CHAPTER VII:

SUMMARY

7.0 Summary:

The focus of this thesis is the use of optical and microwave data to improve the estimation of agricultural crop parameters. Agricultural, ecological, and meteorological applications require an accurate quantitative estimation of vegetation biochemical and biophysical variables. The information about the spatial and temporal distribution of these parameters provides an important input into various models quantifying the exchange of energy and matter between the land surface and the atmosphere. The knowledge of canopy biophysical and biochemical variables is of prime interest in many applications including crop function modeling, evapotranspiration, crop growth modeling and yield prediction. In addition, this information also aid in predicting the soil-vegetation- atmosphere energy transfers. Even at a much smaller scale, as in precision farming and water management, these parameters play a critical role to describe the state of crop development and water needs. Measurement of these parameters during the growing season also provides an opportunity for improving grain yields and quality by site-specific application of fertilizers. Among the many crop parameters, Leaf Area Index (LAI), Leaf Chlorophyll Content (CC), Relative Water Content (RWC) and Biomass are of prime importance.

Direct field techniques for estimating these parameters require frequent destructive harvesting. Such techniques are difficult, extremely labour intensive, and costly in terms of time and money. They can hardly be extended to cover large areas. In order to handle these problems, Remote Sensing (RS) technology offers numerous advantages over traditional methods of conducting agricultural and other resource surveys. Advantages include the potential for accelerated surveys, capability to achieve a synoptic view under relatively uniform lighting conditions, availability of multispectral data for providing intense information, capability of repetitive coverage to depict seasonal and long-term changes and availability of imagery with minimum distortion etc. This proves RS data, both in terms of optical and microwave, beneficial in assessing important biophysical and biochemical parameters of different crops. Optical satellites which operate in the visible and infrared parts of the spectrum, acquire information which are more closely linked to human perception. Examples of information products that can be spatially derived from optical domain are: Colour, Crop Vitality, Canopy temperature, etc. In optical region, both visible and infrared bands are very useful in identifying cultivated areas and eventually in understanding the crop conditions. The most important limitation of optical instruments is their weather dependence for their operational use as clouds are not transparent at visible/ Infrared (IR) wavelengths. This factor requires special attention for agricultural applications as reliable timed images are needed throughout the growing season to understand the crop status. Application of microwave RS has proved to be good in overcoming this weather problem in earlier as well as in the present study. Radar microwaves, owing to their penetrative power, pass not only through clouds, haze or fog but also through crop canopy and reach the soil below. The resulting radar images are influenced by the properties of the soil. These images are primarily sensitive to crop structure and biomass, as well as soil roughness and moisture. The information from radars has proved to be supplementary to that of optical systems when visible/IR sensors are unavailable because of cloud.

The present work which aimed at assessing the agricultural areas of Vadodara district using both optical and microwave data in agricultural studies have generated several interesting results which are highlighted below:

- The trend analysis in terms of area (at country, state and district level), production (at state and district level) and yield (at district level) of three crops namely Cotton, Castor and Banana exhibited variations. Cotton crop showed increasing trend in area under crop at both country and state level while slight ups and downs were observed at district level. Production of cotton also showed overall an increasing trend at state and district level and its yield showed upward trend at district level. Area under castor crop showed an increasing trend at country level and variations were found at state and district level. Its production also showed instability but on average increase was observed at state and district level. Yield of castor crop also showed variations but on average an increasing trend was observed. Area under banana crop showed variations at all three levels. Its production showed annual instability at state level but overall decrease at district level. Its yield also showed decreasing trend at district level.

- Vulnerability assessment performed for agrilands of Vadodara and its nearby vicinity using indicator system method highlighted that climate change has no impact on agrilands of Vadodara district. This could be attributed to high adaptive capacity of farmers of these lands.
- Conventional approach adopting standard methods used to estimate the crop parameters viz. LAI, CC and RWC for three crops namely Cotton, Castor and Banana. These observations were used for retrieving these parameters non-conventionally.
- The two vegetation indices namely Normalized Difference Vegetation Index (NDVI) and Ratio Vegetation Index (RVI) derived from the Landsat 5 TM and LISS IV optical data and one water index namely Normalized Difference Water Index (NDWI) derived from Landsat 5 TM. NDVI, RVI and NDWI values for the selected three crops were extracted which served to be an input for the retrieval of crop biophysical and biochemical parameters.
- Optical RS based empirical statistical models developed for the assessment of LAI in three crops by correlating LAI with vegetation indices namely NDVI and RVI derived from both Landsat 5 TM and LISS IV showed good performance. NDVI was slightly superior to RVI in its correlation with LAI

in both the data. LISS IV data showed a greater potential for the retrieval of LAI when compared to Landsat 5 TM data. Developed empirical relations were used in the generation of LAI maps for the selected crops.

- NDWI derived from Landsat 5 TM data were used to measure RWC in cotton, castor and banana crops. Developed NDWI-RWC models showed good correlation of RWC of the selected crops with NDWI and thus was used as input in generating RWC maps for all three crops.
- Empirical-statistical regression equations were formed by correlating CC of the selected crops and vegetation indices viz. NDVI and RVI extracted from Landsat 5 TM and LISS IV. Fitted regression relationships emphasized good correlations between vegetation indices and CC. R^2 values showed that NDVI was more closely related to LAI than RVI and LISS IV data is better choice for the estimation of CC. Using established models, CC maps were prepared for the selected crops.
- Empirical statistical inversion models developed using optical data viz. Landsat 5 TM and LISS IV data also showed potential to estimate biomass in cotton and banana plants. In terms of data, LISS IV and in terms of vegetation index, NDVI was found to better estimator of biomass.
- The crop parameters retrieved from the optical spaceborne Landsat 5 TM data viz. LAI, CC and RWC were integrated to calculate Vegetation Health Index (VHI), a significant indicator of crop condition for Cotton, Castor and Banana. The village level generated VHI maps for the selected crops during the study can help in better utilization of available resources in the field by

site specific application of the fertilizers and thereby it can aid in maximizing the crop yield.

- The sensitivity of C-band ASAR backscatter signatures to crop LAI was investigated. Microwave RS based empirical 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.
- Performance of Landsat, LISS IV and ASAR data in Landuse classification for the study area was quite promising. The classification results obtained using two different optical sensors (viz. Landsat 5 TM and LISS IV) are comparatively good than those obtained using a single Envisat ASAR image. LISS IV data showed comparatively greater potential of Landuse classification compared to Landsat 5 TM data.
- Crop Classification was performed for optical data (Landsat and LISS IV) and Radar data (Envisat ASAR) data. Amongst optical data, LISS IV data yielded good results compared to Landsat 5 TM data. Performance of ASAR data in terms of crop classification was observed to be good. Compared with the classification results obtained with LISS IV and Landsat 5 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.

To sum up, this work investigates the use of optical and microwave remote sensing for the retrieval of different crop biophysical and biochemical parameters which can be useful in proper monitoring of agricultural areas. For accomplishing this, an important number of in situ measurements were made for estimating different crop parameters in Cotton, Castor and Banana plants using standard techniques. Three different satellite imageries (Optical data: LANDSAT 5 TM and LISS IV; Microwave data: ASAR) are used in the selected area of Vadodara district of study in Gujarat for developing empirical statistical relationships between RS derived parameters (NDVI, RVI and NDWI) and conventionally measured crop parameters (LAI, CC, Biomass and RWC). This study also highlighted the importance of the both optical and microwave remote sensing in agricultural land studies in terms of crop classification. Both data showed quite good accuracy in terms of crop type classification which indicated that at times when optical data is restricted due to its weather dependency, microwave data can help in continuous crop monitoring.