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Climate Proofing for Designing Sustainable Watershed Development Programme Under Changing Climate

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Climate proofing of watershed development programmes is a methodological approach aimed at incorporating climate change impacts into watershed development planning. It helps in assessing adaptation measures in relation to current and future challenges/opportunities and enables implementation of efficient and resilient watershed programmes through identification and prioritization of options for action. For developing net plan for climate resilient watershed management, current climate risks, future climate projections, its impacts on water and agriculture and farmer's experiences/knowledge in facing the extreme weather events were considered. Important suggestions included, soil and water conservation, increasing Water Use Efficiency, mobile phone linked ICT and capacity building.

Key words: Climate change, Climate proofing, watershed development planning

Farming is a gamble with nature. The impact of climate change is expected to be more severe in poor, geographically vulnerable regions with largely agrarian economies. Adaptation to climate change in India requires integrated solutions that simultaneously address livelihood improvements, sustainability, as well as growth issues. While climate change will affect the nation's economy as a whole, its impact will be more severely felt by the poor who also have the least adaptive capacity. Recognizing this, the National Action Plan on Climate Change (NAPCC) clearly outlines its first principle as "protecting the poor and vulnerable sections of the society through inclusive and sustainable development strategy, sensitive to climate change".Climate Proofing of rural development programmes is one of the approaches followed by the Indo-German development project of Ministry of Environment and Forest (MoEF) and lschaftfür InternationaleZusammenarbeit (GIZ) to integrate adaptation to climate change into planning. GIZ supports NABARD in climate proofing of Watershed development programmes piloted in two watersheds of Dindigul district in Tamil Nadu state viz., Appeampatti and Poosaripattiwatershedswhich has more than 70 per cent of its workforce in agriculture and climate change is expected to lower yields in key crops that would have implications on the livelihoods of the people. Through this climate proofing study,a climate proofing table was developed to flag the issues of climate change into the watershed development action and to develop resilient watershed programmes through identification and prioritization of options for action with regard to the current and future challenges and opportunities presented by climate change in the two selected watersheds.

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Materials and Methods

Study area

The two selected watersheds viz., Appiyampatti and Poosaripatti are located in the Thoppampatti block of OttanchathramTalukin Dindigul district (Fig. 1). It is situated between 10˚05' and 10˚09' north latitude and between 77˚30' and 78˚20' east longitude. The two watersheds lie adjacent to each other; both are water starved and depends mainly on rainfall for success of crop production. Normal rainfall received during the North East (NEM) and South West Monsoon (SWM) is 374 mm and 221 mm respectively. In most of the farms, cropping is taken up only once in a year utilizing NEM rainfall. In few farms cultivation is done in two seasons utilizing SWM and NEM rainfall along with supplemental irrigation from underground water resources. Major crops grown are millets and other cereals, pulses, groundnut, gingelly, and cotton. Major soil types present are red sandy soil, red loamy soil and laterite soil.

Historical weather data analysis

Climate resilient watershed planning requires data and information on climate and on agriculture, environmental, and social systems affected by climate, with a view to carrying out realistic vulnerability assessment and looking towards the near future (Levina and Adams, 2006).For understanding the current climate, daily rainfall, maximum and minimum temperatures and wind speed data were obtained from Regional Meteorological Centre (RMC), Chennai for the period from 1969-2005. Analysis of historical weather data of the study region in relation to frequency of occurrence of extreme weather events such as drought, excess rainfall, extremes in temperature and wind speed and its impact on agricultural productivity helped in ranking the climate related risks and the results are presented in Table 1.

Climate change scenario

The future climate change scenario was developed using Regional Climate Models (RCM) viz., PRECIS that was developed by Hadley Centre, UK met office that can be used over any part of the globe (PRECIS, 2011). Special Report on Emission Scenario (SRES) - A1B scenario was selected and from the large number of generated output from the models, only maximum temperature, minimum temperature and rainfall were retrieved. Models were run for 129 years from 1971 to 2099.

Assessing climate change impacts on hydrology and crop productivity

Impact of changing climate on the hydrological parameters of the selected watershed was assessed using Soil and Water Assessment Tool (SWAT) model (SWAT, 2012). A Digital Elevation Map of the study region was derived from a SRTM 30 m elevation dataset. Information on soil was based on the soil map at a scale of 1:50,000 obtained from the Remote Sensing Unit of Tamil Nadu Agricultural University, Coimbatore, India. Land use data was obtained from the open source global land use land cover data (USGS, 2010). Impact of climate change on crops (maize and groundnut) productivity was assessed using DSSAT (Decision Support System for Agrotechnology Transfer) model which is an advanced physiologically based crop growth simulation model and has been widely applied to understanding the relationship between crops and its environment (Jones *et. al*., 1998).

Farmers Survey on climate change

A survey was conducted with 80 farmers using survey questionnaire to understand perceptions of the farmers with respect to (a) Changes in rainfall pattern over time, (b) Impact of climate change on water availability, (c) Frequency of occurrence of extreme weather events and their impact on crop production, (d) Socio-economic consequences due to changing climate, and (e) Developing adaptation strategies for overcoming the impacts of climate change. Participatory Rural Appraisal (PRA) tool used for collecting information from the communitiesare: (a) seasonal calendars, (b) timeline analysis, and (c) hazard mapping (Robert Chambers,1994).

Developing Climate proofing table

Climate proofing table was developed including the direct impacts as well as indirect impacts (e.g. income opportunities) due to expected climate trends on watershed.Information on non-climatic stresses (e.g. land use management practices) that contribute to the impacts of stresses caused by climate variability was also listed. Parameters that make the communities / ecosystem sensitive to the observed or projected impacts of climate change and capacities that the communities have to cope with the impacts were also listed in the climate proofing table. Mal-adaptation with the meaning of activities which further increase the sensitivity to climatic stresses were also identified along with the measures to address impacts of climate change.

Results and Discussion

Current climate analysis

Rainfall and Temperature

The study region received an annual average rainfall of 692 mm, out of that, 374 mm is received in Northeast Monsoon and 221 mm was received in Southwest monsoon season (Fig.2).Among the four different seasons, maximum amount of rainfall with 80% probability was received in NEM season which indicated that rainfed cropping with less climatic risk is possible only during NEM in the study watershed. Rainfall deviation from the normal during SWM and NEM over 37 years (1969-2005) indicated that 14 years received either normal / above normal / excess rainfall during the southwest monsoon and 12 years recorded deficit rainfall and 8 years had scanty rainfall. In the absolute terms, only during 9 years,

Table 1. Climate related Risks

S.No	Risk event	Consequence	Likelihood probability	Risk	Rank
1	Drought	Reduction in crop yields	All most every year	High	1
2	Excess rainfall	Soil erosion	Once in 5 years	Medium	2
3	High wind speed	Physical damage to crops	Often	Low	4
4	Temperature extremes	Increased evapo-transpiration	Frequent	Medium	3

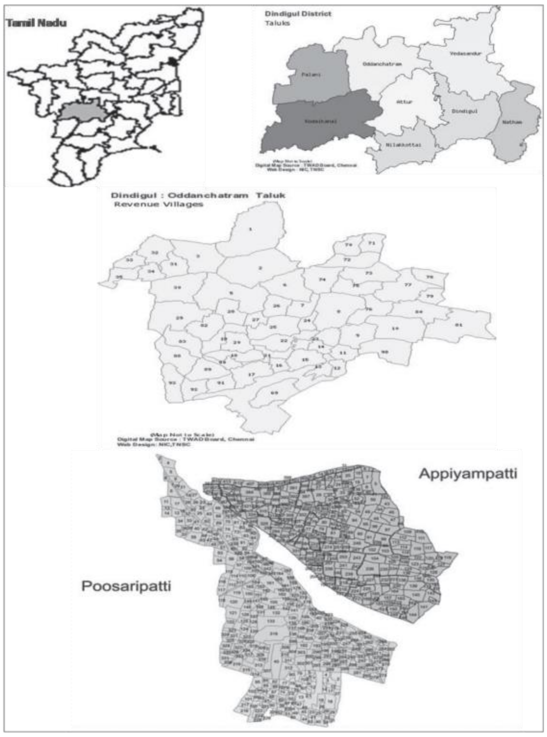

Fig. 1. Location of the Project area

the SWM received more than average rainfall. This indicates that cropping during SWM is highly risky and hence the amount of rainfall received may be properly stored in the soil for utilizing it in the NEM season crop. In contrast, during NEM, among the 37 years, 9 years had normal rainfall and 14 years had excess rainfall and 10 years received either deficit (7 years) or scanty rainfall (3 years).

Table 2. Impact of Cyclonic Depression crossing Tamil Nadu coast on the study region

Year	Date	Category	Event in study region	Maize yield	Tomato yield
1992	Nov 11-17	SCS	112.5 mm of rainfall due to Cyclonic disturbance from 11 – 17 November	-8.34 %	-33.2 %
1993	Nov 8-9	D	310 mm of rainfall in two days (9-10, November) - Super Cyclone that crossed Tamil Nadu coast	-14.95 %	-20.6 %
1993	Dec 19-20	D	81 mm of rainfall received	-3.78 %	-8.5 %
1994	Oct 29-31	SCS	61.8 mm due to depression in BoB	-5.8 %	-3.8 %
1994	Nov 4	D	54.9 mm due to depression in BoB	-5.8 %	-17.8 %
1996	28 Nov- 7 Dec	SCS	172 mm of rainfall in one week (10-16 Dec) due to Cyclonic disturbance	-6.55 %	-62.3 %
2000	Dec 23-28	SCS	December : 191 mm of rainfall	-6.71 %	-54.5 %

*BoB – Bay of Bengal

Temperatures play a major role in determining the growth, productivity, and duration of the crop growth. Both maximum and minimum temperatures are increasing in the study region over the past four decades. Linear trend analysis results (Fig. 3 a-f) clearly state that minimum temperatures are increasing at a faster rate compared to maximum temperature. Increase in maximum temperature was

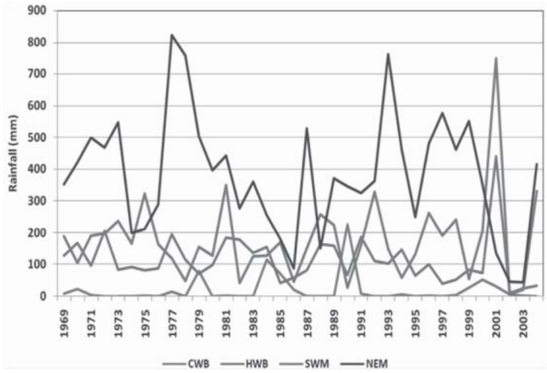

Fig. 2. Rainfall distribution in different seasons (1969-2005)

more during SWM period and the observed rate of increase was 0.9°C over a period of 100 years while it was only 0.5°C during NEM. In the case of minimum temperature, the rate of increase in NEM was higher (1.2°C) compared to SWM season (1.1° C) during the past century. As the major crop growing season was in NEM, the likely trend of higher rate of increase in nocturnal temperature would definitely decline the productivity (Craufurd and Peacock ,1993) of many annual crops.

Extreme Weather Events Analysis

Extreme weather events like flood, drought/dry spell, frost, storms, and even aberration in weather cause obvious impacts on crop production (Rowell, 2006).

Flood:An analysis was made from the historical rainfall data on rainfall with >100 mm/day; 75 mm to 100 mm/day and 50 mm to 75 mm/day to understand the shift in quantum of rainfall received in one day (Fig. 4).Extreme rainfall events analysis indicated that in the recent years higher intensity rains are falling in a shorter time span. Frequency of occurrence of rainfall with more than 100 mm / day are increasing in the recent past which will have implications on soil erosion. The resultant rainfall and its impact on maize and tomato yields are presented in Table 2. High intensity rainfall due to depression reduced the yield of tomato and Maize.

Table 3. Impact of drought on LGP and maize yield

Year	Rainfall deviation in G	LGP (days)	Dry Spell in weeks	Maize yield Kg / Ha
2003	- 90.4	67	7	0
2002	- 89.6	82	7	0
1986	- 73.8	59	5	0
2001	- 63.9	79	5	35
1995	- 46.4	59	3	0
1988	- 44.0	96	6	212
1982	-33.0	91	4	567
1985	-28.2	75	5	55
1990	-22.2	48	2	0

LGP - Length of Growing Period

Drought:The effects of drought became apparent with a longer duration, because more and more moisture–related activities are affected. In the study area, over the 37 years period (1969 – 2005), 11 years (1982, 1983, 1984, 1985, 1986, 1988, 1990, 1995, 2001, 2002, 2003) were severe drought years and the yield of maize crop was reduced to a greater extent due to shorter length of growing period and more dry spells within the growing season(Table 3).

Future Climate projections

Future climate projection as per A2a scenario for the study region indicates that the temperatures are expected to gradually increase over time. By the middle of the century, maximum temperature is expected to be higher by 0.9 degree C and minimum temperature by 1.52 degree C. precipitation is expected to slightly decline till 2030 and thereafter gradually increase. Rainfall is expected to increase by 7 % from the current conditions by 2050 (Table 4).

Impact of climate change on hydrology and crop productivity

The values obtained from SWAT model were averaged for subsequent decades to understand hydrology and the results (Table 5) indicates that rainfall will decrease from the current level during the near future (upto 2030) and again there will be an increasing trend towards the end of the century. Evapotranspiration (ET) as well as potential evapotranspiration (PET) demand will increase with the advancement of time. This must be due to the influence of increased temperature on crop water demand (ET) as well as atmospheric water demand

Table 4. Expected decadal variations in temperature, rainfall and CO_2

Timeline	Expected Maximum Temp	Deviation	Expected Maximum Temp	Deviation	Expected changes in Rainfall	Expected CO2 level
2010	29.97	0	19.13	0	0	370
2020	30.36	0.39	19.48	0.35	- 5 %	385
2030	30.45	0.48	19.73	0.60	0	420
2040	30.62	0.65	20.12	0.99	+ 5 %	470
2050	30.87	0.90	20.65	1.52	+ 7 %	500
2060	31.33	1.36	21.12	1.99	+ 8 %	520
2070	31.75	1.78	21.59	2.46	+ 8 %	535
2080	32.13	2.16	22.00	2.87	+ 10 %	550
2090	32.75	2.78	22.64	3.51	+ 14 %	565
2099	33.57	3.60	23.19	4.06	+ 15 %	588

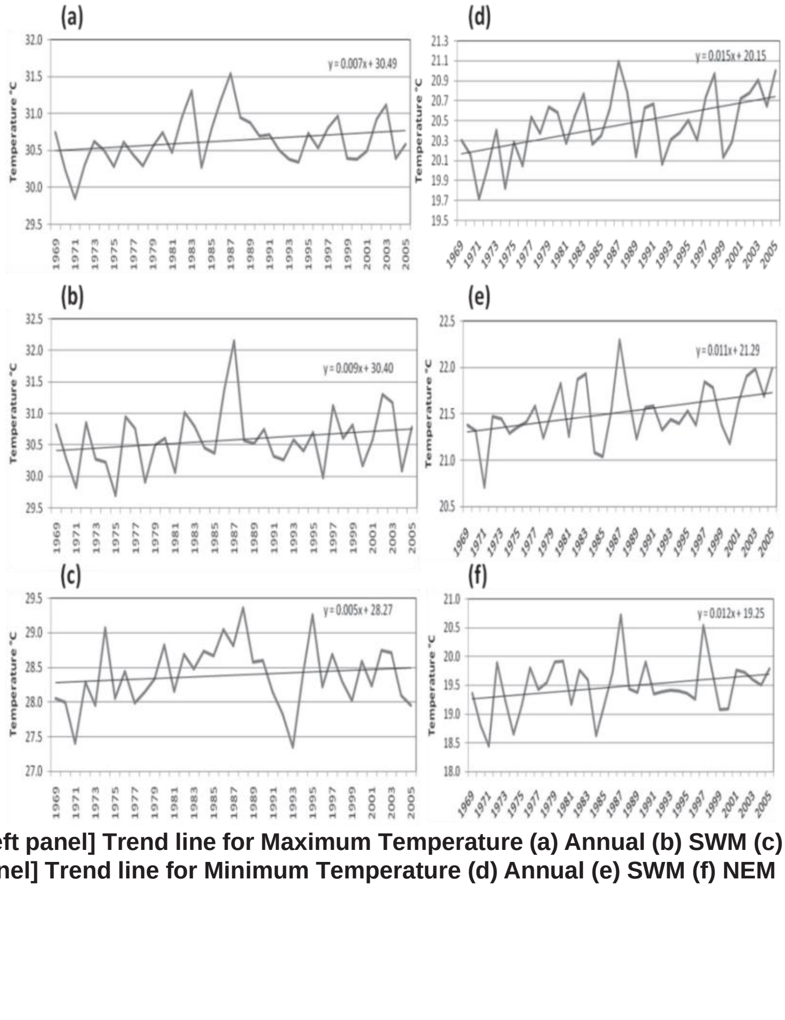

Fig. 3. [left panel] Trend line for Maximum Temperature (a) Annual (b) SWM (c) NEM [right panel] Trend line for Minimum Temperature (d) Annual (e) SWM (f) NEM

(PET). Surface runoff will be highest during the end of the century indicating the possibility of more intense rainfall. DSSAT model simulation shows yield of maize (Table 6a)has reduced by 107 Kg ha^{-1} $decade^{-1}$ for PRECIS output. This reduction in yield might be mainly due to increase in both maximum and minimum temperatures as well as variation in rainfall in addition to shortening of growing period. The evapo-transpiration increased gradually from 2050 indicating more water requirement under future warmer climate. In contrast, water productivity is decreasing over time which warrants measures for increasing water use efficiency. Straw yield is also decreasing which would have impact on dry fodder availability to cattle. DSSAT results clearly indicate that groundnut will be more impacted compared to maize crop due to changing climate(Table 6b). The yields are expected to go down by 60 % by the end of the century if no proper adaptation measures are taken up. Much change could not be observed in evapotranspiration but the water productivity got declined over time (i.e.) the yield produced for every millimeter of water evaporated got declined. Duration of the crop was reduced by a week towards the end of the century.

Table 5. Impact of climate change on ET, PET, Sediment Yield and Crop yield

Perco lation	Evapo-trans-piration	Potential Evapo-transpiration	Sediment yield	Crop yield	Biomass yield
2004	314.23	1519.48	25.13	723.5	2501.8
2020	310.34	1541.54	20.58	646.2	2206.6
2030	314.23	1519.48	25.13	723.5	2501.8
2040	322.9	1558.74	30.26	597.2	2008.3
2050	325.85	1575.04	32.1	453.4	1927.5
2060	328.74	1598.45	33.86	399.1	1756.1
2070	330.61	1619.66	34.69	383.9	1680.6
2080	334.33	1638.62	36.86	369.6	1588.7
2090	341.19	1667.25	40.32	379.3	1541.8
2099	346.08	1713.06	41.27	338.6	1410.2

Table 6(a). Impacts of climate change on maize

Timeline	Yield	ET	Water productivity	Straw yield	Duration
2010	2196	312	7.06	5186	104
2020	1941	312	6.23	5139	101
2030	1925	310	6.4	5021	100
2040	1904	308	6.4	5152	99
2050	1880	350	5.42	5038	95
2060	1813	350	5.52	4971	94
2070	1799	367	4.96	5005	92
2080	1670	366	4.63	4752	89
2090	1570	371	4.29	4526	88
2099	1236	367	3.41	4053	84

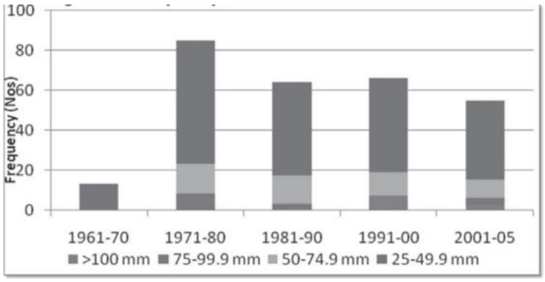

Fig. 4. Frequency of extreme excess rainfall events

Table 6(b). Impact of climate change on groundnut

Time-line	Yield	ET	Water productivity	Haulm yield	Duration
2010	1576	365	6.14		131
2020	1277	362	5.08	3595	130
2030	1211	361	4.86	3415	129
2040	970	360	3.98	3360	128
2050	779	360	3.27	2995	127
2060	749	358	3.14	2940	127
2070	697	367	2.92	2910	126
2080	674	376	2.82	2870	126
2090	631	378	2.63	2820	126
2099	623	365	2.57	2755	124

Outcome of farmers' survey

Farmers have observed reduction in rainfall, lowering of water table in the wells, shift in seasonality of rainfall occurrence, shortening of rainy season, etc. They have also identified the causes for water deficit viz., low rainfall, lack of rainwater harvesting structures, over exploitation of ground water, increasing temperatures and decreasing farm ponds. Farmers felt that the extreme weather events such as drought / flood impacted the agriculture, drinking water, food and fodder shortage, more pest and diseases in plants and animals that led to unemployment, migration and low income

Climate proofing for watershed planning

For designing sustainable watershed plan under changing climate, climate proofing analysis was done. This included listing of climate variability factors, its direct impact, indirect impacts, Non climatic stresses, sensitivities, existing local adaptive capacities to deal with the climatic stresses, existing faulty practices and suggested adaptation strategies (Table 7).Based on the analysis, suggestions for incorporation in the Net Plan such as Water conservation measures(Field bund / Farm pond / Check dam / Loose bolder structure), measures to increase water use efficiency within the field (Agro forestry /Agri Horticulture / Micro irrigation : Drip irrigation, Micro sprinkler / Fertigation / Cross seeding), soil conservation techniques (Summer ploughing / Application of tank silt/ Vermicompost application/ Growing Sesbania and incorporation in the soil during SWM), technologies to increase crop productivity (Using high yielding varieties / Need based fertilizer application/

Table 7. Climate Proofing Table

Climate variability	Direct impacts	Indirect impacts	Non Climatic Stress	Sensitivities	Existing /local adaptive capacities to deal with climatic stresses	Existing Faulty Practices	Suggested Adaptation Strategies
Less rain till 2030/ Increased recurrence of drought	Water scarcity: Poor water availability for irrigation &consumption	Reduce Crop productivity Drop in ground water level Migration	Increase in bore well density, High rate of extraction of ground water, Over Grazing	Non availability of credible agro-meteorological information, High temperatures, High dependence on water intensive crops, Low water table, Poor water holding capacity of the soil, Poor vegetative cover, Lack of enforcement on polices to check tube well. Poor economic profile Lack of affordability of alternatives to agriculture	Livestock as insurance Knowledge of drought resistant millets Pitcher irrigation for horticulture crops Crop Rotation with deep and shallow rooted crops Work as Farm labourers Migration Alternative non-farm sources of income	Increase in the number and depth of bore wells More flood irrigation Incentives for growing water consuming crop species (vegetables) Preference for water intensive crops like ground nut and vegetables	Measures to Increase water use efficiency through Soil & Water Conservation measures Introduction of micro irrigation practices like drip and sprinklers Water harvesting structures like PT and sunken pits, nala bunds etc. Weather advisory Livestock finances Micro finance facility
Increase in temperature and Increase in duration of dry spells during monsoon	Reduced crop productivity	Loss of income for farmers Migration	Poor economic profile	Lack of market access Lack of labour for harvesting and post harvest operations Lack of affordability of alternatives to agriculture	Knowledge of temperature tolerant millets Species specific cropping patterns (mixed, inter and rotational cropping) Livestock as insurance Alternative nonfarm sources of income	High interest loans from money lenders	Weather indexed Crop insurance Agricultural advisory services Livestock finances Micro finance facility
Change in rainfall distribution pattern	Loss of fertile top soils due to Soil erosion	Reduced land productivity	Over grazing	Poor vegetation cover and top soil exposed	Field bunds	Engineering structures without looking into the flow from the catchment	Improved rain water harvesting Farm pond / siltation tanks Agriculture advisory

Climate variability	Direct impacts	Indirect impacts	Non Climatic Stress	Sensitivities	Existing /local adaptive capacities to deal with climatic stresses	Existing Faulty Practices	Suggested Adaptation Strategies
Late setting of season/ Late onset of monsoon	Higher incidences of pests / diseases Lower crop yield	Loss of income	Poor literacy level	Lack of agricultural extension system	Traditional early sowing varieties Trap crops	Overuse of pesticides	Growing short duration varieties Alternate crops (pulses / fodder Crop insurance Moisture conservation structure like farm ponds for critical irrigation.
Slight increase in precipitation after 2030	Increase in frequency of extreme weather events like floods and extended dry spells	Loss of soil fertility Scarcity for irrigation water Reduced Nutrient Use Efficiency New pest and diseases	Pressure on available water	Lack of varieties suitable for changing climate	Information on location specific adaptation technologies Permanent water harvesting structures to manage extreme weather events	Overuse of pesticides Over exploitation of ground water Excess use of fertilizers	Introduction of drip fertigation Micro sprinklers to save the rainfed crops Weather Based Crop Insurance Climate change awareness programs Capacity building to farmers on practicing climate resilient agriculture
High wind speeds	Physical damage of crops / Crop loss Reduction of crop yield Soil erosion	Loss of income Migration		High dependency on agricultural production Lack of vegetation / trees	Tree shelters around fields and houses		Soil conservation Growing shelter Belts / wind breaks:Cashurina

Application of plant growth regulators/ Application of biofetilizers/ Intercropping / Kitchen garden for balanced nutrition :Localization of food/ Alternate energy : Biogas plant/ Alternate Fodder : Azolla), ways to increase the farm income and minimize risk in crop production (Growing shelter Belts / wind breaks : cashurina /Introduction of bamboo cultivation/ Growing fodder sorghum during SWM/ Integrated farming System : Crops + goat/sheep/ dairy/poultry / Alternate crop : Ban yard Millet/ Promotion of Weather Based Crop Insurance) and Mobile linked Information System (Weather Forecast /Agro Advisory / Market Information) were given. In addition to that capacity building to the farmers on crop production technologies, profitable animal rearing, value addition to agricultural products, and irrigation technologies was also suggested for climate resilient watershed management programmes in Appeampatti and Poosaripartty watersheds of Didigul District in Tamil Nadu State.

Farmers felt that the extreme weather events such as drought / flood impacted the agriculture, drinking water, food and fodder shortage, more pest and diseases in plants and animals that led to unemployment, migration and low income. From 1981 -1990, the region experienced severe drought, indicating the importance of water conservation measures and protective irrigation to ensure good yields. If no adaptation measures are taken, the crop yields are expected to go down by 20 per cent in the middle of the century and from 40 to 50 per cent by the end of the century. Crop water requirement would also go up as a result of increasedevapo-Transpiration. Suggested net plans based on climate proofing could sustain the agriculture in the watershed.

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