# Summary


## Background

It is evident that the climate change and variability is affecting human lives in several ways. One of the important effects is seen on agricultural sector. This is more prominent in country like India where, a substantial portion of its population depend on agricultural economy. Further it increases the risk for small and marginal farmers as well as agricultural labors as their coping capacity is limited. Therefore, it is important to study this effect at regional level.

Methodologically, the study is focused on intensive primary field survey to have a micro level insight of socio-economic vulnerability of farmers. The sample size of 1297 farmers and farm workers are selected scientifically to have widespread representation of geographical extent of whole Gujarat State. An in-depth questionnaire was prepared to understand the aspects of socio- economic vulnerability at community level. The study used geo-tagging of field survey to have location-based analysis of vulnerability pattern. It used GIS techniques for mapping pattern of vulnerability. The study has carried out temporal NDVI mapping of the villages where such socio-economicvulnerability is higher. This has provided an idea of impact of socio- economic vulnerability on agricultural growth of backward regions. The study aimed to explore the regional model of Socio-economic vulnerability of agriculture community by quantifying indicators to derive vulnerability index.

## Objectives

Climatic variability poses a serious threat to agriculture sector as the sector ishighly volatile towards any change in climatic parameters. Gujarat agriculture has achieved significant growth in recent years. Nonetheless, thesectors report year to year fluctuation in agricultural production and particularly in the production of food grains. This indicates that the sectors have an inherent socio-economic vulnerability which does not allow it to withstand with climatic shocks and threats. The potential risk due to climatechange and variability does not depend only on climatic parameters but also varies as per the inherent vulnerability of the sector itself. It is, therefore, important to assess the socio-economic vulnerability of the sector for any serious contemplation of adaptation planning.

This study is conducted to identify the socio-economic indicators of vulnerability which leads agriculture sector prone to climatic variability in Gujarat. It was proposed to evaluate the determinants of Socio-economic vulnerability of the sector towards climatic variability.

The specific objectives are

1.To understand the social and economic aspects of vulnerability for farmers and agricultural labours.

2.To identify and measure the indicators of socio-economicvulnerability

3.To assess the regional disparity in the status of Socio-economicVulnerability of the sector

## Major existing research works reviewed

### International

Climate Change and agriculture have two ways relationship of cause and impact. Agriculture is one of the emitters for greenhouse gases. The agriculture practices are the main activities which contribute a major portion of methane and $NO_2$ emissions in atmosphere. At the same time climate change would have significant impact on the sector. Intergovernmental Panel on Climate Change observed that climate change implications such as increase in carbon dioxide, temperature, altered precipitation and increase in extreme events would have collective impact on growth of vegetation. (IPCC, 2007)

Due to climatic change, associated increase in temperatures, and increased variability of rainfall would considerably impact food production in adverse manner. Recent IPCC report and a few other global studies indicate a probability of 10 to 40% loss in crop production in India with increases in temperature by 2080 or 2100. (Rosenzweig *et al*., 1994; Parry *et al*. 2004; IPCC 2007) Although there is high uncertainty prevailing in predictions, there is a general consensus that climate change and variability will have significant impact on food security through the impact on plant's growth and yield. This will increase the socio-economic vulnerability of Agricultural sector towards climatic variability.

### National

Indian Network on Climate Change Assessment (INCCA) is a networkworking on climate change issues and negotiations at an international platform. INCCA also endorses the IPCC observation and quotes that "unless we adapt, there is a probability of 10-40% losses in crop production in India by 2080-2100 due to global warming". It further states that Droughts,

floods, tropical cyclones, heavy precipitation events, hot extremesand heat waves are known to negatively impact on agricultural production and farmers' livelihood. (INCCA, 2010 p.67) In short, it is now fact that Agricultural sector is prone to climatic variability and climate change.

## Identification of Research gap

The concept of socio-economic vulnerability of generally conceptualized internationally in the context of disaster or climate change risk. However, at micro level the vulnerability has more relevance to community and its development. (UNDP, 2017) Although there are efforts made to study micro level analysis of vulnerability for developed countries, they do not apply for developing countries. It is, therefore, important to study the vulnerability aspect at micro level in order to focus on bottom up approach. Micro level analysis of vulnerability provides an insight to regional disparity in adaptivecapacity of community to deal with external threat at state, national and international level. Further, the state and central intervention through welfare and sector specific schemes provides benefits to reach at certain extend depending on the socio-economic vulnerability of the target groups. Because of this, such schemes fail to target those who are geographically and socio-economically marginalized. Therefore, understanding the spatial pattern of vulnerability at micro level can provide a useful insight to policy making and programme implementation. Such an analysis will provide the way to deal with pockets of vulnerability and prepare those vulnerable communities to adapt and strengthen their livelihood in agricultural sector to cope up with any external climatic variability.

## Innovativeness in the proposed research

This research has focused on first-hand information thus reliable and accurate. The selection of sample from scientific sampling technique has provided representative sample size. At the same time, it has captured the diversity of socio- economic vulnerability within the state of Gujarat. The regional differences captured by this survey are useful for appropriate and efficient resource locations. At the same time, it has also documented the most vulnerable district case study which can be replicable to other areas with similar geographical characteristics.

The study has used Geo-tagging in the fields. Thus, it has provided a future scope to carry out pathways analysis for livelihood changes. The maps prepared by GIS software has provided an easy visual analysis of outcome. It can be easy for even laymen to understand and address

the issues of socio-economic vulnerability. Further taluka level temporal NDVI analysis has provided micro level planning with the help of remote sensing techniques. The use of Google Earth Engine for classification models of crops is new initiative in this study.

## Relevance of the proposed study for policy-making

This study has focused on regional disparities prevailing in the state in order to come out with strategic suggestions to deal with climatic variability. This would help planners and policy makers to implement the agricultural related schemes in an efficient manner. Inferences of the study are useful for making action plan to deal with climatic variability in Gujarat under climate change adaptation fund. Technically, this study has established methodology to use remote sensing and GIS software's for the academic fraternity. In addition to this, advanced remote sensing models and Google Earth Engine are used to identify and classify the crops at micro level.

The study aimed to explore the regional model of Socio-economic vulnerabilityof agriculture community by quantifying indicators to derive vulnerability index.
Such an exercise has been carried out at district level and therefore it is very useful for agricultural adaptation at district level planning. It would also help policy makers by an analysis of spatial disparities in prioritizing their interventions in agricultural development planning. The results are shown by maps for visual interpretation and planning in a simplified way which can be understood by nontechnical community also.

Further, the result of the project would help policymakers to prepare strategies for Adaptation planning. Adaptation is the principal way to deal with the impacts of a changing climate. It involves taking practical actions to manage risks from climate impacts, protect communities and strengthen the resilience of the economy. Much of the adaptation strategies which are carried out are reactive in nature but if we study the affected sector in advance then anticipatory adaptation can also be possible and that will be comparatively more effective.

## Limitation of the Study:

The study faced several problems during the field work due to COVID-19 Pandemic. It was tough to get response from the rural community as there were many restrictions and apprehension prevailing in the rural areas. This required lot of efforts to hire field workers for

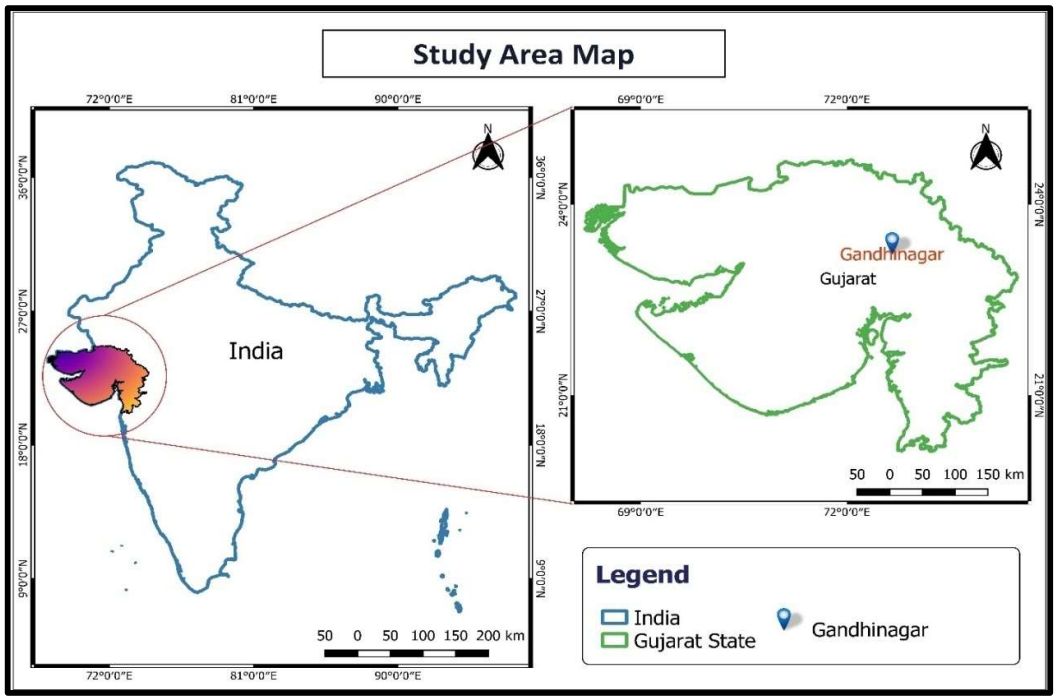
collecting reliable information. People did not respond very Many times, the data received from the various departments were not updated. Therefore, the study used whichever data were available.

## Study Area

Gujarat is one of the western states of India. It is located in the western part of India, between 20° 1' and 24° 7' North latitudes and between 68° 4' and 74° 4' East longitudes. Gujarat has the Arabian Sea on west and south Pakistan in the Northwest, while Madhya Pradesh in the east, Rajasthan in the North and Maharashtra in south.

The coastline of Gujarat is 1596 km long which makes it having the longest coastal line among Indian states. The state has diverse climatic condition.

Figure 1: Study Area Map




## Methodology:

### Methodology used for Agricultural productivity

The measurement of agricultural production in terms of input output cost is known as agricultural productivity. The study has used district wise area under major crops and their production. These data are available as secondary data and have been collected from directorate

of agriculture, government of Gujarat. In order to carry out temporal analysis, the time periods selected for the data were on decadal basis. However, the 1990-91 data had lot of discrepancies and therefore not used. In place of 1990-91 data, data of the year1995-96 were selected. The other selected data were for the years 2000-01, 2010-11 and the latest 2018-19. The data were validated by taking three years average to assess the normal distribution of the agricultural statistics.

Nineteen crops cultivated in the districts of Gujarat were selected carefully to assess the performance of agriculture productivity. They include Rice, Wheat, Jowar, Bajra, Sugarcane, Groundnut, Castor, Musturd, Cotton, Maize, Tobacoo, Fennel, Cumin, Chillie, Isabgul, Onion, Garlic, Banana, Ragi, Tur, Sesamum, Udad, Math, Mung and Potato.

In order to measure the agricultural productivity and efficiency, a composite productivity index suggested by S.S Bhatia (1967) has been used for the current study. According to Bhatia, per hectare yield expresses all the physical and human factors connected with the production of crops and the distribution of area under cultivation among various crops. Thus, a weighted average of yield productivity of all crops, would give a measure of composite agricultural productivity. In order to assess the agricultural productivity pattern, Choropleth maps have been prepared with the help of GIS technique. The study has used Q-GIS Software to create Choropleth maps to represent district wise agricultural productivity in Gujarat for the last three and half decades. The term agricultural productivity or efficiency is used to connote the degree to which the land is put to the best utilization. After calculating the agricultural productivities for four period of time, Choropleth maps have been prepared to show the variation in agricultural productivity among the districts of Gujarat. As the statistics of agricultural productivity did not show normal distribution, the classification of districts was made on the basis of equal interval classification.

**Methodology used for Vulnerability Analysis**

The study has considered long term variation in rainfall, minimum temperature, maximum temperature, and temperature range. Statistically relative variability during thirty years and interannual variability of three decades are calculated to understand the variation in climatic parameters. It is assumed here that higher the variability leads to higher exposure and increase the risk and vulnerability of agricultural sector towards climate change. Later, in order to derive Vulnerability Index, all the selected indicators were normalized with the following formula.

Normalized value for each Indicator = X -MIN/MIX – MIN

The indices of Exposure, Physical Sensitivity, Human Sensitivity and Adaptive Capacity were also derived and mapped.

**Methodology for Crop Identification and Classification**

In order to identify and classify the cropping pattern of the Botad district, CART and Random Forest Classifier model on the Google Earth Engine platform. Both the models have used NDVI, EVI and S2REP parameters from Sentinel 2, SAR VH polarization data from Sentinel 1 C-band, and GCP as input variables. The reason for the selection of Botad district as a case study is mainly because the district has performed the lowest agricultural productivity in the state for the last four decades. Therefore, the farm community in this district is highly vulnerable towards any climatic risk. This chapter focuses on identification, classification, and prediction of crop productivity to understand the dynamics of low productivity.

Sentinel 2 data is used to calculate the indices like NDVI, EVI, and S2REP, and Sentinel 1 C band VH polarization data are used to train the model Random Forest Classifier and Classification and Regression Trees (CART) classifier for classifying the crops and predicting the area in Google Earth Engine API. Supervised classification technique is used in which ground control points were obtained through ground survey and are used as training data to train the models. NDVI and Precipitation data are also used to analyze the usage of water resources for crop cultivation in the area. This chapter aims at predicting vital cash crops of Gujarat state i.e cotton and groundnut in Botad District.

This study has been carried out to forecast the production of cotton and groundnut crops in the Botad district. A supervised classification technique is implemented with the help of the indices like NDVI, EVI, S2REP, derived using Sentinel 2 data. Sentinel 1 C band GRD in VH polarization is used along with the above indices to train the models. Classification and regression tree classifier and Random Forest classifier are applied to distinguish the classes on the cloud platform Google Earth Engine API, which provides a large dataset and robust platform for research-based studies. The study includes Sentinel 2, level 2A data for computing indices NDVI, EVI, S2REP, and VH polarized C band SAR data from Sentinel 1. These bands are utilized to train the classifier. Cotton and groundnut crop is then classified using the Classification and Regression Tree and Random Forest model. The predicted area of cotton and groundnut for the year 2021 with different models can give an idea about the production estimation of both the crops. The accuracy calculated using the ground observations turned out

to be 76.47 percent for Groundnut and 86.20 percent for Cotton for both the classifiers. Though, the areas predicted from both the models vary from each other.

**Methodology for Field Survey**

It is important to understand the pattern and dynamics of Vulnerability at micro level. This chapter focuses on understanding the dynamics of Vulnerability of farmers and agricultural labours at village level. The micro level study has used survey method with the help of schedules. As this study mainly based on primary data source, the method of data collection includes mainly primary level information from Field Survey of farmers and farm workers. As Gujarat being a large state and has around 92.38 lakhs of people involved in farm activities, it requires very strong and scientific sampling design in order to have representative and effective size of sample. For this the study used stratified sampling method for the selection of villages and households.

The first biggest challenge for this study was the calculation to determine an adequate sample size which can estimate results for the whole farm dependent population with a good precision. Therefore, it is important to use a proper technique of the determination of appropriate sample.

The representative sample size is selected as per Cochran's formula as shown below

$$n = \frac{n_0 N}{n_0 + (N-1)} = \frac{1297 * 9238707}{1297 + 9238706} = 1297$$

Where, $n_0 = Z^2 p(1-p)/e^2$

$= (2.17)^2 (0.453648)( 0.546352)/ (0.03)^2$

$= 1297$

Where, n = Total sample size

N = Total workers

Z = Normal ordinate at 97% Confidence Level

p = proportion of Farm workers in Gujarat

1 – p = proportion of non-Farm workers in Gujarat

e = margin of error which is 3%

This sample size of 1297 respondents will be proportionately divided to obtain the effective

sample size from each stratum. The following formula of proportionate stratified random sampling will be used.

$n_h = (N_h / N) * n$

Where, $n_h$ denotes sample size of $h^{th}$ stratum

$N_h$ denotes workforce size of $h^{th}$ stratum

The sub-region wise sample sizes thus obtained are shown in the table below:

**Table 1: Sample**

| Sub-regions | Farm Workers | Sample |
|---|---|---|
| CG | 1961119 | 275 |
| NG | 1330774 | 187 |
| Saurashtra | 2838964 | 399 |
| SG | 3107850 | 436 |
| Grand Total | 9238707 | 1297 |

**The Selection of Districts:**

The next step was to select this sample households from various district so that the variation in agroclimatic parameters is well captured. Subsequently stratified sampling method was designed to select the district, taluka and villages. The strata were identified by calculating Agricultural productivity of major crops for each district in Gujarat.

Table 2: Sampling Districts of Socio-Economic Vulnerability pattern of farmers & Farm Laboure in Gujarat

| **Sr No** | **Agricultural Productivity** | **No. of District** | **Name of the District** | **Selected District** | **Name of the District** |
|---|---|---|---|---|---|
| 1 | >137.5 | 4 | Tapi, Gir Somnath, Navsari, Surat | 2 | Surat and Navsari |
| 2 | 114.5 to 137.5 | 2 | Bharuch and Valsad | 1 | Bharuch |
| 3 | 91.2 to 114.5 | 7 | Sabarkantha, Dang, Arvalli, Mehsana, Gandhinagar, Porbandar and Banaskantha | 2 | Sabarkantha and Porbandar |
| 4 | 67.9 to 91.2 | 12 | Kutch, Dahod, Mahisagar, Ahmedabad, Panchmahal, Chhotaudepur, Bhavnagar, Narmada, Junagadh,Kheda,Vadodara, and Anand | 4 | Kutch, Dahod, Bhavnagar and Kheda |
| 5 | 44.6 to 67.9 | 4 | Rajkot, Devbhumi Dwarka, Patan and Jamnagar | 1 | Patan |
| 6 | <44.6 | 4 | Morbi, Amreli, Surendranagar and Botad | 1 | Botad |

Agricultural productivity was calculated by Bhatia's method for the year 2018-19. Later the districts were ranked and classified in five groups with the help of mean and standard deviation. The groups signified the level of agricultural productivity with lowest to highest values. From each category, 25 percentage of districts were selected keeping the above sub-regions in mind. Subsequently 11 districts were selected having variation in the level of agricultural productivity as well as location.

**The Selection of Taluka and Villages**

The literature review reveals the fact that the impact of climate change and variability is high in small and marginal farmers. Therefore, the proportions of marginal and small farmers in each and every taluka of the selected districts were calculated. The taluka having the highest proportion of the small and marginal farmers were selected for the study. This is how 11 talukas were selected.

In order to obtain the sample size from each sub-region which was calculated by Cochran's method, the sample size was distributed equally from the selected talukas in particular regions. Subsequently, two or three villages were selected from each selected talukas to obtain the targeted number of households which were already calculated from Cochran's formula. We divided the sample households equally to each village to maintain the targeted sample from each sub-region.

Table 3: Region wise selected villages

| Sub-regions | Farm Workers | Sample | Talukas selected | Villages Selected |
|---|---|---|---|---|
| CG | 1961119 | 275 | 2 | 9 |
| NG | 1330774 | 187 | 2 | 4 |
| Saurashtra | 2838964 | 399 | 4 | 10 |
| SG | 3107850 | 436 | 3 | 7 |
| Grand Total | 9238707 | 1297 | 11 | 30 |

## Result and Discussion

## Pattern of Agricultural Productivity in Gujarat

This study has an intention to assess the agriculture productivity performance of various districts of Gujarat over two and half decade. Agricultural productivity is a scientific measure to analyse the inherent fertility, productivity and capability of land.

Table 4: Agricultural Productivity Indices of Gujarat

| Sr No | District Name | Agricultural Productivity | | | |
|---|---|---|---|---|---|
| | | 1995-96 | 2000-01 | 2010-11 | 2018-19 |
| 1 | Ahmedabad | 69.0 | 66.83 | 83.3 | 70.8 |
| 2 | Amreli | 78.2 | 33.43 | 95.8 | 35.0 |
| 3 | Anand | 118.8 | 119.59 | 83.4 | 89.2 |
| 4 | Arvalli | 127.3 | 93.22 | 92.7 | 99.1 |
| 5 | Banaskantha | 88.7 | 137.77 | 98.1 | 109.8 |
| 6 | Bharuch | 73.9 | 80.98 | 74.0 | 119.7 |
| 7 | Bhavnagar | 76.3 | 30.22 | 114.1 | 75.3 |
| 8 | Botad | 73.9 | 80.98 | 74.0 | 19.9 |
| 9 | Chhotaudepur | 75.8 | 69.07 | 89.3 | 73.3 |
| 10 | Dahod | 78.4 | 52.28 | 73.3 | 69.9 |
| 11 | Dang | 79.9 | 89.67 | 78.8 | 98.3 |
| 12 | Devbhumi Dwarka | 48.3 | 23.06 | 102.2 | 65.0 |
| 13 | Gandhinagar | 178.1 | 187.00 | 115.5 | 105.6 |
| 14 | Gir Somnath | 121.4 | 135.22 | 139.0 | 160.4 |
| 15 | Jamnagar | 48.3 | 23.06 | 102.2 | 67.6 |
| 16 | Junagadh | 121.4 | 135.22 | 139.0 | 76.8 |
| 17 | Kachchh | 65.2 | 94.64 | 81.0 | 69.6 |
| 18 | Kheda | 118.8 | 119.59 | 87.6 | 86.5 |
| 19 | Mahisagar | 78.4 | 52.28 | 73.3 | 70.1 |
| 20 | Mehesana | 115.8 | 119.95 | 97.8 | 102.6 |
| 21 | Morbi | 50.0 | 21.11 | 111.8 | 44.5 |
| 22 | Narmada | 76.3 | 30.22 | 76.3 | 75.3 |
| 23 | Navsari | 157.3 | 169.82 | 114.7 | 174.3 |
| 24 | Panchmahal | 78.4 | 52.28 | 73.3 | 72.9 |
| 25 | Patan | 88.7 | 137.77 | 73.9 | 66.6 |
| 26 | Porbandar | 48.3 | 23.06 | 71.5 | 106.5 |
| 27 | Rajkot | 50.0 | 21.11 | 111.8 | 58.3 |
| 28 | Sabarkantha | 127.3 | 93.22 | 92.7 | 93.0 |
| 29 | Surat | 166.9 | 221.91 | 104.2 | 275.4 |
| 30 | Surendranagar | 41.3 | 43.53 | 115.5 | 30.9 |
| 31 | Tapi | 166.9 | 221.91 | 85.8 | 146.5 |
| 32 | Vadodara | 75.8 | 69.07 | 89.3 | 86.6 |
| 33 | Valsad | 157.3 | 169.82 | 94.4 | 123.4 |

**(Source-** Directorate of Agriculture, Government of Gujarat)

Bhatia's method (1963) has been used to find out the agricultural productivity. The agricultural productivity details by district are given in Table 4.

Table 5: Distribution of Districts as per agricultural Productivity

| | | 1995-96 | | 2000-01 | | 2010-11 | | 2018-19 | |
|---|---|---|---|---|---|---|---|---|---|
| **Class** | | **No** | **%** | **No** | **%** | **No** | **%** | **No** | **%** |
| 0 - 30 | Extremely Low | 0 | 0 | 5 | 15.15 | 0 | 0.00 | 1 | 3.03 |
| 30 - 60 | Very Low | 6 | 18.2 | 7 | 21.21 | 0 | 0.00 | 4 | 12.12 |
| 60 - 90 | Moderate | 15 | 45.5 | 6 | 18.18 | 16 | 48.48 | 15 | 45.45 |
| 90 - 120 | High | 3 | 9.1 | 6 | 18.18 | 15 | 45.45 | 8 | 24.24 |
| 120 - 150 | Very High | 4 | 12.1 | 4 | 12.12 | 2 | 6.06 | 2 | 6.06 |
| > 150 | Extremely High | 5 | 15.2 | 5 | 15.15 | 0 | 0.00 | 3 | 9.09 |
| **Total** | | 33 | 100 | 33 | 100 | 33 | 100 | 33 | 100 |

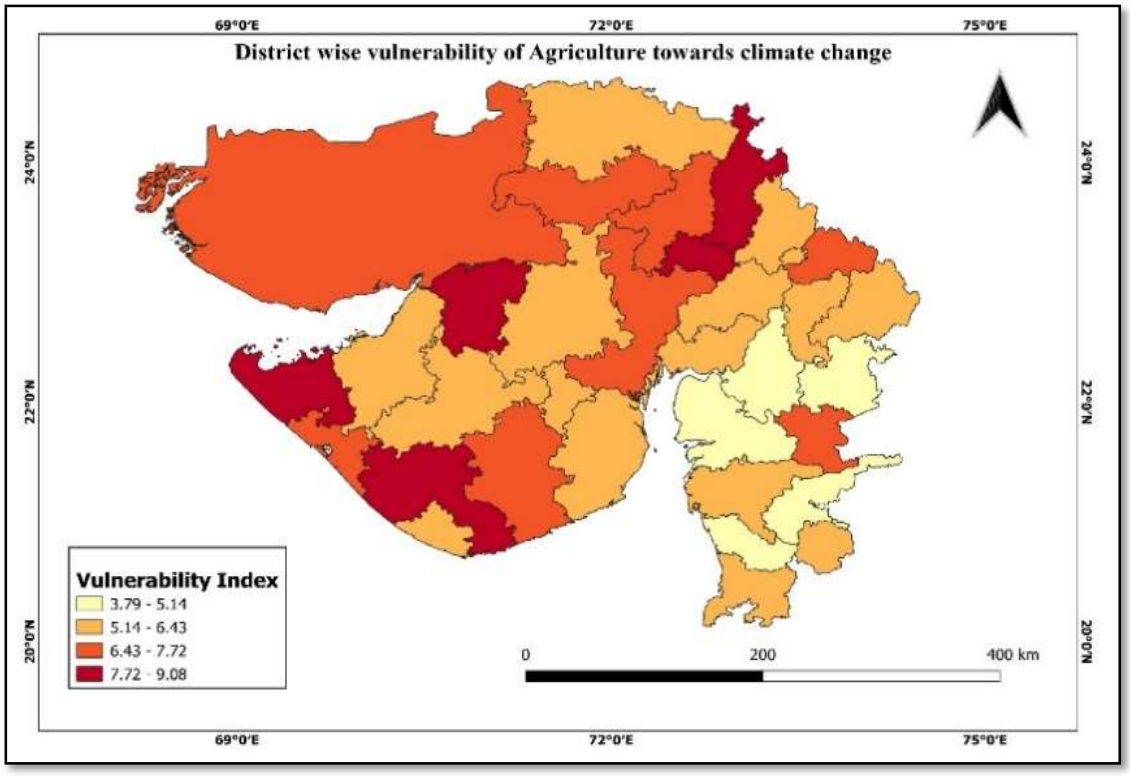
From the above Table, it is observed that the overall agriculture productivity performance of Gujarat is stabilizing. The number of districts with very high productivity and low productivity reduced. The proportion of high productive districts has been reduced from 15 % (in 1995-96) to 9 % (2018-19) while the proportion of low productive districts has been reduced from 18 %(in 1995-96) to 12 % (2018-19). Districts having moderate productivity have increased during these two and half decades. In 1995-96 about 9 % of districts reported high agricultural productivity, which increased to 24 % of Districts in the year of 2018-19. This indicates that more numbers of districts are falling in moderate agricultural productivity group. The reason behind this increase is less dependency on rainfall as well as increase in irrigation facility, use of high yield variety, use of pesticides, insecticides, and various government programs to improve the productivity etc. The recent agricultural beneficiaries' schemes of Government of Gujarat focus on minimum support price, skill development programme, improvement in forecasting weather and agricultural insurance have significantly helped farmers of Gujarat to sustain the agricultural productivity at optimum level.

## Vulnerability Pattern in Gujarat:

The below map depicts district wise vulnerability pattern of Agriculture sector towards climate change in Gujarat. The map clearly shows that the districts of Dev-Bhoomi Dwarka, Junagadh, Morbi, Gandhinagar and Sabarkantha are the most vulnerable districts. Except Rajkot, all other districts of Saurashtra regions fall in worrying zone of vulnerability. Amreli, Porbandar, Kutch,

Patan and Mehsana, Ahmedabad. Dahod and Narmada are also highly vulnerable towards the climatic changes. Districts located on South-eastern belt fall into lower to moderate vulnerability zone. Climatic exposures, system's sensitivity and less adaptive capacity are the major determinants of the higher level of vulnerability in Gujarat.

Figure 2: District wise vulnerability of Gujarat

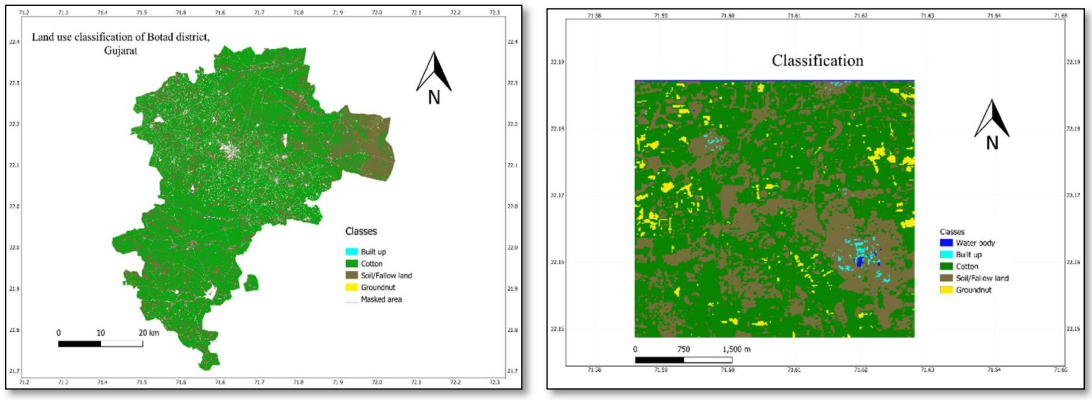



District level analysis shows that there is a vast variation in level of Vulnerability of agricultural sector towards climate change. There are various determinants which make the sector in few districts more vulnerable. The pattern of vulnerability of agricultural sector is also reflected in lower agricultural productivity analysis in the previous section of this report. Less vulnerable districts of South Gujarat have reported the highest agricultural productivity. Few districts such as Amreli, Botad, Bhavnagar, Morbi and Surendrangar have higher vulnerability resulting in less agricultural productivity. It is important to prioritize these districts for the allocation of physical and financial resources for the sustainable agricultural development. Kutch being an arid and dry region requires an input of dry farming practices. Similarly, the border districts of

North and eastern Gujarat also need intervention to improve the adaptive capacity to fight with climatic changes.

## Classification of Crops

Figure 3: Land use classification of Botad district(l) the part of Botad district(r) derived in Google Earth Engine API using Sentinel 1 and Sentinel 2.




Source: European Union/ESA/Copernicus

After deriving all the relevant indices, land use classification was carried out by using random forest classifier and CART classifier. The study area is calculated using the pixel area count method and turned out to be 2498.72 square km. The focus of this study is to predict the cotton and groundnut crop area and it is 1432.53 sq km and 42.84 sq km respectively with the Random Forest Classifier method. However, with the CART Classifier method the areas turned out to be 1348.03 sq km for Cotton and 41.47 sq km for ground nut. We tried to compare these statistics with the published Government data. According to the data of state Government, the four years average crop area of cotton and groundnut is 1661.47 sq km and 15.81 sq km. The Coefficient of Variance is 0.003634 for cotton and 0.829 for groundnut, which is relatively high for groundnut. Comparing with these statistics, Random Forest Classifier provides statistics closer to the Government statistics. Subsequently, the accuracy assessment was carried out for both models.

The study has been carried out to forecast the production of cotton and groundnut crops in the Botad district. A supervised classification technique is implemented with the help of the indices like NDVI, EVI, S2REP, derived using Sentinel 2 data. Sentinel 1 C band GRD in VH polarization is used along with the above indices to train the models. Classification and regression tree classifier and Random Forest classifier are applied to distinguish the classes on

the cloud platform Google Earth Engine API, which provides a large dataset and robust platform for research-based studies.

This study includes Sentinel 2, level 2A data for computing indices NDVI, EVI, S2REP, and VH polarized C band SAR data from Sentinel 1. These bands are utilized to train the classifier. Cotton and groundnut crop is then classified using the Classification and Regression Tree and Random Forest model. The predicted area of cotton and groundnut for the year 2021 with different models can give an idea about the production estimation of both the crops. The accuracy calculated using the ground observations turned out to be 76.47 percent for Groundnut and 86.20 percent for Cotton for both the classifiers. Though, the areas predicted from both the models vary from each other.

This study even highlights the use of water resources in the district and its dependency on rainfall. Botad, Gadhada and Ranpur talukas are observed to have healthier vegetation compared to Barwala. Precipitation and NDVI statistics are used to enhance the study by observing the consistency and the variation of crop production in the area for the entire year. Correlation between precipitation and NDVI shows that the variation in precipitation has a significant effect on NDVI values. The ground survey confirmed usage of diverse water resources like tube wells, wells, and canal. The increase in rainfall certainly has an impact on the better yield of the crops, which can be validated from the study. On the other hand, decline in rainfall has negative impact on productivity.

Pattern of Socio-economic Vulnerability at Micro level

Findings of the study indicated that it is inevitable to combat climatic vulnerabilities in order to address socio-economic vulnerabilities of farmers and farm labours. Some of the broad recommendations from field survey are:

- Conduct a regional study first on long term changes in climate (may be at block level or even watershed unit level or cluster of villages) including rainfall pattern, humidity, temperature etc
- Devise a scientific strategy to combat climate change regionally.
- While various weather prediction data are available it is important that they are conveyed to all farmers on time so that they can plan their cropping pattern, sowing dates beforehand. A lot need to be done for weather Information and Agro Advisory, Knowledge management on climate change.

- Climate change has major impact on irrigation water availability. At village level, water budgeting needs to be worked our first. Integrated water resource management should be adopted. Moreover, micro irrigation systems and water recharging/ harvesting should be promoted intensively.
- To augment agriculture income, improvement in crop productivity, lowering of input costs, soil testing and integrated Pest and nutrient Management, crop diversification to high value crops, increased collective marketing and institutional support like federations etc should be done.
- Improved farming practices like green house, organic farming etc should be promoted and extensive awareness to be done in this direction.
- Awareness on credit sources and micro credit should be given to farmers, especially women farmers for availing support for purchase of good quality inputs and farm machineries where required.
- For better livestock management, increased fodder availability and grading land, veterinary services, and camps etc. should be undertaken.
- Though lots of government programs and schemes are available in terms of subsidy, insurance, micro loan etc, awareness of community and delivery system is still weak. Handholding and awareness are the key so that all avail needed support of government schemes
- Livelihood diversification to augment household income should be promoted amongst farm labour to decrease out migration

The study has shown that the climate change and variability in Gujarat is a significant phenomenon. It has a substantial impact on agricultural sector. The agricultural productivity in the state has changed over time and space. Similarly, there is a regional variation in the vulnerability of the sector towards climatic risk. This has an in overall impact on livelihood of the farmers and agricultural labours. The use of advanced techniques of remote sensing for identification and classification of crops can help estimation of area under crops and production. At micro level, the vulnerability pattern reveals the fact that there is still lack of awareness and capacity building in various districts of Gujarat. Those districts need urgent attention for adaptation planning and capacity building.