4.1. Decadal changes in cotton yield from 1991-2080

Cotton yield simulated using CROPGRO-Cotton model over Tamil Nadu at a decadal scale for a period of 90 years spanning from 1991 to 2080 is depicted in Table 4.1. The current rainfed cotton yield (1991-2020) varied from 1159 kg ha-1 to 2183 kg ha-1 with an average productivity of 1737 kg ha-1. From the analysis, it could be seen that there is decadal variability in the rainfed cotton yield in the 24 cotton-growing districts of Tamil Nadu. The decadal impact analysis on cotton was performed by dividing the 90 years into nine decades, starting from the first decade (1991–2000) to the last decade (2070–2080).

4.1 Cotton yield (kg/ha) at decadal scale in cotton growing districts of Tamil Nadu

District	1991-2000	2001-2010	2011-2020	2021-2030	2031-2040	2041-2050	2051-2060	2061-2070	2071-2080
Ariyalur	1678	1628	1764	1784	1780	1613	1776	1621	1561
Coimbatore	1374	1359	1399	1391	1370	1255	1507	1302	1317
Dharmapuri	1924	1960	2087	1673	1780	1838	1857	1935	1828
Dindigul	1698	1801	1951	1832	1712	1644	1877	1648	1602
Erode	1596	1414	1546	1389	1507	1485	1626	1567	1510
Karur	1475	1693	1800	1696	1613	1553	1698	1497	1380
Krishnagiri	1884	1849	1962	1551	1666	1694	1829	1876	1789
Madurai	1640	1900	2041	1850	1731	1691	1843	1632	1545
Nagappattinam	1701	1687	1742	1856	1818	1573	1753	1602	1605
Namakkal	1603	1739	1855	1631	1636	1644	1741	1635	1505
Perambalur	1946	2028	2232	2121	2108	2035	1949	2011	1849
Pudukkottai	1618	1729	1861	1800	1746	1627	1825	1583	1522
Salem	1867	1904	2035	1725	1811	1852	1856	1883	1772
Sivaganga	1438	1566	1691	1636	1541	1475	1720	1414	1342
Thanjavur	1570	1615	1662	1737	1676	1491	1735	1497	1474

Theni	1659	1780	1910	1741	1573	1526	1776	1549	1563
Thiruvarur	1761	1785	1835	1961	1907	1645	1793	1667	1673
Thoothukkudi	1367	1472	1523	1436	1378	1426	1446	1363	1272
Tiruchirappalli	1739	1975	2081	1924	1863	1821	1835	1777	1643
Tirunelveli	1519	1698	1772	1556	1487	1514	1501	1450	1422
Tiruppur	1078	1148	1251	1200	1150	1028	1327	1055	981
Tiruvannamalai	2068	2076	2231	2026	2051	2036	2090	2076	2062
Vellore	2151	2144	2254	1979	2038	2113	2155	2208	2101
Virudunagar	1263	1422	1600	1452	1360	1311	1555	1266	1166

During the baseline period (1991–2020), the cotton yield had a positive decadal shift as it increased from the previous decade to each subsequent decade. The increase in cotton yield was observed in 20 districts and 24 districts during the second (2001–2010) and third (2011–2020) decades, respectively, compared to the previous decade. Over the baseline period, the average increase in cotton yield was found to be 5% in the second decade (2001– 2010) compared to the first decade (1991–2000), whereas a slight improvement in cotton yield of 7% was noticed in the third decade (2011–2000) compared to the second decade (2001–2010).

In contrast, the dip in cotton yield is anticipated for 80 percent of the districts in all decades over the future period, except the seventh decade (2051–2060). In the future decade, the cotton yield was expected to decrease in 20, 18, 18, 23, 18 and 22 districts during the 2021–2030, 2031–2040, 2041–2050, 2051–2060, 2061–2070, and 2071–2080 decades, respectively (Fig 4.64)

The decadal yield shift during the 2021-2030 varied from (-) 21% in Krishnagiri to 7% in Thiruvarur district. It is excepted that the decadal variation of yield in 2031–2040 would ranges from (-) 10% in Theni to 8% in Erode and the decadal shift is projected to vary from (-) 14% in Vellore to 4% in Thiruvarur during 2041–2050. During 2051–2060, the projected decadal yield variation varies from 4% in Perambalur to 29% in Tiruppur district, while in 2061-2070, the

Tiruppur district is expected to face a decline in yield of 20%. The decadal yield variation is predicted to vary from (-) 20 to 4% (Dharmapuri) and it is expected to range between (-) 8 and 1% in Perambalur and Coimbatore, respectively, during 2071–2080.

4.2. Assessment on the impact of future climate change on cotton yield

The deviation of cotton yield in the future from the baseline (1991–2020) was calculated to understand the climate change effect on cotton yield and presented in Table 4.2 & Fig. 4.1. The results from the analysis of future yield deviation from the baseline yield indicate that climate change poses a negative effect on cotton yield in most of the cotton-growing regions. In the cotton yield, the maximum reduction is expected to be 18.3, 12.2, 14.4, 9.7, 13.1, and 18.3% in 2021–2030, 2031–2040, 2041–2050, 2051–2060, 2061– 2070, and 2071–2080, respectively.

Table 4.2 Impact of climate change on cotton yield in cotton growing districts of Tamil Nadu

District	Baseline yield (kg/ha)						
	1991-2020	2021-2030	2031-2040	2041-2050	2051-2060	2061-2070	2071-2080
Ariyalur	1690	5.5	5.3	-4.6	5.1	-4.1	-7.6
Coimbatore	1377	1.0	-0.5	-8.9	9.4	-5.5	-4.4
Dharmapuri	1990	-16.0	-10.6	-7.7	-6.7	-2.8	-8.2
Dindigul	1817	0.8	-5.8	-9.5	3.3	-9.3	-11.8
Erode	1519	-8.5	-0.8	-2.2	7.1	3.2	-0.5
Karur	1656	2.4	-2.6	-6.2	2.5	-9.6	-16.7
Krishnagiri	1899	-18.3	-12.2	-10.8	-3.7	-1.2	-5.8
Madurai	1860	-0.6	-6.9	-9.1	-0.9	-12.3	-17.0
Nagappattinam	1710	8.5	6.3	-8.0	2.5	-6.3	-6.2
Namakkal	1733	-5.9	-5.6	-5.1	0.5	-5.6	-13.1
Perambalur	2069	2.5	1.9	-1.6	-5.8	-2.8	-10.6
Pudukkottai	1736	3.7	0.5	-6.3	5.1	-8.8	-12.3
Salem	1935	-10.8	-6.4	-4.3	-4.1	-2.7	-8.4
Sivaganga	1565	4.5	-1.5	-5.8	9.9	-9.6	-14.3

Thanjavur	1616	7.5	3.7	-7.7	7.4	-7.4	-8.7
Theni	1783	-2.4	-11.8	-14.4	-0.4	-13.1	-12.3
Thiruvarur	1794	9.4	6.3	-8.3	-0.1	-7.0	-6.7
Thoothukkudi	1454	-1.2	-5.2	-1.9	-0.5	-6.2	-12.5
Tiruchirappalli	1932	-0.4	-3.6	-5.8	-5.0	-8.0	-14.9
Tirunelveli	1663	-6.4	-10.6	-9.0	-9.7	-12.8	-14.5
Tiruppur	1159	3.5	-0.8	-11.3	14.5	-9.0	-15.3
Tiruvannamalai	2125	-4.6	-3.5	-4.2	-1.7	-2.3	-3.0
Vellore	2183	-9.3	-6.6	-3.2	-1.3	1.1	-3.8
Virudunagar	1428	1.6	-4.8	-8.2	8.8	-11.4	-18.3

District	2001-2010	2011-2020	2021-2030	2031-2040	2041-2050	2051-2060	2061-2070	2071-2080
Ariyalur	-3.0	8.4	1.1	-0.2	-9.4	10.1	-8.7	-3.7
Coimbatore	-1.1	3.0	-0.5	-1.5	-8.4	20.1	-13.6	1.1
Dharmapuri	1.8	6.5	-19.9	6.4	3.2	1.1	4.2	-5.6
Dindigul	6.1	8.4	-6.1	-6.5	-4.0	14.2	-12.2	-2.8
Erode	-11.4	9.3	-10.1	8.5	-1.4	9.5	-3.6	-3.6
Karur	14.8	6.3	-5.8	-4.9	-3.7	9.4	-11.8	-7.9
Krishnagiri	-1.9	6.1	-21.0	7.4	1.6	8.0	2.6	-4.7
Madurai	15.9	7.4	-9.4	-6.4	-2.3	9.0	-11.5	-5.3
Nagappattinam	-0.8	3.3	6.6	-2.1	-13.4	11.4	-8.6	0.2
Namakkal	8.5	6.7	-12.1	0.3	0.5	5.9	-6.1	-7.9
Perambalur	4.2	10.0	-5.0	-0.6	-3.5	-4.2	3.2	-8.1
Pudukkottai	6.8	7.6	-3.3	-3.0	-6.8	12.2	-13.2	-3.8
Salem	2.0	6.9	-15.2	5.0	2.2	0.2	1.4	-5.9
Sivaganga	8.9	8.0	-3.3	-5.8	-4.3	16.6	-17.8	-5.1
Thanjavur	2.8	2.9	4.5	-3.6	-11.0	16.4	-13.8	-1.5
Theni	7.3	7.3	-8.9	-9.7	-2.9	16.4	-12.8	0.9
Thiruvarur	1.4	2.8	6.9	-2.8	-13.8	9.0	-7.0	0.3
Thoothukkudi	7.7	3.4	-5.7	-4.1	3.5	1.4	-5.7	-6.7
Tiruchirappalli	13.6	5.4	-7.6	-3.2	-2.3	0.8	-3.2	-7.5
Tirunelveli	11.8	4.3	-12.2	-4.4	1.8	-0.8	-3.4	-1.9
Tiruppur	6.5	9.0	-4.1	-4.2	-10.6	29.1	-20.5	-7.0
Tiruvannamalai	0.4	7.5	-9.2	1.2	-0.7	2.7	-0.6	-0.7
Vellore	-0.3	5.1	-12.2	3.0	3.7	2.0	2.5	-4.9
Virudunagar	12.6	12.6	-9.3	-6.3	-3.6	18.6	-18.6	-7.9

Fig 4.1 Decadal changes of cotton yield (% deviation) in cotton growing districts of Tamil Nadu

The weather conditions that prevail during the growing season play a major role in determining the development and yield of crops. The most important climatic variables that significantly influence crop growth and production are rainfall and temperature. The effect of warming and changing rainfall on cotton productivity was evaluated using the ensemble climate mean of CMIP6 models for the SSP585 scenario. The responses of cotton to future changes in climate as projected by the CMIP6 climate model ensemble under SSP585 scenarios over Tamil Nadu showed notable differences in cotton yield. The percent change in cotton yield with respect to the future climate is depicted in figure 4.2.

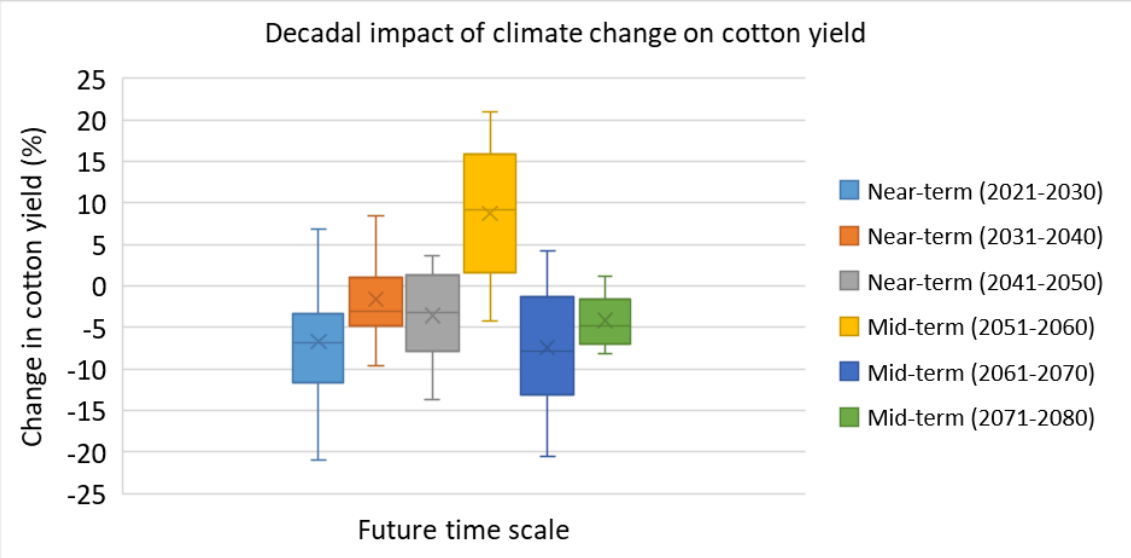


Figure 4.2. Climate change impact on cotton yield at decadal scale over Tamil Nadu

The adverse effect of climate change on cotton is expected to intensify with the advancement of time. All the cotton-growing districts would experience yield loss due to climate change in the near-term (2040s) and mid-term (2070s) future. The reduction in yield is predicted to be 18.3% in the future. This yield reduction in the future might be due to the negative impact of increased temperature on the growth and yield of cotton (Kumar Panda *et al*., 2012). The magnitude of the negative effect of climate change is expected to increase in the mid-term future compared to the near-term future under the SSP 585 scenario.

The less negative effect found in the near-term future might be due to a lower increase in

temperature and a relatively moderate increase in rainfall projected by climate models (Waha *et al*., 2013).

The moderate yield decrease in the near term could also be attributed to the positive effect of enhanced CO_2 by increased photosynthetic efficiency to some extent, combined with the lessening increase in temperature. Enhanced CO_2 would increase the water use efficiency due to a decrease in the stomatal conductance of the leaves, which would reduce the rate of transpiration and help in maintaining the leaf water potential. Rosenberg *et al*. (1988) found a positive relationship between elevated CO_2 and stomatal resistance and the resultant decrease in transpiration.

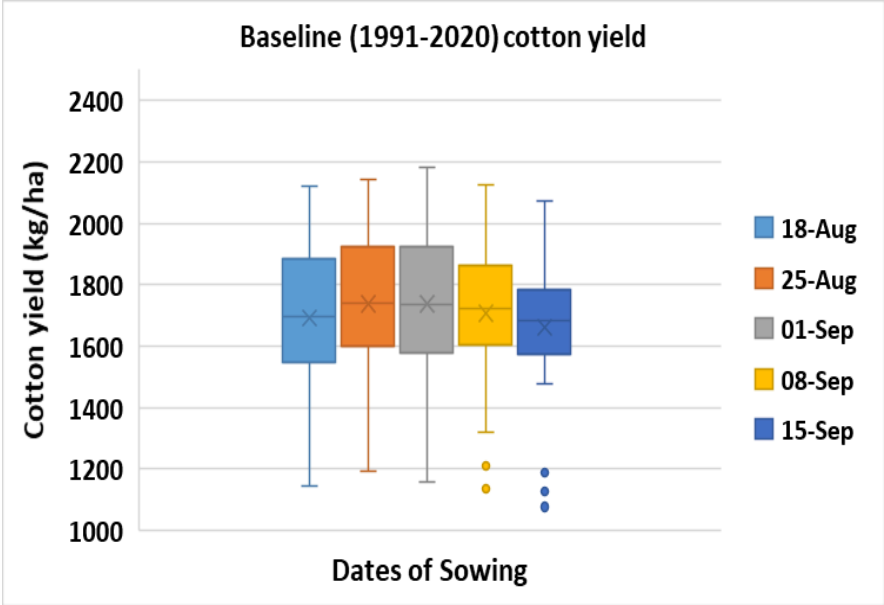
4.3. Climate change adaptation strategies

Impact of climate change on crops could be minimized through devising the potential adaptation strategies. The present investigation tested the advantageous effect of selected adaptation strategies under current and future climate conditions generated using the ensemble of selected CMIP 6 climate models. Sowing the crop at an appropriate time could be one of the most critical climate-resilient options to enhance the yield. The wellcalibrated and validated CROPGRO-Cotton model was deployed to evaluate the cotton response to varied sowing windows in order to determine the optimum sowing window for cotton under future climatic conditions. Five sowing windows at a seven days interval was taken from 18th August to 15th September for examining the performance of cotton crop under different sowing time.

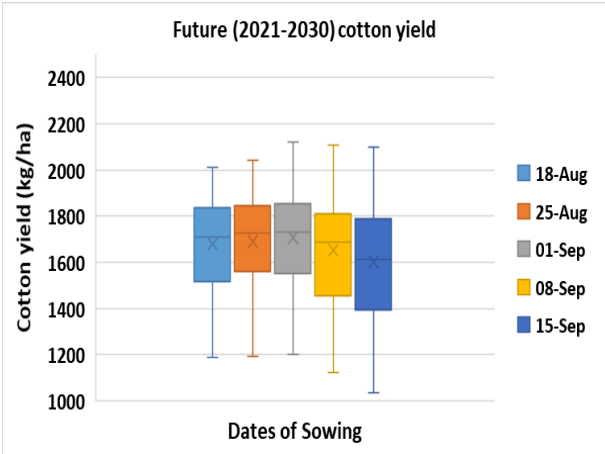
4.3.1. Response of cotton to different sowing window under future climatic conditions

The simulated cotton yield for five sowing windows at a 7-day interval were portrayed in the Fig.4.3 From the box plot, it can be observed that 1st September sowing produced higher cotton yield under both current and future climatic conditions which was at par with the yield obtained from the 25th August sowing window. In the mid-term future (2070s), sowing performance of 18th August is expected to be almost close to the 25th August and 1st September sowing. The late sowing after 1st September is predicted with reduction in cotton yield.

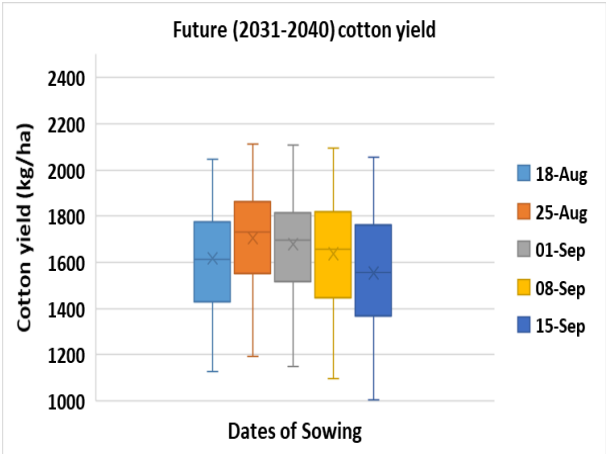
a. **Baseline (1991-2020)**



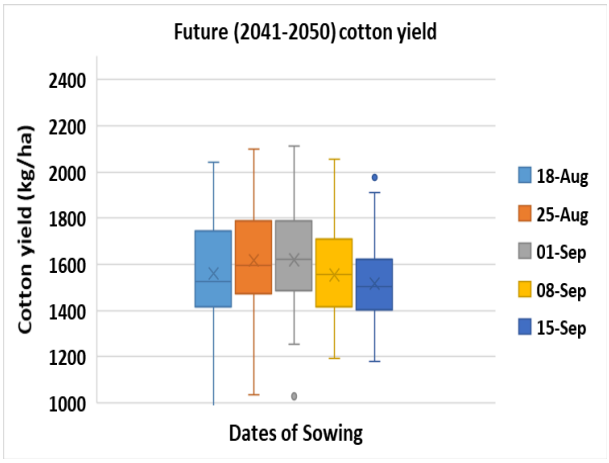
b. **Future (2021-2030)**



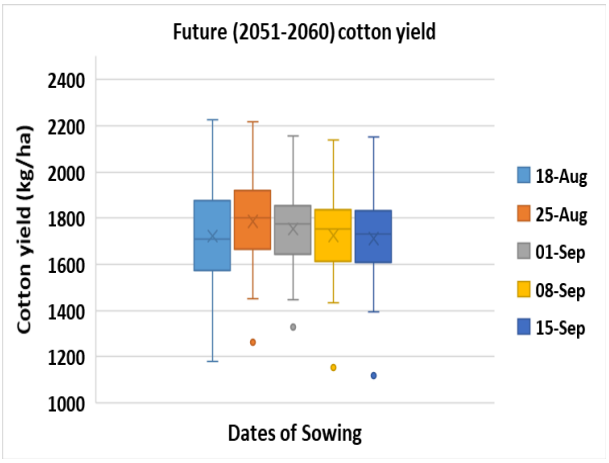
c. **Future (2031-2040)**



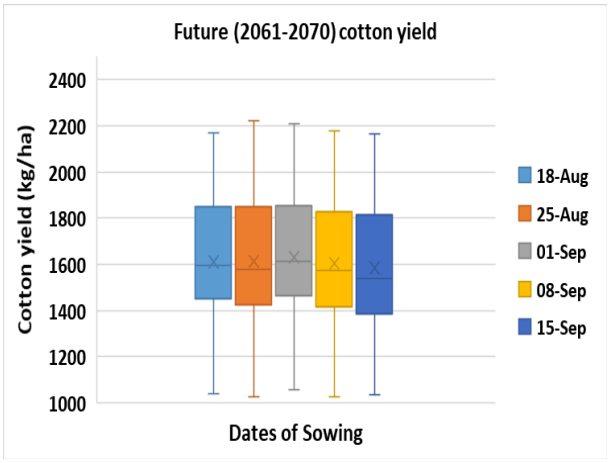
d. Future (2041-2050)



e. Future (2051-2060)



f. Future (2061-2070)



g. Future (2071-2080)

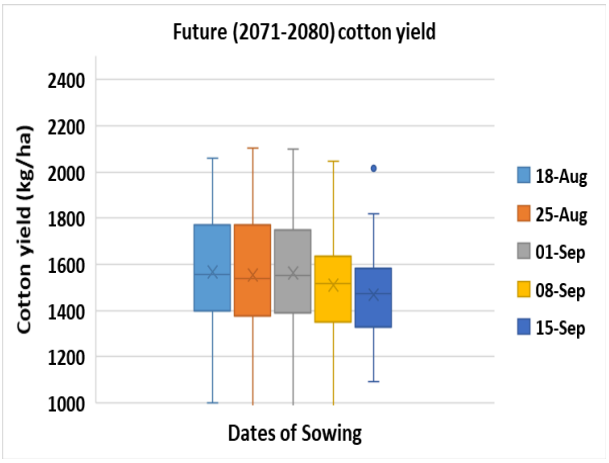


Figure 4.3. Influence of sowing dates on cotton in Tamil Nadu under current and future climatic condition