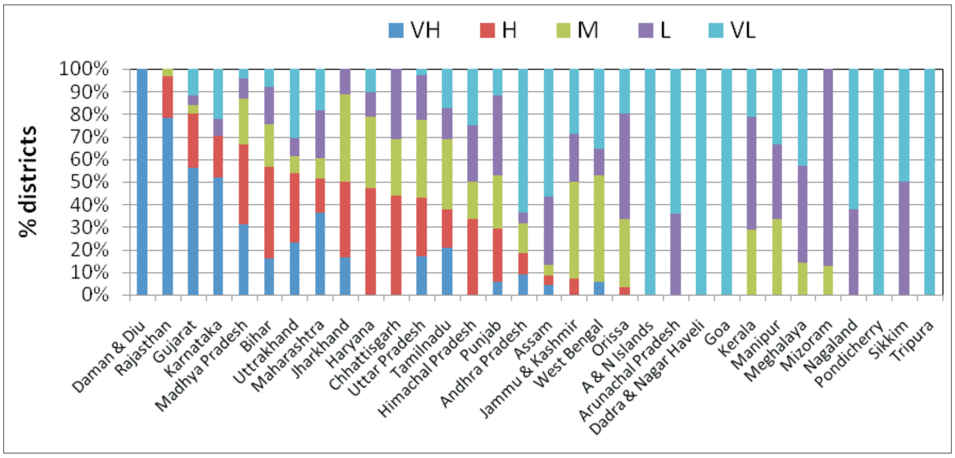
4.
Climate Change

Seasonal variability in rainfall and long term warming trends are posing serious threats for sustainable crop and livestock production. 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).

Identification of vulnerable districts

District level vulnerability atlas was prepared to develop and target appropriate adaptation measures to regions that are more affected by climate change. The Atlas classifies vulnerable districts into very high, high, medium, low and very low categories, based on the combined evaluation of exposure, sensitivity and adaptive capacity, as per the IPCC protocol. Most of the districts with very high and high vulnerability are situated in the states of Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Karnataka and Maharashtra. Similarly, of the 115 districts that are highly vulnerable, 18 are in Uttar Pradesh, 16 in Madhya Pradesh, 15 in Bihar, 9 in Haryana, 7 in Chhattisgarh and 6 each in Jharkhand, Gujarat and Rajasthan.



State-wise distribution of districts with different levels of vulnerability
(VH: Very high, H: High, M: Medium, L: Low, VL: Very low)

Terminal heat stress during wheat growing season

A study was conducted to monitor terminal heat stress conditions in real-time at regional scale across all the districts in six wheat growing states of Haryana, Punjab, Uttar Pradesh, Rajasthan, Bihar and Madhya Pradesh. A database of weekly day-time and night-time Land-Surface-Temperature (LST) from MODIS satellite sensor was generated for January to March period over 2010–2013. The LST values for each week were aggregated district-wise. The district *rabi* season LST of 2013 was compared with the respective values in past three years temporally and spatially: 2010 was the hottest year while 2012 was the coldest. Majority of the districts showed negative value indicating absence of terminal heat conditions during 2013. Further, it was observed that all the districts of Madhya Pradesh and few neighbouring districts of Uttar Pradesh and Rajasthan remained very cold (as shown by large negative anomaly values) during February–March 2013 period as compared to the past three years, a condition beneficial for grain filling in wheat.

Community initiatives for fighting monsoon variability in Jharkhand

Gumla district in Jharkhand has a sub-tropical climate with temperatures of 20 to 40°C during summer and 3 to 21°C during winter and a mean annual average rainfall of 1233 mm. With no irrigation facility available, majority of the farmers cultivate the lands during *kharif* and leave them fallow thereafter.

Participatory Rural Appraisal conducted by KVK, Gumla, under the aegis of the National Initiative on Climate Resilient Agriculture, recognized that there is immense potential for harvesting rainwater from the small streams so that availability of water for agriculture during *rabi* season could be augmented. Gumla covers over 500 ha of cultivated area in a cluster of hamlets called Gunia, Burhu, Balagada and Kuhipat that are predominantly inhabited by small and marginal farmers. The KVK organized a *shramadaan* of the villagers for laying a sand bag check dam in December 2011 in the storm water drain called *Mahasaria*, a seasonal stream, to impound water and to prolong water availability beyond *kharif*, i.e. after the cessation of rains. The check dam (100 m long, 3 m wide and 2 m tall) impounded a large amount of water. Once the water level rose, farmers dug channels to divert water to their fields for cultivating vegetables and wheat. About 50 ha came under wheat during *rabi* 2011–12 while 10 ha was planted with vegetables like okra, tomatoes, cowpea and different types of gourds. Nearly 140 farmers were benefitted. The net return from wheat cultivation was ` 17,900/ha while that from vegetable cultivation ranged between

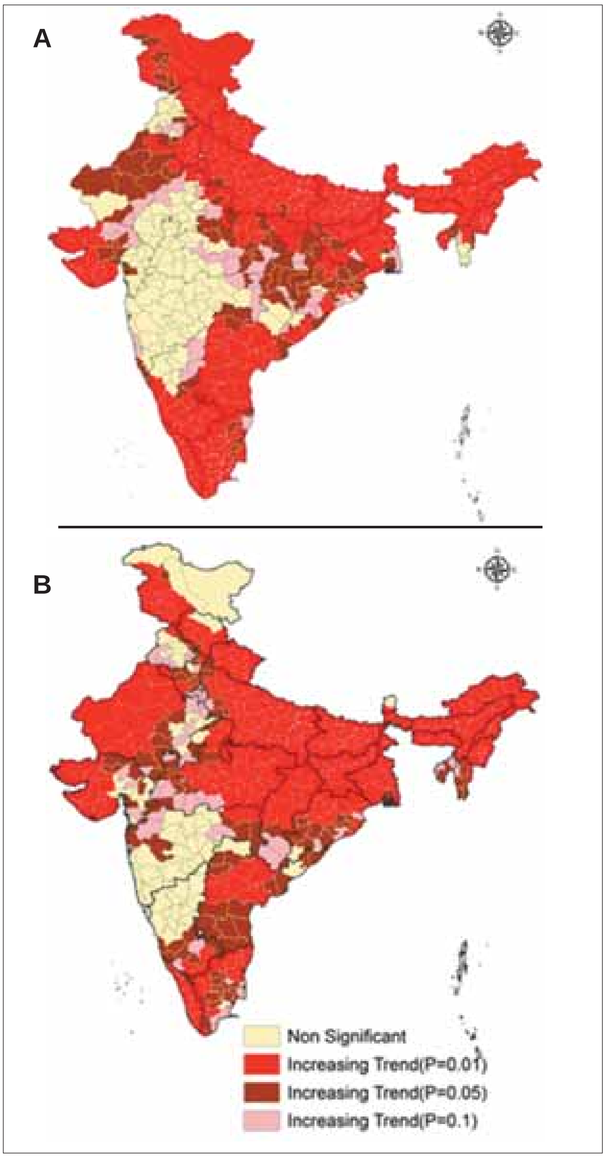
` 51,000 and ` 95,000.

As the news about the success of sand bag check dam in Gunia spread across the district of Gumla, the district officials attempted to replicate this intervention to other locations. For example, the minor irrigation division of the Gumla district administration identified nine locations for constructing a series of *pucca* check dams on Ghaghri nala, Bansari nala and Gomath nala in Ghaghra block and floated a tender worth ` 3,94,72,402. Two *pucca* check dams, one each at Gunia and Jargatoli, were completed by end of February 2013. The Member of Legislature Assembly of Bishunpur constituency visited the check dam at Jargatoli and was impressed with the work. Keeping in view the utility of the intervention, he funded the installation of water lifting device (currently operated by diesel on cost sharing basis) under the MLA-LAD. The device is shortly going to be provided with electric power. The past two years were eventful in the history of Gunia cluster during which saw several transformations: from laying of a sand bag check dam to cement check dam and other improvements for which the villagers give credit to the NICRA Project of ICAR. The farmers of Gunia are now confident of facing the challenge of droughts and monsoon aberrations.

Rising minimum temperature trends over India

The rising minimum temperature has become a concern for *rabi* crops. In order to have a clear assessment of the minimum temperature trends over the entire country, monthly surface minimum temperatures were computed using 0.5 degree grid data from CRU. The magnitude of change on annual basis over the entire country is 0.24°C for a 10 yr period. The extent of area with a strong increasing trend forms about 81.8% of the total geographical area.

Temperature rise during the *kharif* season is 0.19°C



Trends in minimum temperature over India (1971-2009) during (a) *kharif* and (b) *rabi* seasons

Magnitude of changes in minimum temperature over different seasons, regions and timeperiods

Season	Districts cluster based on temperature rise	No. of districts	1971-2009 (°C/10 yr)	1980-1989 (°C/10 yr)	1990-1999 (°C/10 yr)	2000-2009 (°C/10 yr)
Kharif	Entire country		0.19	-0.18	0.50	0.09
	Slightly warm	42	0.12	0.00	0.35	0.22
	Moderately warm	90	0.16	-0.17	0.47	0.10*
	Strongly warm	366	0.24	-0.16	0.59	0.03*
Rabi	Entire country		0.28	-0.06	0.36	0.25
	Slightly warm	56	0.17	-0.62	-0.01	0.51*
	Moderately warm	112	0.21	-0.49	0.12	0.37*
	Strongly warm	359	0.34	-0.15	0.39	0.41*
Annual	Entire country		0.24	-0.05	0.36	0.25
	Slightly warm	13	0.12	-0.66	0.20	0.36*
	Moderately warm	50	0.15	-0.31	0.00	0.21*
	Strongly warm	508	0.26	0.00	0.41	0.25*

(* t test significant at 5%)

over a 10 year period, with profound regional variations. Minimum temperatures during the *kharif* showed strong warming trend in southern states, Indo-Gangetic Plains (IGP), northeastern parts, most parts of Jammu & Kashmir, Gujarat and entire Himachal Pradesh. A strong warming trend was noticed over 52.7% of geographical area with a warming of 0.24°C/10 yr (Table 1). Though the magnitude of change was more during 1999, the trend line for the sub-period 2000–2009 for moderately and strongly warm regions was statistically significant.

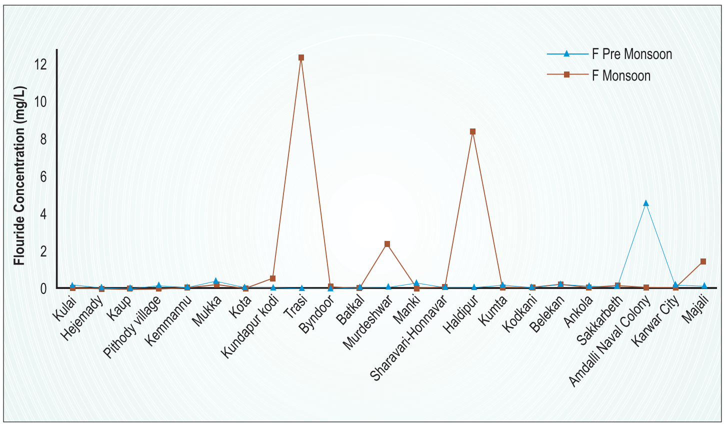
Minimum *rabi* temperatures during 1971–2009 showed strong warming over IGP, West Bengal, northeastern states, Chhattisgarh, Rajasthan, Gujarat and eastern parts of Madhya Pradesh. The rise during *rabi* over the country as a whole was greater in magnitude compared to *kharif*. The temperature rose @ 0.28°C/10 yr. The warming during 2000–2009 decade (0.25°C/10 yr) for *rabi* was about three fold more than *kharif*. A strong warming tendency was noticed over 54.9% of the geographical area, which was 2.2% more than the area during *kharif* season under the same category. The magnitude of change in area classified as slightly warm covering 7.7% of the geographical area was relatively high and proceeded @ 0.51°C/10 yr during 2000–2009 period, which was the highest across regions and sub-periods.

Monsoon rainfall pattern in North Eastern Region

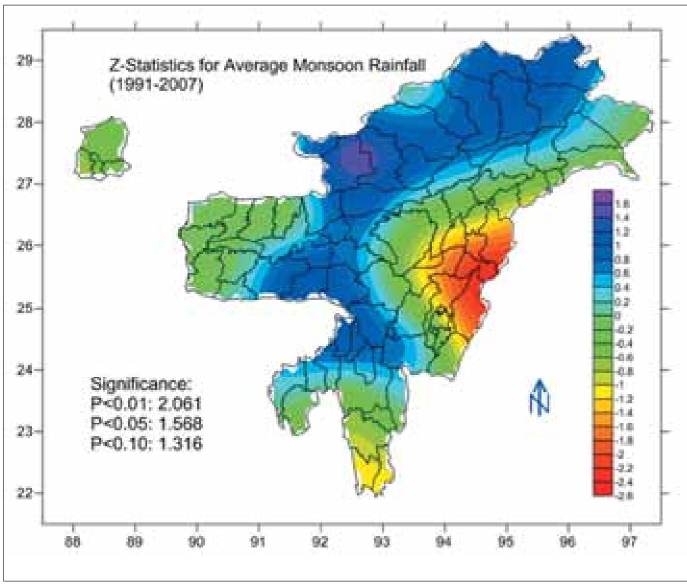
Long term rainfall trends in the NEH region was assessed to know its impact on agriculture and horticulture. Average amount of monsoon rainfall decreased from 900–3000 mm (1951–90) to 850–2350 mm (1991–2007), indicating an average reduction of 18% rainfall in the recent period. The study indicates significant ($P<0.01$) decrease in rainfall in Ukhrul and Senapati districts of Manipur and Phek, Zunheboto and Wokha districts of Nagaland. Similarly, the number of rainy days reduced from 65 to 91 days (1951–90) to 57 to 85 days (1991–2007) indicating an average reduction of 9% rainy days over the region. The reduction was significant ($P<0.01$) for all the districts of Nagaland; upper Asom districts of Tinsukia, Dibrugarh; and Tirap, Changlang, Lower Dibang valley districts of Arunachal Pradesh. The traditionally wet north eastern region has shown a tendency of moving towards a drier monsoon regime in recent times as evidenced through standardized precipitation index (SPI). More locations in the region moved to the negative side of SPI indicating water stress of varying degrees during the *kharif* crop season.

Sea water intrusion in the coast of Karnataka

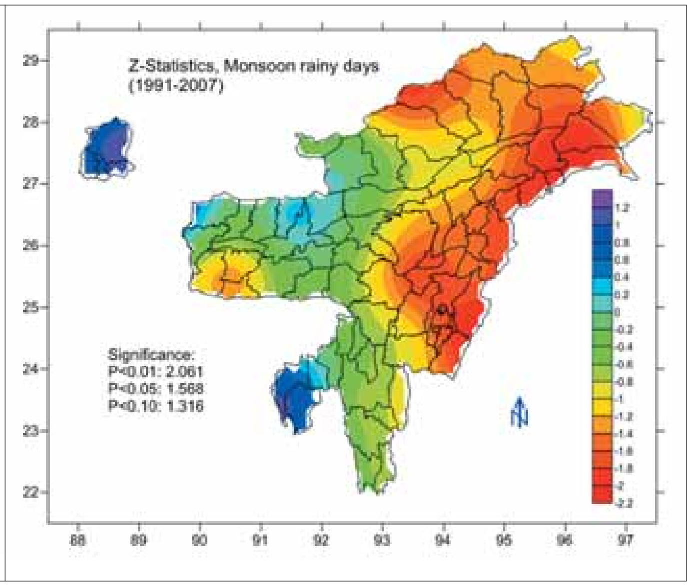
To evaluate the extent of salt water intrusion in the coastal Karnataka, soil and water samples were collected from 24 benchmark sites interspersed at every 10 km interval in the 320 km stretch along the coast in January 2012. At each location, five samples representing approximately 0 m, 0.5 km, 1 km, 3 km and 5 km were collected from shore towards inland to assess salt water incursion in land. To study the depth to which salt water has leached into the soil samples at 10, 50, 100 cm depth were collected. In total, 120 water samples and 360 soil samples were analyzed. Chloride, sulphate, bromide, fluoride, sodium,



Fluoride concentration measured from benchmark sites in coastal Karnataka



Average monsoon rainfall



Monsoon rainy days

potassium, calcium and magnesium concentrations in ground water were estimated during pre- and post-monsoon to assess the extent of coastal salinity. Fluoride concentration was below 1 mg/L except in a few locations, but it was more in winter. Bromide was present in 50% of the locations and very high concentrations of bromine (0.50–1.80 mg/L) was observed at Mukka and Kumta indicating that the region has experienced intrusion of sea water from the ocean.

Modeling pigeonpea yields under changing climate

Pigeonpea is the second most important pulse crop after chickpea in India. In Karnataka, Gulbarga area is the "Pulse Bowl of Karnataka". Pigeonpea area in Gulbarga has steadily increased from 0.14 M ha in 1970 to 0.43 M ha in 2007. Average pigeonpea productivity, however, is low at about 0.42 tonne/ha. Pigeonpea productivity in Gulbarga is affected by large variations in rainfall amount and distribution, increased temperatures and depleting soil fertility.Field experiments were conducted in 2011 and 2012 with three popular varieties of pigeonpea (ICP 8863-Maruti, ICP 87119-Asha and TS-3R) and one hybrid ICPH 2671 on farmers' fields at Farhatabad, Gulbarga district and at ICRISAT, Patancheru (Andhra Pradesh). Using the pigeonpea model in APSIM, genetic coefficients for the variety TS-3R were derived based on observed phenology, crop growth and yield data. Based on daily weather data of 41 years (1969–2009) of Gulbarga, productivity and water use of pigeonpea variety TS-3R under eleven climate scenarios were assessed. Simulations show that increase in temperature by 2°C would reduce pigeonpea yields by about 16%. Rainfall decrease of 10% from present coupled with 2°C increase in temperature would reduce yields further by 4%, making the total reduction as high as 20%. Crop duration decreased by about 10 days and water use declined by 25 mm with increase in temperature. Increased rainfall have considerably reduced the adverse effects of higher temperature. Breeding varieties tolerant to higher temperature and adoption of better water management practices (both *in-situ* and *ex-situ*) can help sustain pigeonpea yields in the region under changing climate regimes.

Inter-specific grafting in tomato for enhancing flood tolerance

Scions of tomato cv. hyb. ArkaRakshak (AR) were grafted on to self and four brinjal rootstocks: AR/BPLH-1, AR/MattuGulla, AR/ArkaNeelkanth, AR/ArkaKeshav, self-grafted (AR/AR) and ungrafted Arka Rakshak (ungrafted-AR). Within 24 hr of flooding there was a decrease in photosynthesis and 70.0 to 83.0% decrease by day 6 in the grafts with brinjal rootstocks, while in self-grafted and ungrafted plants the decrease in photosynthesis was 93.0 to 98.0%. In general, rootstock grafted plants had significantly higher gas exchange levels than AR/AR and ungrafted-AR under flooding. The effect of flooding on root growth was greater in AR/AR and ungrafted-AR as indicated by higher percentage reduction (36–49%) in these plants

Tomato plants grafted with brinjal root stock with better flooding tolerance

Effect of projected climate on phenology and productivity of pigeonpea cv. TS-3R

Climate scenario	Days to flower	Days to maturity	Total biomass (kg/ha)	Grain yield (kg/ha)	Change in yield (%)
Present (P)	103	157	8708	2057	0
P+1°C	101	151	8286	1875	-9
P+1°C-10%RF	99	150	7798	1771	-14
P+1°C-20%RF	99	150	7090	1615	-21
P+1°C+10%RF	101	151	8659	1961	-5
P+1°C+20%RF	101	152	8866	2005	-3
P+2°C	99	148	7943	1734	-16
P+2°C-10%RF	98	147	7465	1636	-20
P+2°C-20%RF	98	147	6763	1486	-28
P+2°C+10%RF	100	149	8302	1809	-12
P+2°C+20%RF	99	148	8525	1854	-10

after flooding. Further, brinjal rootstock grafted plants had more number of adventitious roots (5–7) than AR/AR and ungrafted-AR. In the flooded plants, 50% yield was maintained by rootstock grafted plants and in AR/ArkaNeelkanth the reduction in yield under flooding was only 11.7%. Tomato scions grafted over brinjal rootstocks showed better tolerance to flooding than the self-grafted and ungrafted plants based on physiological parameters like photosynthesis and chlorophyll fluorescence. The best recovery was found in AR/ArkaNeelkanth.

Short duration crop varieties to face with frequent droughts in Tumkur, Karnataka

Durgada Nagenahalli (DN) village situated in the central dry agro-climatic zone of Karnataka receives an average rainfall of 690 mm. The major climatic vulnerabilities of the village are drought particularly during the critical stages of the crop growth and farmers lose their crops. Finger millet, maize and groundnut are major crops grown in this village. The village experiences acute water shortage, soil erosion and there is a preponderance of wastelands and common lands. NICRA project implemented by KVK, Tumkur in this village covers nearly 270 households with a cultivable area of nearly 200 ha.

Ragi being the staple food crop in this region, every farmer cultivates it for meeting his consumption requirements. Due to frequent droughts in the recent past, however, many are unable to harvest enough. Ragi cv. ML 365 developed by UAS, Bangalore to cope with early season drought was introduced in this village over an area of 20 ha involving 70 farmers. Seedlings of ML 365 were raised in nursery and transplanted after 25 days with the onset of rainy season. The performance was significantly superior to local varieties. The farmers have retained the seed and also shared it with fellow farmers for sowing in the ensuing season. Salient characteristics of the variety ML 365 are:

- Short duration (about 105 days)
- Medium plant height
- High yielding (grain and fodder) due to more panicles and grain filling
- Tolerant to drought
- Resistant to leaf spot, neck blast and lodging
- Good cooking quality
- Suitable for dryland agriculture and late sowing (transplanting)
- Requires low seed rate (5 kg/ha)

Success of this intervention was evident during 2012 when a severe drought struck Karnataka. The DN villagers harvested reasonable quantities of grain while the neighbouring villages nearly lost the crop.

Climate-resilient aquaculture for Sundarban Islands

Flooding the freshwater ponds with saline water during cyclones is a major problem affecting the fish/prawn culture in Sundarbans. Studies over a 2 year period revealed that two hours of continuous aeration (0.2 kg/m^3 pressure with 4 L / m^3 / minute volume) at 4 hr interval is an effective adaptation strategy for salinity up to 5 ppt for freshwater fishes (*Cyprinus carpio* and *Puntius sarana*). Inclusion of additives like immune-stimulant (Immutron)/ probiotic (Gut Act)/ prebiotic @ 10 ml/kg high energy floating feed (having 30% protein, 4% fat and 8% fiber) increased the growth rate under salinity stress. High energy feed fortified with immune stimulant showed best growth ($P< 0.05$) followed by probiotics and then prebiotics in *Cyprinus carpio*, *Labeo rohita* and *Oreochromis mosambicus*.

Snowmelt harvesting saves orchards during dry spells in Kashmir

About 3.3% of total geographical area of Kashmir is under cultivation, of which 60% is rainfed. Horticulture-based farming systems are predominant. However, frequent dry spells during *kharif* affect cultivation of apples and pears, which are major crops of Pulwama region. In Drubgam village of the district where NICRA is being implemented, most of the cultivated area is rainfed and the apple and pear orchards generally suffer due to erratic rainfall. Further, the productivity of these crops is low due to lack of irrigation and low input use. In particular, irrigation is essential to ensure higher fruit retention if dry spells occur. To cope with this climate related problem, the KVK, Pulwama introduced rainwater/snowmelt water harvesting interventions and micro irrigations systems in the village.

Rainwater/snowmelt water harvesting structures have been demonstrated at select farmers' fields as effective means of collection and storing runoff and snow melt water. The stored water is used for providing irrigation at critical stages of growth of fruit crops and vegetables. This water is also useful for spraying orchards, vegetables in the absence of water source in nearby areas. During the past two years, it was observed that not only the growth of apple trees and other crops improved but also there was improvement in the yield and quality of the produce due to efficient utilization of harvested rainwater and snow. Impressed with the benefits, many farmers are coming forward to adopt this technology.

Water footprints for milk production

Consumptive water use (CWU) in milk production comprises direct (drinking, bathing and servicing) and indirect (feed and fodder) components. For stall-fed animals, the entire direct water requirement is met from groundwater and/or surface water sources (blue component of water footprint). For animals partly or fully under grazing system, however, rainwater may partly account for the water use (e.g. drinking and bathing). Direct water use by animals was estimated by assessing seasonal drinking water requirement of different breeds of dairy animals. Based on the diameter of water pipe, time of water flow and number of animals in the enclosure, the average water use of servicing and bathing worked out to be 50 L /day on the NDRI

Total water footprints (m^3/tonne) of milk production in organized and unorganized farms

Breed	Average milk yield (L/day)	CWU (m^3/t)		
		Blue (Direct+ Indirect)	Green (Indirect)	Total
Organized farm				
Karan Fries	9.0	996	216	1212
Murrah	7.4	1031	238	1269
Sahiwal and Tharparkar	7.2	1279	304	1583
Unorganized farms				
Cross bred	8.3	1166	812	1977
Buffalo	5.2	1201	746	1947
Local Cow	4.5	981	563	1544

farm and marginally lower (40 L/day) on the farmer's field. Based on the monthly feed intake data of crossbred cattle, buffaloes and local cows at NDRI farm and the seasonal (three seasons) data from the farmer's field, total water footprints (m^3/tonne) of milk production were estimated. Results indicate that total consumptive water use (m^3/tonne) at organized farm was less than that of unorganized farms. Water use was more for buffalo and crossbred cattle than *desi* cattle breeds. Unorganized farm used 1950 to 1980 m^3/tonne water (cwu) for crossbreds and buffaloes as against 1540 m^3/tonne for local cows.

Mitigating climate change through plant growth promoting bacteria: Bio-priming of seeds with osmo-tolerant plant growth promoting bacteria was observed to improve and reduce the time taken for seed germination and enhanced seedling growth in tomato under osmotic stress conditions.

Mango phenology: In a roving survey of the coastal Konkan region of Maharashtra, it was observed that more than 95% of the mango orchards showed phenological stages between vegetative flush to panicle emergence leading to staggered flowering in all the varieties and even fruits at different stages of growth on the same tree. Pollen viability was the most important parameter determining fruit setting in Alphonso and Totapuri.

Fruit fly infestation: Climate change is expected to have adverse effect on the potential distribution of fruitfly (*Bactrocera dorsalis*) in India. The fly is expected to spread northwards into colder regions. A roving survey undertaken for the mango orchards in Karnataka revealed that the severity of black banded disease; leaf blight and mango malformation is increasing. Under conservation horticulture, inclusion of legume (*Mucuna* sp.) as cover crop has resulted in appreciable increase in the levels of soil organic carbon and nutrients.

Effect of elevated CO_2 and temperature on coconut: At the present level of available soil moisture, coconut would produce more biomass under changed climate scenario with higher CO_2 and increased temperature. However, inordinately delayed jorquetting is expected in cacao plants due to increased temperature as compared to plants grown at ambient temperatures.

Shift in fish maturity and breeding period

A shift in fish maturity and breeding period of Indian Major carps (IMC) rainbow trout, golden mahseer and snow trout, was recorded recently due to climatic variations along Himalayan and sub Himalayan regions. The maturity of IMCs in North-eastern region of country has advanced by one month (from April to March) and the period extended one month (from July to August). The full matured rainbow trout was observed during December end to January, golden mahseer during April to June, and snow-trout in August in Uttrakhand. Increase in water temperature due to the global warming affects habitat, metabolism, growth and reproduction of fishes. Hatchery survey data comprising various aspects of breeding and spawning of fishes was compiled in the form of E-Atlas for West Bengal and Asom.

Carbon sequestration through cassava cultivation: On the basis of soil fertility test, cultivation of NPK-efficient cassava genotype (Ac. No.130) along with optimum nutrient management practice and low-input integrated practices could sequester atmospheric CO_2 (13.867 ppm) to soil organic carbon (0.74–1.67%).

Potato: Climate change impact on potato productivity in Punjab was carried out using WOFOST crop growth model. It was estimated that productivity of potato cultivars in Punjab will not be affected in 2020 over the baseline scenario but will decline in 2055 (–2.62%–5.3%). However, if the present distribution of potato acreage in Punjab remains unaltered in future, there will be benefits from climate change as the potential productivity of potato will increase (+3.1 to +3.6%) in 2020 but it will again decline to baseline values in 2050.

Quantification of greenhouse gases: The green house gases (GHGs) N_2O, CH_4 and CO_2 emission were quantified from four *Litopenaeus vannamei* farms (at different stocking densities) and one *Penaeus monodon* farm in Andhra Pradesh and Tamil Nadu for four months. In addition, traditional farming system (Pokkali fields) of Kerala was also studied. Average emission of GHGs in g/ha/day was high in traditional farming compared to scientific shrimp farming with *L. vannamei* and *P.monodon*. Global warming potential (GWP) values in kg CO_2 eq/ha/season were 91 in tiger shrimp farm, 218 to 351 in *L.vannamei* farms, and 405 in pokkali shrimp farm.

Quantification of microbial biomass carbon: Microbial biomass carbon (MBC), an indicator for increased atmospheric carbon dioxide (CO_2), accelerates global warming. The changes in soil MBC were studied in scientific farms in Tamil Nadu and Andhra Pradesh and traditional farms in Kerala. In scientific shrimp ponds, MBC in soil ranged from 50 to 938 µg C /g and 70 to 721 µg C / g in *L. vannamei* and *P. monodon* culture ponds, respectively, whereas in traditional shrimp farming ponds, the MBC in soil ranged from 584 to 2114 µg C /g. Organic matter content in pond soils ranged from 0.36 to 1.24% and 0.62 to 2.2% in the scientific and traditional shrimp ponds, respectively. The values of MBC and total organic carbon (TOC) were significantly correlated with days of culture (DOC) and were very high during summer crop compared to winter crop of *L.vannamei*.

❑