



A Review of Impacts and Mitigation Strategies of Climate Change on Dryland Agriculture

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Authors' contributions

This article was written in collaboration among all authors. Author KMK has come up with an idea and collected all the reviews pertaining to the topic and compiled all the information. Authors CJS, MH and SM has helped in correction of the article and making it in crispy format for final publication.

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ABSTRACT

The climate change poses a great challenge to the agriculture sector compared to any other sector in the country as it is highly a weather dependent enterprise. The study results reveal that the climatic variation such as the occurrence of drought due to irregular distribution, lesser rainfall have a high level of impact on the dryland farming by adversely affecting the yield levels of the crops. The farmer's perception of the impact of climate change on the crops grown in Rainfed condition, such as yield reduction and reduction in net revenue. The farmers already act to the changes in the climatic changes both by adopting the technological coping mechanisms on the positive side and negatively through shifting to other professions especially more pronounced in dryland farming regions of the country. It is concluded that the small and medium Rainfed farmers were highly vulnerable to climate change and to a larger extent the small and medium Rainfed farmers adopted coping mechanisms for climate change compared to large farmers. The studies suggest that as the impact of climate change is intensifying day by day, it should be addressed through developing

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appropriate mitigation strategies and supported through policy perspective at the earliest to avoid short-term effects such as yield and income loss and long-term effects such as quitting agricultural profession by the dryland farmers of the country.

Keywords: Climate change; Dryland agriculture.

1. INTRODUCTION

Indian agriculture is predominantly rainfed agriculture under which both dry farming and dry land agriculture are included. Out of the 143 million ha of total cultivated area in the country, 85 million ha (68%) area are rainfed. It is contributing 44 percent of food grains and supporting 40 percent of the population. Since climatic factors serve as direct inputs to agriculture, any change in climatic factors is bound to have a significant impact on crop yields and production. The change in climate variables is challenging the Indian agriculture [1].

Dryland Agriculture is extremely vulnerable to climate change. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation [2]. Pests management become less effective, meaning that higher rates of pesticides will be necessary to achieve the same levels of control. Heat waves can cause extreme heat stress in crops, which can limit yields the overall impacts of climate change on farming are expected to be negative, threatening global food security, and it should be addressed through policy perspective at the earliest to avoid short-term effects such as yield and income loss and long-term effects such as quitting agricultural profession.

2. CLIMATE CHANGE IMPACTS ON AGRICULTURE

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Climate change affects farming in a number of ways, including through changes in average temperatures, rainfall, and climate extremes (e.g. heat waves), changes in pests and diseases, changes in atmospheric carbon dioxide and ground-level ozone concentrations, changes in the nutritional quality of some foods and changes in sea level.

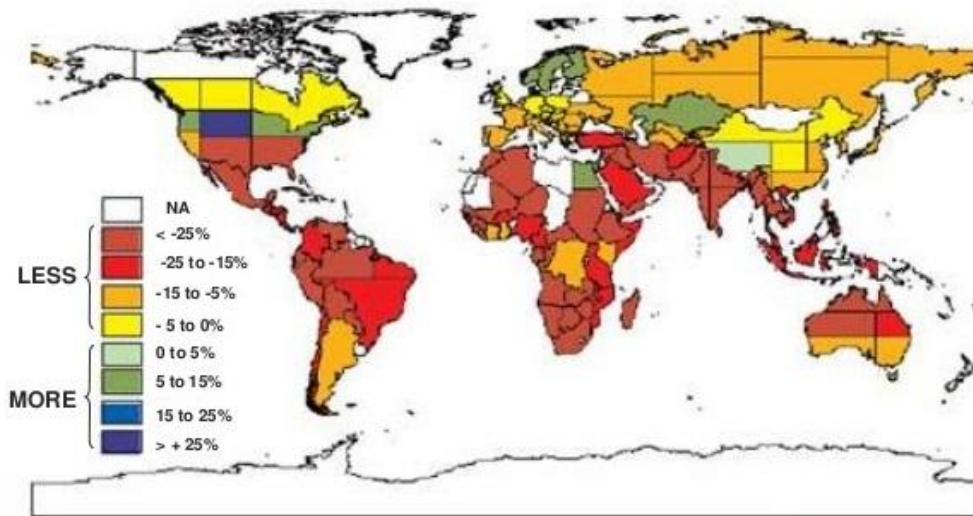
Climate change is already affecting dryland agriculture, with effects unevenly distributed across the world. Future climate change will

likely negatively affect crop production in low latitude countries, while effects in northern latitudes may be positive or negative. Climate change will probably increase the risk of food insecurity for some vulnerable groups, such as the poor. For example, South America may lose 1–21% of its arable land area, Africa 1–18%, Europe 11–17%, and India 20–40%.

The agricultural productivity has seen a rapid growth since the late 1950s due to new crop varieties, fertiliser use and expansion in irrigated agriculture. The world food production outstripped the population growth. However, there are regions of food insecurity. Of the 6.5 billion population today, about 850 million people face food insecurity. About 60% of them live in Asia and Africa. According to a Comprehensive Assessment, it is possible to produce food – but it is probable that today's food production and environmental trends if continued, will lead to crises in many parts of the world [3].

The accelerating pace of climate change, combined with global population and income growth, threatens food security everywhere. Agriculture is extremely vulnerable to climate change. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Pest management becomes less effective, meaning that higher rates of pesticides will be necessary to achieve the same levels of control. Heat waves can cause extreme heat stress in crops, which can limit yields if they occur during certain times of the plants' life-cycle (pollination, pod or fruit set). Also, heat waves can result in wilted plants (due to elevated transpiration rates) which can cause yield loss if not counteracted by irrigation. Heavy rains that often result in flooding can also be detrimental to crops and to soil structure. Most plants cannot survive in prolonged waterlogged conditions because the roots need to breathe. The overall impacts of climate change on farming are expected to be negative, threatening global food security.

Modelled % change in agricultural production due to climate change, 2080



Source: Cline WR, 2007: Global warming and agriculture: Impact estimates by country. Washington, D.C.: Center for Global Development, Peterson Institute for International Economics (cited in von Braun J (IFPRI), 2007

Fig. 1. Climate change will impair farm production in many poor countries and regions

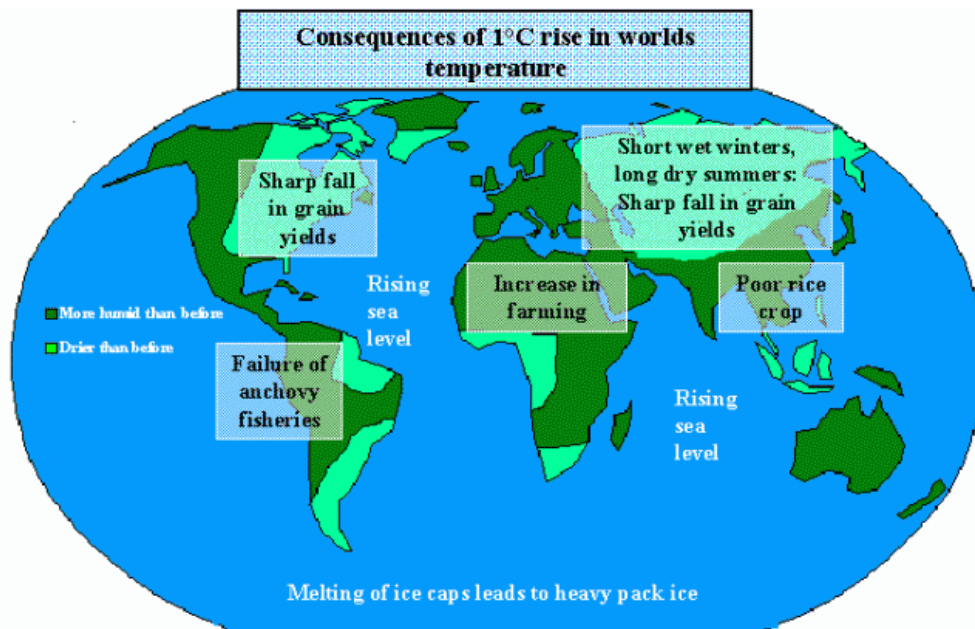


Fig. 2. Consequences of 1°C rise in world's temperature

A number of countries in Africa already face semi-arid conditions that make agriculture challenging, and climate change will be likely to reduce the length of growing season as well as force large regions of marginal agriculture out of

production. Projected reductions in yield in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers being the most affected.

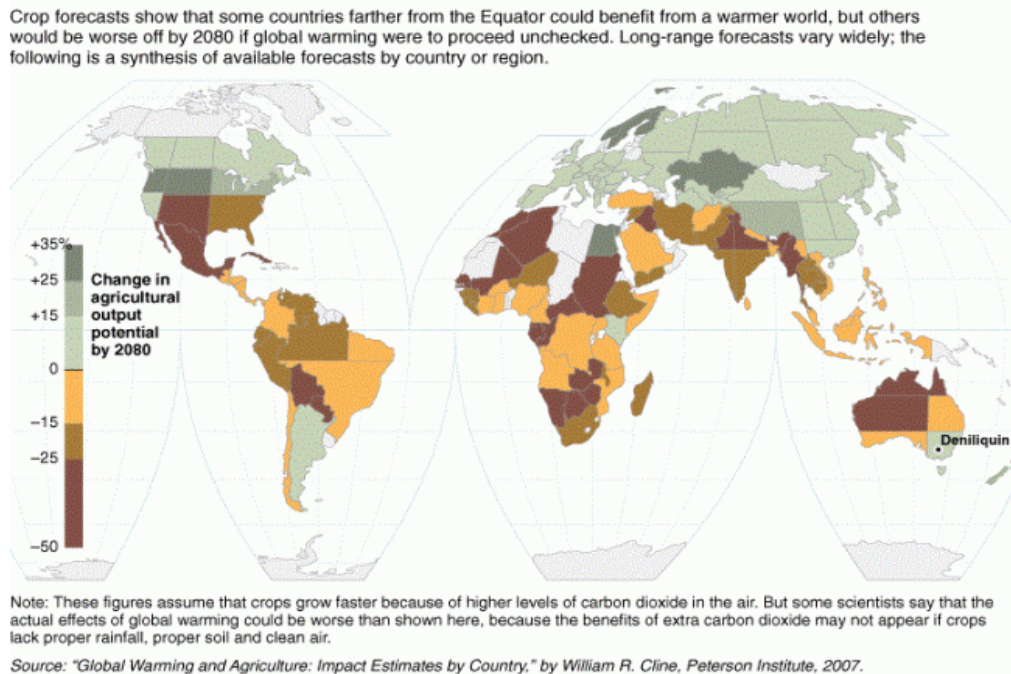


Fig. 3. Farming in a warmer world

Changes in climate may also impact the water availability and water needs for farming. If temperature increases and more sporadic rainfall events result from global warming, it is possible that irrigation needs could increase in the future. In anticipation of these changes, plant breeders are currently working to develop new varieties of crops that are considered to be drought tolerant, and more adaptable to varying levels of temperature and moisture.

3. CLIMATE CHANGE PROJECTIONS FOR INDIA

The possible range of variations in the future projections for the periods of the 2020s

(2005-2035), 2050s (2035-2065) and 2080s (2065-2095) with respect to the baseline period (1975-2005) as shown in Table.1. The analyses concentrated on maximum temperature, minimum temperature and rainfall over the region. For the whole India, the projections of maximum temperature from all the six models showed an increase within the range 2.5°C to 4.4°C by end of the century with respect to the present day climate simulations. The annual rainfall projections from all the six models indicated a general increase in rainfall is within the range 15-24% [4].

Table 1. Climate Change Projections for India

Year/ Scenarios	Season	Temperature change (°C)		Rainfall change (%)	
		Lowest	Highest	Lowest	Highest
2020s	Annual	1.0	1.41	2.16	5.97
	Rabi	1.08	1.54	1.95	4.36
	Kharif	0.87	1.17	-1.81	5.10
2050s	Annual	2.23	2.87	5.36	9.34
	Rabi	2.54	3.18	-9.92	3.82
	Kharif	1.81	2.37	7.18	10.52
2080s	Annual	3.53	5.55	7.48	9.90
	Rabi	4.14	6.31	-24.83	-4.50
	Kharif	2.91	4.62	10.10	15.18

4. GLOBAL SCENARIO OF DRY FARMING

Dryland farming cover about 41.3% of the earth's surface. Mostly in 72% in developing countries. In India - 228 m ha of the area falls under dryland, *i.e.*, arid, semi-arid and dry sub-humid (Keane et al. 2009). Rainfed agriculture is practised on 80% of the world's agricultural area and generates 60–70% of the world's staple food (Anon, 2005). In semi-arid and dry sub-humid zones, rainfed agriculture dominates food production systems, and water is a key limiting factor to crop growth. Agriculture plays a key role in economic development (World Bank, 2005), poverty reduction and economic growth [5]. Every 1% increase in agricultural yield translates to a 0.6–1.2% decrease in the percentage of absolute poor [6].

From time immemorial, the chief form of agriculture in the dryland tracts of India was the cultivation of drought-resistant crops *viz.*, millets for food and fodder. It used to be a gamble with rainfall. During good rainfall years, the hardships of farmers seem to have been mitigated, as surplus grain and fodder were available. But, as water is the most important single factor of crop production, the inadequacy (200-800 mm/year) and extremely uncertainty (cv: 60-70%) of rainfall often caused partial or complete failure of crops leading to periodic food scarcities and famines. The drought was a frequent phenomenon. These factors made the economic life of the dryland cultivator extremely difficult and insecure. Although efforts were made to create irrigation facilities, most of the scarcity tracts of southern and some in north India had to depend on rainfall for crop production [7]. In the mid-sixties, the Green Revolution acted as a boon. However, this brought an alarming disparity between the productivity of irrigated and rainfed agriculture. The rainfed ecosystems are embedded with complex problems relating to soil, water, climate, bio-diversity, investment and market.

An insight into the inventories of natural resources in rainfed regions shows a grim picture of water scarcity, fragile environments, drought and land degradation due to soil erosion by wind and water, low rainwater use efficiency (35–45%), high population pressure, poverty, low investments in water use efficiency (WUE) measures, poor infrastructure and inappropriate policies [8]. Drought and land degradation are interlinked in a cause and effect relationship, and

the two combined are the main causes of poverty in farm households.

Rainfed soils are generally of poor quality (low fertility, high erodibility, fragile, shallow and susceptible to loss of physical integrity). These have very weak buffering and resilience capacity. The soils suffer from an excess of salts (saline-alkali soils) in arid and semi-arid areas and acids (acid soils) in sub-humid and humid regions. Micronutrients and ameliorants (mainly lime) are deficient and need supplementation periodically. The soils are mostly coarse-textured, highly degraded with low water retentive capacity, multiple nutrient deficiencies, and thus are not conducive for intensive cropping.

Water scarcity is a significant problem for farmers in the dryland ecosystem. Water, a finite resource, the very basis of life and the single most important feature of our planet, is the most threatened natural resource at the present time. In many SAT situations, water quantity per se is not the limiting factor for increased productivity but its management and efficient use are the main yield determinants. Instead, the major water-related challenge for rainfed agriculture in semi-arid and dry sub-humid regions is to deal with the extreme variability in rainfall, characterised by few rainfall events, high-intensity storms, and high frequency of dry spells and droughts.

Increasing intra-seasonal variability of rainfall, however, has become a major concern now. In several meteorological divisions, the rainfall distribution is becoming more skewed with less number of rainy days, with high intensity causing more soil erosion. The coefficient of variation of decadal rainfall distribution is increasing in several meteorological divisions indicating inter-annual variability. This has implications on the length of dry spells in rainfed regions.

5. DRY FARMING REGIONS OF INDIA

From the table it is evident that even though the areas are receiving a higher amount of rainfall, the distribution of the rainfall is not uniform throughout the crop growing season, so it makes to fall majority of the areas under rainfed agriculture situation and also the poor economic situations of the farmers, fragmented land holdings, financial inability of the farmers forced to adopt the traditional rainfed farming.

Regions	States	% Rainfed area
Cold arid Northern States	Jammu & Kashmir, Uttaranchal and Himachal Pradesh,	60-81
Arid Western States	Rajasthan, Gujarat	66-68
Semi-arid to arid Central & Southern States	Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu	76-82
Sub-humid to humid Eastern States	Eastern Uttar Pradesh, Bihar, Jharkhand, Orissa, West Bengal	33-73
Humid to Per humid North Eastern States	Assam & North Eastern Hill States	Up to 90%

Table 2. Dry farming districts of Tamil Nadu

Region	Taluk / District	Mean annual Rainfall (mm)
Northwest	Dhammpmi Dt., Taluks of Omalur,	844
	Attur, Rasipuram Sankagiri in Salem Dt.	842
	Parts of Tirupattur and Vellore Taluks	900
Western	Palladam, Kangeyam Dharapuram Udumalpet Coimbatore taluks.	711
East central	Parts of Tiruchi, Pudukkottai, Madurai and Dindugul Dts.	876
Southern	Tirunelveli Dt.	940
	Thoothukudi Dt.	677
	Virudunagar Dt.	817
	Ramanathapuram Dt.	819
	Sivagangai Dt.	910

5.1 Dry Farming Districts of Tamil Nadu

Based on the mean annual rainfall received across the different agro-climatic zones of Tamil Nadu, the following areas are designated as dry farming regions mainly because majority of the regions of the Tamil Nadu receives rainfall due to northeast monsoon, so even though the bimodal pattern of rainfall received at some regions may contribute to the total mean annual rainfall, it is not useful for the agriculture in those regions as the quantum of rainfall is inadequate to meet the crop water requirement as shown in Table 2.

6. POTENTIAL CLIMATE CHANGE IMPACT ON CROPS

The productivity of most cereals would decrease due to increase in temperature, CO₂ and decrease in water availability. A projected loss of 10-40% in crop production by 2100. 1°C increase in temperature may reduce yields of major food crops by 3-7%. Much greater losses at higher temperatures with longer duration. Greater loss expected in *rabi*. Length of growing period in rainfed areas is likely to reduce, especially in peninsular regions. Increased climatic extremes - likely to increase production variability. Increase in CO₂ to 550 ppm increases

yields of rice, wheat, legumes and oilseeds by 10-20%.

6.1 Impacts Observed through Modelling/Experimentation

Kharif crops to be impacted more by rainfall variability while *rabi* crops by minimum temperature. Wheat is likely to be negatively impacted in *rabi* due to terminal heat stress. Rice to be impacted both by temperature and water availability. Legume crops like soybean and groundnut are likely to be benefited due to increased temperature/CO₂ if water availability is not limited. More opportunities for rainwater harvesting due to high-intensity rainfall but greater loss of topsoil due to erosion.

Table 3. Effect of drought on rainfed crop yield [9]

Crop	% loss of normal yield
Sorghum	43.03
Maize	14.09
Groundnut	34.09
Wheat	48.68
Onion	29.56
Cotton	59.96

[10] – showed that for every one-degree rise in temperature the decline in rice yield would be about 6%. Major impacts of climate change will likely be on rainfed crops (other than rice), which account for nearly 60 percent of cropland area. In India, poorest farmers often practice rainfed agriculture. For the temperature rise of 2°C in

mean temperature and a 7 per cent increase in the mean precipitation would create a 12 per cent reduction in net revenues for the country as a whole [11]. [12] on the basis of recent climate change scenarios estimated impacts on wheat and other cereal crops as shown in Table 3.

Table 4. Impact of climate change on average potential grain yield of sorghum, maize, groundnut and pigeon pea [13]

Crop	Potential** grain yield kg ha ⁻¹	CO ₂ effect on yield	Rainfall effect on yield	Temperature effect on yield	CC* effect on yield
Sorghum	2753	n/a	-6%	-16%	-22%
Maize	2125	n/a	-8%	-16%	-25%
Groundnut	1979	+8%	-7%	-31%	-30%
Pigeonpea	1230	+6%	-7%	-3%	-8%

Climate change – combined effects of increased temperature and reduced rainfall, and increased CO₂ in the case of groundnut and pigeon pea, and of increased temperature and rainfall in the case of sorghum and maize as shown in Table 4 and 5.

** Potential yield of the current rainfall, CO₂, temperature and radiation environment averaged over 50 seasons, with no nutrient, pest or disease constraints.

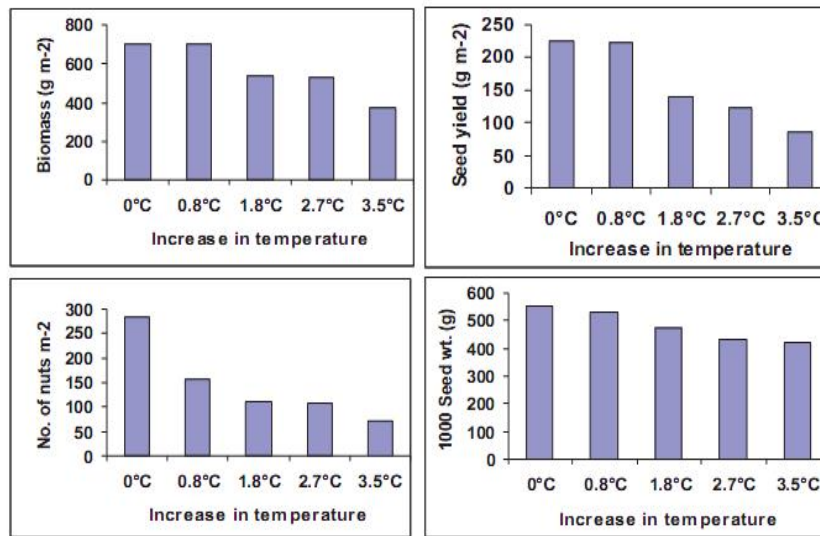


Fig. 4. Effect of elevated temperature on yield attributes of Groundnut crop

Table 5. Yield reduction by drought in different growth stages in field crops

Crop	Growth stage	Yield reduction	References
Barley	Seed filling	49–57%	Samarah (2005)
Rice	Reproductive (severe stress)	48–94%	Lafitte <i>et al.</i> (2007)
Rice	Grain filling (severe stress)	60%	Basnayake <i>et al.</i> (2006)
Maize	Vegetative	25–60%	Atteya <i>et al.</i> (2003)
Maize	Reproductive	63–87%	Kamara <i>et al.</i> (2003)
Maize	Grain filling	79–81%	Monneveux <i>et al.</i> (2005)
Cowpea	Reproductive	60–11%	Ogbonnaya <i>et al.</i> (2003)
Sunflower	Reproductive	60%	Mazahery-Laghab <i>et al.</i> (2003)
Pigeonpea	Reproductive	40–55%	Nam <i>et al.</i> (2001)
Chickpea	Reproductive	45–69%	Nayyar <i>et al.</i> (2006)

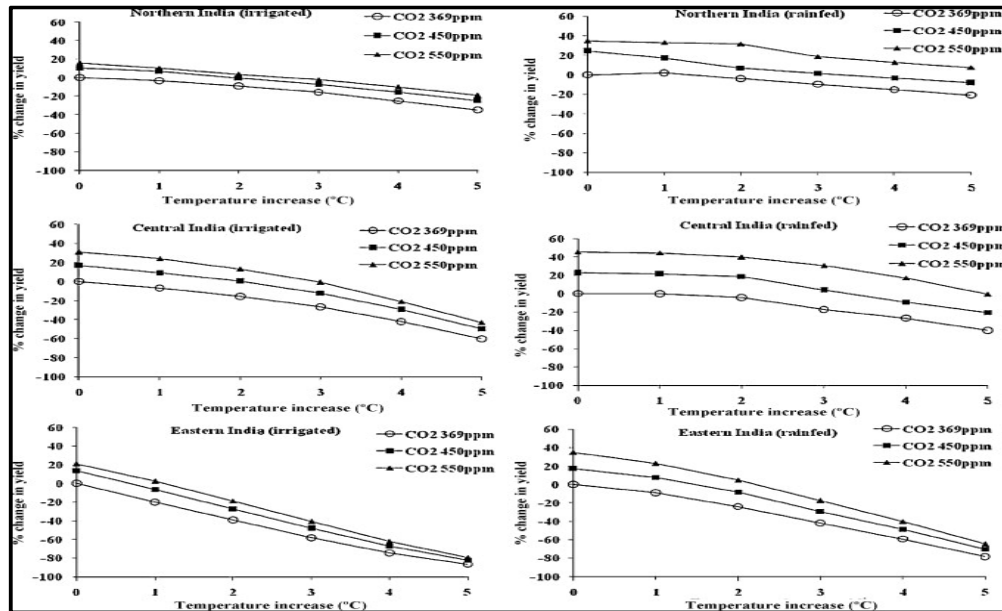


Fig. 5. Impact of climate change on Mustard yield [14]

7. CLIMATE CHANGE ADAPTATION AND MITIGATION STRATEGIES IN DRYLAND AGRICULTURE

Adaptation options:

- ❖ Altered agronomy of crops
 - ✓ Altering dates of planting and spacing
 - ✓ Alternate crops or cultivars
 - ✓ Change in cropping system
- ❖ Conservation agriculture
 - ✓ Zero tillage/direct seeding
 - ✓ Reduction in summer fallow
 - ✓ Conservation of soil moisture
 - ✓ Crop diversification
 - ✓ Forage in rotations
- ❖ Integrated farming system
- ❖ Integrated nutrient management
- ❖ Improved land use and NRM policies
- ❖ Risk management- early warning systems and crop insurances

Mitigation options:

- Afforestation
- Watershed management
- Organic agriculture
- Changing land use- Horticulture, Agroforestry, Silviculture
- Integrated farming system
- Use of nitrification inhibitors and fertilizers placement practices
- Improved management of livestock population

- Feed and fodder bank
- Solar power

8. FUTURE RAINFED/DRY LAND FARMING

Current rainfed/ dry land agriculture cannot sustain the economic growth and food security needed. There is an urgent need to develop a new paradigm for soil and water management. We need to have a holistic approach based on converging all the necessary aspects of natural resource conservation, their efficient use, production functions and income-enhancement avenues through value-chain and enabling policies and much-needed investments in rainfed areas. The future rainfed ecosystem can be sustained through the strategies mentioned below:

8.1 Integration of Crop Improvement and Natural Resource Management

Traditionally, crop improvement and NRM were seen as distinct but complementary disciplines. Improved varieties and improved resource management are two sides of the same coin. Most farming problems require integrated solutions, with genetic, management related and socio-economic components. In essence, plant breeders and NRM scientists must integrate their work with that of private- and public-sector change agents to develop flexible cropping

systems, which can respond to rapid changes in market opportunities and climatic conditions.

8.2 Soil Health Enhancement

Soil health is severely affected due to land degradation and is in need of urgent attention. Micro-nutrient deficiencies are widespread because of imbalanced nutrient management in most part of the country. In addition, soil organic matter, an important driving force for supporting biological activity in soil, is very much in short supply, particularly in India. Management practices that augment soil organic matter and maintain it at a threshold level are needed. Farm bunds could be productively used for growing nitrogen-fixing shrubs and trees to generate nitrogen-rich loppings. For example, growing *Glyricidia* at a close spacing of 75 cm on farm bunds could provide 28–30 kg nitrogen per ha annually in addition to valuable organic matter. Also, large quantities of farm residues and other organic wastes could be converted into a valuable source of plant nutrients and organic matter [15].

8.3 Water Resource Management

Yield gaps in rainfed areas are large, not due to lack of water per se, but rather due to inefficient management of water, soils, and crops. Knowledge on the importance of water and its management exists regarding technologies, management systems, and planning methods. A key strategy is to minimise risk for dry spell induced crop failures, which requires an emphasis on water harvesting systems for supplemental irrigation. Large-scale adoption of water harvesting systems will require a paradigm shift in Integrated Water Resource Management (IWRM), in which rainfall is regarded as the entry point for the governance of freshwater, thus incorporating green water resources (sustaining rainfed agriculture and terrestrial ecosystems) and blue water resources (local runoff). The divide between rainfed and irrigated agriculture needs to be reconsidered in favour of governance, investment, and management paradigm, which considers all water options in agricultural systems. A new focus is needed on the meso-catchment scale, as opposed to the current focus of IWRM on the basin level and the primary focus of agricultural improvements on the farmer's field. The catchment scale offers the best opportunities for water investments to build resilience in small-scale agricultural systems and

to address trade-offs between water for food and other ecosystem functions and services [8].

8.4 Contingency Resilience for Climate Change

Rainfed agriculture is a risky business due to high spatial and temporal variability of rainfall. Rainfall is concentrated in short rainy seasons, with reduced rainy days, which are unreliable in temporal distribution, manifested by high deviations from the mean rainfall under rainfed ecosystem. Temporal and spatial variability of climate, especially rainfall, is a major constraint to yield improvements, competitiveness and commercialization of rainfed crop, tree crops and livestock systems in most of the tropics. Management options should, therefore, start by focusing on reducing rainfall-induced risks.

8.5 Conservation Agriculture

Conservation agriculture, often defined as conservation tillage or conservation farming, includes tillage systems with no inversion of soil, i.e. without conventional ploughing, and ranges from no-tillage to minimum tillage and tillage systems aimed at opening the soil for rainfall capture without inversion. These systems include crop rotations and a mulch cover, which according to the convention should allow at least an average 30% cover of the soil throughout the year. It is an alternate system, can arrest resource degradation and can enhance productivity under rainfed ecosystem. It helps for capturing maximum rainwater into the soil profile through SWC measures where residues have multiple uses, sustainable intensification of rainfed production systems through conserving soil water, sowing of *rabi* crops in the standing residues of the *Kharif* crops through machines.

8.6 Crop Diversification and Alternate Land Use

In a rainfed ecosystem, crop diversification through technologically feasible and economically viable enterprise seems to be the only option to achieve poverty alleviation through food security by overcoming the problems of land degradation and climatic aberrations. Location-specific alternate land use systems viz., agri-horti, silvi-pasture, agri-silvi, horti-pasture systems have greater advantage in minimizing climatic risks. Diversification of agriculture has shown several important benefits besides ecological advantages [16].

8.7 Farm Mechanisation

Limited farm mechanisation for smallholder farms is necessary to reduce the gap between draft power available and the need for maintaining timeliness in farm operations. Effective farm mechanisation helps in meeting out the labour scarcity especially in the dryland farming situations and hence the overall cost of production can be decreased, and the net outcome from the farms can be effectively enhanced.

8.8 Integrated Farming Systems

It is a resource management strategy, ensures livelihood security apart from food, nutrition, income and employment security. For the sustainability of dryland agriculture, a holistic approach based on biophysical resources of farmers would help in the efficient use of natural resources by small and marginal farmers. The system should encompass food, fuel, fibre, fodder, fruit and livestock *etc.* components to achieve sustainability. Combination of Crop + Dryland Horticulture / sericulture + Sheep / goat for dryland areas Crop + dairy + mushroom in irrigated, Crop + fishery + Dairy for coastal areas are the ideal integrations.

8.9 Development of Market-oriented Smallholder Production System

It should be market-led, demand-driven and follows the commodity chain approach to address limiting constraints along the value chain. Also, the formation of farmer producer organisations at the village level helps in effective production and marketing of their produces by adding values to their produces which fetches better prices in the markets and hence overall living standards of those farmers can be enhanced.

9. FUTURE STRATEGIES FOR DIFFERENT RAINFALL EVENTS

Depending upon the rainfall availability, crop production technologies are to be mounted as suggested hereunder.

9.1 For areas Receiving <500 mm Rainfall

- ✓ Linking arable cropping with animal husbandry.

- ✓ Adoption of arable cropping (limited to millet and pulses), arid-horticulture agroforestry, horti-pasture and silvi-pasture systems.
- ✓ Growing drought-tolerant perennial tree species for fodder, fruit and fuel.
- ✓ Adopting efficient methods of irrigation for higher productivity.
- ✓ Efficient management of rangelands and common grazing lands, with improved grasses, reseeding techniques and creating fodder banks.
- ✓ Small farm mechanization.

9.2 For Areas Receiving 500-750 mm Rainfall

- Energy-rich crops like oilseeds and pulses in intercropping systems.
- Emphasis on high-value crops (fruits, medicinal, aromatic, dyes, pesticide yielding) and high tech-agriculture (drip irrigation, processing, extraction, value addition).
- Stressing *in-situ* moisture conservation, rainwater harvesting and effective recycling and off-season tillage in a watershed approach.
- Mounting efficient alternate land use systems with agriculture-forest-pasture-livestock, based on land capability criteria.
- Afforestation in highly degraded / wastelands.
- Adoption of seed village concept for self-sufficiency in seeds of improved varieties.
- Small farm mechanization.

9.3 For Areas Receiving 750-1050 mm Rainfall

- Developing aquaculture in high rainfall, double-cropped regions with the rationalization of area under rice.
- Use of improved crop varieties of maize, soybean, groundnut, sorghum, pigeon pea, cotton and other crops in intercropping and double cropping wherever possible to increase cropping intensity.
- Rainwater harvesting/conservation including groundwater recharge.
- Improving sustainability of rice-wheat cropping system in the Gangetic plains.
- Rehabilitation of degraded lands through perennial vegetation.

10. CONCLUSIONS

Impact of climate change on dry land be one major deciding factors influencing the future food security of mankind on the earth. Understanding the weather changes over a period of time and adjusting the management practices towards achieving better harvest is a challenge to the growth of agricultural sectors. So timely adaptation strategies can help to minimize negative impacts to some extent whereas mitigation options can help in the long run, but the solutions need to be standardized in the coming years to cope up with the ever-changing scenarios, these need research and policy support to have a wider adoption and to have a positive impact on the farming community.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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