4. Climate Change

Climate variability in terms of uncertain or delayed rainfall, extreme events like floods, droughts, hailstorms, cyclones and changing temperature have adverse effects on crops, livestock and fisheries. Planning and implementing mitigation and adaptive measures through systematic research is thus very important to meet future challenges of food and livelihood security. The National Agricultural Research System (NARS) has been carrying out comprehensive research and technology demonstration activities on coping with climate change under the flagship programme of ICAR on National Initiative on Climate Resilient Agriculture (NICRA).

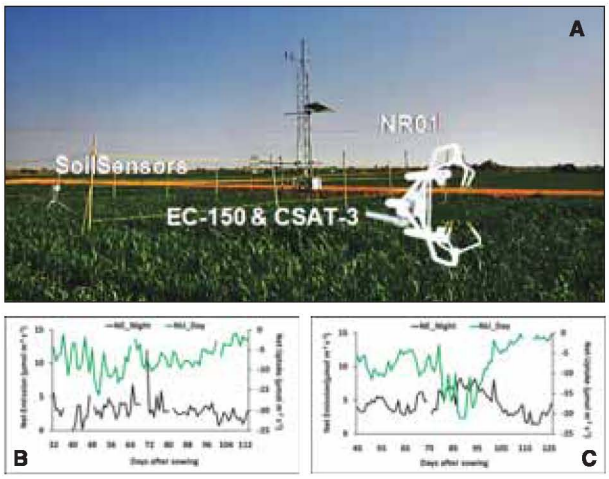
Mitigation of drought: Farm pond technology package: Farm pond technology package developed by CRIDA led to cultivation of sorghum during *rabi* in the tribal areas of Adilabad district in Telangana State, where this crop was not grown previously. Seeds of CSV 22 were supplied by the Directorate of Sorghum Research (DSR), Hyderabad in a consortia mode. Of the total 30 ponds, 10 were perennial receiving base flow from the adjoining areas and making sand bag checks in the adjoining stream improved the flow. All farmers having access to pumpsets irrigated cotton and the increase in Bt cotton yield was 1.0 q/acre for one irrigation. Two supplemental irrigation to cotton

Low cost sand bag check for enhancing surface water storage and sub-surface flow to adjoining farm ponds

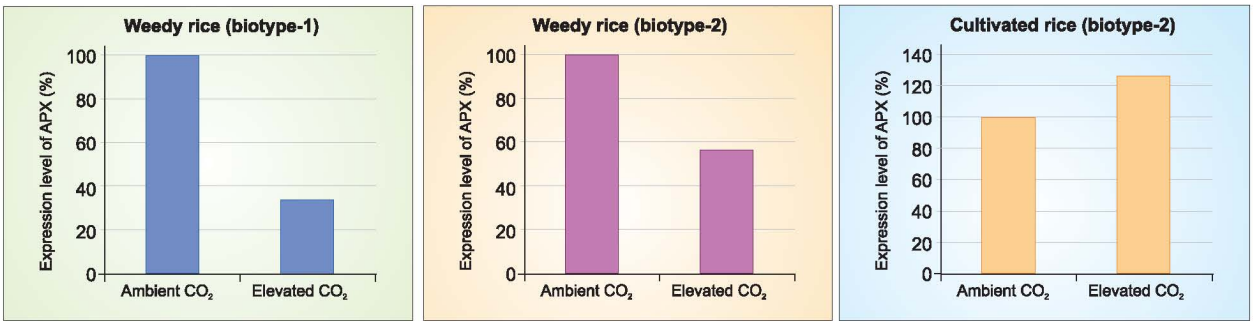
gave an additional net income of ₹ 5,000/acre and the farmers additionally saved ₹ 2,000 being the cost of hiring bullock carts for fetching water for taking up pesticide sprays. The area under *rabi* sorghum which was nil during 2011 went up to 50 acres in 2013, providing food and fodder security. Grain yield of sorghum was 1.0 tonne/ha. This technology not only resulted in improved productivity of cotton but also increased cropping intensity and crop diversity. The action research has created mass awareness among the tribal farmers and a scheme is being promulgated by Government of Telangana.

Quantification of greenhouse gas (GHG) emissions: A project to reduce greenhouse gas emissions was implemented in three contiguous villages (Jaffergudem, Mekalagattu and Mangali banda) of Raghunatha pally madal of Warangal district, Telangana to explore the possibilities of linking such activities to clean development mechanism (CDM). The total area covered was about 5,000 ha and involved approximately 2,000 households. Baseline emissions were quantified as per the IPCC methodology and the quantum of emissions were to the tune of 32,409 tonnes/year. Emissions were highest for electricity consumption (11,826 Mg CO_2 equivalent/year), followed by fuel wood use for cooking and heating (8,258 Mg CO_2 equivalent/year), and the remaining from agriculture sector. The extent of emission reduction due to mitigation interventions in these villages was about 216 Mg CO_2 equivalent/year due to the adoption of CFL bulbs, 1,117 Mg CO_2 equivalent/year due to the energy efficient stoves, and 1,399 Mg CO_2 equivalent/year due to the integration of trees in arable systems. The study assumes importance in the context of climate change and the opportunities for mitigation at the village level and it showed that highest potential of mitigation exists in tree based interventions and by integration of trees on the landscape.

Monitoring agro-ecosystem based fluxes of greenhouse gases: Fluxes of CO_2 were quantified using open path Eddy covariance technique from rainfed *dhaincha* fields and irrigated wheat in a shallow basaltic soil. The release of CO_2 on an average was 4.1 and 2.7 µmol/m^2/sec during night in *dhaincha* (Aug–Nov) and wheat (Dec 2013–Mar 2014) fields respectively. There was, however, a net CO_2 uptake of 7.1 and 6.9 µmol/m^2/sec during day time by the respective crops. On the whole, *dhaincha* and wheat acted as CO_2 sinks with seasonal average intake of 1.5 and 2.1 µmol/m^2/sec respectively.



Eddy covariance system (A), net CO_2 emissions for dhaincha (B), and wheat (C)



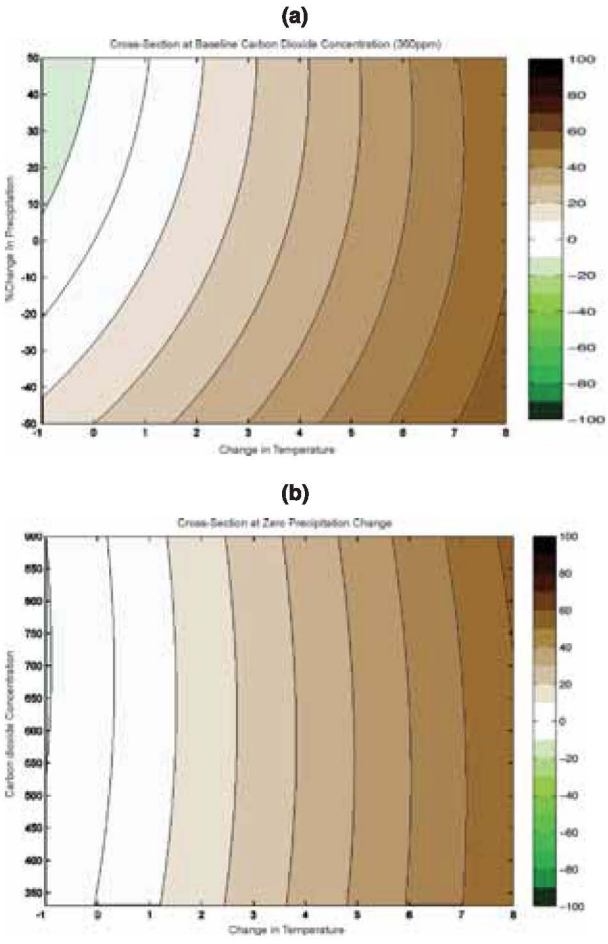
Ascorbate peroxidase levels in cultivated and weedy rice biotypes at ambient and elevated CO_2

Response of elevated CO_2 on cultivated and weedy rice: Weedy rice is emerging as a severe problem in rice cultivation in many parts of India. The effect of elevated CO_2 (550 ± 50 ppm) on its growth was studied in open-top chambers (OTCs). Two weedy rice accessions along with cultivated rice were germinated and grown in the OTCs maintained at elevated and ambient CO_2 levels. There was no significant variation in germination amongst the lines tested. Elevated CO_2 had a significant effect on total leaf area, tillers/plant, net photosynthesis and transpiration in cultivated rice and weedy rice biotypes. Real-time PCR of ascorbate peroxidase (APX) revealed variations in expression levels amongst weedy rice and with cultivated rice. The expression levels of APX decreased in weedy rice biotypes but increased in cultivated rice at elevated CO_2 as compared to that at ambient CO_2, suggesting possible role of this enzyme in adaptation to high CO_2 environment.

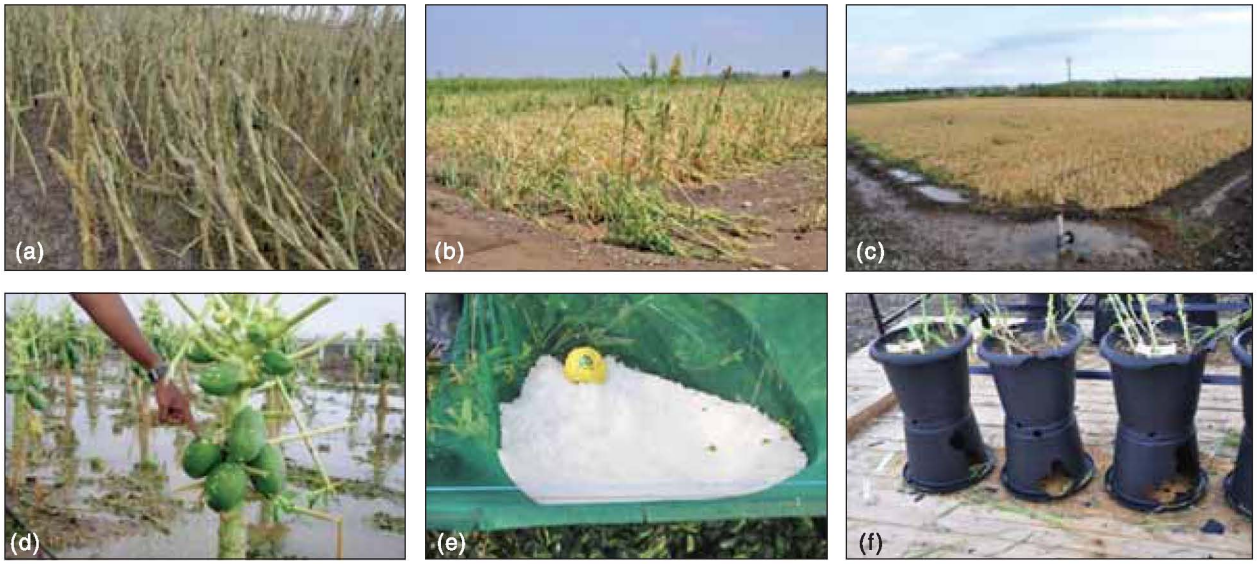
A new technique of weed and crop seed preservation: A liquid preservative of 20% (w/w) calcium chloride in glycerol extended the longevity of seeds of 19 crops and 19 weeds (mean moisture content about 10% on fresh weight basis) to varying degrees at ambient temperature 30±15°C. *Phaseolus vulgaris* seed, with 9% moisture content preserved in the liquid preservative at ambient temperature after 24 years and those preserved at –10°C in hermetic storage had comparable germination percentages. The liquid preservative thus offers an alternative for seed storage at ambient temperature by ultra-drying of the seeds and removing air (oxygen) from the seed environment.

Seeds of papaya, French bean, chickpea and greengram preserved in $CaCl_2$ at ambient temperature since 1989

Quantifying effect of climate change on soybean productivity: To assess the consequences of global warming on productivity of crops, the changes in the simulated yield potential per unit area for soybean caused by changes in the temperature, CO_2 and rainfall over the period 1980–2010 for Bhopal region were investigated. The simulations were performed for a widely cultivated soybean cultivar JS 335 using the coordinated climate-crop modelling pilot team (C3MP) sensitivity tests. Sensitivity simulation experiments (99) using APSIM model statistically fitted with an emulator to estimate mean yield response surfaces to the range of changes in temperature, rainfall and CO_2 indicated that increase in temperature by 1.5°C during soybean



Effect of changes in (a) temperature, and precipitation at constant CO_2 concentration and (b) temperature and CO_2 concentration, without changes in precipitation on soybean grain yield



Damaged crops of maize (a), sorghum (b), wheat (c), papaya (d) and the shade net (e) and pot experiments (f) due to hailstorm

Pomegranate orchard 20 days before (a), on the day (b) and 26 days after (c) hailstorm

growing period would decrease soybean yield by 20% while decrease in temperature from the current climate would favour soybean yield. Further, decrease in the temperature from the current climate by 1°C coupled with increasing the rainfall by more than 10% favours soybean yield the most. Decrease in rainfall pattern and increase in temperature reduced soybean yield drastically. However, increase in temperature with increase in rainfall did not favour soybean growth. Increasing the temperature to 1.5°C along with increase in rainfall up to 50% during soybean growth reduced soybean yield to the tune of 5 to 10%. Beyond 1.5°C increase in temperature, the increase in rainfall did not show any positive impact on soybean yield.

Increase in CO_2 concentration (360 to 720 ppm) favoured soybean growth when the temperature was reduced by 1°C during 1980–2010. However, with increase in CO_2, the yield is masked by the adverse impact of rise in temperature on crop growth. Even with increasing the temperature by 1°C and CO_2 concentration to double from the current stage, the yield decline in soybean was as high as 10%.

Post-hailstorm recovery: Maharashtra witnessed unprecedented hailstorm during the second week of March 2014 in various districts that caused havoc in agricultural fields. In many places hailstorm resulted in accumulation of 30 to 50 cm thick hailstones. The experimental fields and orchards at NIASM, Baramati experienced severe hailstorm on 9 March 2014. To minimize pests and disease attack on exposed plant parts and to hasten recovery of damaged crops, bio-regulators and nutrients were applied. For instance, two month old hailstorm damaged sugarcane crop recovered when treated with foliar spray of Bavistin + copper oxychloride mixture @ 2 g/L with additional N (50 kg/ha) along with either spraying of KNO_3 (1.5%) or drenching urea + P_2O_5 + K_2O (2.0% of each). Copper oxychloride was sprayed on the day after hailstorm to prevent secondary infection in orchard crops like pomegranate, guava and mango. Chemical treatment with cytozyme (100 ppm), thiourea (0.02%), potassium nitrate (2%), hydrogen cyanamide (0.02%), silixol (4 ml/L), and C7 (bio-formulation, which can prevent fungal infection and stimulate the growth) helped in recovery of plants to almost original level in about a month's time.

Effect of climate on horticultural crops: Under Network Project on Transgenic Crops (NPTC) the tomato plants of 36 independent events of *rd29A:AtDREB1A/CBF3* of cv. Kashi Vishesh carrying single transgene copy were screened for salt stress tolerance by imposing 300 mM NaCl stress. Four events (D53, D76, D86, and D90) showing higher salt stress tolerance were selected. In addition, earlier developed *BcZAT12* transformed transgenic tomato lines have the ability to withstand drought and heat-shock stress which are useful for improving productivity of tomato for heat and drought stressed regions.

In order to improve flooding tolerance in tomato (*Solanum lycopersicum*), which is highly susceptible to flooding stress, a study was conducted to determine the effect of grafting tomato plants (cv. Arka Rakshak, AR) onto different eggplant (*Solanum melongena*) rootstocks [BPLH 1, Arka Neelkanth (AN), Mattu Gulla (MG) and Arka Keshav (AK)] against flooding during rainy season (July–September). The study indicated that the eggplant rootstock grafting is of great relevance in improving physiological tolerance in tomato under flooding. Among the eggplant rootstock grafted tomato plants, AR/AN showed better survival and plant yield after experiencing flooding and recorded high sugar and starch accumulation. The recovery was better in eggplant rootstock grafted plants as reflected by recovery of photosynthesis rate, stomatal conductance and leaf water potential, and decline in sugar and starch levels.

The impact of climate change on potato productivity in Uttar Pradesh was assessed using WOFOST crop growth model. The model projected a decline in productivity of Kufri Badshah, Kufri Bahar and Kufri Pukhraj to the tune of 5.5, 6.1 and 7.0%, respectively, by 2020 and 9.4, 10.9 and 13.4%, respectively by 2055, without adaptation. With the existing cultivars, changing planting date and choice of appropriate variety can cut down the yield reduction by about half in 2020 and by one-third in 2055.

A core set of 220 lines of *Cucumis* species was selected for moisture stress, which includes 87 lines of *C. sativus,* 65 of *C. melo,* 3 of *C. melo* var. *conomon,* 34 of *C. melo* var. *agrestis,* 23 of *C. melo* var *momordica,* 5 of *C. melo* var. *flexuous* and 3 of *C. melo* var. *chate.* Based on physiological, biochemical and enzymatic parameters, lines BAM-VR 256, BAM-VR 253, BAM-HR 239 and BAM-VR 251 of muskmelon, BAM-VR 311, BAM-VR 316, BAM-VR 317 of snap melon (*Cucumis melo* var *momordica*), BAM-VR 623, BAM-VR 624 of *agrestis*, BAM-HR 504 of conomon and BAM-VR CH1 of chate were tolerant to moisture stress.

Moisture stress tolerant and susceptible genotypes were selected for transcriptome profiling in *Cucumis*. A total of 13,448 curated transcripts were identified in *Cucumis* and 26,307 transcript sequences generated, which are potential resources for allele mining for moisture stress tolerance in this crop.

In black pepper, expression level of water deficit stress induced genes, viz. dehydrin, osmotin and dehydration responsive element binding (DREB) was studied. The genes showed significantly higher expression in tolerant varieties under stress, maximum being observed for dehydrin. The expression analysis of these three genes suggested that drought tolerance is associated with a rapid modulation of genes from different gene families.

Soil samples were collected (0–25 cm) from high-density cropping systems having coconut, banana, nutmeg, cinnamon and black pepper as component crops and the C build-up in terms of total organic carbon (TOC) and particulate organic carbon (POC) at the basin of different component crops was studied. POC and TOC contents were higher in the black pepper basin (11.6 and 35.2 g/kg, respectively) followed by nutmeg and coconut. The total organic N content was also higher in the black pepper basin followed by coconut. The POC constituted 18–33% of the TOC content.

In coconut, 12 varieties comprising 6 talls (FMST, TPT, AGT, WCT, CCNT and PHOT) and 6 dwarfs (KGD, LCOD, CGD, COD, MYD and MOD) were screened for water-use efficiency under shade net condition. Field evaluation of adult coconut palms showed that Zanzibar and WCT × GBGD were the preferred cultivars for stress conditions based on drought susceptibility index and yield performance.

Climate impact on fisheries along south-west coast: Along the south-west coast of India, off Kerala, data on impact of climate change on coastal fisheries revealed vicissitudes. The spawning season of *Nemipterus randalli* has shifted from October–March to August – November. The diet composition of oil sardine has altered over the years, from 1948 to 2013 indicating changes in occurrence of plankton.

Carbon life cycle assessment (LCA): Carbon life cycle assessment (LCA) of fishing activities from Vishakhapatnam showed that C emitted/kg of fish is least for motorised boats (0.186) compared to mechanised boats (0.466).

Water footprints for prawn production: Blue and green water footprint for *Litopenaeus vannamei* was 0.44 m^3/kg with production of about 11.5 tonnes/ha in 120 days. In zero water exchange farming the water requirement was 0.47 m^3/kg. For *Penaeus monodon* with production of about 2.72 tonnes/ha, the water footprint was 1.9 m^3/kg with 20% water exchange at fortnightly intervals after one month and 2.1 m^3/kg with zero water exchange.

Bearing of cyclone *Phailin* on ecology and fisheries in Chilika lagoon: Phailin, a very severe cyclonic storm with wind speed of about 200 km/h crossed Odisha and adjoining northern Andhra Pradesh coast during 8–14 October 2013 causing extremely heavy rainfall in Odisha. In the Chilika lagoon, the post-Phailin period (22–31 October 2013) experienced reduction in salinity due to cyclonic flood (0.02–4.7 ppt from 0.02 to 13.25 ppt during pre-Phailin period). This affected fish species composition and catch contributions. During the post-Phailin period, freshwater fish species were abundant, while the catches of brackishwater species declined. The low salinity regime and high proportion of freshwater fishes in catches were observed up to December 2013.

Advisories to farmers under technology demonstrations (*kharif* 2014): Technology demonstrations under the National Initiative on Climate Resilient Agriculture (NICRA) project were implemented in 100 Krishi Vigyan Kendras (KVKs) aimed at enhancing the resilience of crop and livestock production systems to current climate variability in different agro-ecologies spread across 28 states in the

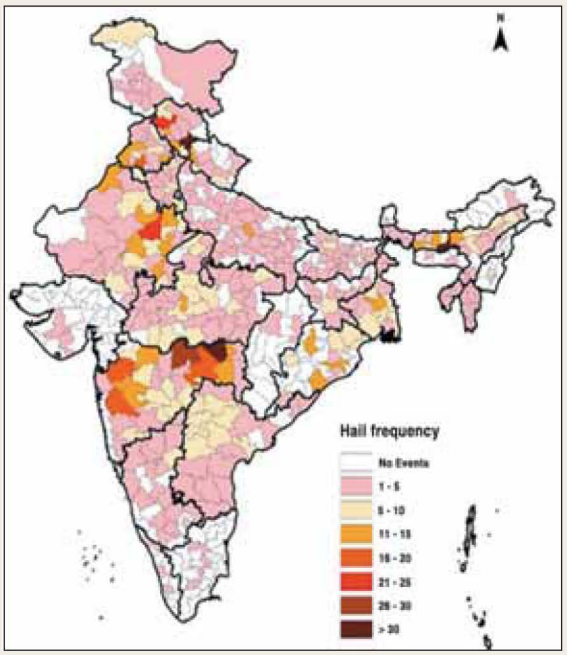
country. Contingency action plans were prepared and advisories issued to the NICRA villages in all the drought affected states. Similarly, pilot implementation of district contingency plans was undertaken in the farmers' fields on real time basis and advisories were issued by the dryland network centers. Suggested contingency measures for delay in monsoon onset included adoption of short duration and drought tolerant cultivars to suit the shortened season; adoption of crop combinations instead of sole cropping; suitable choice of grain or fodder crop and cultivars for advancing *rabi* planting in case of *kharif* crop failure due to drought.

Carbon balance study: Greenhouse gas emissions (CO_2, CH_4 and N_2O) following adoption of climate smart management practices from various production systems (viz. annual crops, perennial crops, irrigated rice, inputs, livestock, forestry and land use change) were estimated in different villages of Gujarat and Rajasthan. The overall C balance due to adaptation of climate smart mitigation technologies in various production systems was positive. The extent of C balance, however, varied from village to village depending on a number of factors such as soil type, rainfall, crop land area and area under perennial crops, degree of adoption of management practices etc.

Hudhud advisories: The Hudhud cyclone hit the coast on 12 October 2014 with a maximum sustained wind speed of 180 kmph near Visakhapatnam. Paddy, sugarcane, maize and cotton were extensively damaged, besides coconut, banana, cashew and oil palm. Many fish hatcheries were damaged leading to heavy economic losses. In the command areas breaching of canals was reported. As short term measures to reduce the extent of damage, top dressing of paddy fields with N and P; crown treatment in coconut and oil palm; stalking in sugarcane; draining of water and top dressing in cotton; supply of contingent crop seeds like blackgram for replanting in the fields where crop is totally damaged; harvesting of sugarcane for jaggery making; promotion of medium duration paddy varieties and crop diversification; harvesting paddy, maize; subsidizing inputs; and necessary plant protection measures wherever the crops are prone to biotic stresses post-cyclonic floods were recommended. Besides, medium term (development and validation of insurance products based on climatological features and subsidizing premium for high risk prone regions; establishing mobile repair workshops for repair of fishing crafts and gear; intercropping in plantations for risk reduction; basin management in plantation crops; planting suitable shelter belts along the coast; arranging planting material of coconut for replanting; provision of funds for repair of soil and water conservation structures; arranging seed and fodder slips; soil testing and providing crop specific micro-nutrient packages; compensation to small and marginal poultry farmers for bird mortality and establishment of low-cost fish processing facility) and long term measures (bunding of Nagavali and Vamshadhara rivers to reduce flood ravages; strengthening R&D systems for holistic research on dynamics of coastal agro-ecosystems; mitigation measures to reduce warming through fuel efficient fishery systems; shift to concrete shelters for poultry units; better weather forecasting systems; revitalizing Coastal Zone Management Authority; flood plain zoning regulation; introduction of professional courses in disaster management; financial help by both Central and State Governments to the research institutions that have suffered huge losses in terms of infrastructure; and technical support to conduct long term studies to avoid/minimize such losses in future) were advocated. ❑

Hailstorm occurrence in India

The hailstorm data of 38 years for the period 1972–2011 (excluding 1977 and 1984, for which data are not available), has been used for frequency analysis. More than 61% of the districts have experienced at least one hail event in a 38 year period. Highest frequency is noticed over districts in the northern parts of Vidarbha region of Maharashtra that are adjoining the state of Madhya Pradesh.



Spatial distribution of hail frequency over 38 years period