUTIVE SUMMARY

1. Agriculture in the state is mainly dependent on rainfall.

Recommendations

1. Due to decrease in rainfall during monsoon season and increase in rainfall in post monsoon season sowing dates of Kharif crops in Konkan and Madhya Maharashtra should be redefined according to the changed rainfall conditions. This may require one or two protective irrigations to be given to cereals, pulses and oil seeds in kharif season Similarly in rabi season also one or two protective irrigations are required to sustain the productivity of these crops.

Financial implications:
Nil. It should be accommodated in the present cost of research of the Universities.

Authority to Act upon:
Agricultural Universities of the State.

2. No crop planning as per the climate of the area.

Recommendations

Crop planning in Maharashtra needs to be done as per the agro-climatic zones of different regions. To achieve this research should be directed for developing better genotypes for corresponding rainfed conditions. Development agencies should extend the use of seeds of drought tolerant crop varieties to the farmers matching local agro-climatic conditions.

The project unit be established at CASAM, Pune with additional staff positions of One Associate Professor and two Assistant Professor. The time limit should be of 3 years.
Financial implications:

Rs 20 lac (One Associate Professor and two Assistant Professor for 3 years). It should be accommodated in the present cost of research of the Universities.

Authority to Act upon:

Agricultural Universities of the State.

3. No planning for drought and excess rainfall conditions.

Recommendations

1. Strategies for drought and excess rainfall years should be prepared to fight drought situations each village should have village pond, for which necessary technical support should be provided.

The drought indices defined by India Meteorological Department are moderate drought $-20 < P < -49\%$ and severe drought as $P < -50\%$. However, this does not include break in monsoon with normal rainfall. Break in monsoon of two weeks or less during vegetative growth and again of two weeks or less during reproductive growth stage is managed by the crop. But, of longer duration and more then two occasions are not manageable by the crop. Break in monsoon of three weeks or more causes irrecoverable damages and should be considered as moderate drought.

Financial implications:

Rs 10 lac per pond per village (50,000 villages).

Authority to Act upon:

State Government.

4. No seasonal or climatic forecast to the farmers at state level.

Recommendations

1. Forecast of rainfall should be made available to the farmers throughout the state for which necessary infrastructure should be developed. Hybrid models based on computer simulation, remote sensing and astro-meteorology be developed.

The infrastructural development needs installation of rain gage per village, and installation of Automated Weather station per taluka with Super computer at the Head Quarter for supporting the network of all taluka stations.

Financial implications:

Rs 5,000 per village for raingauge. It should be accommodated in the present cost of development of Department of Agriculture.

Rs 2.0 lac per taluka for Automated weather station.

Rs 50 lac. (Installation of Indigenous Super Computer)
Authority to Act upon:
    State Government, NABARD.

5. No forecast for incidence of pests and diseases.

Recommendations

1. **Further research be directed to develop weather based forewarning systems for important crop pest and diseases in various agro climatic conditions in the state.**

   It needs to develop models for forecasting incidence of pests and diseases for important crops of Maharashtra. The research be conducted in each Agricultural University for important crops of that region and their popular genotypes.

Financial implications:
   Rs 1 crore for six important crops.

Authority to Act upon:
Agricultural Universities of the State.

6. No forecast for yield of different important crops.

Recommendations

1. **Genetic coefficients of all important cereals, pulses and oilseeds popular in Maharashtra should be determined so that crop models can be operationally used. To achieve this research should be directed to forecast yield of important crops in Maharashtra state based on various available models.**

   The genetic coefficients of important genotypes be determined at CASAM Pune for which a research unit be established with technical staff positions. The staff positions required will be One Associate Professor, two Assistant Professor two SRA and two JRA. The work have to be completed in a given frame of time. Other facilities of field and instruments are already available.

   The research unit needs to be established to forecast the yields of important crops. The unit needs to ensemble METSAT data and soil data to prepare the individual crop pictures by which area under a crop will be estimated by Remote Sensing Techniques and yield forecast will be done by dynamic crop growth models. The unit needs position of one Professor, one Associate Professor and two Assistant Professor. This unit may be kept under CASAM Pune, in collaboration with Department for operational use.
Financial implications:
Rs 10 lac per crop for two years (one Professor, one Associate professor and two Assistant professor).

Authority to Act upon:
Agricultural Universities of the State.

7. Climate change and its impact on Agricultural production.

Recommendations

1. Research be directed to evaluate the impacts of climate change on agricultural production to meet the growing need of preparing the state for any contingency.

The research unit be established at CASAM, Pune with additional facilities of CO2 and O3 sensors and advanced micro meteorological techniques of the measurement of trace gases. The unit needs scientist’s position of one Professor, two Assistant Professor, two SRA and two JRA. This unit will need foreign collaboration on measurement of trace gases, which will be a pioneering work in India.

Financial implications:
Rs 50 lac per year (one Associate professor, two assistant professor, two SRA and two JRA + CO2 sensor and other instruments).

Authority to Act upon:
World Bank

8. Regional climate modification.

Recommendations

1. State may take up plantation of Sahyadri to maintain natural biodiversity and to green the hilly terrain and slopping regions of the state exposed to soil degradation to favorably modify the regional climate of scarcity and central plateau zone.

The land on the slopes of Sahayadri is to the tune of 12 lac ha. Plantation be done at a rate of 100 plants per ha with an spacing of 10x10 m. If pit digging, filling and cost of seedling are considered to be at Rs 10/- per pit for digging, Rs 10 per pit for filling and fertilizer and Rs 10 for seedling, the cost per ha will be Rs 3000/-. Thus, for total area it will need Rs 360 Crore.

Financial implications:
Rs 360 crore

Authority to Act upon:
State government and World Bank
9. Sub-standard conditions of observatories and data collection.

Recommendations

1. *Data collection system should be automated, interlinked and modernized through out the state.*

As referred earlier each village should have a rain gage and each taluka an Automated Weather Station. All the AWS should be connected to Central computer to transfer data on line. The cost of hard ware is shown below. The cost of staff will be in the establishment of Department of Agricultural meteorology under Commissionerate of Agriculture.

**Financial implications:**
- Rs 5000 per rain gage per village
- Rs 2.0 lac per Automated Weather station per taluka
- Rs 50 lac Indigenous super computer

**Authority to Act upon:**
State government

1. *METSAT data retrieval and interpretation facilities be created at state level so as to provide weather based agro-advisories to the farmers*

10. Inadequate Human Resource Development.

Recommendations

1. *A cell of Agricultural Meteorology should be established under Commissionerate of Agriculture to improve the human resources and to coordinate the development efforts of climate based agriculture and Department of Agricultural Meteorology be established under Agricultural Universities to develop the human resources in this field.*

The cell of Agricultural Meteorology is proposed with a view that more then 75 % land will remain as rainfed agriculture. The data collection at village level be done by the agricultural worker of the Department or by the school teacher. At taluka level an Automated weather Station be installed with a SRA level worker to process the data of whole taluka and to transmit that to head quarter with on line transfer of data from AWS. It needs staff positions of SRA at taluka level, one Assistant professor at District Head Quarter and one Associate Professor at Divisional level and one Professor level at State Head Quarter with supporting ministerial staff and other facilities.
Financial implications:
Rs 8.40 crore per year (One SRA per taluka, One Assistant Professor per District, One Associate Professor per Division and Professor at the Head Quarter along with supporting staff)
Infra-structure Rs 10 crore

Authority to Act upon:
State government
CLIMATE AND AGRICULTURE

Introduction:

Climate is the first and foremost resource gifted by the God to the mankind. Climate along with land and life is the essential component of Biosphere. Earth is enveloped by atmosphere, which is composed of gases viz., Oxygen, Nitrogen, Carbon dioxide and water vapors. Water from oceans is brought to the earth surface by hydrological cycle driven by solar energy. But, it is neglected and exploited by mankind indiscriminately.

Rainfall:

Maharashtra with its geographical area of 30.76 M ha receives 1464.0 mm mean annual rainfall as against 1094.4 mm mean annual rainfall of India. Thus, Maharashtra receives more than mean rainfall of the country. The state is divided in 4 meteorological subdivisions named Konkan and Goa, Madhya Maharashtra, Marathwada and Vidarbha. Konkan receives 2998 mm, Madhya Maharashtra 902 mm, Marathwada 844 mm and Vidarbha 1113 mm mean annual rainfall. Out of that major share Konkan and Goa (93.4%), Madhya Maharashtra (82.6%), Marathwada (85.0%) and Vidarbha (87.7%) rainfall is received in summer monsoon season (June to Sept.) (Table 1).

Table 1. Season wise mean rainfall in different regions of Maharashtra state and its percentage with the mean annual rainfall

<table>
<thead>
<tr>
<th>Region</th>
<th>Jan-Feb</th>
<th>Jan-Feb</th>
<th>Mar-May</th>
<th>Mar-May</th>
<th>June-Sept</th>
<th>June-Sept</th>
<th>Oct-Dec</th>
<th>Oct-Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>%</td>
<td>mm</td>
<td>%</td>
<td>mm</td>
<td>%</td>
<td>mm</td>
<td>%</td>
<td>mm</td>
</tr>
<tr>
<td>Konkan &amp; Goa</td>
<td>2.0</td>
<td>0.4</td>
<td>48.0</td>
<td>1.6</td>
<td>2801</td>
<td>93.4</td>
<td>147.0</td>
<td>5.0</td>
<td>2998.0</td>
</tr>
<tr>
<td>Madhya Maharashtra</td>
<td>6.0</td>
<td>0.6</td>
<td>45.0</td>
<td>4.9</td>
<td>745.0</td>
<td>82.6</td>
<td>108.0</td>
<td>11.9</td>
<td>902.0</td>
</tr>
<tr>
<td>Marathwada</td>
<td>6.0</td>
<td>0.8</td>
<td>36.0</td>
<td>4.2</td>
<td>717.0</td>
<td>85.0</td>
<td>85.0</td>
<td>10.0</td>
<td>844.0</td>
</tr>
<tr>
<td>Vidarbha</td>
<td>24.0</td>
<td>2.1</td>
<td>40.0</td>
<td>3.6</td>
<td>975.0</td>
<td>87.7</td>
<td>74.0</td>
<td>6.6</td>
<td>1113.0</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>10.0</td>
<td>1.0</td>
<td>42.0</td>
<td>3.6</td>
<td>1309</td>
<td>89.4</td>
<td>103.0</td>
<td>8.4</td>
<td>1464.0</td>
</tr>
</tbody>
</table>

The Maharashtra state is divided into nine agro-climatic zones;
1. South Konkan Coastal Zone
2. North Konkan Coastal Zone
3. Western Ghat Zone
4. Submontane Zone
5. Plain Zone
6. Scarcity Zone
7. Central Maharashtra – Plateau Zone
8. Central Vidarbha Zone
9. Eastern Vidarbha Zone

Rainfall is having high variability, having very high rainfall in North Konkan, South Konkan, Western Ghat and Eastern Vidarbha Zone and minimum rainfall in scarcity zone. Onset of monsoon is from 10 June (Fig. 1a) and withdrawal of monsoon is from 1st Oct (Fig. 1b). No. of depressions and cyclonic storms which bring high intensity rainfall ranges between 5 to 10 for Maharashtra State (Pant and Rupa Kumar, 1997).

Scarcity zone constitutes 23.8% and Central Maharashtra plateau zone 24.8% of total geographical area of the state. Thus, the two zones together comprise almost 50% of the geographical area of the Maharashtra, which has less rainfall. In these areas variability of rainfall is high and agriculture is risk prone.

Normalized area weighted seasonal (June – September) rainfall of India (1901-2001) is given in Fig. 2 and of different regions of Maharashtra (1971- 2001) in fig. 3 (a – e). It is clear that rainfall for last three consecutive years (1999, 2000, 2001) was deficient. But, it was more than normal in the earlier three consecutive years viz. 1996, 1997, 1998. However, there is no periodicity or trend in deficient or/ and excess rainfall years. Sometimes, it is presumed to be 11 years as per the periodicity of Sunspot cycle. In Maharashtra rainfall was deficient in 2000 and 2001so also in Madhya Maharashtra and Vidarbha. However, it was slightly excess in Konkan and Marathwada in 2001 and almost normal in 2000.

The drought years in the last thirty years are given in Table 2. It is obvious that area under severe drought was 17.9% in 1987, while; area under moderate drought was maximum 36.6% in 1972. Obviously, there is no specific periodicity in the occurrence of drought and excess rainfall.

### Table 2. Years of drought in last thirty years (1970- 2000) and area affected

<table>
<thead>
<tr>
<th>Years</th>
<th>Moderate drought (%)</th>
<th>Severe drought (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>36.6</td>
<td>3.8</td>
</tr>
<tr>
<td>1974</td>
<td>27.1</td>
<td>6.9</td>
</tr>
<tr>
<td>1979</td>
<td>33.0</td>
<td>1.8</td>
</tr>
<tr>
<td>1982</td>
<td>29.1</td>
<td>00</td>
</tr>
<tr>
<td>1985</td>
<td>25.6</td>
<td>6.7</td>
</tr>
<tr>
<td>1987</td>
<td>29.8</td>
<td>17.9</td>
</tr>
</tbody>
</table>

Moderate drought: 26< D <505,  Severe drought: D < 50%

**Temperature:**

Variations of all India mean annual maximum, minimum and mean temperatures and diurnal temperature range during 1901 to 1990 are given in Fig. 4 (a to d). The maximum temperature (30.6°C) is increasing significantly in all seasons except the monsoon season. While, minimum temperature (19.7°C) does not show a significant trend in any of the season. Similarly mean temperature (25.7°C) and diurnal range of temperature (10.9°C) is also increasing.
Maharashtra is considered under west coast region in which maximum temperature is varying as winter (+1.6°C), pre-monsoon (1.0°C), monsoon (0.9°C), Post-monsoon (+1.5°C) and annual (+1.2°C) highly significantly. While, minimum temperature is varying as winter (+0.2°C), pre-monsoon (0.1°C), monsoon (-0.1°C) post monsoon (-0.3°C), annual (+0.1°C) but, non-significantly.

Mean annual surface temperature (25.2°C) is also showing an increasing trend during 1881-1988. Increase in surface temperature during this period is 0.5°C [25.4°C (1988) - 24.9°C(1988)] Fig. 5. Season-wise trends (°C per 100 yr) of Indian surface temperatures during 1901-82 are pre-monsoon (0.5°C) and monsoon (0.3°C) significantly.

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**a. Annual rainfall anomaly for Konkan**

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**b. Annual rainfall anomaly for Madhya Maharashtra**
and winter (0.8°C), post- monsoon (0.9°C) and annual (0.6°C) highly significantly. (Hingane et al. 1985).
Crop Production:

Productivity of important crops in Maharashtra, of last ten years, are given in Table 3. The light use efficiency of C4 crops of present genotypes, under semi-arid conditions, is to the tune of 2.2 g MJ⁻¹ (Sivakumar et al., 1984 and Steiner et al., 1987). Incident radiations are 28 MJ per day in summer, 22 MJ per day in winter and 16-25 MJ per day in rainy season. Hence, biomass produced in kharif season should be to the tune of \((2.2 \times 8 \times 10,000 \times 110 \times 0.9)\) \(17.4\) t ha⁻¹ or yields should be to the tune of \(8.7\) t ha⁻¹ while, targets set are to the tune of \(2.0\) t ha⁻¹ only.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total rainfall</th>
<th>Cereals</th>
<th>Pulses</th>
<th>Oil seed</th>
<th>Cotton (Lint)</th>
<th>Sugarcane</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-92</td>
<td>1236.6</td>
<td>857.7</td>
<td>418.0</td>
<td>479.8</td>
<td>71</td>
<td>80130</td>
</tr>
<tr>
<td>1992-93</td>
<td>1245.5</td>
<td>1236.1</td>
<td>542.0</td>
<td>653.1</td>
<td>125</td>
<td>76720</td>
</tr>
<tr>
<td>1993-94</td>
<td>1445.3</td>
<td>1212.4</td>
<td>724.0</td>
<td>759.6</td>
<td>180</td>
<td>81000</td>
</tr>
<tr>
<td>1994-95</td>
<td>1357.1</td>
<td>1148.0</td>
<td>550.0</td>
<td>645.4</td>
<td>145</td>
<td>85680</td>
</tr>
<tr>
<td>1995-96</td>
<td>1186.5</td>
<td>1167.5</td>
<td>554.5</td>
<td>667.9</td>
<td>155</td>
<td>83800</td>
</tr>
<tr>
<td>1996-97</td>
<td>1260.6</td>
<td>1333.2</td>
<td>670.5</td>
<td>756.4</td>
<td>174</td>
<td>81830</td>
</tr>
<tr>
<td>1997-98</td>
<td>1389.4</td>
<td>993.0</td>
<td>380.0</td>
<td>544.8</td>
<td>95</td>
<td>83000</td>
</tr>
<tr>
<td>1998-99</td>
<td>1593.4</td>
<td>1244.9</td>
<td>712.5</td>
<td>728.3</td>
<td>139</td>
<td>89000</td>
</tr>
<tr>
<td>1999-00</td>
<td>1316.8</td>
<td>1170.0</td>
<td>838.5</td>
<td>709.4</td>
<td>162</td>
<td>90000</td>
</tr>
<tr>
<td>2000-01</td>
<td>1401.1</td>
<td>947.9</td>
<td>561.0</td>
<td>608.7</td>
<td>100</td>
<td>83000</td>
</tr>
</tbody>
</table>

Tropical climate is characterized by high radiation and temperature and summer monsoon rainfall. Most of the time crops are light saturated and excess radiation produces heat load on the canopy, increasing evapotranspiration losses. The radiations are reduced by 35% by 100 micron UV treated film, 75% by shading net and 85% by shading net inside the poly house. Thus, only 15% of radiations are sufficient for crop growth and development. It means that remaining radiations increases heat load only and are not useful. Therefore, farmers should be advised to practice multi-storied cropping in Konkan and Eastern Vidarbha region and intercropping in Scarcity, Central plateau and Western Vidarbha zone.

Major Concerns of the State

1. Agriculture in the state is mainly dependent on rainfall.
2. No crop planning as per the climate of the area.
3. No planning for drought and excess rainfall conditions.
4. No seasonal or climatic forecast to the farmers at state level.
5. No forecast for incidence of pests and diseases.
6. No forecast for yield of different important crops.
7. Climate change and its impact on Agricultural production.
8. Regional climate modification.
9. Sub-standard conditions of observatories and data collection.
10. Inadequate Human Resource Development.
1. Agriculture in the state is mainly dependent on rainfall:
Productivity of cereals, pulses and oil seeds along with rainfall is presented in Fig 6. It is obvious that productivity of cereals increased with increase in rainfall except in 1996 where productivity increase was more then rainfall. While, in 1991 and 1998 productivity increase was less in comparison to rainfall. Similarly, productivity of pulses and oil seeds increased with increase in rainfall.

Presently irrigation is to the tune of 15%, which can increase up to 23% only. Hence, more than 75% area will remain dependent on rainfall. Water requirement of sorghum is 250- 450 mm, pearl millet 200- 350 mm, rice 1200 mm and wheat 450 mm, while for sugarcane it is 2500+ mm. Hence, rainfall is sufficient to raise all crops except sugarcane which needs irrigation. Further, productivity of cereals, pulses and oilseeds can sustain, if one or two protective irrigations are provided.

The trends of rainfall in different regions of Maharashtra indicate that it is declining in Konkan slightly and in Madhya Maharashtra sharply during monsoon season and increasing in post monsoon season (Fig.7a-j). Thus, annual rainfall is not affected much. But, kharif crops productivity is affected adversely. Increasing trend in post monsoon season in whole Maharashtra increases black mould in sorghum and favors incidence of *Heliothis* spp. in cotton and red gram.
Recommendations

1. Due to decrease in rainfall during monsoon season and increase in rainfall in post monsoon season sowing dates of Kharif crops in Konkan and Madhya Maharashtra should be redefined according to the changed rainfall conditions. This may require one or two protective irrigations to be given to cereals, pulses and oil seeds in kharif season Similarly in rabi season also one or two protective irrigations are required to sustain the productivity of these crops.

- Cultivation of Rabi sorghum (M 35-1) without irrigation is not economical in Pune region. But, two irrigations one at panicle initiation and another at anthesis is the most economical.
- Wheat yields can increase up to 40 qha⁻¹ if irrigated at ±0.5 °C canopy - air temperature differentials.

Financial implications:
Nil. It should be accommodated in the present cost of research of the Universities.

Authority to Act upon:
Agricultural Universities of the State.

2. No crop planning as per the climate of the area:
Yield of the rain-fed crops are much less than potential yield. Broad crop planning based on “Climate of that area” should be prepared and farmers be guided to adhere to the suggested crops. It will help the State Govt. in deciding the production of each crop keeping in view of productivity of that area. Strategies of increasing the productivity of rain fed crop and approaching to the potential productivity may be decided.
The area under a crop could be estimated through remote sensing techniques. But it is under experimental stage and needs to be supported by ground truth.
Recommendations

1. Crop planning in Maharashtra needs to be done as per the agro-climatic zones of different regions. To achieve this research should be directed for developing better genotypes for corresponding rainfed conditions. Development agencies should extend the use of seeds of drought tolerant crop varieties to the farmers matching local agro-climatic conditions.

The project unit be established at CASAM, Pune with additional staff positions of One Associate Professor and two Assistant Professor. The time limit should be of 3 years.

Financial implications:
Rs 20 lac (One Associate Professor and two Assistant Professor for 3 years). It should be accommodated in the present cost of research of the Universities.

Authority to Act upon:
Agricultural Universities of the State.

Fig. 7 Trends for Monsoon season
b. Trend of rainfall for Madhya Maharashtra

Years
Rainfall (mm)


Years
Rainfall (mm)


Years
Annual rainfall (mm)


Years
Annual rainfall (mm)
e. Trend of rainfall for Maharashtra (Monsoon)

\[ y = -4.9054x + 1295.8 \]

Trends of rainfall for Post Monsoon season

f. Trend of rainfall for Goa & Konkan (post monsoon season)

\[ \text{Rainfall (mm)} \]

Series1

Series2

Linear (Series2)

Trend of Rainfall for Madhya Maharashtra (Post monsoon season)

\[ \text{Rainfall (mm)} \]

Series1

Series2

Linear (Series2)
h. Trend of Rainfall for Marathwada (Post monsoon Season)

I. Trend of rainfall for Vidarbha (Post monsoon season)

j. Trend of rainfall for Maharashtra (Post monsoon season)

\[ y = 1.6973x + 87.48 \]
3. **No planning for drought and excess rainfall conditions:**
Whenever drought/ excess rainfall occurs contingency measures are taken without a long-term strategy. Whenever, monsoon fails, agricultural labours become unemployed and are employed under Employment Guarantee Scheme (EGS) by the Govt. of Maharashtra. Usually, they are assigned the work of road construction and in recent years of Horticultural Plantation. In the drought years they should be allowed to desilt the farm, village ponds and reservoirs. Rajsamand lake in Rajasthan became totally dry in 2001. This was first time in the history of Rajasthan that Rajsamand lake was dry. The Govt. of Rajasthan appealed the farmers to desilt the lake and to carry the silt from the lake bed to spread it in their fields. Farmers desilted the lake and Raj samand lake became deep and revived in the monsoon of 2002. On similar lines reservoirs and ponds should be desilted during drought years. In excess rainfall years river streams should be cleaned from weeds such as water hyacinth and other sedimentation. An aggressive policy to clean the river stream should be adopted, even by using the dredgers, if necessary.

**Village pond:** State is having more than 50,000 villages. Out of which 25 to 50% are facing acute water shortage. Maharashtra is having a history of village ponds in vedic literature along with Tamil Nadu and Bengal. Each village should be encouraged to dig a village pond at the lowest point. For which machinery and financial support be provided by the Government and labor and human resource be provided by the village.

### Recommendations

1. **Strategies for drought and excess rainfall years should be prepared to fight drought situations each village should have village pond, for which necessary technical support should be provided.**

The drought indices defined by India Meteorological Department are moderate drought \(-20 < P < -49\%\) and severe drought as \(P < -50\\%\). However, this does not include break in monsoon with normal rainfall. Break in monsoon of two weeks or less during vegetative growth and again of two weeks or less during reproductive growth stage is managed by the crop. But, of longer duration and more then two occasions are not manageable by the crop. Break in monsoon of three weeks or more causes irrecoverable damages and should be considered as moderate drought.
Financial implications:
  Rs 10 lac per pond per village (50,000 villages).

Authority to Act upon:
  State Government.

4. No seasonal or climatic forecast to the farmers at State level:
State Agricultural Universities, in Maharashtra, issue medium range weather forecasts given by National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi from eight stations viz., Pune, Rahuri, Igatpuri, Dapoli, Mulde, Parbhani, Akola and Sindewahi. The scheme is in experimental stage. Forecasts are issued twice a week for four days overlapping one day in each week. The agro-advisory is relayed on All India Radio and sent to contact farmers by post. Rainfall forecasts are true by 75% on Yes/ No basis for Pune.
Government of India, New Delhi issues long-range forecasts (LRF) on annual basis for whole country. Now LRF is also issued for three zones but, in experimental stage. LRF is issued in the last week of May hence, is not very much useful for crop planning. Moreover, it is not updated during the season. Farmers of Maharashtra depend mainly on these two forecasts.
Astro- Meteorological Society of India issues forecast six months in advance. The forecasts are region specific and giving information on daily basis. In 2001 forecasts were true by 75% for Pune and 70% for Maharashtra on Yes/ No basis. Rainfall calendar nakshatrawise for 2003-2004 published by Bhtt, V. V. for Astro- Meteorological Society of India is enclosed.
However, there are no arrangements to issue either short term or long term forecast at state level to the farmers of Maharashtra.

**Recommendations**

1. **Forecast of rainfall should be made available to the farmers through out the state for which necessary infrastructure should be developed. Hybrid models based on computer simulation, remote sensing and astro-meteorology be developed.**

- Crop yields of contact farmers in eleven villages in Pune district increased by 20% by following the Agromet Advisory Bulletin containing weather forecast for next 4 days and field operations to be carried out by them.

1. **Forecast of rainfall should be made available to the farmers through out the state for which necessary infrastructure should be developed. Hybrid models based on computer simulation, remote sensing and astro-meteorology be developed.**

The infra structural development needs installation of rain gage per village, and installation of Automated Weather station per taluka with Super computer at the Head Quarter for supporting the network of all taluka stations.
Financial implications:

- **Rs 5,000** per village for raingauge. It should be accommodated in the present cost of development of Department of Agriculture.
- **Rs 2.0 lac** per taluka for Automated weather station.
- **Rs 50 lac.** (Installation of Indigenous Super Computer)

Authority to Act upon:

State Government, NABARD.

5. **No forecast for incidence of pests and diseases:**

About 30 per cent of the food production in the country is lost due to attack of insect pests and diseases. Of this loss, in food production, losses by weeds are 33 per cent and by diseases 26 per cent, by insects and rodents 26 per cent, while birds, nematodes, etc. accounting for rest. So far, use of pesticides dominated the pest control strategies in India. The average consumption of pesticides in the country has gone up from 3.2 g/ha in 1954-55 to 640 g/ha in 1980 (David, 1986) and to more than 1000 g/ha at present. The indiscriminate use of pesticides led to problem of pest resistance to chemicals, resurgence of pests and risks to human and animal health besides environmental pollution. The strategy of Integrated Pest Management (IPM) has emerged with the sole objective of reducing losses from pests with minimum ecological implications. Weather based prediction and control of pests is a part of the broader integrated pest management strategy.

The severity of damage caused by population build up of pathogens and insect pests depends on favourable atmospheric weather conditions. Intensity of many of the weather parameters like temperature, rainfall, cloudiness, leaf wetness, solar radiation, humidity at various growth stages of crops, influence the various stages of infection/infestation.

There is a urgent need to forecast the occurrence of pests and diseases based on the prevailing weather conditions for serving a better purpose by providing lead time and saving on resources of farming community. The feasibility of anticipating from weather data, the actual or potential occurrence of an epidemic has been established in case of a number of pests and diseases in other countries. Weather-based warnings have been reported to have led to a saving of 2½ billion francs per year in France on the spraying of the grape crops against downy mildew (Venkatraman, 1992).

In India, the All India Coordinated Research Project on Apple Scab gives forecast for the orchards in apple growing regions. Prediction system and computer models have been developed and tested for wheat rusts, potato late blight and other crop pests. Further the possibility of evolving weather based disease forecasting system in rice blast, groundnut tikka disease, post-harvest disease in groundnut rust (Mayee, 1996) highlight the urgent need to undertake lead research and extrapolate this methodology for developing appropriate pest/disease forewarning techniques for the major food and cash crops grown in the country.

Pesticide consumption statistics show that crops like cotton, rice and wheat use 80 per cent pesticides sold in India. Farming community due to lack of awareness of the minimum threshold values and weather conditions conducive or otherwise for pest outbreak resorts to often indiscriminate use of pesticides. There is thus a need
to develop weather based prediction models for diseases and pests for minimizing the use of pesticides and degradation of environment.

Recommendations

1. Further research be directed to develop weather based forewarning systems for important crop pest and diseases in various agro climatic conditions in the state.

- Powdery Mildew on grape is predicted at Maximum temperature 31.1-33.3 °C, Minimum temperature 7.7-10.5 °C, Morning Humidity more then 86% and After noon humidity 47-57 %.
- Powdery Mildew on okra is predicted at Maximum temperature 26-28°C, Minimum temperature 7-11°C, Morning Humidity more then 95% and After noon humidity 46-60 %.

1. Further research be directed to develop weather based forewarning systems for important crop pest and diseases in various agro climatic conditions in the state.

It needs to develop models for forecasting incidence of pests and diseases for important crops of Maharashtra. The research be conducted in each Agricultural University for important crops of that region and their popular genotypes.

Financial implications:

Rs 1 crore for six important crops.

Authority to Act upon:
Agricultural Universities of the State.

6. No forecast for yield of different important crops:
Presently yields are predicted on the basis of area under a particular crop and average productivity of that crop. Productivity is estimated on the basis of crop cutting experiments in progress at State level. These figures are having manual errors but collected through widest network. Now a day, area under a particular crop is estimated through remote sensing technique. However, this is under experimental stage. Yields can be predicted with the help of dynamic crop growth models well in advance. In America simulation models of Cotton (GOSYM), Soybean (SOYGRO), Maize (CERES-Maize) and Wheat (CERES-Wheat) are used for prediction of yields.
Software named Decision Support System for Agro-technology Transfer (DSSAT3.5) has been developed. Dynamic crop growth models for cereals viz., Wheat, Rice, Sorghum, Pearl millet, Maize and Barley; pulses viz., Chick pea, Soybean; oil seeds viz., Ground nut; vegetables viz., Potato and Tomato have been
incorporated in that. This software can be used for prediction of yields of these crops. In America genetic coefficients have been determined for their genotypes to predict the yield. Software DSSAT3.5 contains those genetic coefficients. In India, genetic coefficients of five Indian sorghum genotypes have been determined (Varshneya and Karande, 1999). In all the other validation experiments approximate values derived from the values of American genotypes have been used, which predicts approximate values of yields. Therefore models cannot be validated with confidence.

Recommendations

2. Genetic coefficients of all important cereals, pulses and oilseeds popular in Maharashtra should be determined so that crop models can be operationally used. To achieve this research should be directed to forecast yield of important crops in Maharashtra state based on various available models.

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The genetic coefficients of important genotypes be determined at CASAM Pune for which a research unit be established with technical staff positions. The staff positions required will be One Associate Professor, two Assistant Professor two SRA and two JRA. The work have to be completed in a given frame of time. Other facilities of field and instruments are already available.

The research unit needs to be established to forecast the yields of important crops. The unit needs to ensemble METSAT data and soil data to prepare the individual crop pictures by which area under a crop will be estimated by Remote Sensing Techniques and yield forecast will be done by dynamic crop growth models. The unit needs position of one Professor, one Associate Professor and two Assistant Professor. This unit may be kept under CASAM Pune, in collaboration with Department for operational use.

Financial implications:

Rs 10 lac per crop for two years (one Professor, one Asssociate professor and two Assistant professor).

Authority to Act upon:

Agricultural Universities of the State.
7. Climate change and its impact on Agricultural production:
Climate, in general and of Maharashtra, in particular, is showing sign of change. Global temperatures have increased by 0.7 °C and snow cover of Antarctica and Arctic region has decreased by which mean sea level has risen by 15.0 cm. Similarly CO₂ concentration has increased from 300 ppm (Parts Per Million) to 360 ppm. While in extreme cases it has gone as high as 670 ppm.

In stratosphere Ozone concentration is depleting, creating holes near Polar Regions. Depleting Ozone allows ultra violet radiation to pass through the earth’s atmosphere and impinging over earth’s surface. The ultra violet radiation affects the crop growth adversely, reducing leaf, flower, fruit and grain size. Ozone layer is depleting because of increase in the concentration of Chloro-Fluro-Carbon (CFC) gases, which are added in the atmosphere by vehicles, and modern gadgets. Vehicles also add in the atmosphere carbon monoxide, suspended carbon and other trace gases. The trace gases are responsible for increasing temperature of the earth - atmosphere system.

Methane is also increasing in the atmosphere. Increase in methane concentration is due to release from marshy lands and rice fields. But, rice fields are having standing water only for a very short period and in a limited area of rice cultivation. Standing water in crop fields absorbs the heat of earth atmosphere system because of high thermal capacity. Thus, it also helps in maintenance of thermal budget.

Increase in concentration of Carbon dioxide, Methane, Chloro-Fluro Carbon, trace gases and suspended carbon particles have resulted in green house effect by which short wave solar radiations passes through atmosphere and are incident over earth surface. While long wave radiations emitted from earth are trapped in the atmosphere because of absorption by CO₂ and water vapours. This resulted in increase in global temperature. Change in global temperature and presence of carbon particles in the atmosphere changes the cloud formation patterns. Change in temperature results in formation of low pressure and high-pressure zones, thus affecting pressure gradients and movement of wind. Finally it changes the rainfall patterns. Therefore, some places are experiencing drought conditions while other places experiencing high rainfall. Change in rainfall distribution affects crop growth and development. Increase in carbon dioxide concentration increases rate of photosynthesis and dry matter production, thus, enhancing crop growth and yield.

Recommendations

1. Research be directed to evaluate the impacts of climate change on agricultural production to meet the growing need of preparing the state for any contingency.
The research unit be established at CASAM, Pune with additional facilities of CO2 and O3 sensors and advanced micro meteorological techniques of the measurement of trace gases. The unit needs scientist’s position of one Professor, two Assistant Professor, two SRA and two JRA. This unit will need foreign collaboration on measurement of trace gases, which will be a pioneering work in India.

Financial implications:
Rs 50 lac per year (one Associate professor, two assistant professor, two SRA and two JRA + CO2 sensor and other instruments).

Authority to Act upon:
World Bank

8. Regional climate modification:
Maharashtra receives rainfall mainly from South – West monsoon (86%). The South – West monsoon winds strike on the windward side of Sahyadri and rises orographically creating compression at the top of Sahyadri range giving very high rainfall in Konkan region and Western Ghat Zone. (Maximum 8000 mm at Mahabaleshwar). These winds roll on the leeward side of Sahyadri, which increases speed of surface wind and temperature giving minimal rainfall in scarcity zone (extreme low: 198 mm – Chas) and assured but less rainfall in central plateau zone of Maharashtra State. The regional climate of scarcity zone and central plateau zone can be modified if plantation is done on leeward side of Sahyadri. The plantation crop increases roughness coefficient and decreases speed of the wind. Traditional plants such as Banian, Pipal, Neem, Bamboo, Jambhool and Babool (Acacia) should be encouraged on low attitude while, other shade and social forestry plants should be preferred on high attitudes. Plantation of fruit trees such as cashew, coconut, mango and guava should also be encouraged. The rural youth can be allotted 10 acre land, on lease of 30 years, on the slopes and they should be provided seedlings, fertilizers etc. for plantation. Under the terms of the lease young farmers should have rights on produce but should have no rights on sell and transfer of land and cutting of trees.

Recommendations

1. State may take up plantation of Sahyadri to maintain natural biodiversity and to green the hilly terrain and slopping regions of the state exposed to soil degradation to favorably modify the regional climate of scarcity and central plateau zone.

The land on the slopes of Sahayadri is to the tune of 12 lac ha. Plantation be done at a rate of 100 plants per ha with an spacing of 10x 10 m. If pit digging, filling and cost of seedling are considered to be at Rs 10/- per pit for digging, Rs 10 per pit for filling and fertilizer and Rs 10 for seedling, the cost per ha will be Rs 3000/-. Thus, for total area it will need Rs 360 Crore.
Financial implications:
Rs 360 crore
Authority to Act upon:
State government and World Bank

9. Sub-standard conditions of meteorological observatories and data collection:
Maharashtra state has four Agricultural Universities and 84 research stations. Out of which 48 research stations have surface observatories. Data on rainfall, air temperature, humidity and other weather parameters are recorded manually. Automated weather stations are there at few places, such as Pune, Parbhani and Akola. Data of all the 48 research stations are collected at Pune but there is no unit to digitize and analyze that. Similarly, no arrangements are there for maintenance, calibration and testing of the equipments of the observatory. Rainfall data is collected at Taluka level and compiled at District Level by revenue staff. Again, data collection is manual and suffers from the drawback stated above. It needs to improve whole data collection system at State Level. It will involve expenditure on equipment, staff and data collection system. Rain gauge should be installed in each village (50,000) and temperature and humidity recording should be done at Taluka and research station. In Australia rainfall is recorded at village level. In USA forecasts are issued at state level also and data collection centers are under Universities Data collection is automatic and transmitted on real time basis.

Recommendations

1. Data collection system should be automated, interlinked and modernized throughout the state.

2. METSAT data retrieval and interpretation facilities be created at state level so as to provide weather based agro-advisories to the farmers

1. Data collection system should be automated, interlinked and modernized throughout the state.

As referred earlier each village should have a rain gage and each taluka an Automated Weather Station. All the AWS should be connected to Central computer to transfer data on line. The cost of hard ware is shown below. The cost of staff will be in the establishment of Department of Agricultural meteorology under Commissionerate of Agriculture.

Financial implications:
Rs 5000 per rain gage per village
Rs 2.0 lac per Automated Weather station per taluka
Rs 50 lac Indigenous super computer
Authority to Act upon:
State government

2. **METSAT data retrieval and interpretation facilities be created at state level so as to provide weather based agro-advisories to the farmers**

10. **Inadequate Human Resource Development:**
Govt. of Maharashtra has no Department of Meteorology/ Agricultural Meteorology either independently or under Commissionerate of Agriculture. Govt. of India, New Delhi has India Meteorology Department under Department of Science and Technology (DST), which is having a nationwide, network. Rainfall data are collected at Taluka level and research stations by unqualified staff. A qualified observer to maintain the quality of data and upkeep of instruments should record it. MPKV, Rahuri is having a Department of Agril. Meteorology, where postgraduate program is operational. Six students for M.Sc. and two students for Ph.D. are enrolled every year. Up till now 60 M.Sc. students have completed their masters degree in Agril. Meteorology. Marathwada Agril. University, Parbhani has also established the department. Since, Govt. of Maharashtra has no clear policy of macro or micro level research in Agril. Meteorology, graduates are not employed properly.

In a study of Experimental Agromet Advisory Serviced under MPKV, Rahuri it is found that farmers return increases by 20% if Agromet information is provided and other recommendations are implemented keeping in view of prevailing climatic conditions. Thus, gap between potential productivity and actual can be abridged if weather forecasts are given regularly to the farmers by technically qualified staff.

A cell of Agril. Meteorology be established under Commissionerate of Agriculture on similar lines as Horticulture and Animal Husbandry. Each taluka should have one Agril. Meteorological Officer. Thus, in total 250-300 scientists/ experts will be required.

**Recommendations**

1. **A cell of Agricultural Meteorology should be established under Commissionerate of Agriculture to improve the human resources and to coordinate the development efforts of climate based agriculture and Department of Agricultural Meteorology be established under Agricultural Universities to develop the human resources in this field.**
The cell of Agricultural Meteorology is proposed with a view that more then 75% land will remain as rainfed agriculture. The data collection at village level be done by the agricultural worker of the Department or by the school teacher. At taluka level an Automated weather Station be installed with a SRA level worker to process the data of whole taluka and to transmit that to head quarter with on line transfer of data from AWS. It needs staff positions of SRA at taluka level, one Assistant professor at District Head Quarter and one Associate Professor at Divisional level and one Professor level at State Head Quarter with supporting ministerial staff and other facilities.

**Financial implications:**
Rs 8.40 crore per year (One SRA per taluka, One Assistant Professor per District, One Associate Professor per Division and Professor at the Head Quarter along with supporting staff)
Infra-structure Rs 10 crore

**Authority to Act upon:**
State government

**ACTION PLAN**:

1. Target yields for agricultural production crop-wise be fixed from 2003 to 2025 based on the population increase and considering export potentials.
2. Irrigation facilities available and to be increased by 2025 be established.
3. Crop planning be completed for each agro-ecological zone **2003-2004**.
4. Department of Agricultural Meteorology be established in each Agricultural University with following objectives: *(2003-2005)*
   a. Redefining sowing dates of important crops in accordance with prevailing weather conditions.
   b. Determination of genetic coefficients of important genotypes of that region for use in crop modeling.
   c. Validations of crop models for yield forecasting.
   d. Developing models for important crop pests and diseases.
5. Directorate of Agricultural meteorology be established with following objectives *(2003-2006)*
   a. Developing rain gauge station in each village.
   b. Modernizing data collection at taluka level.
   c. Giving weather forecasts zone wise within the district.
   d. Giving yield forecasts and working out strategy for movement of grain and export.
   e. Giving pests and disease forecasts.
7. Scheme for plantation of Sahayadri hills and village ponds. *(2003-2025)*

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