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IMPACT OF CLIMATE CHANGE ON AGRICULTURE AND FOOD SECURITY

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ABSTRACT

The traditional agriculture was soil and climate driven farming systems that encompasses the animal husbandry. It provided socio-economic, food and nutrient security with the healthy food. Those were the "Golden Days" in the history of farming. It was an environment-friendly system and was highly successful and sustainable form of agriculture. No pollution, no worry about seeds and fertilizer adulteration as they used good grain as seed and compost of farmyard manure and green manure as fertilizer. This system of agriculture is clouded by the chemical inputs-GM seeds agricultural technologies after 1960s. Under this system of agriculture around 30% of what is produced is going as waste and thus the inputs used to produce that is going as waste. This is a most ineffective system of agriculture practice. Seed adulteration, fertilizer adulteration, food adulteration, water pollution, etc. are growing with the time along with government's incentives/subsidies. Farm sizes are coming down and still around 60% of the cultivated area is at the mercy of "Rain God". To achieve food security, we need sustainable agriculture system under variable soil and climate conditions wherein the soil is static and the climate is dynamic. Climate is beyond human control and thus needs to adapt to it. Climate is always changing through the natural cycles. What we are experiencing now is part of this system only. Traditionally farmers adapted to this based on their hundreds of years of experiences. The two main climatic parameters that play vital role in agriculture are temperature and precipitation. Temperature presents high seasonal and annual variations. Agriculture is adapted to such variations in temperatures. Since, around the last two decades groups are polluting agriculture research under the disguise of global warming, a component of climate change. However, it is insignificant to influence agriculture. Moisture is the limiting factor for crop growth in tropical warm regions wherein most of the developing countries are located. Moisture availability varies with space and time in association with the natural variability in rainfall and snowfall that forms the principal component of the climate change. Droughts and floods are part of it. That is moisture availability varies with country to country, region to region within the country and station to station within a region based on the general circulation patterns in association with the climate systems. In such scenarios, studies based on the truncated data sets lead to misleading inferences. These are discussed with reference to India, Andhra Pradesh and Kurnool rainfall data series. Annual rainfall at all-India level follows the 60-year cycle and at Andhra Pradesh level 132 year cycle. Water availability in Godavari River [northwest Indian rivers] and Krishna River follows these patterns, respectively. For Kurnool the growing period follows the southwest monsoon rainfall pattern of 56-years cycle with drought in 45% of years – 30% and 70% of the years during above and below the average periods. Western Ghats played the major role here.

KEYWORDS

Water availability, Climate change, Macro, Micro levels, Rhythmic variation, River water, Dry-land agriculture, Krishna river and Godavari river.

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INTRODUCTION

"Dr. Jeevananda Reddy – writes Droughts, floods, heat and cold waves will keep threatening India. We cannot expect the Paris Agreement to solve the crisis associated with these extreme weather events. The way was to minimize their impact is through the mechanism in which they occur by quantifying the agro-climate of the region – Ecologise.in, 6th June 2016; Precautionary measure for natural calamities: A letter to the Prime Minister" – such analysis was carried out for few countries and the summary was included in Reddy (1993, 2019a)[1,2].

The traditional agriculture was soil and climate driven farming systems that encompasses the animal husbandry (Reddy, 2019a)[2]. It provided socio-economic, food and nutrient security with the healthy food. Those were the "Golden Days" in the history of farming. Traditionally farmers adapted to this based on their forefathers hundreds of years of experiences. To achieve food security, we need sustainable agriculture system under variable soil and climate conditions wherein the soil is static and the climate is dynamic (Reddy, 1993 and 2019b)[1,3]. Climate is beyond human control and thus needs to adapt to it. Climate is always changing through the natural cycles. What we are experiencing now is part of this system only. The two main climatic parameters that play vital role in agriculture are temperature and precipitation. Temperature presents high seasonal and annual variations (Table No.1). Agriculture was/is adapted to such variations in temperatures. However, in the last two decades groups are polluting agriculture research under the disguise of "fictitious" global warming, [Reddy, 2016][4].

CLIMATE CHANGE

Climate change consists of (a) Natural or rhythmic variations and (b) Human induced trend. WMO (1966)[5] presented methods to separate them, one such method is "Moving Average Technique". Figure No.1 presents the annual march of onset dates of southwest monsoon over Kerala along with 10-year moving average.[Reddy, 1977][6]. This suggested 52 year cyclic pattern. Figure No.2 presents the annual march of global annual average temperature anomaly along with 10-, 30- and 60 year moving averages. This suggests a 60 year cyclic pattern – after removing 60-year cyclic pattern the trend is shown clearly [BRMS, 2014][7].

Temperature

Trend and Natural variation

Figure No.3 presents the natural variability and trend in global annual average temperature anomaly of 1880 to 2010 – not raw data; it is an adjusted data (Reddy, 2008)[8]. From the figure it is seen that the natural variability followed 60-year cycle and the sine curve varied between - 0.3 and + 0.3 ^oC. Linear Trend is 0.6 ^oC century. According to IPCC (i) more than half is associated with greenhouse effect; and (ii) less than half is due to non-greenhouse effect [changes in land use and land cover]. Greenhouse effect component consists of global warming and others; if we assume global warming itself is 50%; then global warming is 0.3^oC /century. According to IPCC, starting year of global warming is 1951. Thus the global warming from 1951 to 2100 is 0.45^oC under linear trend. However, from IPCC reports it is seen that "climate sensitivity factor" is gradually coming down -- 1.95 in AR4 and 1.55 in AR5 – and thus it can be said that the trend must be non-linear and therefore global warming is insignificant. Figure No.4 presents the Sydney hottest daily maximum temperature annual march during 1896 to 2016. This shows no trend.

Temperature impact on crop production

Figure No.5 presents the crop progress and condition for corn in Indiana (USA) in terms of withdrawal and onset of winter season. This defines the period conducive for growth or effective growing period in which production comes down with the decreasing effective growing period. Figure No.6 presents Yield per hectare in India versus El Nino events in India. No systematic impact is evident on crop yield with changing El Nino temperature rise or fall.

Figure No.7 presents the (a) changes in crop areas with fertilizer technology in Andhra Pradesh [AP] in India, (b) yield increase with chemical fertilizers in rice in AP, (c) soybean production in top five countries, (d) World corn, wheat and rice production, (e) IPCC projection on food, water, etc. with reference to global warming levels in temperature; (f) Crop production in India in terms of inputs; (g) USA Corn – Inputs and Outputs [Components of the yield trend. Observed yields averaged over the US Midwest between 1981 and 2017 (black dots) along with our temperature-driven model estimate (gray line). The yield trend is broken into components attributable to an improvement in climate [red, 0.2 (0–0.5) t/ha, best estimate and 95% CIs, timing adjustments [blue, 0.2 (0-0.3) t/ha per decade], and other factors improving yields [green, 0.9 (0.9-1.0) t/ha per decade]. Also shown is the baseline yield referenced to 1981 (6.2 t/ha). The stacked bar on the far right side shows the total contribution, as of 2017, from each of these components and the associated 95% CIs.].

Rainfall

Moisture is the limiting factor for crop growth in tropical warm regions wherein most of the developing countries are located. Moisture availability varies with the climate change expressed by the natural variability in rainfall and snowfall. In rainfall there is no trend except abrupt shifts due to modifications in the local terrain/land use.

All over the world, rainfall presents clear cut rhythmic variations and showed variations with latitude, coast to inland, etc. (Reddy, 1993 and 2019b)[2,3]. However, they vary with national, regional and local level with the climate system and general circulation patterns. Recently a report [Marvel *et al*, 2019][9] "NASA Study: Human Influence on Global Droughts Goes back 100 years, May 3, 2019, by Jessica Murzdorf, NASA Goddard Space Flight [GISS] in New York" states that human generated greenhouse gases and atmospheric particles were affecting global drought risk as back as the early 20th century. This is a false theory. Let me present from my study in 1986 as FAO Expert: Recently both national and international media made big hue and cry on Sofala-Beira cyclone and Cape Town and Brazil Drought. Even the Secretary General of WMO made such statements attributing to global warming. I sent mail to him referring to my book of 1993 available in WMO Library. Durban in South Africa presented 66/22 years cycles and Beira in Mozambique presented 54/18 years cycles. The integrated predictive patterns were presented in a book of 1986 submitted to Mozambique government. According to this, 2012-22 in Beira is wet period with more than 1480mm and 2010-23 is a dry period with less than 1050mm (Reddy, 1986)[10].

It is common to researchers and planners use truncated data set with Natural Variability series. This type of selection leads to misleading conclusions or lead to biased inferences. For example, let me present few cases in this direction wherein the data series present rhythmic variations at national, state and station levels.

National Level

Figure No.8 presents the annual march of all-India annual rainfall [June to May] from 1871-72 to 2014-15 (Reddy, 2019c)[11]. It presents a 60-year cycle. Two cycles were completed and the above average 30-year part of third cycle was completed. Now, we are in the below the average 30-year part of the third cycle. Few examples related to river water and truncated data use implications are discussed below.

Here let us see five segments in Figure No.8

Godavari River annual water availability [*Bachawat Tribunal Award data of 1880 to 1946 – with one year data missing*] follows the pattern of 60-year cycle as seen in Figure No.9. The difference of between the means of 30 year below and above the average periods is 650tmc ft (Figure No.9)

With reference to a question raised in the Parliament, IMD/IITM scientists prepared a report and submitted to the concerned minister, who in turn informed the parliament that the Indian rainfall is decreasing. Here they used the data set of 1930 to 1990 – if they would have used the data set of 1960 onwards, it would have shown increasing trend. This is fallacy of random selection in a rhythmic data series;

Table No.2 presents the frequency of occurrence of high magnitude floods in few northwest Indian Rivers (Chenab, Ravi and Beas). It shows that during the below the average period the frequency is around one in ten years; and during the above the average period is around one in three years;

Tree Rings study over Brahmaputra River basin followed Figure No.8.

***State of Environment Report, India – 2009, MoEF/GoI**

The frequency of floods in India is largely due to deforestation in the catchment area, destruction of surface vegetation, changes in land use, increased urbanization and other developmental activities –

this is a false statement but it is more in association of cyclic variation in rainfall.

CWC used the data of high annual rainfall period 30 years 1985-86 to 2014-15 and estimated annual water availability in Indian rivers. This over estimates as they used the above the average part of the cycle (Figure No.8). In addition the method adapted in the runoff estimation overestimates the water availability.

State Level

Reddy (2000)[12] analysed the data series of Andhra Pradesh (AP) rainfall comprising of three met sub-divisions, namely Coastal Andhra, Rayalaseema and Telangana and found the data series following 56 years cycle in the southwest monsoon (SWM) rainfall and though it also showed 56 year cycle in the northeast monsoon (NEM) rainfall but in the opposite direction. The cyclonic activity in the Bay of Bengal followed the SWM rainfall pattern [Table No.3]. The annual data series followed 132 year cycle (Reddy, 2016)[4]. Figure No.10a presents the annual march of rainfall and Figure No.10b presents the annual march of water availability in Krishna River. The water availability in Krishna River follows the Andhra Pradesh rainfall pattern. Before 1935, the 66 years part is below the average in which 24 years were drought years and 12 years were flood years; and from 1935 to 2000, the 66 years part is above the average in which 12 years were drought years and 24 years were flood years. From 2001, the below the average part of 66 years started and so far majority of the years [including the last three years] presented deficit rainfall [2002 and 2009 were drought years at all India level and showed a temperature raise of 0.7°C and 0.9°C, respectively]. Water reached Srisailam dam during 2009-10 to 2018-19 in tmc ft are: 1222, 1028, 736, 197, 848, 614, 59, 345, 489 and 562. 1876 presented deficit rainfall less than 50% and on either side also presented less than average rainfall. British Memoirs showed severe drought in Bangalore during 1876/78 [Figure No.11].

Station Level

For agriculture planning in real time, we need to study the time variation in rainfall and agro-climatic parameters (Reddy, 1993)[2]. Figure No.12 presents one such an example for Kurnool in AP state. S and G in the figure refer to week of commencement time of planting rains and G is the available effective rainy period from S. This figure presents the pattern of 56-year cycle in which the drought risk is 45% of the years on an average. During below the average 28 year period, drought risk is 70% and during above the average 28 year period it is 30%.

Figure No.13a presents the average drought risk in the semi-arid tropics in India and using the same procedure Akumunchi Anand *et al*, (2009)[13] presented for Maharashtra [Figure 13b]. This clearly shows the impact of climate system (Reddy, 2016)[4] – here it is Western Ghats – on rainfall and thus drought proneness.

Table No.1: Hyderabad temperature extremes

S.No	Month		Temperature (°C)					
		Tw	Tmax	Tmin	Thm	Tlm	Th	Tl
1	Highest	23.7	38.7	26.2	42.4	22.5	44.4	19.4
2	Lowest	17.2	27.8	13.4	30.6	09.9	33.3	06.1
3	Range	06.5	10.9	12.8	11.8	12.6	11.1	13.3

Tw = mean afternoon wet bulb, Tmax = mean maximum, Tmin = mean minimum, Thm = highest mean, Tlm = lowest mean, Th = highest in a day, Tl = lowest in a day

Table No.2: Frequency of occurrence of high magnitude floods in few northwest Indian Rivers

S.No	Frequency of high magnitude floods*			
	River	**Period**	**Frequency**	**Climatic cycle**
1	Chenab	1962-1990	1 in 9 years	(a) below the average cycle
2		1990-1998	1 in 3 years	(b) above the average cycle
3	Ravi	1963-1990	1 in 14 years	(a) below the average cycle
4		1990-1998	1 in 3 years	(b) above the average cycle
5	Beas	1941-1990	1 in 8 years	(a) below the average cycle
6		1990-1995	1 in 2 years	(b) above the average cycle

Table No.3: SWM and NEM and cyclonic activity in Bay of Bengal statistics

S.No	Period	Rainfall [% years with < 90% of average] Cyclones in Bay of Bengal						
	SWM	**NEM**			**[May to November] $**			
		CA	**R**	**T**	**CA**	**R**	T	**number**
1	1861-1888*	72	61	72	33	28	66	<10
2	1889-1916	53	43	46	60	71	71	>10
3	1917-1944	75	78	68	46	50	60	<10
4	1945-1972	43	43	32	64	60	46	>10 [10-16]
5	1973-2000**	54	54	54	41	45	41	<10 [0-8]
6	2001-2027	-	-	-	-	-	-	>10

*1871-1888; **1973-1994, average cyclones 10; SWM = southwest monsoon; NEM = northeast monsoon; CA = Coastal Andhra, R = Rayalaseema, T = Telangana met sub-divisions

$: Joint Typhoon Warning Centre – Bay of Bengal Region Cyclones per year during 1945-2000 (May-November) – Reddy (2008)[8] 160.

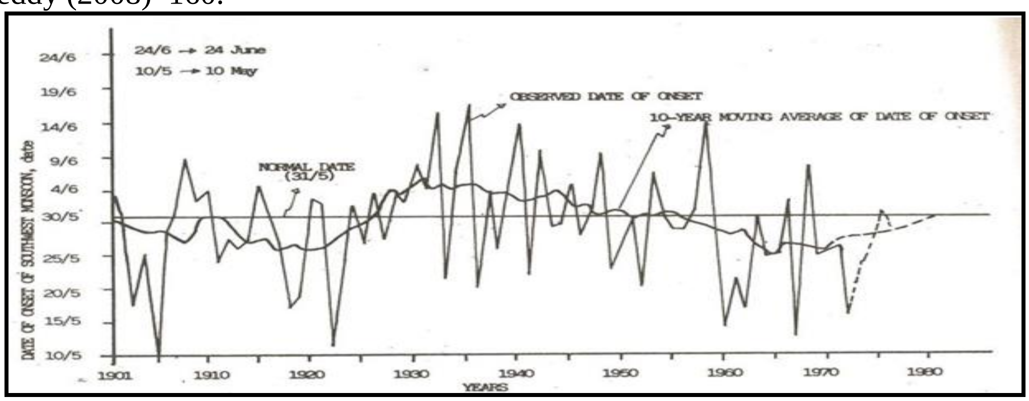


Figure No.1: Annual march of data of southwest monsoon over Kerala Coast in India

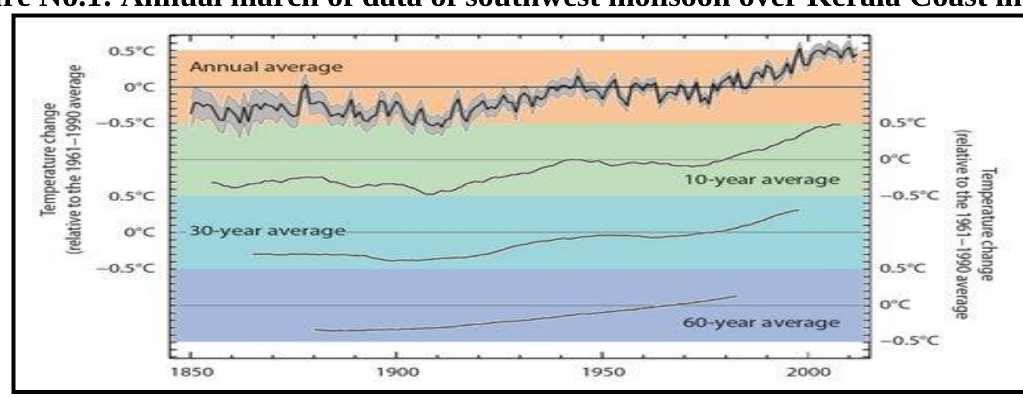


Figure No.2: Global annual averages and moving averages temperature

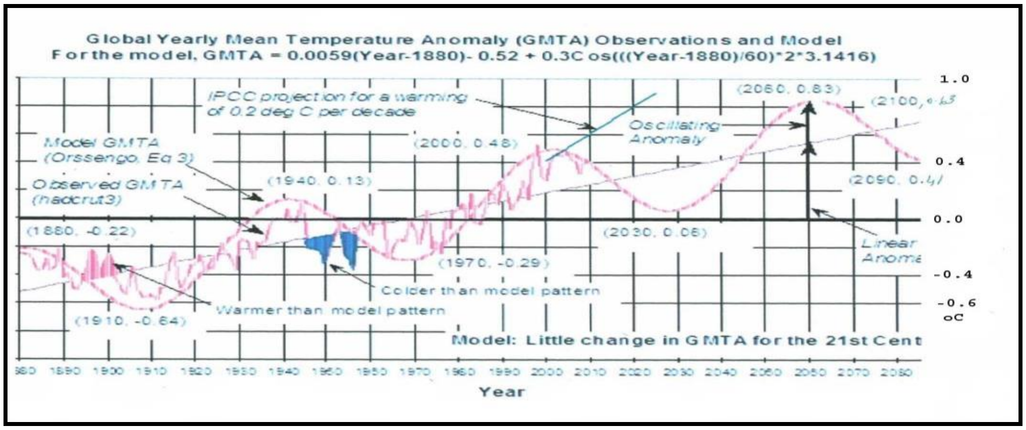


Figure No.3: Global yearly mean temperature anomaly patterns (Observed and Predicted)

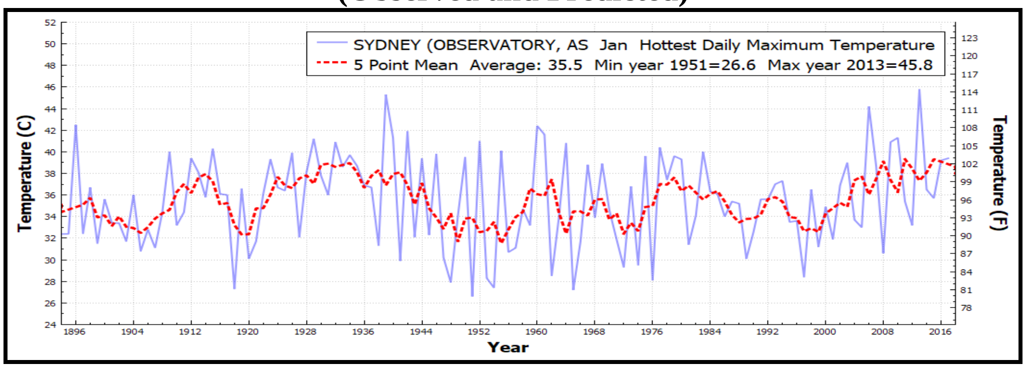


Figure No.4: Annual march of Sydney maximum temperature

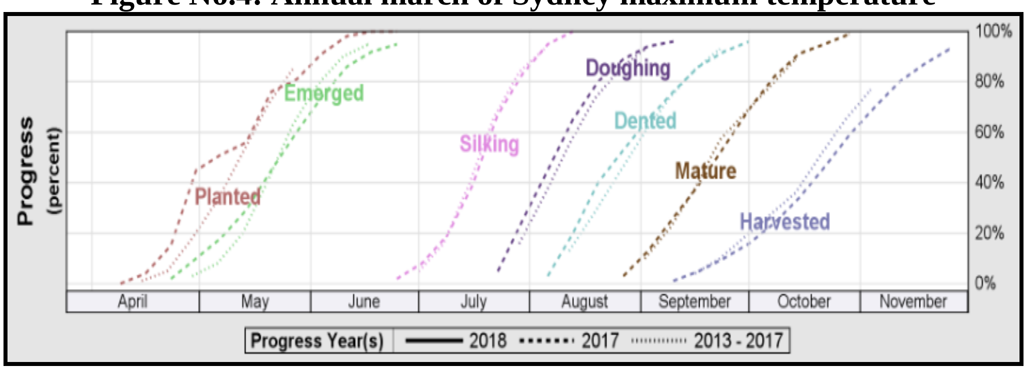
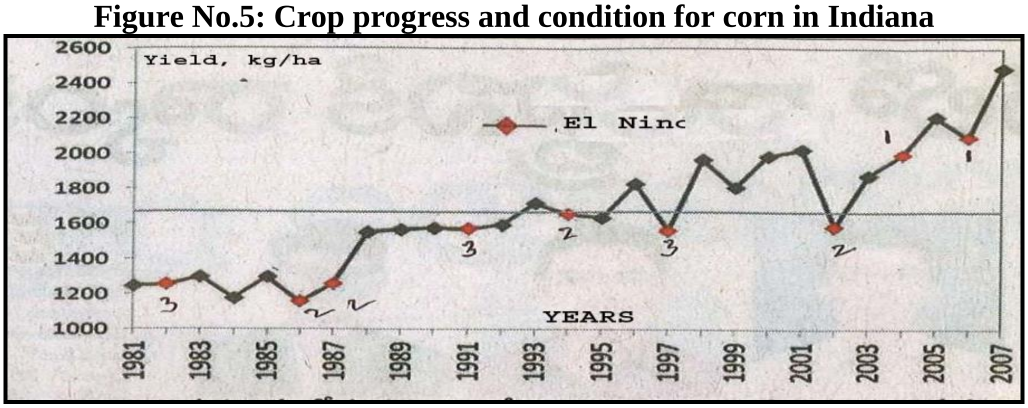
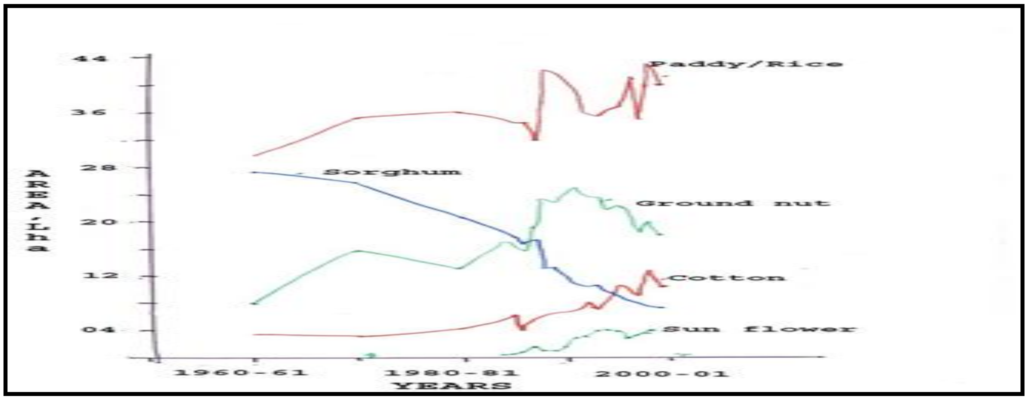


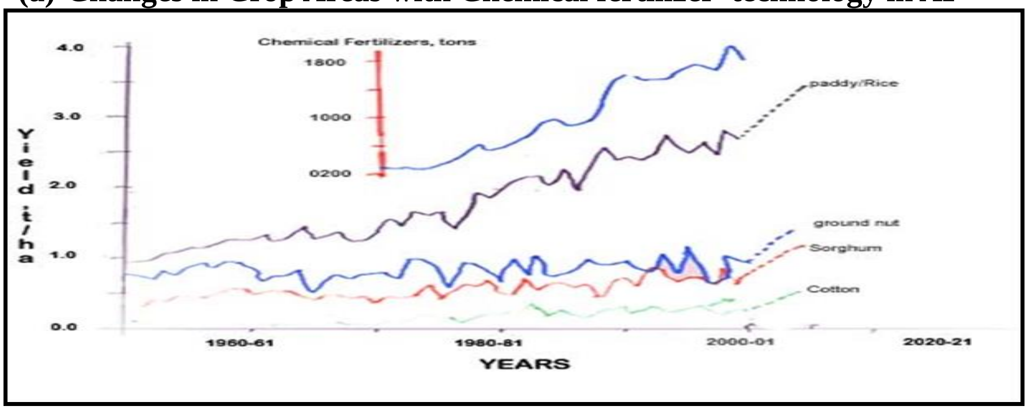
Figure No.5: Crop progress and condition for corn in Indiana



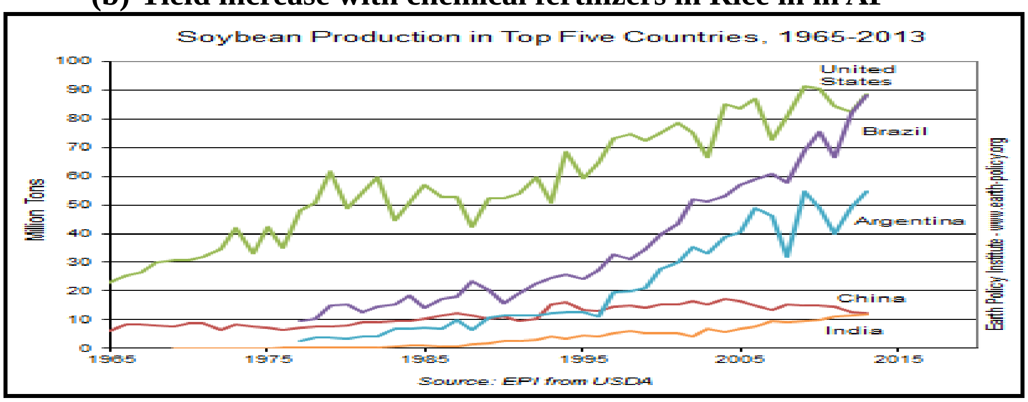
El Nino years with 1 = weak, 2 = moderate and 3 = Strong
Figure No.6: Yield per hectare in India versus El Nino events



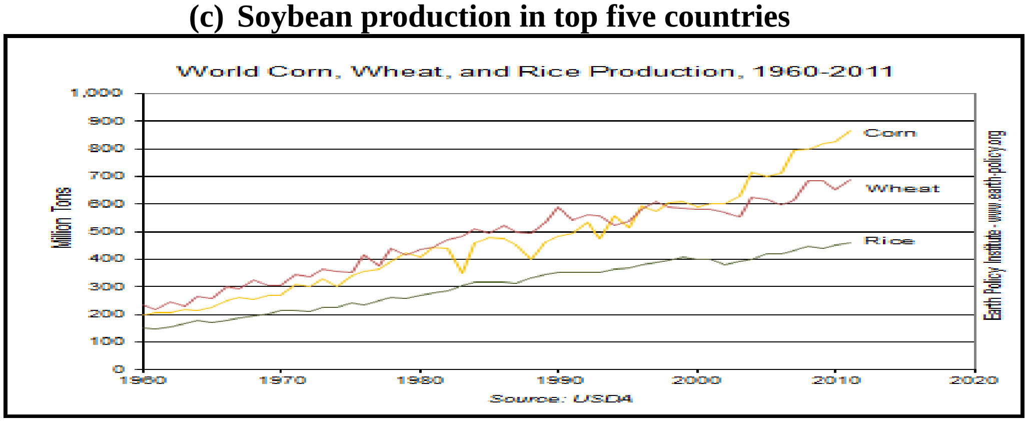
(a) Changes in Crop Areas with Chemical fertilizer technology in AP



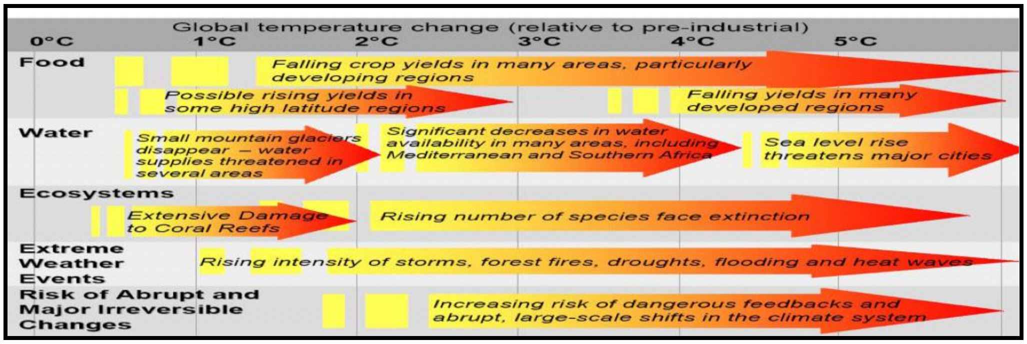
(b) Yield increase with chemical fertilizers in Rice in in AP



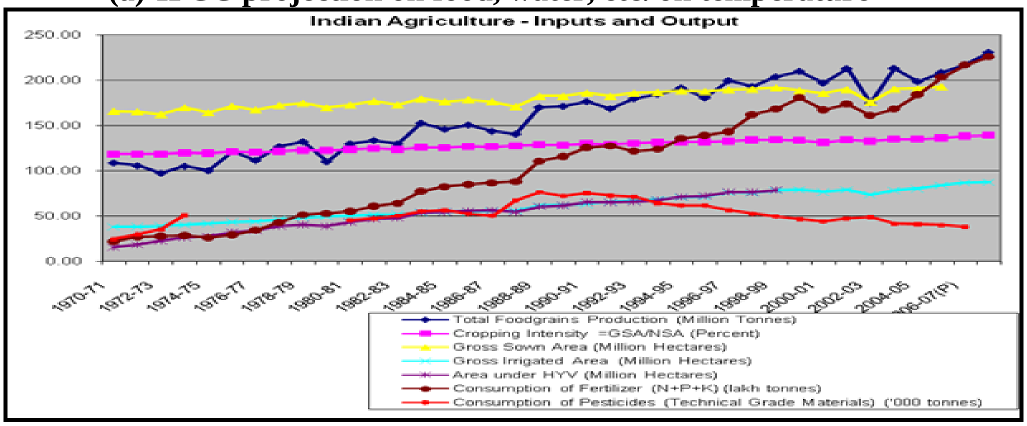
(c) Soybean production in top five countries



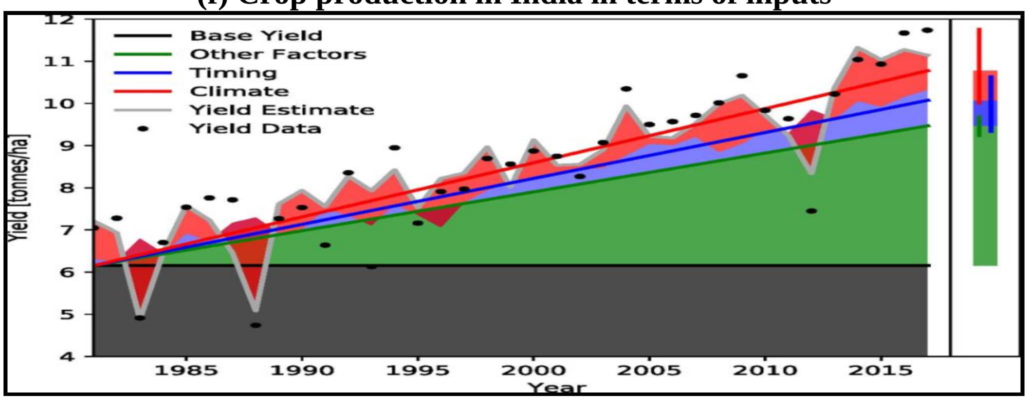
(d) World Corn, Wheat and Rice Production



(a) IPCC projection on food, water, etc. on temperature



(f) Crop production in India in terms of inputs



(g) USA Corn – Inputs and Outputs

Figure No.7: Few examples of crop production [a, b, c, d, e, f, g]

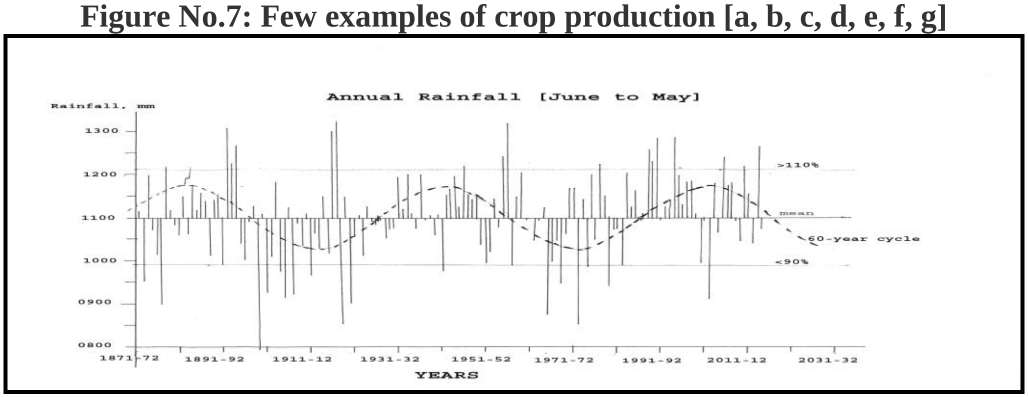


Figure No.8: Annual march of all India Annual Rainfall [Observed, vertical lines and Predicted, dotted curve]

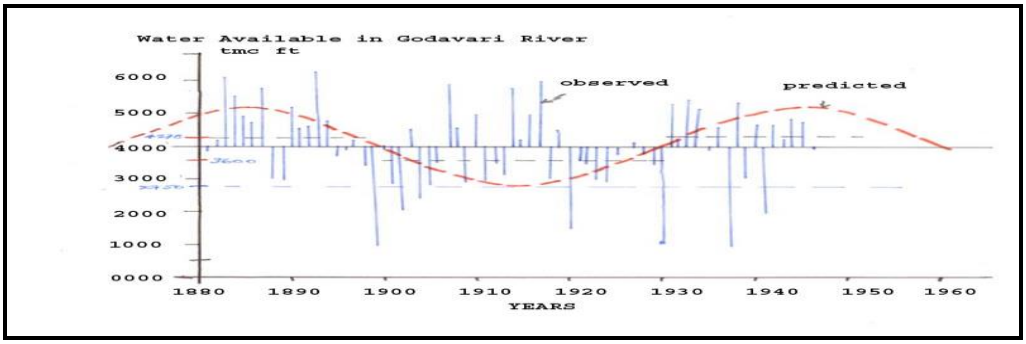


Figure No.9: Annual march of annual Water Availability in Godavari River [Observed, vertical lines and Predicted, dotted curve]

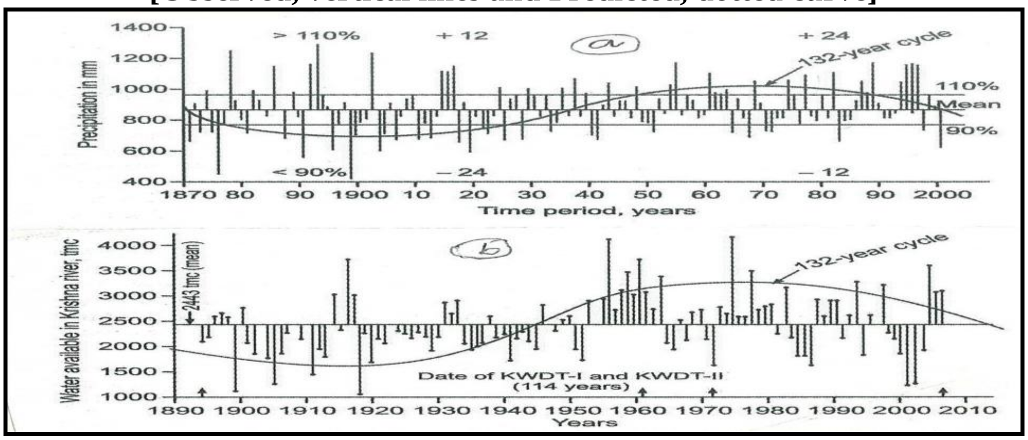


Figure No.10: (a) Annual Rainfall of AP and (b) Annual Water Availability in Krishna River

Figure No.11: 1876-78 severe drought impacts on Bangalore

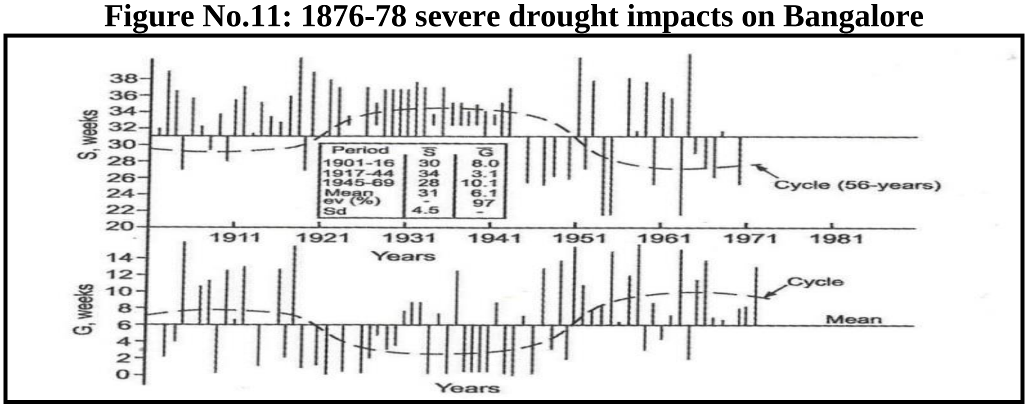
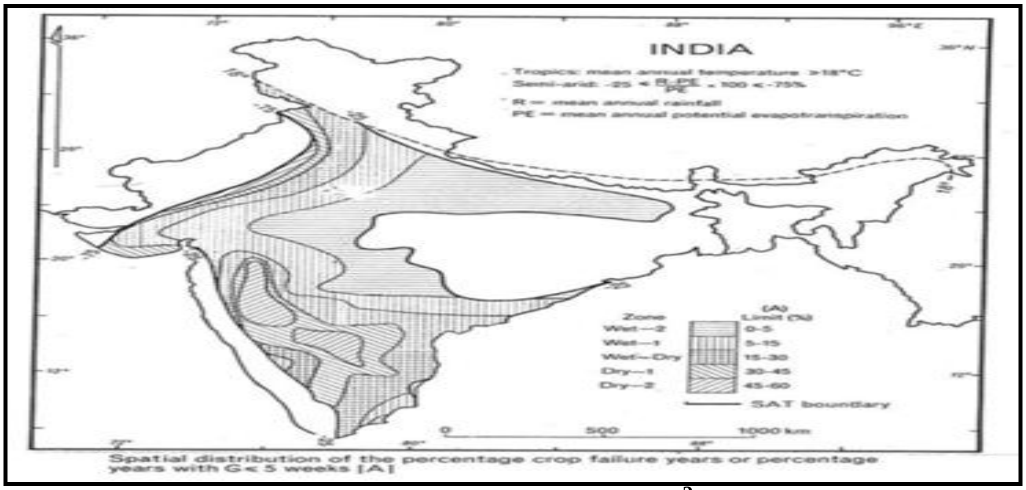
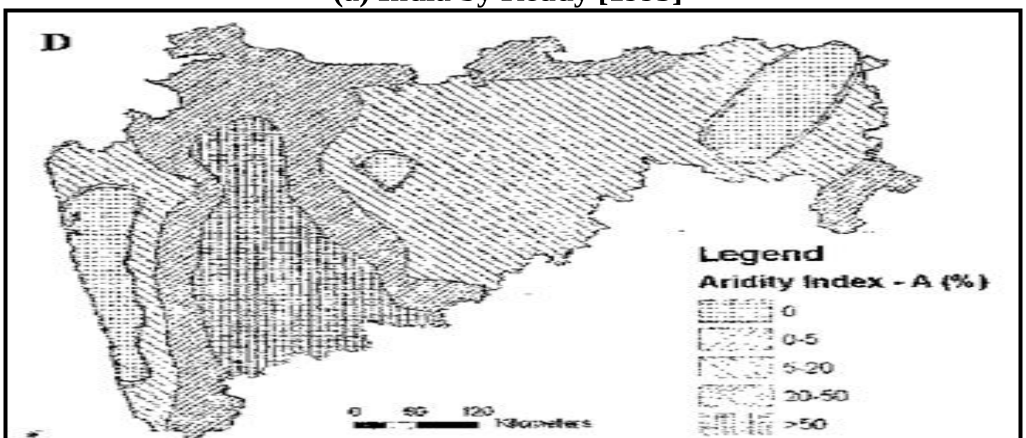


Figure No.12: Annual march of agroclimatic variables: G and S



(a) India by Reddy [1993][2]



(b) Maharashtra by Akumunchi Anand *et al*, [2009][13].

Figure No.13: Drought Risk (a) India and (b) Maharashtra

SUMMARY AND CONCLUSION

Climate Change and Agriculture

Soil and climate

Are the two natural resources that are vital for agriculture. Soil is static but climate is dynamic. Climate change was there in the past and people adapted to it; climate change will be there in future needs developing adaptive measures. However, climate change varies with space and time. Too generalization is too dangerous; scientific institutions must change from copycat mode to real science mode. In fact the word climate change is used as de-facto “global warming and carbon credits” to get a share in green fund. Many a time climate change is used as an adjective and media uses to get hype. However, man on the street to editors of technical magazines/media along with governments, research institutes, UN agencies attribute every unusual event to global warming as it cannot defend against such onslaughts.

Agriculture point

Global warming has no impact as it is insignificant when compared to annual and seasonal variations wherein agriculture is adapted to them. Climate change in terms of natural variability impacts agriculture. The natural variability or rhythmic variations in rainfall data series may differ at different scales of studies in space, such as national, state and station level. Climate change is modified at local and regional levels by “climate system and general circulation patterns”. It is common to researchers and planners use truncated data set of a natural variability series. This type of selection leads to misleading conclusions or lead to biased inferences.

Natural Variability in Rainfall at different space scales

All India level

The study of Annual and SWM rainfall showed a 60-year cycle and the frequency of occurrence of high magnitude floods in the northwest Indian rivers followed this pattern. Also, water availability in Godavari River followed this pattern only. The knowledge of such variations plays vital role in broad long-term agriculture planning to minimize weather related risks.

State of Andhra Pradesh

Annual rainfall showed 132-year cyclic pattern. Water availability in Krishna River followed this cyclic pattern. This plays major role in water availability planning. However, AP receives rainfall in SWM and NEM and from pre-monsoon with the sporadic cyclonic activity. The three met sub-divisions in AP followed 56-year cycle in SWM & NEM rainfalls but in reverse order. Cyclonic activity in the Bay of Bengal followed the SWM rainfall pattern Coastal AP. This is not the same with other states.

Kurnool

The yearly effective moisture availability periods followed the SWM rainfall's 56 year cyclic pattern, in which it showed average drought proneness as 45% of the years; and during above and below the average cyclic parts of 28 years they are respectively 30% and 70% of the years. This helps planning of farming system.

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CONFLICT OF INTEREST

We declare that we have no conflict of Interest.

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