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CLIMATE SMART AGRICULTURAL PRACTICES FOR RESILIENT GROUNDNUT-BASED CROPPING SYSTEMS

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Cover photo (F) : A jubiliant farmer (Center) & climate resilient practices (periphery)

Cover photo(B) : ICAR-DGR Office

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Preface

In India, among the nine oilseed crops, groundnut ranks third in area and production (5.33 Mha and 7.40 M tonnes) after soybean and rapeseed and mustard, but second in productivity (1374 kg/ha) next only to castor (average of 2010-11 to 2013-14, IIOR). However, productivity of groundnut in India is much lower when compared with USA (4537kg/ha), China (3573kg/ha) and world average (~1700 kg/ha). Cultivation of groundnut in less fertile soils under rainfed conditions, lack of proper management practices like non-adoption of good quality seed of varieties recommended for the region, optimum plant stand, plant nutrition, plant protection measures, harvest losses in heavy soils, less favourable climatic conditions etc. are among the major reasons for low yield of groundnut in India. Gujarat has largest area and production of groundnut in India, but yield levels are moderate mainly due to unsuitability of soil, and moisture deficit stress at different growing stages of crop. To exacerbate these effects, climatic variabilities are becoming increasingly conspicuous mainly in the form of unpredictable rain pattern and temperature regimes affecting groundnut yield in the country. This underlines the need to make available suitable technologies to the farmers to make production systems climate resilient. With the sincere efforts of scientists, technicians and field staff a number of technologies have been developed in the country which are helpful in minimizing the adverse impacts of climate variabilities on groundnut. Besides, farmers also follow innovative approaches based on their experiences and local conditions. There is need to bring together this important information and make available to farming community through all means of extension. With this objective, authors have attempted to bring together scattered pieces of knowledge on the subject in the form of this technical bulletin. Hope it will be useful to the farmers in their efforts for sustainable intensification of groundnut based cropping systems in the country in the face of ever increasing evident climate variabilities.

Authors

1. Introduction

The United Nations has adopted 'sustainable development goals' targeted to be achieved by 2030 and has set 17 agendas out of which two are of prime relevance as far as agriculture is concerned viz., 'Goal 2' i.e., *"End hunger, achieve food security and improved nutrition and promote sustainable agriculture"* and 'Goal 13' i.e., *"Take urgent action to combat climate change and its impacts"* (UN, 2015). The agriculture, which is largely seen through input-output paradigm needs to be redesigned in a framework where the sustainability is not just talked about but is achieved in the real sense. However, the issue is not just that we need to be only sustainable in our production systems, but also need to increase the production so as to achieve the food and nutrition security and ultimately end the hunger from the face of globe. Thus, we need to enhance the production sustainably, to meet the food demands for burgeoning human population, which is projected to be 9.6 billion by the end of 2050 (UN, 2015). This task is especially challenging when our natural resources are in a state of continuous utilization, exploitation, and degradation for our ravenous demands for food, fodder, fiber, energy, etc. To add further, it is more difficult to achieve these goals when the adverse impacts of climate change on agriculture are looming large. And to be sure, the climate change and variabilities have already begun to affect farming in India and elsewhere around the globe. With existing challenges, which would be further exacerbated by climate change, the agriculture sustainability with improved production and therefore food security, can be attained through identifying, developing, refining, and up-scaling and out-scaling the location specific climate change adaptation measures.

9.6 billion

Saurashtra, lies in the western part of Gujarat and looks like a land projection into the sea and is surrounded by the Arabian Sea from three sides. The climate in the region is warm with hot summers and cool winters which is quite different from the typical climate of the North Indian plains. The maximum temperature during summer shoots as high as >40 °C and minimum temperature during winter goes belwo 11 °C. The rainy season commences in the first fortnight of June and ends by mid of September with an average rainfall varying from 1358 mm (Junagadh) to 655 mm (Surendaranagar) (Sahu et al., 2010). Saurashtra is an agriculturally prosperous region and known for cultivation of commercial crops like groundnut, cotton, castor in *kharif* and cumin, coriander etc. in the *rabi* season. With surplus water in tubewells/wells many farmers also grow sesame and greengram as catch crops during summer. Saurashtra is also famous for growing delicious *kesar* mango in the areas surrounding Sasan Gir forest. Agriculture in the Saurashtra has been mainly dependent on rainfall until the supply of Narmada canal water in some areas, since preceding few years. However, Saurashtra is witnessing climate change anomalies, with increasing intensities, in the form of variations in the amount and distribution of rainfall, reduced number of cold days, and increase in annual minimum temperature, more particularly, over the last decade and so (Sahu 2008 and Sahu et al., 2010). This is affecting agriculture in the region in the form of crop failures due to mid-season droughts or terminal droughts during *kharif* season. Late sowing, in case of late arrival of monsoon, leads to decreased yield of *kharif* crops like groundnut or farmers have to resort to less remunerative short duration crops. Likewise, high temperatures during winter and summer affect productivity of wheat and coriander, and summer sesame and groundnut, respectively. Holding in perspective these problems, a one day workshop was organized on "Regional Climate Change Adaptations: Envisioning Resilience Building for Communities of Saurashtra" on 22nd March, 2016 on the occasion of World Water Day by ICAR-Directorate of Groundnut Research, Junagadh, Aga Khan Rural Support Program- India, and Coastal Salinity Prevention Cell. There were total 44 participants in the workshop consisting of representatives from 16 different NGOs working in Saurashtra; innovative farmers representing different regions of Saurashtra, Center for Climate Change and Sustainability Studies, TISS, Mumbai; and subject matter specialists from ICAR-Directorate of Groundnut Research, Junagadh and Junagadh Agricultural University, Junagadh (Annexure-1). The venue of the workshop was Conference Hall, ICAR-Directorate of Groundnut Research, Junagadh, Gujarat (India).

1.1 Objectives of the workshop

The main objectives of the workshop were to impart the basic understanding of climate change and variability, consequent impacts on agriculture, and identify potential climate change adaptation strategies for the region based on on-station research and experiences gathered from the field and prepare climate change adaptation guidelines with major focus on groundnut based cropping systems in the region.

1.2. Scope of guidelines

- A reference material to be used by the rural development organizations for promoting climate smart agricultural practices and building resilience of farming communities against the climate change related anomalies.

- To serve as a preliminary guiding document on climate change adaptation strategies in groundnut-based production systems for line departments, policy makers, students, etc.

2. Climate change: The science

It is wisely said that to solve a problem, first you must know and understand the problem. The preliminary discussion with the participants revealed that they have had a hazy picture about the climate change and had many biases on the subject largely due to the news emanating from the local media. Therefore, one of the objectives of the workshop was to make the representatives of rural development organizations and participating farmers aware about the realities of the problem of climate change. Climate change has happened in the past also and is a normal and natural process occurring in a cyclical manner due to changes in the planetary movements. As per the Milankovitch Cycle, there are four planetary movements viz., obliquity, eccentricity, axial precession, and apsidal precession, which cause a major shift in the climate over a period of 41000, 100000, 26,000 and 112000 years, respectively. But the current climate change is not normal and natural process, rather it is largely anthropogenic in nature(Hegerl, 2007).

Research over the past one century by scientific communities across the world has indicated that the alarming increase in the amount of different greenhouse gases (GHGs), which include carbon-di-oxide, methane, nitrous oxide, and water vapor in the atmosphere, has buttressed warming of the planet. It has also been discovered that there is a proportional change in the global temperature with the GHGs released in the atmosphere and has caused the planet to warm by 1°Celsius in the last one century and is still continuing (IPCC, 2014). Among the GHGs, the share of carbon-di-oxide in global warming is highest due to its higher proportional release. The greenhouse effect caused by such gases, is though, important to keep the planet congenial for living as in the absence of 'normal warming' earth will become a cold planet. The excess of anything is detrimental so is the case with GHGs. The CO_2 levels today stands at 402 ppm (IPCC, 2014) and is further increasing at an alarming rate. Figure 1 explains how the release of CO_2 by various anthropogenic activities determines its concentration levels in the atmosphere. Figure 2 shows the rate of increment of different GHGs since 0 AD.

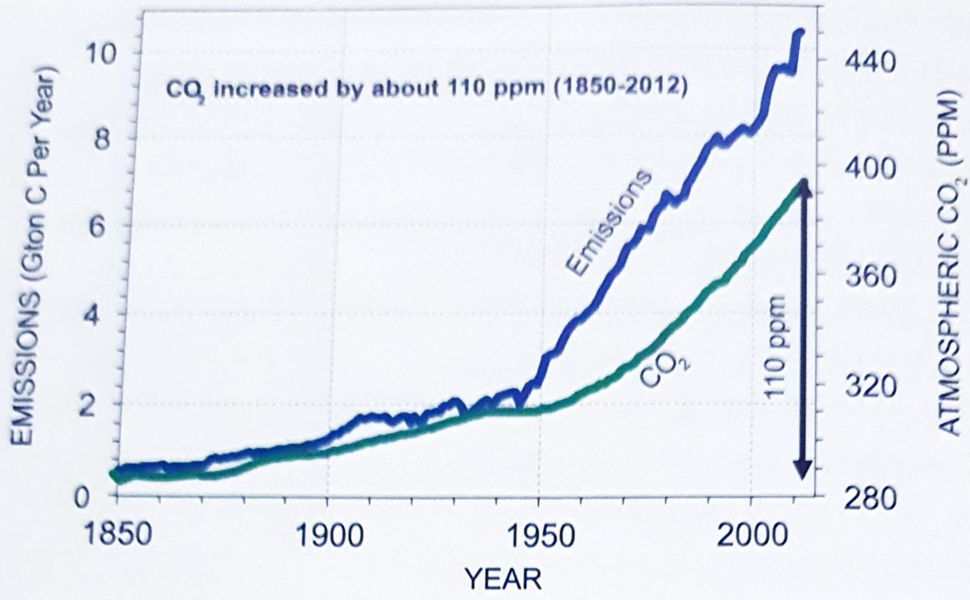

Figure 1: Relationship of global carbon emissions and CO2 concentrations on earth (data from CDIAc and from Etheridge et al., 1998)

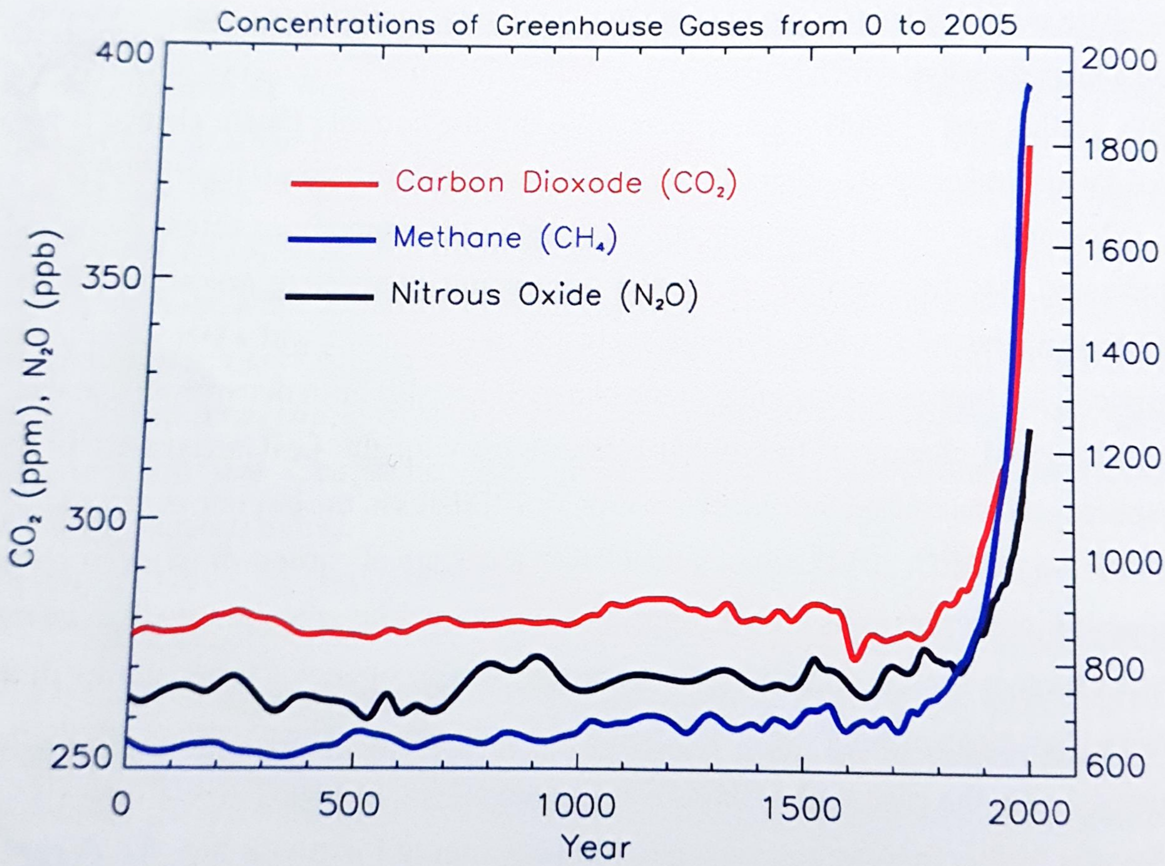

Figure 2: Concentration levels of different greenhouse gases: A trend over the past (Source: (IPCC, 2002)

3. Changes observed over the past

The unusual change in global temperature which has been occurring due to additional amount of GHGs, since the beginning of the industrial revolution, is having several deleterious consequences on planet earth. These consequences can be seen in a simplistic fashion as illustrated below in Fig 3:

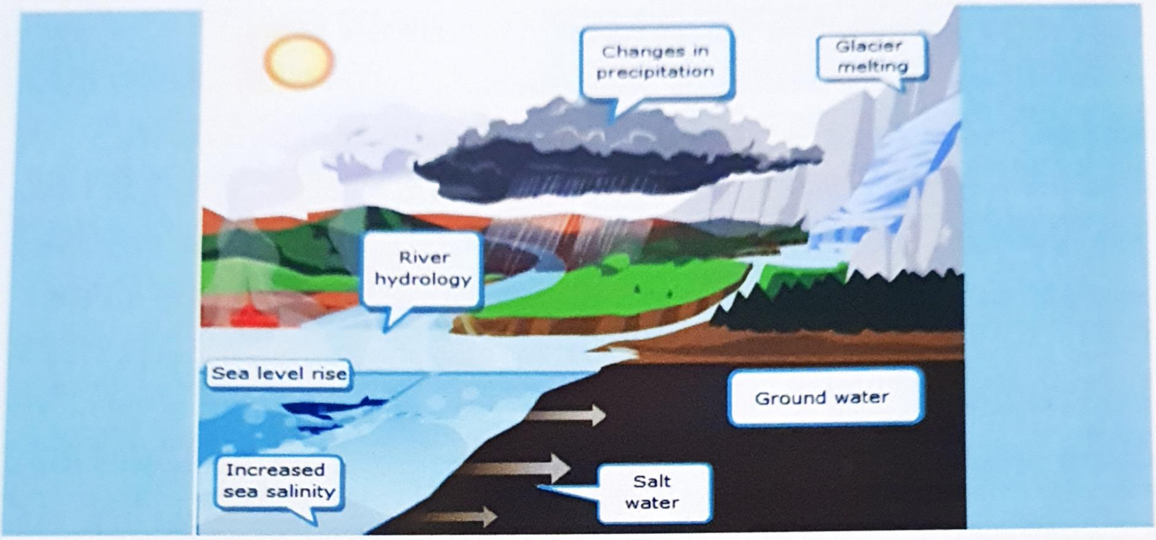

Figure 3: Different global phenomena which are getting affected by global warming (Source: FAO)

3.1 Changes in rainfall pattern

The impact of climate change on the precipitation is widely researched topic across the world. The analysis of long-term weather data and predictions of weather models has indicated that the overall impact on rainfall will be in the form of decrease in the number of rainy days, with a corresponding increase in rainfall intensity causing droughts and floods of more common occurrence. The Chennai disaster in 2015 triggered by the unprecedented heavy rains within a short span of time is one such example. During the recent years, changes in rainfall pattern have also been observed in the Saurashtra region. Such 'extreme rainfall events' which used to be normally isolated instances in the past could be more frequent in future. The rainfall seasonality index in Gujarat has increased from 0.216 (1932-41) to 3.416 (2002-2011) (Kumar et al., 2014). The higher the index, higher will be the distortions in rainfall. The changes in timing, frequency, and amount of rainfall would adversely affect agriculture for worse.

3.2 Rise in sea level:

The rising global temperatures due to release of GHGs have a clear impact on the polar ice in the two zeniths of hemispheres in South and North. It is causing melting of polar ice, adding more water to the oceans. Along with the polar ice, the glaciers have also been observed starkly to be affected, thus releasing more water in the streams and rivers which ultimately pour into the oceans. Also, enhanced heating of water in the oceans also leads to ocean expansion. These phenomena are reportedly causing a rise in sea water levels and thus leading to inundation in coastal areas which is causing greater distress in low lying regions. This problem is expected to accentuate in the near future with devastating effects on island nations and coastal regions which may force many people to migrate. Over the period 1901 to 2010, global mean sea level rose by 0.19 (0.17 to 0.21 m) (IPCC, 2014). Hence, the sea level has risen progressively due to pouring of melted water from polar ice sheets and glaciers, and thermal expansion of the oceans caused by planetary warming (NRC, 2011). The rise in sea levels will cause submergence of land in coastal areas. Since Saurashtra is surrounded by sea from three sides and has a long coastline of 865 km, the sea level rise will become a matter of concern for communities residing along the coastline.

3.3 Heat waves

As an obvious result of global warming caused by GHGs, heat waves have begun to get amplified across most of the globe. The heat waves are likely to affect the crops of all kinds, particularly *rabi* and summer crops causing more of terminal stress. The incidences of the shift in the sowing of wheat crop beyond 15th November have been reported by many farmers and NGOs in the Saurashtra region.

3.4 Saline water ingression:

The rise in sea levels due to global warming will accentuate the already manifesting problem of salinity ingression in coastal areas, making shortage of quality water for drinking and irrigation purposes. The effect is imminent not only on crops and human, but also on the cattle as ground water is the only reliable source for drinking, irrigation and producing green fodder during dry months in the coastal areas. With ground water turning saline, there will be escalated issues of water shortage along the coast.

4. How climate change will affect crops?

The climate change is likely to affect crops throughout the growth and development stages due to increased temperature, moisture stress, heat waves, the possible emergence of new major insect-pests and diseases etc.

4.1 Effects on germination: Crop seeds germinate in a particular range of temperature. Increase in soil temperature by global warming will adversely affect germination and therefore, crop stand. For example, groundnut which is a major crop of Saurashtra has an optimum temperature of 25-30°C for germination. Increase in temperature beyond this range during the sowing time is likely to affect crop germination adversely.

4.2 Effects on growth and development: Temperature higher than the optimum range adversely affects growth and development of plants due to harmful effects on plant metabolic activities. The rate of photosynthesis may get more sluggish as the temperature increases due to closure of stomata. Besides, higher temperature enhances the rate of evapotranspiration causing moisture stress in plants under dryland situations. Also, at higher temperature the dry matter accumulation becomes less.

4.3 Effects on reproduction: Higher temperature has harmful effects on flowering, pollination, fertilization, fruit setting, and maturation in different crops. Higher temperatures may increase flower and fruit dropping in some crops and drying of stigma and pollens in others.

4.4 Effects on crop duration: The higher temperature will hasten the maturity, thereby, reducing the total duration of the crop. This will result in lower dry matter accumulation and lower yield.

4.5 Effects on crop productivity: Lower plant stand due to poor germination, low dry matter accumulation, adverse effects on flowering and fruiting, reduced crop duration caused by an increase in temperature will ultimately reduce the crop yield. Still, in case of C3 plants the enhanced level of CO_2 may result in higher rate of photosynthesis and increase yield. But such effects of CO_2 fertilization may get negated due to higher temperature and moisture stress caused by climate change.

5. The region of reference

The discussions during the brainstorming Workshop were mainly focused to climate change and adaptation strategies for Saurashtra region of Gujarat. Saurashtra is divided into two agro-climatic zones and covers the districts of Rajkot, Jamnagar, Junagadh, Bhavnagar, Porbandar, Amreli, Surendranagar, Devbhoomi Dwarka, Morbi, Gir Somnath and Botad. Saurashtra accounts for about 865 km out of the total coastline of 7517 kms in India. The major crops which are cultivated in Saurashtra are groundnut, cotton, and castor in *kharif* and wheat, coriander, cumin, chickpea in the *rabi* season. Bajra is a staple food for many people in the region, and grown across the three seasons for household use. The annual rainfall in this region varies from 1358 mm (Junagadh) to 655 mm (Surendaranagar) (Sahu et al., 2010). As such drought on every third year is a common feature in this region. Likewise, mid- and late-season droughts are common which severely affect crop production in the region. Most of the soils in Saurashtra region are shallow (25-50 cm) to moderately shallow (50 to 75 cm) from crop production point of view. The majority of soils in Saurashtra region are highly calcareous and clayey while some scattered areas also have loamy soils. The coastline is very prone to sea water ingression leading to water and soil salinity, drought, and cyclones.

6. Climate Change related impacts likely to strike the region

The major impacts due to climate change which have already started to affect agriculture in the region and their severity is expected to increase in the near future are discussed in brief below:

1. Decrease in the number of cold days and minimum temperature during winter, which affect productivity of *rabi* crops, especially wheat, as observed since last few years.
2. Increase in summer temperature and heat waves across the region, which is detrimental not only to crops and animals but also to human beings.
3. Irregular rainfall with high intensities but less frequency. This causes both floods and droughts damaging crops.
4. Saline water ingression which is expected to escalate in the near future in coastal areas of Saurashtra with rise in sea level.

5. Accelerated soil erosion due to high intensity rain storms, and decrease in soil organic matter due to increase in temperature.
6. Higher incidences of insect-pests and disease outbreaks. White grub, which is not a major insect-pest in the region, has caused severe crop losses, particularly in groundnut during *kharif*, 2016.
7. Unseasonal rains and cyclones which are being observed more frequently in the recent past.
8. Scarcity of water for irrigation and drinking purpose.
9. Ecosystem stresses due to soil degradation, water scarcity, and loss of vegetation caused by climate change and variability.

7. What can be done to overcome the impacts of Climate Change related anomalies? The possible adaptation measures:

While addressing the problem of Climate Change at the global level, there is need to address both mitigation and adaptation options. **Mitigation** deals with the causes of the problem, which involves reducing emission of GHGs in the atmosphere and sequestering atmospheric carbon into soil (FAO, 2014). Mitigating climate change is important for long-term solution of the problem at the global level. **Adaptation** measures deal with the impacts of climate change on crops, livestock, fisheries, vegetation etc. There are a number of strategies which can be engaged to overcome the challenges and adapt to climate change related anomalies. The possible adaptation strategies, for resilient groundnut based production systems in Saurashtra, identified during the brainstorming workshop are discussed below:

7.1 Water Resource Management

7.1.1 Water harvesting:

The studies indicate that most of the rainfall will occur in the form of high intensity but less frequent storms. This would lead to loss of rain water from the field as runoff and cause soil erosion and flooding in downstream areas until the measures to harvest rain water are not in place. This warrants to give greater emphasis on the need to conserve and store run-off water through both *in-situ* and *ex-situ* methods. Rain water can be retained in the field itself through measures like suitable land configuration, e.g. broad bed and furrows, ridge and furrows (Figure 4), conservation furrows; addition of organic matter for increasing water holding capacity of soil, location specific adoption of Conservation Agriculture etc. Sub-soiling would help improve infiltration and percolation of water through the soil. Making conservation furrows can help enhance productive use of runoff water.

Similarly, rain water can be stored through *ex-situ* measures like farm ponds, open wells, check dams etc. (Figure 5). Runoff water can also be used to recharge wells and low depth bore wells (Figure 6). The rain water harvesting programmes may be taken up extensively by government agencies and developmental organizations with the active support of local communities and SHGs.

Figure 4: Broad bed and furrow system (right), and ridge and furrow system (left).

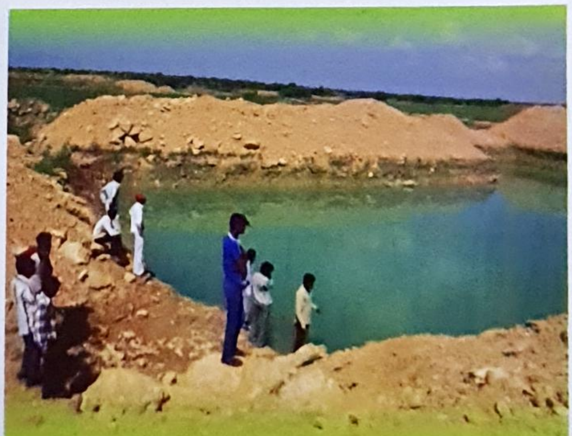

Figure 5: A check dam (left), and a farm pond in Gaga village in Devbhumi Dwarka district.

Sub-soiling: Now a days greater reliance on heavy machinery like tractors and combine harvesters for various field operations, and continuous tillage at a fixed depth over a period of time leads to formation of hard pan below the plough zone. This obstructs percolation of rain water into deeper soil layers and rather favours loss of rainwater as runoff instead of its productive use by crops in the field. Hard pan also obstructs deeper penetration of plant roots, thus depriving plants of water and nutrients from deep layers. Hence, sub-soiling, once in 4-5 years, would help break hard pan and enhance water infiltration and percolation of water down through the soil profile. Breaking of hard pan also allows roots to penetrate deeper into the soil to cater water and nutrients (Figure 7).

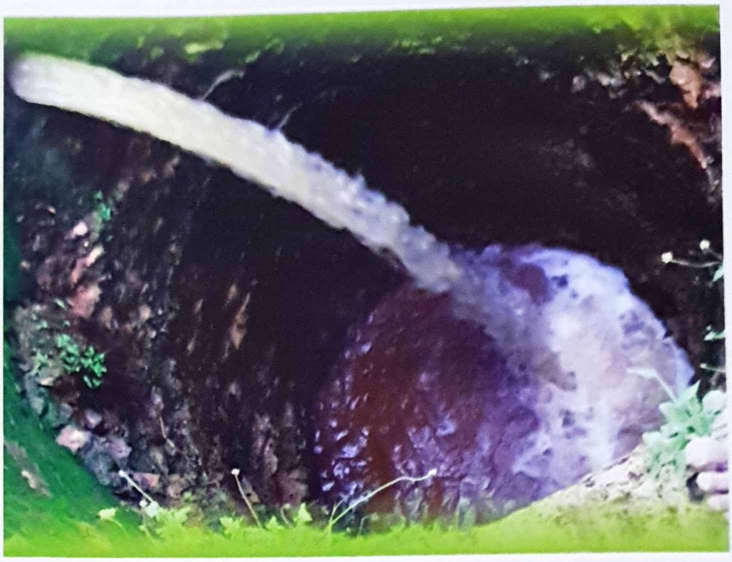

Figure 6: Recharging an open well with runoff water.

Figure 7: Sub-soiling for improving rain water infiltration.

7.1.2 Moisture conservation: The stored soil moisture is lost through the processes of evaporation, transpiration by plants, and deep percolation. Stored moisture in soil can be conserved by adopting the following practices:

Inter-culturing: Frequent inter-culturing helps reduce moisture losses through evaporation and weeds (Figure 8).

Mulching: Use of organic waste material as mulch helps check evaporation losses of conserved soil-moisture (Figure 8)

Timely weed control: Weeds compete more for water compared to nutrients and space under dryland situations, therefore, timely weed control would help prolong the soil moisture supply for crop plants (Figure 8).

Spray of growth retardants and anti-transpirants: In Saurashtra, particularly in coastal areas, cloudiness promotes excessive vegetative growth in groundnut during *kharif* season. This makes peg entry into soil difficult and also leads to higher loss of stored soil moisture through transpiration causing moisture stress during critical stages of pod development and maturity. Spray of growth retardants prevents excessive growth and help reduce yield losses due to moisture stress. Likewise, anti-transpirants can be sprayed to reduce transpiration losses.

Application of organic manures and retention of crop residues: There is need to promote retention of crop residues in field itself instead of burning which is rampant in Saurashtra. Similarly, cow dung which is available in limited amount, should be applied in field rather than using as fuel. Application of organic matter in soil improves rain water infiltration, water holding capacity of soil and reduce evaporation loss of stored soil moisture.

Figure 8: Different moisture conservation practices: Interculturing, timely weeding, spray of growth retardants, application of organic manures, mulching, and live fencing with local herbs (clockwise from top left).

Planting of bund holders and hedge crops: Bund holders such as fodder grasses e.g. Napier grass, and planting rows of pigeonpea, *Gliricidia*, cactus, etc. on farm bunds depending on suitability in the region would help to reduce evapo-transpiration losses caused by strong gusty winds (Figure 8). Similarly, windbreaks can be planted along the field boundaries to reduce wind speed in arid and semi-arid regions.

7.1.3 Precision in water application: There are many practices which farmers need to discontinue so as better adapt to climate change related anomalies. One such practice is injudicious use of irrigation water. Precision in irrigation water application is important to maximize productive use of harvested rainwater.

Use of plastic pipes for conveying water: Farmers generally use *kachcha* earthen channels for carrying water for long distances from source to the field. It causes loss of water through seepage and evaporation during conveyance. The use of PVC pipes for carrying water helps reduce losses of water during conveyance, and it is being used by several farmers since last 2-3 years in the Saurashtra (Figure 9).

Micro irrigation: Surface irrigation methods have low water use efficiency due to high water losses caused by seepage and evaporation. Besides, when water having high TDS is applied through surface methods leads to salt injury to plants. Hence, rain water stored in farm ponds, open wells, and bore wells should be judiciously applied using micro irrigation methods for giving life-saving irrigations. Sprinkler irrigation can be used in *kharif* groundnut for life saving irrigation (Figure 9) while drip irrigation should be widely promoted in summer groundnut and wide spaced crops like cotton (Figure 10), sugarcane, castor etc. Furrow irrigation to establish cotton crop is highly helpful to save irrigation water during pre-monsoon period when water is available in limited amount (Figure 10).

Figure 9: Use of PVC pipeline for water conveyance (left) and sprinkler irrigation to relieve mid-season moisture stress in groundnut (right).

Subsurface irrigation: Sub surface irrigation can be promoted as a water saving technique, especially in coastal areas where clogging of emitters in drip system is a serious problem.


Figure 10: Furrow irrigation (left) and drip irrigation (right) in cotton

7.2 Soil Management

The UN has recognized the fact, by stating *"Right now, **our soils**, freshwater, oceans, forests, and biodiversity are being rapidly degraded"* (UN 2015), that the resources on which we rely for food production are vulnerable and disposed to degradation. Among these resources, one resource that is **'soil'** has been belittled as dirt or considered just one physical raw material in the current industrial paradigm of agriculture. Such notion would lead us to our own peril. It takes about 1000 years at normal climatic pace to form a 2.5 cm thick layer of fertile soil. The top soil degradation mainly occurs by the agents such as water and wind. Western Ghats, coastal, and north eastern hill region are reported to lose 20-40 tons of soil per hectare per year due to soil erosion (NBSS&LUP, 2005; ICAR, 2013 and Bhattacharyya et a., 2015). The soil erosion not only affects the land by taking away top soil rich with nutrients, but also leads to siltation of water bodies downstream leading to localized floods and degradation of coastline (NBSS&LUP, 2005). As mentioned earlier, the ramifications of short, intense rains are likely to be seen in the form of losses of top fertile soil with water splash. Sheet erosion is more likely to happen in a tilled land than on a covered soil. Figure 11 shows an unprotected field eroded by flood waters. As soil is pivotal to all forms of life on the planet, it is important to protect the soil from being degraded.

Figure 11: A higly eroded field by flood waters in Amreli district (Photo couretsy: T.C. Poonia)

A healthy soil would better help to adapt to climate change impacts on production systems. The potential measures identified for soil management in Saurashtra region are:

7.2.1 Farm bunding: Making bunds around fields will ensure preventing entry of flood waters into the field and protect the soil from water erosion. Bunds will also prevent dumping of weed seeds coming along with flood waters.

7.2.2 Leveling: Unleveled fields are more vulnerable to erosion. Likewise, lack of proper leveling leads to lower irrigation water use efficiency. Hence, proper leveling of fields is essential for soil and water conservation.

7.2.3 Recycling of organic waste: Organic waste generated on the farm such as straw, weed biomass, tree leaves, cow dung, biogas slurry, household waste etc. should be recycled to prepare compost (Figure 12). Compost prepared from farm wastes can partially substitute the requirement of FYM which is short in supply due to mechanization. Making compost will not only help to do away with the practice of burning of organic wastes by farmers, but also improve soil health and moisture conservation in the soil.

Figure 12: Compost making, using farm organic waste and biogas slurry

7.2.4. Conservation Agriculture:

The current paradigm of agriculture needs to be re-thought as intensive tillage based agriculture not only speeds up the loss of soil organic matter (SOM) but also increases vulnerability of soils to erosion (Jat et al., 2012). According to FAO Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment (FAO, 2014). CA is characterized by three linked principles, namely: zero or minimal mechanical soil disturbance, maintenance of a permanent organic mulch on the soil by crop residues, crops and cover crops; and diversification of crop species grown in sequence or associations through rotations or, in case of perennial crops, associations of plants, including a balanced mix of legume and non legume crops (Figure 13). CA has been reported to protect soil against water and wind erosion, help retain more moisture in soil by increasing infiltration, water holding capacity of soil, and checking evaporation losses and thus, reducing irrigation water needs (Jat *et al.*, 2014). In CA the mulch cover helps reduce soil erosion, allow water to stand on soil surface for more time, thus facilitating more water to infiltrate and percolate down to recharge underground aquifers rather than losing as runoff (Hobbs et al., 2008). CA also promotes biodiversity through intercropping, growing cover crops, and rotation of crops in contrast to the monocultures, and minimum mechanical soil disturbance. Under CA soil health enhances due to increase in SOC which is in decline due to frequent tillage, lower availability of farm yard manure due to mechanization of farming and crop residue burning (IARI, 2012 and Wehrmann and Johannes, 1965). CA systems are practiced globally on about 157 M ha, corresponding to about 11% of field cropland in the world (Kassam et al., 2015). Paraguay is the leading country to adopt CA on a large scale with over 52 per cent of its cultivable land under CA, followed by Australia, Canada, and the USA.

7.3 Crop management

There are several climate smart crop management practices which farmers can adopt to make production systems resilient to the impacts of climate change and variability. These are discussed briefly below:

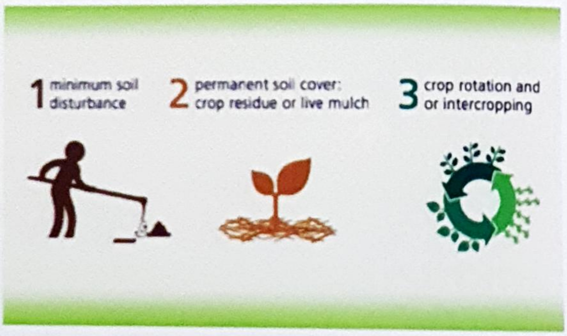

Figure 13: Schematic illustration of three basic principles of Conservation Agriculture (Source: FAO, 2014)

7.3.1 Strategic shifting in crops

The factors like high labour demand, fluctuations in market prices, high water requirement, and low returns from crops like wheat and cotton have forced farmers to think about less risky, high remunerative and low water requiring crops like coriander, cumin, *etc.* in rotation with groundnut in the Saurashtra region (Figure 14). Some farmers are shifting to unconventional crops like watermelon in the region, but more so in the Kutch region. Other crops such as Safflower which can grow relatively well in rainfed and saline conditions and is also less damaged by wild animals can also be grown.

7.3.2 Crop Diversification: Monoculture, which is a common phenomenon among the farmers of Saurashtra, needs to be changed with diversified cropping systems. Relying on single crop increases chances of vulnerability to climatic variabilities, insect-pests, diseases, and price fluctuations. Contrary to this, diversified systems, provide some sort of insurance against crop failure due to climate variabilities, insect-pests, diseases *etc*. Crop diversification also promotes agro-biodiversity, enriches soil, attracts friendly insects, and is instrumental in providing a balanced diet for farm families. In *kharif* 2015, *Bt*-cotton was severely damaged by pink bollworm and whitefly in Saurashtra. The farmers who relaycropped mungbean in cotton earned better returns compared to those who preferred sole cotton crop. Likewise, due to low rainfall in 2015, many farmers got lower yield of groundnut and also could not raise *rabi* crops due to non-availability of groundwater but, farmers who relaycropped pigeonpea in groundnut fetched handsome economic returns. The crop diversification can be promoted in the region through practices like inter-croping, relay-croping, mixed cropping, border cropping, by growing catch crops *etc*.

Figure 14: A booming crop of coriander which is preferred over wheat under low water availability conditions in the region

7.3.3 Intercropping: Intercropping provides multiple benefits such as enriching soil with nitrogen when legumes are intercropped, additional income with small amount of extra inputs, alternate host for beneficial insects such as *Chrysoperla* in maize *etc*. The selection of crops, spacing, and variety may vary from region to region. Some of the common intercropping systems in the Saurashtra region are: cotton+groundut/mungbean/urdbean/cowpea, groundnut+maize/pigeonpea, castor+groundnut/mungbean/urdbean, wheat+chilly/chickpea etc (Figure 15).

Figure 15: Groundnut based intercropping systems in Saurashtra: groundnut+pigeonpea, groundnut+castor, groundnut+maize and groundnut+cotton (clockwise from top left).

7.3.4. Strategic relay cropping: Strategic relay cropping of pigeonpea in groundnut is being adapted as one of the major climate change adaptation strategies in this part of the country. After final inter-culturing and earthing up operation, about 40-45 days after sowing of groundnut, relay crop of pigeonpea is sown after every two or three rows of groundnut with bullock drawn seed drill (Figure 16). Relay sowing of pigeonpea by this time has minimum adverse effects on growth and productivity of the main crop of groundnut. The fate of relay crop is sometimes decided by the availability of ground water in wells/bore wells at the end of rainy season. If ground water is sufficiently available for raising more remunerative *rabi* crops like coriander, wheat, *etc*., farmers plow down the relay crop of pigeonpea as green manure crop and prepare the field for sowing of *rabi* crops. This helps improve fertility of the soil as the availability of FYM has declined drastically since last few decades. Contrary to this, if ground water is not sufficient to raise *rabi* crops, farmers do allow relay crop of pigeonpea to grow till grain maturity. The relay crop of pigeonpea has rewarded farmers richly during 2015-16 with yield levels as high as 2000 kg/ha and net monetary benefits varying from Rs. 40,000 to 70,000/ha.

7.3.5 Border cropping: This intervention can provide multiple benefits like protecting the main crop from heat waves and strong winds, e.g. castor and pigeonpea can be planted as border crops for groundnut in the region. Border crop can also be used as fodder crop after harvest of the main crop (Figure 17). Border crops also save the main crop from insect damage, e.g. maize, sunflower, okra, sorghum, pigeon pea in cotton. Sunflower is an efficient trap crop for the American bollworm. Besides, border crops protect main crop from damage by stray and wild animals.

7.3.6 Mixed cropping: Mixed cropping of groundnut with maize is done many a time to reap multiple benefits such as: protecting main crop from wind stroke, getting fodder for cattle, attracting friendly insects such as Chrysoperla, adding variety to farm family food basket *etc*. (Figure 18).

7.3.7 Catch crops: In case of availability of ground water, catch crops like sesame and mungbean can be taken to get extra income and protect soil from wind erosion during the summer (Fig. 19). Such crops can also be taken in case of late arrival of monsoon rains during *kharif*.

Figure 16: Relay cropping of pigeonpea in groundnut in 2:1 (left) and 3:1 (right) ratio

Figure 17: Border-cum-fodder crop of maize around the main crop of onion

Figure 18: Mixed cropping of maize in the main crop of groundnut

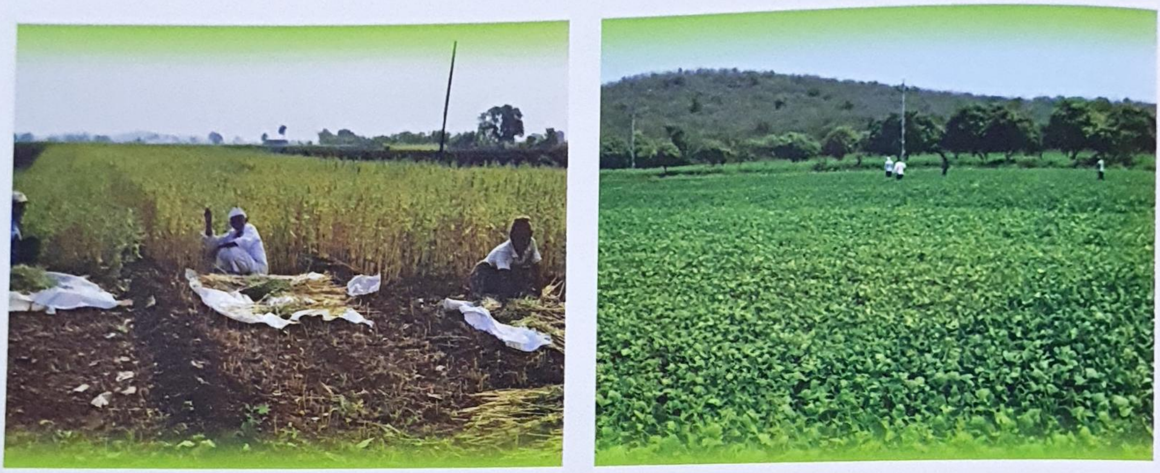

Figure 19: Summer catch crops: Harvesting of sesame (left) and field view of mungbean (right)

Figure 20: Paired row cropping of spanish groundnut (left) and sesame (right)

Figure 21: Cotton seedling for transplanting.

7.3.8 Suitable crop geometry:

Crop geometry should be such that it allows mechanical inter-culturing for timely weed control. Paired row sowing in groundnut is helpful to ensure required plant population and perform inter-culturing with mini tractor or bullock drawn implements (Figure 20).

7.3.9 Transplanting of field crops:

In case of delayed onset of monsoon, transplanting of pigeonpea will help to reduce yield losses due to late sowing. Similarly, transplanting of cotton seedling raised in polythene bags, can be done to avoid yield penalties due to lack of timely sowing (Figure 21).

7.3.10 Checking germination percentage:

Seed viability is a major issue in crops like groundnut. Therefore, farmers need to be encouraged to check gemination percentage by taking a random sample from seed lot, preferably one week before sowing. This would help adjusting seed rate to ensure optimum plant population in the field.

7.3.11 Integrated pest and disease management (IPM/IDM)

The problem of crop damage by insect-pest and pathogens may accentuate with climate change. Relying on any one method would not suffice to achieve satisfactory insect-pest and disease control. Therefore, integrated pest/disease management through amalgamation of different methods-physical, mechanical, cultural, biological, and chemical- should be stressed upon. Some bio-products such as *Trichoderma*, *Beuvaria bassian*, *Neem* oil *etc*. have proved to be very effective in managing insect-pests and diseases in Saurashtra region and should be outscaled in the region.

7.4 Agro-forestry measures

As field crops are relatively more vulnerable to rainfall and temperature variations as compared to trees and livestock, there is a need to give adequate emphasis

Figure 22: Some Agroforestry components for Saurashtra: Fodder maize in mango orchard, timber trees, goat, and cattle with poultry birds (clockwise from top left).

on Agro-forestry systems for imparting resilience to production systems in the region. Tree species like drumstick (*Moringa*), coconut, custard apple, mango, jamun *etc*. can be planted around fields. Besides, dairy cattle, sheep and goat, poultry, piggery, sericulture etc. should also be promoted based on suitability and resource availability with the farmers (Figure 22). Trees around fields also provide protection to field crops from warm gusty winds thus, help reduce moisture loss through evapotranspiration and reduce chances of moisture and heat stress in crops.

7.5 Farm mechanization:

With climate change crop losses are likely to increase due to unseasonal rains and cyclones. Therefore, it would be important to perform field operations timely, particularly harvesting. Crop losses are observed in groundnut and wheat crops many a

Figure 23: Groundnut digger (left) and combine harvester (right) in operation

times in Saurashtra due to late season rain. Promotion of mechanical harvesting will help save produce from rain and cyclones (Figure 23) Similarly, mechanical inter-culturing helps in timely weeding during *kharif* when incessant rains make weeding difficult .

7.6 Coping with salinity:

Salinity tolerant crops like barley, sugar-beet, cotton, *etc.* may be preferred in salinity affected areas. Groundnut is relatively tolerant to low salinity water. Some horticulture plants such as gunda (*Cordia dichotoma*), ber, coconut, kharik, *etc.* may also be promoted in the region. Fresh rain water in rivers/rivulets coming from upstream areas can be stored in ponds and tanks for irrigation and drinking purpose in coastal areas. A canal network connecting rivers and rivulets in coastal areas is good step towards supplying sweet rain water for drinking and irrigation needs in salinity affected coastal areas. A dugout canal of 10 m depth and 3-4 meter width linking rivers and rivulets has been constructed by the government of Gujarat along the coastline of Mangrol block to supply fresh rainwater in the

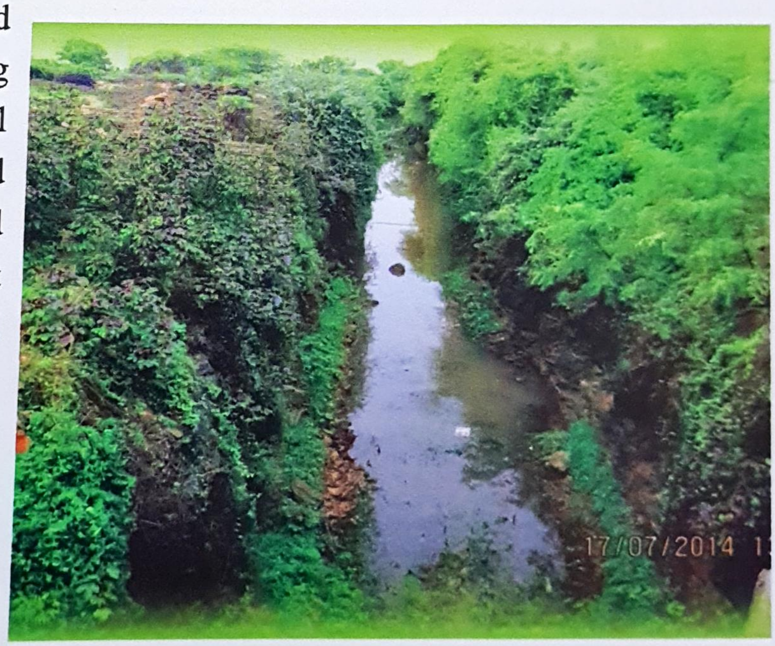

Figure 24: A dugout canal in Mangrol block to connect rivers and rivulets to supply rainwater in coastal areas.

coastal areas (Figure 24). This intervention has greatly helped in coping with salinity and ,therefore, can be replicated along all the coastal areas of Saurashtra. Locals have also reported that it has also helped to raise ground water levels and prevent saline water ingression in the region.

7.7 Seed Bank

Farmers generally face difficulty in storing seed for next season due to damage caused by storage pests and loss of viability due to inappropriate storage conditions. Therefore, farmers have to mostly rely on the local market for purchasing seed at exorbitantly high prices. Sometimes, due to poor germination farmers need to do re-sowing and they have to rush to market for seed under emergency situations. The crop failure may be more common with climate change, as also seen in previous years in Mangrol block. The time factor -availability of seed on right time - can push the farmers towards exploitation by input suppliers. Therefore, to meet the seed requirement of farmers, particularly small and marginal farmers, community seed banks should be established. Seed banks are pivotal for seed supply in a short period of time at relatively cheaper rates. Seed banks can be managed with the support of village level institutions like producers' group and *Gram Panchayats*.

7.8 Real time information

The cyclone Nilofar during October, 2014 came when the groundnut crop was just harvested and kept in the fields for sun drying in Saurashtra. But, the timely information from IMD helped the farmer to take necessary precautionary measures to save the produce. The frequency and intensity of inclement weather conditions such as cyclones, unseasonal rains, heat waves, stormy winds, hailstorms, *etc*. may increase with climate change; and therefore, providing real time information at village level would be crucial. Real time information not only about weather anomalies, but also the biotic stresses such as the emergence of a particular insect-pest or disease outbreak need to be provided to the farmers. It is imperative that real time information systems are made more user-friendly. Mobile based advisories may be more helpful for farmers. For the real time information system, models such as mKRISHI® can help to a great extent to the farmers.

7.9 Strengthening community based institutions

Large farmers may be better able to adapt to the challenges posed by climate change, however, small-holders will be among the most vulnerable communities due to their limited access to resources. Strengthening community based organizations like seed bank, fodder bank, credit lines, cooperatives for input supply would greatly enhance the capacity of small and marginal farmers to cope with climate change related variabilities. Similarly, communities can unite together in creating community assets like water harvesting structures, tree plantation as wind barriers and supply of fuel wood, small agro- processing units for value addition *etc*.

7.10 Insurance schemes

As the risk factor in crop production will increase with climate change due to greater possibilities of crop losses caused by factors like-droughts and floods, insect-pest and disease infestations, heat waves, *etc*., therefore, it would be imperative to provide a sort of cushion in the form of insurance to farmers. The newly launched *Pradhanmantri Fasal BimaYojana* is a welcome step in this direction by government.

7.11 Platforms for knowledge sharing

Experiences of innovative farmers on climate change adaptation strategies can be shared with fellow farmers through knowledge sharing platforms. Organization of *kisan melas*, field schools (Fig. 25), e-*choupals*, *etc*. on a regular basis can provide platforms for exchange of knowledge among the farmers. Besides, exclusive TV channels and FM radio dedicated to agriculture can be launched in vernaculars where innovative farmers can be invited to share their experiences in the local dialects.

Figure 25: Discussion between experts and growers during a field school in Keshod taluk of Junagadh district (left) and participants of a field school organized in Malya-Hatina region of Junagadh district of Gujarat.

Summing Up

Climate change is clear more then ever and its impacts on agriculture are increasingly getting reflected in different parts of the globe in the form of abnormal rainfall pattern, increase in temperature, reduced number of cold days, heat waves, *etc*. Such climate variabilities are leading to partial or complete crop failures threatening livelihood of millions of smallholders. Hence, there is a need to identify, refine, and develop region specific climate change adaptation technologies for different regions. Saurashtra is also not an exception as the climate variability is affecting production of groundnut and other crops in the region. Water harvesting and conservation through different *in-situ* and *ex-situ* practices should remain at the center of any climate change adaptation strategy. Giving life saving irrigations through micro-irrigation methods is important for judicious use of stored rain water. Soil moisture can be conserved by checking ET losses through frequent shallow interculturing, mulching, timely weed control, live fencing, and spray of anti-transpirants and growth regulators, *etc*. Soil conservation and fertility management need to be prioritized as healthy soils are basic for sustained high yields under changing climatic conditions. Protecting soils against water and wind led erosion through measures like bunding, leveling, mulching, *etc*. and enriching fertility through recycling of organic wastes needs to be promoted. Conservation Agriculture, which involves a paradigm shift in production system needs to be promoted actively. Crop diversification, through practices like intercropping, realy cropping, mixed cropping, border cropping, catch cropping, and Agroforestry systems need to be promoted to provide insurance against inclement weather. Changes in crop management like selection of suitable crops and varieties, proper seed rate, crop geometry, transplanting of crops, farm mechanization *etc*. are required to face the challenges posed by climate change. Salinity management, through a range of practices, is important for livelihood protection particularly in the coastal areas. Besides, real time information is required for timely action at the level of farmers to save crops. Government needs to have proper policies in place to help adapt to climate change through providing incentives for setting up of seed banks, strengthening community based organizations, and implementation of agriculture insurance schemes.

Important web links

http://www.climate.nasa.gov/

http://www.fao.org/climate-change/en/

http://www.climatechange.ifpri.info/

http://www.sri.cals.cornell.edu/

http://www.ccafs-climate.org/

http://www.foodtank.com/section/climate-change

http://www.nicra-icar.in/nicrarevised/

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