Policy Support: Challenges and Opportunities in Abiotically Stressed Agroecosystem

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Abstract

Abiotic stress causes more than 50% losses in crop productivity and hence got major concerns for food and nutritional security. Two case studies addressing the impacts of abiotic stress on agricultural sector, adaptation measure taken up and needed policy options are included. The first case addresses the impact of climatic variables in Godavari River basin of Telangana where the impact of climate change on yield of paddy, groundnut and maize crops had been assessed using the Just-Pope production function. Climate change has serious effect on groundnut (with high yield variation of 69–90%), rice (with moderate yield variation of 23–38%) and maize (with negligible yield variation). Case two discusses about different adaptation strategies followed by agro-silvipastoral farmers to manage the abiotic (drought) stress in Tamil Nadu where among the 17 strategies identified, 12 were indexed as important strategies undertaken. At the time of severe drought stress, farmers used cotton waste as livestock feed, gave vaccination and added shade to protect the livestock from cold and heat stress. Majority of the farmers are only medium adopters, and hence there is an increasing need for creating awareness among the farmers on latest stress management practices by strengthening the extension services and capacity building programmes.

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23.1 Introduction

Agriculture sector in general and crop production in particular are more sensitive to different kinds of stresses that occur in different periods of time and space. These stresses are normally classified into biotic and abiotic stresses. Biotic stress in agriculture encompasses pests and diseases of crops, inimical parasites and microbial infections in animals as well as zoonotic disease-based health problems in animals and humans. Abiotic stresses are "suboptimal environmental conditions caused by non-living factors that are harmful to a living organism". Some types of primary abiotic stresses include drought, salinity, cold, heat, etc. Abiotic stress-related factors affect severely the agricultural production and the livelihood of farmers especially in tropical and subtropical countries where larger proportion of work force is directly depending on climate-sensitive agriculture sector. Among the countries, India is more challenged with multitude of several abiotic and biotic stresses as a result of unfavourable climate and soil conditions resulting in salt stress, low and high temperature stress, flooding stress, chemical stress, oxidative stress and other related stress types. Droughts encompass the global ecosystem as a whole, but the impacts may vary from region to region. According to Miyan (2015), the increasing biophysical vulnerability contexts and intensity in the Asian LDCs cause adverse effects on food security, human health, biodiversity, water resources, hydroelectric power generation, streams, perennial springs and livelihood. Drought is also responsible for increasing pollution, pests and diseases and forced migration and famine. In recent years, there has been a general increase in extreme events including floods, droughts, forest fires and tropical cyclones in the Asian continent (Grover et al. 2003). Climate change-resultant abiotic environment especially changes in hydrological cycles (Rowntree 1990) and temperature regimes may alter the composition of agroecosystems; (Sutherst et al. 1991; NACCAP 2012).

Abiotic stresses, which cause more than 50% losses in crop productivity, are the major concerns for food and nutritional security of additional 0.4 billion Indians by 2050 (Wang et al. 2007). This loss is caused mainly by high temperature (40%), salinity (20%), drought (17%), low temperature (15%) and other forms of stresses (Ashraf et al. 2008). Further it is estimated that only 9% of the world area is conducive for crop production, while 91% is afflicted by various stressors (NIASM 2015).

Agroecosystem environment is largely governed by interactions between abiotic (temperature, humidity, rainfall, soil factors, pollutants, etc.) and biotic (crop plants, weeds, insect pests, pathogens, nematodes, etc.) components. The abiotic stress factors modulate the effects of biotic stresses and are most harmful when they occur in combination (Mittler 2006), greatly influencing crop growth and productivity to the extent of 80% (Oerke et al. 1994; Theilert 2006). Thus, climate-induced changes may affect our ability to expand the food production area as required to feed the burgeoning population of more than ten billion people projected for the middle of the next century. Therefore, understanding abiotic stress responses in plants, animals and fishes and enhancing stress resilience are the most demanding areas in agricultural research. In this context, Bennet et al. (2003) had indicated the possible

Table 23.1 Management of abiotic stress – possible interventions and likelihood progress

Abiotic stress	Possible interventions	Likelihood of progress (in 5 years)
Saline soils and water (presence of salts and of sodium salts)	Increase salt tolerance of rice	High
	Improve leaching; apply gypsum, improve various agronomic practices	High
Waterlogging	Improve water and salt management	High
	Increase tolerance for waterlogging	Medium
	Improve water management	Medium
Water pollution (agrochemicals, industrial waste products)	Improve dosage of agro-chemicals and waste water treatment	Low
Acid sulphate soils (low pH, toxic anaerobic conditions in root zone)	Short duration varieties and seedling vigour	High
	Improve water management	Medium
High and low temperatures	Increase heat and cold tolerance at flowering	Medium
	Improve cooling mechanism for leaves	High
Dry periods and droughts	Improve irrigation infrastructure	Medium
	Increase drought tolerance	High
	Short duration varieties and seedling vigour	High
Floods	Increase tolerance for submergence	High
	Improve water management at river basin level	Low
Air pollution	Improve environmental quality (industrial and urban waste gases)	Low

Source: Bennett (2003)

interventions and the likelihood of major progress that can be done for the management of abiotic stresses (Table 23.1).

Impact of climate change on crop production has been well documented in the works of Palanisami et al. 2015. It is observed that the Indian climate has also undergone significant changes showing increasing trends in annual temperature with an average of 0.56 °C rise over last 100 years (IPCC 2007; Rao et al. 2009; IMD 2010). Warming was more pronounced during post monsoon and winter season with increase in number of hotter days in a year (IMD 2010). Even though there was slight increase in total rainfall received, the number of rainy days has decreased. The rainfed zone of the country has shown significant negative trends in annual rainfall (De and Mukhopadhyay 1999; Lal 2003; Rao et al. 2009). The semiarid regions of the country had maximum probability of prevalence of droughts of varying magnitudes (20–30%), leading to sharp decline in water tables and crop failures (Lal 2003; Rao et al. 2009; Samra 2003). By the end of next century (2100), the temperature in India is likely to increase by 1–5 °C (De and Mukhopadhyay 1999; Lal 2003; IPCC 2007; IMD 2010). According to the estimates of NATCOM (2004), there will be 15–40% increase in rainfall with high degree of variation in its distribution. Apart from this, the country is likely to experience frequently occurring extreme events like heat and cold waves, heavy tropical cyclones, frosts, droughts and floods (NATCOM 2004; IPCC 2007).

Already, the productivity of Indian agriculture is limited by its high dependency on monsoon rainfall which is most often erratic and inadequate in its distribution (Chand and Raju 2009). The country is experiencing declining trend of agricultural productivity due to fluctuating temperatures (Samra and Singh 2004; Aggarwal 2008; Joshi and Viraktamath 2004), frequently occurring droughts and floods (Samra 2003), problem soils and increased outbreaks of insect pests (Joshi and Viraktamath 2004; Srikanth 2007; Dhawan et al. 2007; IARI News 2008; IRRI News 2009) and diseases. These problems are likely to be aggravated further by changing climate which put forth major challenge to attain food security.

Intensive agriculture practices to meet the demands of ever increasing population have caused land degradation problems and also consequently increased the magnitude of abiotic stressors. Further, agricultural intensification through modifications to the environment (like increasing use of irrigation, agrichemicals) and the expansion of farming into undisturbed lands affect natural ecosystems. Hence, in the context of global climate change, it is important to address the abiotic stresses threatening sustainability of agricultural production systems. Hence, understanding abiotic stress responses in crop plants, insect pests and their natural enemies is an important and challenging area in future agricultural research and education. In this context, there is a need to develop simple and low-cost biological methods for the management of abiotic stress, which can be used easily on short-term basis. Also, there is much scope for abiotic stress management and improving the adaptation mechanisms. This chapter includes salient issues that underpin the economics of addressing the impacts of abiotic stress on agricultural sector, adaptation measure that can be taken up and some policy options. Two case studies are discussed below with respect to the impacts and adaptation aspects of abiotic stresses.

23.2 Case Study 1: Impact of Temperature and Precipitation on Crop Yields

Given the importance of abiotic stresses in agriculture, this case study mainly addresses the impact of temperature (both max and min) and precipitation in Godavari River basin of India under varying climate change scenarios.

23.2.1 Approach and Methodology

More accurate region-specific predictions for changes in temperature and rainfall are needed to capture the impact of climate change. Gosain (2011) has applied data from Providing Regional Climates for Impact Studies (PRECIS), a regional circulation model (RCM) for projecting climate changes in Godavari basin. PRECIS is the Hadley Centre portable regional climate model, developed for a grid resolution of

Table 23.2 Projected changes in climatic variables

Change from baseline to	Mean temperature (°C)		Mean precipitation (Per cent)		
	Kharif	Rabi	Kharif	Rabi	Overall
Mid-century (2021–2050)	1.93	2.22	12.5	17.6	13.6
End-century (2071–2098)	4.03	4.28	13.0	53.4	17.8

Source: Calculations based on those reported by Gosain (2011)

0.44° × 0.44°. It captures important regional information on summer monsoon rainfall missing in its parent GCM simulations. The changes in temperature and precipitation (from base line period, 1960–1990) predicted for mid-century (2021–2050) and end-century (2071–2098) (Gosain 2011) were used in getting the projected change in temperature and precipitation for the *Kharif* (June to November) and *Rabi* (December to April) season in study region (Table 23.2).

Based on these changes, two scenarios are formulated, one for the mid-century and the other one for end-century. The mid-century scenario for *Kharif* season is an increase of 1.93 °C and an overall increase of 13.6% in precipitation. This scenario is denoted by 1.93 °C/13.6% for *Kharif*, and for the *Rabi* season, the scenario is 2.22 °C/13.6%. Similarly for the end-century, the scenarios for *Kharif* and *Rabi* are 4.03 °C/17.8% and 4.28 °C/17.8%. It should be noted that in all these scenarios only the annual change in precipitation (and not seasonal changes) is considered. The reason is annual precipitation reflects inter-seasonal water accumulation. These predicted changes are used in the mean and variance functions to predict the climate change-induced average yield and variability in yield.

23.2.2 Study Area, Data and Variables

The Sri Ram Sagar Project (SRSP) in Godavari River basin was selected for the analysis. The SRSP covers four neighbouring districts, viz. Adilabad, Karimnagar, Nizamabad and Warangal. The project is located at Nizamabad, and it augments the irrigation needs of these districts besides providing drinking water to Warangal town. The crop data for the present study consisted of 39 years (1970–2008) panel data on yield of three important crops, viz. rice, maize and groundnut. The data were collected from various sources, publications and websites. The yield data for the crops were collected from season and crop reports of erstwhile Andhra Pradesh and also from the website www.andhrapradeshstat.com. The climate variables were annual precipitation and average seasonal temperature. Meteorological data were collected from various publications and also from the website www.indiawaterportal.org. The annual precipitation data (time series) was collected, which reflects both precipitation falling directly on a crop and inter-seasonal water accumulation within a year (Isik and Devadoss 2006). The temperature data collected is the average temperature observed over the *Kharif* (June to November) and *Rabi* (December to April) seasons.

23.2.3 The Model

In the present study, we focus on the yield and its variability in the context of climate change. Following Isik and Devadoss 2006, we assume that the relation between yield (also known as yield or production per hectare) y_{it} of a crop at district i during year t and the climatic variables x_{it}, viz. precipitation and temperature, is given by the Just-Pope stochastic production function (Just and Pope 1978).

$$y_{it} = f\left(x_{it};\beta\right) + \omega_{it} h\left(x_{it};\delta\right)^{0.5} \tag{23.1}$$

where ω_{it} is the stochastic term with mean zero and variance σ^2, β and $\delta$are the production function parameters to be estimated using historical data. The independent variables (x_{it}) used for the estimations include a constant, annual precipitation (P), temperature (T), trend (t) and three district dummy variables. The expected crop yield is given by $E(y_{it}) = f(x_{it};\beta)$, and crop variability is given by $V\left(y_{it}\right) = \sigma_{\omega}^{2} h\left(x_{it};\delta\right)$. Hence the functions $f(x_{it};\beta)$ and $h(x_{it};\delta)$are called *mean* and *variance* functions, respectively. Estimation of the above production function can be considered as estimation with heteroscedastic errors as in the following equation (Saha et al. 1997; Kumbhakar 1997):

$$y_{it} = f\left(x_{it};\beta\right) + u_{it} \tag{23.2}$$

where $u_{it} = \omega_{it} h(x_{it};\beta)^{0.5}$ with $E(u_{it}) = 0$ and $Var(u_{it}) = \sigma^2 h(x_{it};\delta)$. There are two approaches suggested in many studies to estimate the mean and variance functions of the Just-Pope production function. They can be estimated using feasible generalized least squares or the maximum likelihood method. For example, Barnwal and Kotani (2010) applied the first method. However, Saha et al. (1997) have shown that the estimators under the maximum likelihood method are consistent and more efficient than the feasible generalized least squares method. Hence in our study, maximum likelihood method has been used. Following Ranganathan (2009) and Isik and Devadoss 2006, the following quadratic form is assumed for the mean function:

$$f\left(x_{it};,\beta;,d\right) = \beta_0 + \beta_1 P + \beta_2 T + \beta_3 t + \beta_4 P^2 + \beta_5 T^2 + \beta_6 PT + \sum_{i=1}^{i=3} d_i D_i \tag{23.3}$$

where, D_i, i = 1,2,3 are the district dummy variables taking values 1 and 0. The variance function $\sigma_{\omega}^{2} h\left(x_{it};,\delta;,\eta\right)$ with $\sigma_{\omega}^{2} = 1$ was assumed to have exponential form:

$$h\left(x_{it};,\delta;,\eta\right) = \exp\left(\delta x_{it} + \eta D\right) = \exp\left(\delta_0 + \delta_1 P + \delta_2 T + \delta_3 t + \sum_{i=1}^{i=3} \eta_i D_i\right) \tag{23.4}$$

23.2.4 Results and Discussions

A summary statistics of rice yield, precipitation and temperature of the four districts (average for 39 years, (1970–2008) is given in Table 23.3. The major share of annual precipitation is from *Kharif* season in all the districts. Temperature during the *Kharif*

Table 23.3 Summary statistics of yield of rice and climate variables

	Kharif season (June to November)			Rabi season (December to April)		
District	Yield (kg ha^{-1})	Precipitation (mm)	Temperature (°C)	Yield (kg ha^{-1})	Precipitation (mm)	Temperature (°C)
Adilabad	1543	941.4	27.3	2179	43.1	26.5
Karimnagar	2437	905.8	27.0	2523	56.1	26.2
Nizamabad	2241	888.2	26.7	2242	47.0	26.5
Warangal	2167	817.8	27.8	2039	50.5	26.7

Source: Palanisami et al. (2015)

Table 23.4 Just-Pope production function for rice: parameter estimates

	Kharif		Rabi	
Mean yield	Coefficient	Std. error	Coefficient	Std. error
Precipitation (R)(in mm)	7.2104**	3.5083	2.4397**	0.995
Temperature (T)(in ºC)	2245.9150**	1015.6600	2284.363**	1098.4
Trend(year)	42.4363***	2.3439	42.7376***	2.88
R^2	−0.0013***	0.0003	−0.0016***	0.00038
T^2	−40.1724	50.3485	−43.6677	57.13
R*T	−0.1519	0.1944	0.0528	0.19
Adilabad	−710.6665	59.2652	159.4246**	79.32
Karimnagar	119.0369**	62.4787	427.0203***	67.17
Nizamabad	5.2939	95.3290	215.0166	74.92
Constant	−31671.7	39543.3500	−30787.6	42010.98
Variability in yield				
Precipitation (R)	−0.0014**	0.0006	−0.0004	0.0007
Temperature (T)	0.6296**	0.2775	0.2830	0.246
Trend	0.0267**	0.0126	0.0315**	0.0138
Adilabad	1.0743**	0.3636	−0.3060	0.402
Karimnagar	0.8547**	0.4534	−0.6833*	0.41
Nizamabad	1.9225***	0.4638	−0.2294	0.37
Constant	−6.1009	7.6631	3.8732	6.69
Likelihood fun.	−1096.8		−1106.4	

*Significant at 10% level; ** Significant at 5% level; ***Significant at 1%t level.
Source: Palanisami et al. (2015)

season is slightly higher than that of Rabi season. The most of the coefficients of the climate variables and their square terms are significant for both mean and variance functions (Table 23.4). The coefficient of trend is positive and highly significant in the two seasons showing the technological advancement in rice production in the four districts of Telangana. The percentage losses are computed based on normal yield (Table 23.5). The normal yield is the average yield during the last 5 years ending 2008–2009. For the first climate change scenario, i.e. an increase of 1.93 °C in temperature and 13.6% increase in precipitation, the expected loss in yield during *Kharif* season varies from 1.9 to 9.4%. The highest loss corresponds to Warangal

Table 23.5 Impact of climate change on rice yield in the two seasons (kg ha^{-1})

Climate change (temperature/ rainfall variation)	Parameter	Adilabad district	Karimnagar district	Nizamabad district	Warangal district	All districts
Kharif season						
Mid-century 1.93 °C/13.6%	Normal yield	2262	3115	3226	3009	2972
	Max yield	2616	3445	3332	3326	3180
	MC-predicted yield	2140	3056	3028	2726	2747
	Percent loss	5.4	1.9	6.1	9.4	7.6
	Standard deviation	616	511	763	455	575
End-century 4.03 °C/17.8%	EC-predicted yield	1395	2401	2438	1989	2065
	Percent loss	38.3	22.9	24.4	33.9	30.5
	Standard deviation	1160	964	1439	860	1086
Rabi season						
Mid-century 2.22 °C/13.6%	Normal yield	2460	3338	3214	2929	2985
	Max yield	2544	3374	3260	3255	3108
	MC-predicted yield	2248	3129	2975	2882	2814
	Percent loss	8.6	6.2	7.4	1.6	5.7
	Standard deviation	536	458	828	371	523
End-century 4.28 °C/17.8%	EC-predicted yield	1596	2550	2355	2274	2200
	Percent loss	35.1	23.6	26.7	22.4	26.3
	Standard deviation	998	853	1542	692	975

Source: Palanisami et al. (2015)

district and the lowest to Karimnagar. The standard deviation ranges from 511 to 763 kg. The second climate change scenario produces greater percentage of losses and variability in yield. The percentage loss varies from 22.9 to 38.3% and yield in Adilabad and Warangal district area is expected to suffer maximum losses. A similar conclusion can be drawn for the yield losses and variability for Rabi season also. The variability in yield for end-century is more than that for mid-century. Thus it can be concluded that climate change induces not only loss in yield but also greater variability in yield of rice. This conclusion coincides with the results of (Ranganathan 2009; Barnwal and Kotani 2010).

Parameter estimates of the fitted Just-Pope production functions for maize and groundnut are given in Table 23.6. As in the case of rice, coefficients of most of the climate variables are significant for the two crops in mean function as well as in variance function. Coefficients of precipitation, temperature and temperature square are significant for maize with temperature having negative effect on the mean yield. For groundnut, temperature has positive significant effect. Trend has positive

Table 23.6 Just-Pope function parameters for maize and groundnut

	Maize		Groundnut	
Mean yield	Coefficient	Std. error	Coefficient	Std. error
Precipitation(R)(in mm)	1.458***	0.624	−0.140	5.488
Temperature (T)(in °C)	−1684.180**	901.492	4621.546**	2272.849
Trend(year)	73.988***	4.854	20.096***	3.243
R^2	−0.001	0.001	0.000	0.000
T^2	29.238***	7.480	−86.010***	31.296
R*T	−0.005	0.364	−0.002	0.193
Adilabad	−443.900***	117.295	−237.896***	69.177
Karimnagar	317.455***	123.596	−40.902	71.334
Nizamabad	168.429	149.899	78.230	130.970
Constant	24377.590	68948.460	−61385.950	40394.420
Variability in yield				
Precipitation (R)	−0.001	0.001	0.000	0.001
Temperature (T)	0.133*	0.075	0.281**	0.130
Trend	0.035**	0.014	0.029	0.022
Adilabad	0.443	0.350	0.656	0.455
Karimnagar	−0.136	0.420	0.347	0.473
Nizamabad	0.368	0.404	1.576	0.501
Constant	8.376	7.709	2.566	7.871
Likelihood fun.	−1182.2		−1081.3	

Source: Palanisami et al. (2015)

significant effect on the two crops. Interaction between precipitation and temperature is not significant for the two crops. Since the coefficients of temperature in the variance function for the two crops are positive and significant, temperature is a risk-increasing factor for the two crops where increase in temperature results in higher variability in yield.

Table 23.7 presents the climate change impact on the two crops. The percentage of loss in yield for maize is small for the first scenario in all the districts. The maximum loss will be about 8% for Warangal district. Surprisingly, for the scenario 4.1 °C/17.8%, the percentage loss seems to decrease, and the maximum loss will be 5.5% for Nizamabad district. However, variability in yield increases by about 10–12%. Thus we can conclude that climate change may not have considerable impact on maize yield in the four districts. However, impact of climate change on groundnut production will be considerable. For the first scenario, the percentage loss varies from 13.8 to 25.2. Nizamabad district will have maximum loss. The standard deviation in yield ranges from 292 to 383 kg. The second scenario will have more damaging effect with the percentage loss varying from 69 to 90% while the standard deviation ranges from 387 to 802 kg. Thus we can conclude that groundnut production will be very much affected by climate change.

Table 23.7 Impact of climate change on maize and groundnut yield (kg ha^{-1})

CC-scenario	Parameter	Adilabad	Karimnagar	Nizamabad	Warangal	Average
Maize						
	Normal yield (kg ha^{-1})	3340	4185	4162	3999	3922
	Max yield (kg ha^{-1})	3248	4010	3861	3692	3703
Mid-century 2.05 °C/13.6%	MC-predicted yield (kg ha^{-1})	3249	4022	3866	3687	3708
	% loss in yield	2.7	3.9	7.1	7.8	5.5
	Standard deviation	785	587	763	667	696
End-century 4.1 °C/17.8%	EC-predicted yield (kg ha^{-1})	3321	4064	3932	3788	3778
	% loss in yield	0.6	2.9	5.5	5.3	3.7
	Standard deviation	889	665	865	757	789
Groundnut						
	Normal yield (Kg ha^{-1})	1344	1602	1865	1412	1556
	Max yield (Kg ha^{-1})	1203	1400	1519	1441	1391
Mid-century 2.05 °C/13.6%	MC-predicted yield (kg ha^{-1})	1072	1325	1394	1217	1254
	% loss (base/ normal yield)	20.2	17.3	25.2	13.8	19.4
	Standard deviation	382	319	606	292	383
End-century 4.1 °C/17.8%	EC-predicted yield (kg ha^{-1}/)	140	490	485	224	338
	% loss (base/ normal yield)	89.6	69.4	74.0	84.1	78.3
	Standard deviation	506	422	802	387	507

Source: Palanisami et al. (2015)

In summary, climate change will have very serious effect on groundnut, moderate effect on rice and negligible effect on maize. Further, stronger climate change will induce higher variability in yield in all the crops. In this context, the following management options have been examined to address the impact of climate change on yield of selected crops:

- System of Rice Intensification (SRI) (with 20% reduction in water use)
- Machine Transplanting (MT) (with 15% reduction in labour use)
- Alternate Wetting and Drying (Maize Water Management (MWM) (with 10% reduction in water use)

Adoption of the water- and labour-saving technologies helps the rice production in the project AWD (with 10% reduction in water use) area. It is observed that in all the cases, the SRI resulted in higher production, gross income and water saving compared to alternate drying and wetting and machine transplanting. Nonetheless, adoption of SRI is less due to its challenges in sowing, cono weeding, etc. As an alternate strategy, machine transplanting can help the rice production releasing the labour to cover additional area under rice. It is understood that in the future, the labour scarcity is expected to reduce the area under rice as it will constraint the transplanting operations. Hence machine transplanting helps to ease the labour scarcity to the extent of 20–25%.

23.3 Case Study 2: Drought Stress Management in Dryland Agrosilvipastoral System

Abiotic stress is to be either managed through mitigation or abatement strategies, while biotic forces are tackled mechanically/chemically or biologically. A wide range of adaptation and mitigation strategies are required to cope with the severe impacts of abiotic stress. Efficient resource management and crop/livestock improvement for evolving better breeds can help to overcome abiotic stresses to some extent. Hence, this case study focuses on the adaptation strategies followed by the dryland farmers to manage the drought stress that accounts for 17% of the crop loss.

23.3.1 Study Area, Data and Methodology

This case study investigates the strategies followed by the livestock-based integrated farmers to manage the drought stress in the dry land area of Tamil Nadu. The study covered Tiruppur district in Tamil Nadu which is a rain shadow region with a rainfall of 600 mm per annum. The district often suffers from severe drought stress due to the increased frequency of drought and erratic pattern of rainfall. As a resilience mechanism, the district leads in mixed farming with animal husbandry as one of the key enterprises where in several locations unique agrosilvipastoral farming is followed. Under this silvipastoral system, Velvel (*Acacia leucophloea*) is allowed to grow in rainfed lands with naturally emerging perennial grass called Kolukattai grass (*Cenchrus ciliaris*) which encourages sheep rearing and became a popular subsidiary occupation in the area. However, the adoption level of this practice is also not increasing over the years in spite of erratic and uncertain rains. The study analysed the adoption aspects of these adaptation strategies by covering 180 farmers from six blocks of the district who were selected using multistage purposive sampling.

23.3.2 Adoption Index

The farmers' were categorized into two groups based on their adoptability: adopt (score 1) and non-adopt (score 0). Data were tabulated using frequency distribution and were analysed descriptively. The adoption level of the respondents was measured by making use of adoption index (Karthikeyan 1994 in Rahman 2007).

$$\text{Adoption Index} = \frac{\text{Respondent Total Score}^{*}}{\text{Total Possible Score}} 100$$

23.3.3 Extent of Adoption

$$\text{Extent of Adoption} = \frac{\text{Number of respondants who had adopted the practice}^{*}}{\text{Total number of practices}} 100$$

where:

Respondents total score = total number of practices adopted by a farmer multiplied by the respective practice weight age and summated.

Total possible score = total number of practices recommended, multiplied by the respective practice weight age and summated.

23.3.4 Results and Discussions

Among the 17 strategies identified, viz. change in sowing dates, change in cropping pattern, summer ploughing, deepening of exiting bore well and/or drilling of new bore wells, barbed wire fencing, usage of drought-tolerant varieties, crop insurance and usage of drip irrigation, shifted to nonfarm activity and construction of water harvesting, waste management, purchase of feed and fodder, sell and reduce the herd size, provide shade, lease in more lands, livestock insurance and reviewed vaccination; 12 were indexed as important strategies followed by the sample farmers (Table 23.8). The change in planting dates and the change in cropping pattern were given with high score since the majority of the farmers cope with the drought stress. When the precipitation is lesser than the normal level, they changed their cropping system from agricultural crops to forage crops, as these crops require less water and can be sustained even in the drought conditions. Deepening of exiting bore well or drilling of new bore wells has been followed by the large farmers. Usage of drip irrigation to the crops like coconut was also observed. Marginal farmers and many agricultural labourers were adversely affected by the impact of climate change and therefore shifted to other business like finance, sweet stalls, etc. Some farmers constructed few water-harvesting structures such as farm ponds and drainage channels in their field with the help of the government schemes and on their own to collect the rainwater which recharge their wells. Although many drought-tolerant varieties

Table 23.8 Adoption indices of strategies followed in abiotic stress management

Adoption strategies	Adoption index
Change in cropping pattern	82
Usage of drought-tolerant variety	17
Usage of drip irrigation	35
Deepening of existing wells or drilling new bore wells	75
Shift to nonfarming	29
Change in planting dates	93
Crop/livestock insurance	3
Investing in water-harvesting structures	26
Providing shade	37
Waste management to supplement fodder	83
Reduction in number of livestock	77
Providing livestock vaccination	59

Note: All parameters are assumed to carry equal weight.
Source: Mohanasundari (2015)

Table 23.9 Different Adoption level of farmers (n = 180)

Extent of adoption in crops	Frequency	Percentage
Low (<33 score)	38	21.11
Medium (33–74)	103	57.22
High (>74)	39	21.67
Total	180	100.00

Source: Mohanasundari (2015)

are available, farmers are not aware of those, and hence usages are also very limited. In spite of being aware and avail the crop/livestock insurance schemes, farmers are not interested to avail them because of the low compensation paid and the complex procedures involved.

Farmers use cotton waste as livestock feed from Tiruppur textile industry to supplement the fodder. To sustain their livestock at the time of severe drought stress, farmers purchase the waste at very low cost. When the farmers are unable to meet the fodder demand for livestock at the extreme drought situations, they are reducing the number of livestock by selling. On the other hand, to avoid some seasonal and climatic disease infections, regular vaccination is given for the livestock. Farmers built some sort of infrastructures to provide shade which protects the livestock from severe cold and heat stress. The majority of farmers (57%) were medium level adopters. And about 21% of farmers are low adopters and 22% of farmers' high level adopters (Table 23.9).

23.4 Conclusions and Way Forward

The key message is that water is the key constraint in rice production in the long run, and land put under current fallow due to water scarcity will be a key issue to be dealt with. Implementation of various rice water- and labour-saving technologies will minimize the reduction in rice production between 20–25% under the medium-term and long-term basis. Hence, simply implementing the water management technologies will address the rice production constraints without making any structural interventions such as construction of new storage structures. Already field-level studies in the project area had shown that water-saving technologies will have a higher rate of return in rice production systems (Palanisami et al. 2011). The key question is how and what scale these technologies should be introduced and what kind of institutional and capacity-building mechanisms are needed to achieve this.

The results of the agrosilvipastoral study convey that most of the farmers do not have awareness about the drought-resistant varieties, and even in farmers with some awareness, they are not insuring their crop or livestock for losses. Drilling bore wells in drought prone regions is not a good option due to increasing well failure. However, agrosilvipastoral farmers adopted few strategies such as change in crop pattern, change in planting dates and micro irrigation for fodder to cope with the increasing drought-related stresses. But still, there is an increasing need for creating awareness among the farmers on latest practices and strengthening the extension services. Given the importance of climate change and its impact on agriculture, it is important that abiotic stress-related interventions need to be prioritized. The following are considered important.

Irrigation Ecosystems

- Water management technologies should be piloted in selected locations of the project, and based on the success of these technologies, the upscaling mechanisms should be initiated.
- A cluster approach (covering a group of villages in a location) will be more useful in upscaling the water management technologies, and farmers will be free to interact and follow up with the relevant technologies.
- Labour-saving technologies such as machine transplanting have proved to increase the rice area and production in all the climate scenarios studied. Hence, given the future labour scarcity in rice production, machine transplanting package should be organized at village level through the involvement of local community. A custom hiring unit can be established in the cluster of villages, and farmers can easily forecast their requirement for paddy seedlings and planting in a given time schedule.
- The existing government programmes with the agriculture departments should include the water management technologies in their programme.
- Adequate capacity-building programmes in technology upscaling and mainstreaming should be established. The expertise with the agricultural university research stations and KVKs should be explored for strengthening the capacity-building programmes.

- As the transaction cost of adoption of the adaptation strategies is comparatively high, it is important to address how these costs could be reduced for quick adoption by the farmers (Palanisami et al. 2015).
- There is need for a greater number of dedicated laboratories which deal solely with the production of abiotic stress-tolerant transgenic crops and sharing the results with SAUs.

Rainfed Ecosystem

- In the case of rainfed situation, availability of adequate credit, yield-increasing technology packages to suit drought situations, creating opportunities for off-farm employment, conducting further research on the crop and livestock combination package, introduction of crop and livestock insurance product and investing in water-harvesting structures in dry lands are important components for upscaling agro-silvipastoral systems.

23.5 Areas for Policy Support

Technical and policy instruments complement each other for reduction of harmful impacts and thereby build climate change resilience among crops. Therefore, it is imperative that various dimensions of adoption of different management strategies that have been discussed in the paper are taken into account in implementing techno-economic interventions. As a way forward, the following issues need to be considered in the long-term planning process (Kareemulla and Rama Rao (2013):

- Land degradation and implications – socioeconomic medium and long term. Over the years, land degradation is becoming an issue, and policies that help to manage the land and water ecosystems should be developed along with implementation procedures.
- Community actions for mitigation and coping mechanisms. Already in several locations, community-based mitigation strategies to address abiotic stresses have been identified and tested. It is important to find pathways to upscale them.
- Public policies for communities and regions affected by abiotic stress. Guidelines to develop policy frameworks that are relevant to address the abiotic stresses to suit different agro-ecological environment need to be developed and practiced.
- Relationship of abiotic stress on poverty and resource-poor farmers. As discussed in the paper, in the long run, agriculture production may be affected due to climate change impacts, and it is highly warranted that poverty alleviation programmes with adequate social safety nets particularly in rural sector need to be introduced. Resource-poor farmers should be supported with needed inputs and technology backups to sustain their farming and shared values. The concept of smart villages with package of affordable and appropriate practices is more relevant now.

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