CHAPTER V:

DISCUSSION

5.0 Discussion:

India is an agrarian country occupying 43% of India's geographical area. It ranks second world wide in farm output and accounts for 13.7% of Gross Domestic Product (GDP). It has been observed that there was a drastic drop in the agriculture GDP due to higher growth in the other sectors. In such circumstances, it is necessary that analysis of factors responsible for decreasing GDP should be looked into. Several workers have considered crop area, production and yield as few of the factors which are directly associated to GDP (Akintunde et al., 2013; Golder et al., 2013). The present study has confirmed to such association from the trend analysis of the selected crops viz cotton, castor and banana with respect to their area, production and yield. The analysis has shown that no doubt country's GDP is crippling but Gujarat is quite vigilant in this matter both at state as well as district level.

With the current satisfactory situation of the sector, it is required to make it more sustainable by taking into account the factors which can alter the present scenario. Climate change is one such factor that can create an impact on this sector (Kiran and Malhi, 2012). Several workers have highlighted the impact of the climate change on agriculture limiting the crop production (McCarthy et al., 2001; Tao et al., 2011). This makes imperative the assessment of the vulnerability of agricultural lands of these areas to the changing climate. Vulnerability assessment of agrilands of Vadodara and those in its nearby vicinity using indicator system method have shown no such impact of climate change on agrilands of Vadodara district. This could be attributed to high adaptive capacity of farmers of these lands. This has proved that reduction in vulnerability of an area requires improvement in the existing adaptive capacity of that area.

Other than the above factors an important factor is the maintenance of food security with an increasing population. The growing human population throughout the world is invariably exerting the tremendous pressure on the land under agriculture for the food security reasons. To keep pace with this increasing population, it is estimated that food production in the coming 40 years should be equal to the food produced over the last 12,000 years that too in the phase of climate change. Identifying several measures to increase crop production and adopting them is need of the hour. In order to achieve this, information or inputs leading to the increased crop production are must. These outputs will help in designing the strategies at both local and national scale. One such strategy is the knowledge regarding the status of biophysical and biochemical parameters of the crops. Reliable and timely estimates of these parameters can prove to be fruitful inputs, not only for the individual farmers, but also for regional and national agronomists (Zhang et al., 2005; Jongschaap, 2006). Such knowledge will help them in optimizing or increasing crop production. This is because it will give an understanding on the stress or deficiencies in the crop plants and thereby help in mitigating potential crop damages.

The present study for the estimation of crop biophysical and biochemical variables viz. LAI, CC and RWC by the conventional and the non-conventional means highlighted the better potential of the non-conventional technique over the conventional. The results generated during this study are in accordance to various studies where satellite sensors have proved to be faster, cheaper and objective data providers for these variables when compared to the conventional field-based surveys (Bartholome, 1988; Pandya et al., 2003; Thenkabail, 2003) which are most of the time work intensive and time consuming. A variety of methods have been proposed to measure crop parameters from the spatial data. Number of studies have used the empirical-statistical relationships between the crop parameters of interest and vegetation indices. Development of numerous VIs has been done in framework of RS vegetation monitoring. The large contrast between vegetation reflectance observed in the red and the infrared wavebands are the basis of all existing VIs. Other features on earth's surface like bare soil, rocks, water bodies do not show such a contrast. As a consequence, this contrast acts as an indicator of vegetation presence and status. Vegetation characterization not only includes large reflectance values in the infra-red wavebands, but also considers the large transmittance values. This makes the pertinent use of the infra-red wavebands to get information on the vegetation under-stories (Gausman, 1974; Clevers, 1988). Based on this fact, the first empirical relationship between VIs and LAI was established (Bunnik, 1978). Since then, not only for the retrieval of LAI but also for soil canopy coverage, leaf density, etc. VIs have been widely used. Several researchers have developed various VIs for improving the sensitivity of the indices to the parameter to be estimated. The interferences arising due to the external factors such as soil background, illumination and observation conditions, atmosphere diffusion were also minimized. List of few well known indices includes the Ratio Vegetation Index (RVI) also known as Simple Ratio (SR), the Normalized Difference Vegetation Index (NDVI), the Soil Adjusted Vegetation Index (SAVI) (Huette, 1988) the Weighted Difference Vegetation Index (WDVI) (Clevers, 1989), etc.

In the present work, the utility of vegetation indices namely NDVI and RVI were made to retrieve LAI by developing empirical statistical models. It is well known that there exists a strong correlation relationship between NDVI and RVI values. A simple linear regression model has been used in this analysis for the estimation of crop parameters using optical satellite data as these methods have been found to be fast and easily implementable for the large data sets. The estimation of LAI is useful in knowing the status of the vegetation growth and serves as a key input parameter in a crop growth and yield models (Doraiswamy et al., 2005), plant photosynthesis (Duchemin et al., 2006), Evapo-Transpiration (ET) and carbon flux (Chen et al., 2007c). The models developed from both Landsat 5 TM and LISS IV data for cotton, castor and banana showed good performance. NDVI proved to have a better potential for the LAI retrieval. The outputs generated were in accordance with outputs by Houborg and Eva (2008) who in their work on barley, wheat and maize highlighted the good performance of LAI-NDVI models.

These methods which were found to be fast and easily implementable over large data sets were also used to retrieve Chlorophyll Content (CC) by the non-conventional means. CC estimates are used as indicators of crop stress through their potential influence on nutritional deficiencies. Such deficiencies results into crop chlorosis that can be timely and successfully treated resulting into improved yields and crop quality. Analysis of data of the present work showed that NDVI and RVI can successfully determine CC in cotton, castor and banana crops. Similar to that of LAI, in the estimation of this parameter NDVI provided better results when compared to RVI. Precisely for LAI, CC and biomass estimations, NDVI gave a relatively better correlation when compared to RVI. This may be due to relatively insensitivity of NDVI to background soil reflectance and more sensitivity of RVI (Nayak, 2005) to this factor. Moreover, NDVI is less affected by atmospheric conditions and topographical variations while RVI is affected the most by atmospheric haze and topography. A relative disadvantage of NDVI is its saturation at higher LAI values (Ludeke et al., 1991; Gitelson, 2004; Gonzalez-Dugo and Mateos, 2006; Le Maire et al., 2006; Ferrara et al., 2010; Herrmann et al., 2010; Zhao et al., 2012) as compared to RVI which indicated the inappropriateness of NDVI is in the discrimination of high-density covers (Srinivas et al., 2004; Chaurasia, 2011). The other important index viz. the NDWI is sensitive to changes in liquid water content of vegetation canopies. NDWI derived from Landsat 5 TM data were used to measure RWC in cotton, castor and banana crops. NDWI-RWC established models also showed good performance. The limitation for these generated models is area restriction. Their utility will remain valid only for that specific area for which they were developed.

The parameters retrieved from the optical spaceborne data viz. LAI, CC and RWC are the most important crop growth variables and are indicators of the crop vitality. LAI, CC and RWC can be indicator of agricultural productivity, crop nutrient stress (mainly nitrogen) and water stress in the crop respectively. Integrating these parameters to calculate Vegetation Health Index (VHI) can prove to be a significant indicator of crop condition (Tripathi et al., 2009). Knowledge of this indicator can play a vital role in the enhancement of the crop yield. The VHI derived for cotton, castor and banana crops during the study will prove to be an important input for site specific crop management. It will also aid in better utilization of available resources in the field and thereby maximizing the crop yield.

Optical data analysis have proved its suitability in the crop parameter retrieval. Use of optical data is simple and non-complex, but unfortunately its use is often limited by certain factors. This data is vulnerable to data gaps during critical crop growth stages due to its dependency on atmospheric conditions such as cloud, haze, rainfall, etc. (Kumar et al., 2013; Revill et al., 2013). SAR data images of the agricultural fields during kharif season have their own significance as it can penetrate through the clouds very easily. This is a common hindrance for the optical data. At this point it was interesting to study the potential of radar data in the crop parameter retrieval of field crops. All weather capability and sensitivity of this data to canopy structure and moisture increases its utility for retrieving the crop parameters. The interaction of a crop canopy with radar waves is in the form of a group of volume scatterers. The crop canopy is composed of discrete plant components, such as leaves, stems, stalks, limbs and so on. In addition, the energy that penetrates the crop canopy can result in surface scattering by underlain soil. In general, shorter wavelengths are best suited for the agricultural applications. The reason being the wavelength ranges of X (2.5cm-3.75cm) and C (3.75cm-7.5cm) bands, match with the typical size of leaves and stems which are also of the order of several centimetres. At these wavelengths, volume scattering predominates and surface scattering from the underlying soil is minimized (Barett et al., 2012). The longer wavelengths, of approximately 10 to 30 cm are best suited for sensing tree trunks or limbs (Tsolmon et al., 2002; Ratnayake, 2004). The analysis in this study has also shown the significance of the C-band. Other than wavelength, backscatter in case of SAR is attributed to several factors viz. incidence angle, row spacing and direction of planting, soil and crop water content, and crop phenology and, henceforth, must be taken into consideration in the analyses (Brown et al., 1992; Baghdadi et al., 2009; Silva et al., 2009). The interaction of microwave radiation with vegetation is directly related to the polarization (Silva et al., 2012) as it is a function of the structural characteristics of the features observed. Furthermore, the polarization of the transmitted microwaves states which components of the vegetation and soil contribute to the total amount of energy scattered back to the SAR sensor. Vertically polarized microwaves (V) coupled with the predominant vertical structure of most vegetation contribute to a reduction of the signal penetration through the canopy. Hence, VV-polarized radar returns will provide good contrast among crop types having different vertical canopy structures. Differences in this vertical structure resulting from changes in growth stage or health may also be detected in VV-polarized images. Horizontally polarized microwaves (H) tend to penetrate the canopy to a greater extent compared to vertically polarized waves. Thus, HH images acquired at steep incidence angles tend to provide information about the underlying soil condition. Cross-polarized radar returns (HV or VH) result from multiple reflections within the vegetation volume. C-HV and C-VH images are sensitive to crop structure within the total canopy volume and thus provide information that is complementary to HH and VV imagery (Soria-Ruiz et al., 2007). Thus, for the discrimination among the field crops and for the retrieval of specific crop parameters, polarization is an important source of information. Several authors have exhibited good correlations between SAR backscatter data and crop variables (Macelloni et al., 2001; Mattia et al., 2004; Liu et al., 2006; Chen et al., 2009a; Fontanelli et al., 2013). The present study makes the use of C-band Envisat ASAR data with dual polarization viz. HH and VV to investigate the sensitivity of ASAR backscatter signatures to crop biophysical variables. In this data, the linear relationship of Cotton and Banana LAI with VV and HH backscatter was found to be poor. LAI retrieval using the VV/HH backscattering ratio of ENVISAT/ASAR data showed promising results. Thus, equation obtained using the VV/HH polarization backscattering ratio as the independent variable could be used for the LAI retrieval.

Low correlation obtained between crop LAI and HH and VV backscatter can be due to the reason that the outcome of the horizontal polarization giving measure of horizontal dimension of scattering elements and vertical polarization of vertical dimension. Moreover, LAI changes with change in horizontal and vertical structure. This leads to variation in HH and VV backscatter from crop fields. In addition, volume scattering and attenuation from crop fields changes due to any change in horizontal and vertical components. Increase in HH backscatter due to volume scattering and decrease in HH backscatter due to attenuation continues to play till the crop reaches its maturity.

These factors played a key role for the occurrence of such relation. Unlike HH and VV, the VV over HH polarizations ratio showed good correlation with crop LAI. The advantages of using a ratio are that factors that might affect the absolute backscatter will not impact the relationship with the biophysical variables in VV/HH ratio as long as these factors are affecting HH and VV to the same magnitude. This ratio can therefore reflect the variation of the plant components as the crop grows, and avoids the problem of calibration, data processing and environmental effects (Chen et al., 2009b). For explaining it in better way, more experiments need to be carried out in the future. These established empirical relationships are based on a statistical analysis of experimental data set. It consist in rather simple mathematical relations between the backscattering coefficient and crop LAI. The developed empirical statistical models are hence specific to selected data set as well as site and cannot be generalized.

Land use statistics along with area statistics form the backbone of the Indian agricultural statistics system. Reliable and timely data on land use is of great significance to the planners and decision makers for monitoring changes in time and will aid them for efficient agricultural development. They can take decisions on procurement, storage, public distribution, export, import and many other related issues. Generating statistics of land use conventionally involves compiling of the village land records maintained by the *patwari* (Singh, 2004). This being very much tedious, time consuming task is prone to human errors and so not widely accepted. These limitations could be overcome by utilizing satellite data. Remote sensing data is effective tool for producing the land use statistics which can be useful to determine the distribution of agricultural land. The present study revealed the potential of different satellite data namely Landsat 5 TM, LISS IV data and ASAR data in delineating different land uses. Actual land in the study area under agriculture practice was identified. LISS IV optical data showed good performance in classifying different land use types when compared to Landsat data. It was found that Wishart classifier produces more accurate results than MLC for radar data classification. Baseline information generated in this work on land use pattern would be of immense help to the district planners and decisions makers for monitoring changes in time and will allow them to formulate policies and programmes needed for planning proper agricultural land use.

Spatially mapping the crop types using remotely sensed image is a common exercise that many scientists have been improving upon for decades (Ozdogan, 2010). Due to continuous expanding population, potential climate variability and growing demand for agriculture-based alternative fuels, an accurate agricultural land-cover classification for specific crops and their spatial distributions have become prime interest to researchers, policymakers, land managers and farmers (Atzberger and Rembold, 2013). It is very much required in land change studies, climate change, hydrological studies and other applications like yield prediction and the efficient management of water resources, the later usually based in the estimates of ET (Simonneaux et al., 2008). Crop maps are usually used in combination with crop growth models for yield prediction or to model for example soil carbon sequestration (Doraiswamy et al., 2007). Furthermore and more importantly to assure an accurate retrieval of crop specific biophysical and biochemical parameters for proper agricultural monitoring, crop classification is an important step. The advantages of using remote sensing techniques for crop classification, instead of field survey, are the low cost and the large area coverage. Another important reason is that it is easier to update the classifications, due to the possibility of repeated time frequency of the data. Till date, both single date RS data as well as spectral temporal vegetation profiles (Badhwar et al., 1982) are used to discriminate various crops. For carrying out the crop discrimination, the differences in the geometry and growth habits of crop types which are manifested in their differential spectral responses are exploited (Oza et al., 2008).

The utility of optical RS data is well established for spatially mapping crop types and their methodologies have been proved to be quasi operational. Often the use of data with a spatial resolution compatible with the field size at regional scale is made. Medium or coarse resolution optical data are often considered as insufficient with regard to the field size. The use of such data is made for multi-year temporal surveys, and for generating land use/land cover maps at continental or global scales (Strahler et al., 1999; Loveland et al., 2000; Bartholomé and Belward, 2005). Optical data has a limitation in kharif season as its acquisition is hampered due to the presence of the cloud cover. It makes availability of desired image at the desired time impossible. Microwave data due to its independency from cloud cover shows a great potential for the crop classification when there is unavailability of an optical data. For monitoring a specific crop at a specified phenological stage, this data can prove its potential. Several authors have explored SAR for this purpose and have proved the potential of microwave data as a crop classifier (Bush and Ulaby, 1978; Brisco and Protz, 1980; Shanmugan et al., 1983). Earlier the use of a SAR-only approach for the crop classification was difficult as radar data was available with limited dimensionality. Satellites were only capable of measuring single linear polarizations at a single frequency. Information provided by these was not sufficient for accurate classification of crops even when multi-temporal acquisitions were exploited (Shang et al., 2006). With the availability of space-borne multi-frequency and multi-polarization data, possibility of delivering accurate crop maps using SAR data alone has increased. In the present study, optical data (Landsat 5 TM and LISS IV) and Radar data (Envisat ASAR) data was used for the crop classification. The results demonstrated that, for identifying crop classes using MLC technique, LISS IV data yielded good results compared to Landsat 5 TM data. In the study area, due to comparatively coarse resolution of Landsat data, crop classification using such data has been a challenge, because of the small field size and the highly diversified cropping pattern. Mixing of the classes was a major problem observed. This indicates with an increase in resolution of an image, accuracy for crop classification improves. Performance of single date C band dual polarization ASAR data in terms of crop classification was observed to be good. Compared with the classification results obtained with LISS IV and Landsat TM the classification results of the C-band Envisat image were rather poor. But this can definitely prove to be useful in kharif season when an acquisition of an optical data becomes difficult.