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K Shekar
Ph.D. Scholar, PJTSAU, Hyderabad, Telangana, India

Dr. P Laxminarayana
Professor, PJTSAU, Hyderabad, Telangana, India

P Prashanth
Assistant Professor, PJTSAU, Hyderabad, Telangana, India

Vijay Didal
Ph.D. Scholar, PJTSAU, Hyderabad, Telangana, India

Correspondence
K Shekar
Ph.D. Scholar, PJTSAU, Hyderabad, Telangana, India

Climate resilient agronomic innovations for rainfed farming in sub tropics

K Shekar, Dr. P Laxminarayana, P Prashanth and Vijay Didal

Abstract

One of the most important challenges faced by agriculture today is to conserve/sustain natural resources, including soil and water, for increasing food production while protecting the environment. Change in the composition of the atmosphere that began with the industrial revolution, are the result of human activities (IPCC 2007). Present day atmospheric CO2 level hovers around 400 ppm which is a significant increase over the pre-industrial level of 280 ppm. It is anticipated that the concentration level will double by the end of this century (IPCC, 2007). A consequence of increased greenhouse gas (GHG) emissions is the entrapment of heat within the earth's atmosphere leading to an alarming rate of global warming. Significant negative impacts have been projected with medium-term (2010-2039) climate change, eg. Yield reduction by 4.5 to 9%, depending on the magnitude and distribution of warming. Since agriculture makes up roughly 15% of India's GDP, a 4.5 to 9.0% negative impact on production implies cost of climate change to be roughly at 1.5% of GDP per year. Agriculture and climate experts have warned for some years now that rising temperatures and frequency of extreme climate events including heat waves experienced in many parts of the world will lead to drop in yields of major staple foods like maize and wheat.

Most cereals like rice or maize cannot tolerate temperatures over 30 to a maximum of 35 degrees Celsius at grain filling state while, pearl millet will fill its grain in temperatures of up to 42 degrees Celsius (Mashingaidze *et al*, 2017). Climate resilience agriculture implies incorporation of the adaptation, mitigation and other practices in agriculture which increases the capacity of the system to respond to various climate related disturbances by resisting damage and recovering quickly (Ravindra chary *et al*, 2016). Broadly there are two approaches under agro techniques for adaptation and mitigation to climate change.

Keywords: Climate resilience, agronomic, rainfed, cropping system

Introduction

Climate change given as "Change in the composition of the atmosphere as a result of human activities" - (IPCC, 2007). Climate change and variability are posing the serious challenges influencing the performance of Indian agriculture. The fourth IPCC report clearly brought out the global and regional impacts of projected climate change on agriculture. India being a large country with diverse agro-climatic regions is more vulnerable in view of huge population dependant on agriculture and poor coping mechanism. There are evidences already of negative impacts on yield of wheat, rice and other crops in parts of India due to increased temperature, increased water stress and reduction in number of rainy days which in turn would result in greater instability in food production. Researchers and policy framers should develop a comprehensive adaptation and mitigation strategies for coping the adverse impact of climate change. Changes in land use management, development of multiple stress tolerant varieties, efficient cropping systems that match with changed rainfall patterns, resource conservation technologies, water harvesting and supplemental irrigation for drought proofing in rainfed areas can help in mitigating the adverse impact of climate change and variability. At the same time, agriculture has been shown to produce significant effects on climate change, primarily through the emission of GHGs as about 12.5% of total emission is from agricultural products globally. Land use change such as deforestation and desertification, together with the use of fossil fuels are the major anthropogenic sources of carbon dioxide.

Climate Change and Indian Agriculture

In India, agriculture sector contributes 28% of the total GHGs emissions (Table 1) which are primarily due to enteric fermentation in ruminant animals (59%), methane emission from rice paddies (23%) and nitrous oxides from application of manures and fertilizers to agricultural soils. The emissions from Indian agriculture are likely to increase significantly in future due to our need to increase food production.

The latter would require greater emphasis on fertilizers and other inputs which will lead to increased emissions of nitrous oxides and other GHGs. Increase temperatures would lead to higher emissions even at the current level of fertilizers consumption.

Table 1: Contribution of major sectors to emission of GHGs in India

S. No	Major sectors	Relative emission
1.	Energy	61
2.	Agriculture	28
3.	Industrial processes	8
4.	Wastes and land use change and others	3

Source: NATCOM, 2004

Table 2: Projected changes in climate in India (2070-2099)

Region January-March		April-June	July-September	October-December
Change in temperature (°C)				
Northeast	4.95	4.11	2.88	4.05
Northwest	4.53	4.25	2.96	4.16
Southeast	4.16	3.21	2.53	3.29
Southwest	3.74	3.07	2.52	3.04
Change in precipitation (%)				
Northeast	-9.3	20.3	21.0	7.5
Northwest	7.2	7.1	27.2	57.0
Southeast	-32.9	29.7	10.9	0.7
Southwest	22.3	32.3	8.8	8.5

Source: Kavikumar (2010)

Methodology

In Telangana the climate is under semi-arid condition and the variation in rainfall varies according the occurance of drought. The contingency crop planning can be adopted in delayed conditions of monsoon. A study was also taken up on growing irrigated dry crop maize instead of rice in Karimnagar and there a comprehensive approach for resilent technologies including the following methodologies were popularized among the farming community mainly focusing on resilient techniques. Climate Resilient Agriculture referred as "Incorporation of the adaptation, mitigation and other practices in agriculture which increases the capacity of the system to respond to various climate related disturbances by resisting damage and recovering quickly".(Source: Modern Concepts of Agronomy, 2016) [3]. There are two Approaches for climate resilience adaptations and Mitigation strategies. Few of them can be reviewed here.

Choice of crops and cultivars: The varieties selected (Table 3) were mostly short duration, quick responders to the improved agronomical practice with high yield potential and tolerant to pests and diseases. Spread of area and output indicators under each variety is present in Table-4. Yield enhancement due to cultivation of recommended varieties over local varieties ranges from 0.5 to 3 quintals per hectare. This substantiates the increased adoption (percent change in area) within a year. MR-6 variety of ragi and BRG-1variety of red gram were adapted to larger extent when compared to KMR-204 and BRG-2 varieties, respectively.

Table 3: Introducing resilient crop varieties

Existing crop/variety	Introduced crop/variety	Characteristic of introduced crop variety	Area in 2012-13 (ha)	Yield (q/ha)			Spread in 2013-14 (ha)	Yield (q/ha)			Change in Area (%)
				Demo	Local	Change		Demo	Local	Change	
Red gram/TTB7	Red gram/BRG-1	High yielding under protective irrigation	3.0	13.0	11.5	2.5	12.0	12.5	10.0	2.5	300.0
	Red gram/BRG-2	Short duration	6.0	11.5	10.2	0.7	10.0	11.0	10.0	0.5	66.7
Ragi/GPU 28	Ragi/MR-6	Long duration with more fodder yield	14.0	14.0	12.0	2.0	35.0	14.5	11.5	3.0	150.0
	Ragi/KMR-204	Medium duration	14.5	14.5	12.5	2.0	10.0	14.0	12.0	2.0	-28.5

Climate Resilient Intercropping Systems for Rainfed Black Soils of Andhra Pradesh and Maharashtra

The main objective is to popularize climate resilient rainfed intercropping systems in black soils to mitigate climate variability. Intercropping of foxtail millet + pigeonpea (5:1) was identified as best climate resilient system in black soils (Kurnool district) of Andhra Pradesh. This system on an average enhanced pigeonpea seed equivalent yields by 406 and 191 kg/ha compared to sole crops of foxtail millet and pigeonpea and recorded 41% of yield advantage over sole crops. In Aurangabad district of Maharashtra, soybean + pigeon pea (4:2) and pigeonpea + green gram (1:2) were identified as climate resilient intercropping systems. Cotton + green gram (1:1) intercropping system was suitable during medium and good rainfall years in black soils of Aurangabad district. In Nan durbar district of Maharashtra, soybean + pigeon pea (3:1) was found stable over different rainfall patterns. On an average, the intercropping system of soybean + pigeon pea (3:1) recorded 73% higher net income than sole pigeon pea. Though the seed yields of intercrops were reduced by 15-20% than respective sole crops in intercropping system, the seed yields of intercropping system was always higher (30 to 60%) than sole crops. Hence, adoption of intercropping systems in rainfed black soils is climate resilient system and also helps in improving food security in rainfed areas.

Agro-techniques to mitigate climate change

Residue burning traditionally provides a fast way to clear the agricultural field of residual biomass and facilitating further land preparation and planting. Other reasons for intentional burning include clearing of fields, fertility enhancement, and pest and pasture management. It also provides a fast way of controlling weeds, insects and diseases, by both eliminating them directly or by altering their natural habitat. Further, the time gap between rice harvesting and wheat sowing in northwest India is only 15-20 days. Hence, farmers prefer burning the rice stalk in the field instead of harvesting it for other uses. Burning is also perceived to boost soil fertility, although burning actually has a differential impact on soil fertility. The use of biochar as soil amendment is proposed as a new approach to mitigate man-induced climate change along with improving soil productivity. The use of biochar in agriculture is not new; in ancient times farmers used it to enhance the production of agricultural crops. Biochar provides a facile flow of carbon from the active pool to the passive pool. In comparison to burning, controlled carbonization converts even larger quantities of biomass organic matter into stable C pools which are assumed to persist in the environment over centuries (Glaser *et al.* 1998; Schmidt and Noack 2000; Glaser *et al.* 2001) [5]. Resource conservation technology means a practice that conserve and/or enhances resource or input-use efficiency.

Table 4: Technological options to reduce GWP

Technology	CO2-C sequestration (kg/ha)	Total GWP (kg CO2/ha)
Conventional tillage	0	1808
Zero tillage	0	1519
INM	300	-171
Organic	600	-1880

Agronomical solutions to changing climatic conditions:

- Application of crop & land management practices for sustainable use of natural resources to realize full yield potential of cultivars
- Implementation of both management & breeding strategies to reduce GHGs emission (precision applin. & genetic enhancement of input use efficiency)
- Crop breeding with emphasis on rapid deployment of lines adapted to the harsher environments, while improving genetic yield thresholds in general
- Integrated use of research methodology & ICT
- Determination of theoretical limits to resource use efficiency of cropping systems for estimating potential productivity in future climatic scenarios
- Monitoring & modelling the spread of diseases and pests in response to climatic factors.
- Establishment of research consortia to solve common problems.

Integrated Farming System modules
Climate vulnerability: Drought, flood

Existing practice
In areas prone to floods and extreme weather events such as frost/ cold stress in addition to water scarcity, mono cropping is generally practiced. In these vulnerable areas, dependence on single farm enterprises by farmers is risky as they have limited resilience to cope with climatic constraints.

Resilient practice/technology
Several integrated farming system modules with a combination of small enterprises such as crop, livestock, poultry, piggery, fish and duck rearing were demonstrated to farmers in NICRA villages in the eastern, northern and north eastern states where mono cropping is mostly practiced due to climatic constraints.

Custom Hiring Centers

- Water saving devices especially drip and sprinkler sets is very popular in areas predominant with horticulture crops.
- Seed cum fertilizer drills helped in introduction or expanding the intercropping area.
- This also helped improve fertilizer use efficiency, as fertilizer placement particularly urea, DAP was appropriate. This has implication in reducing nitrous oxide emissions.
- Deployment of power weeders in CHCs helped timely weed control, which improved the water and nutrient use efficiency
- Different kinds of crop threshers available in CHCs enabled farmers in timely harvesting operations at a lower cost. This could help avoid crop damage in weather abbreviations such as cyclone, frost etc.
- Zero till drills helped save time, water, fuel and escape terminal heat stress besides enabling farmers to make early harvest of *Rabi* crops.
- Broad bed furrow technology for wheat, soybean, and maize saved crop damage due to excess soil moisture by aiding quick drainage and avoiding water stagnation
- There is a need for positioning multiple numbers of equipments like planters, zero till drills, harrows, weeders *etc.*

Conclusions

- Resilience of dryland cereal pearl millet to rising temperatures is more diverse than other major staple foods like maize and wheat
- Crop rotation with corn and sweet sorghum in the dry season can significantly reduce annual GHG emissions
- The adoption of direct seeding of rice and zero tillage in wheat along with residue application can significantly reduce GHG emission.
- Finger millet + Pigeonpea (8:2), groundnut + Pigeonpea (8:2) and Pigeonpea + field bean/cowpea (1:1) were found to be economical and climate resilient in dryland situations of Karnataka.
- Farm ponds are considered as one among the technologies for rain water harvesting in drought prone area to provide lifesaving irrigation during mid-season drought which enhanced ground water storage capacity and Re-chargeability of bore well.
- Moderate AWD can improve rice quality, reduce arsenic accumulation in grain, and reduce CH4 emission from the paddy field, thereby decreasing GWP and greenhouse gas intensity.
- Agro forestry provides assets and income from carbon, wood energy, contributing to global efforts to control atmospheric greenhouse gas concentrations creating environmental secure options of carbon sequestration.

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