

SUMMARY AND CONCLUSIONS

This study demonstrates the capability of satellite data-sets to provide the useful information for mapping, monitoring of different crop growth and retrieval of soil moisture covered by the winter wheat, barley and corn crops. The methods and techniques were developed for the optical and microwave satellite data applications and arrived to draw the following conclusions:

- In the present thesis, SVM, ANN, RF, ML and NDVI algorithms were investigated for the crop classification and mapping using different parameters of these algorithms. The multi-sensor satellite data-sets such as LISS-IV, Landsat 8-OLI and RISAT-1 were used and the classification accuracy assessment results were compared.
- The statistical significance of the classification results was also performed using Z-test and χ^2 -test. Before the classification of different crops, the separability analysis was performed using *TD* and *J-M* distance methods. The high separation was found between the crops using *TD* method in comparison to *J-M* distance method.
- The kernel based SVMs have shown better results in compare to the ANN, RF ML and NDVI classification algorithms. The different accuracy measures such as marginal rates, *F*-measure, *JCC* and *CSI* were also used to check the classification accuracy.
- The LISS-IV data was found very effective for the classification of the crops such as corn, lentil, linseed, barley, mustard, pigeon pea, wheat, sugarcane, pea and other crops and also for non-crop using supervised classification algorithms.

- The ANN classification algorithm was performed at changing learning parameters using LISS-IV and Landsat 8-OLI data-sets and compared the results. The overall high classification accuracy was achieved using LISS-IV data but this data didn't show the consistency in the classification accuracies except using learning rates 0.003 and 0.01. However, a good overall consistency was found in the classification accuracies using Landsat 8-OLI data excluding few results.
- The utility of Indigenous satellite RISAT-1 was also evaluated for the crop classification using ANN algorithm. The accuracy results were higher for the data acquired on 28 September 2013 in comparison to the data acquired on 9 August 2013. In future studies, the different combinations of these two polarizations HH and HV of RISAT-1 data may be useful for the crop classification and monitoring.
- RFR, SVR, ANNR and LR algorithms were evaluated for the estimation of winter wheat crop growth parameters using the C-band Sentinel-1A SAR images at VV polarization. The RFR algorithm achieved relatively more accurate results in comparison to SVR, ANNR and LR algorithms. RFR algorithm provided a useful exploratory and predictive tool for estimating winter wheat crop growth parameters.
- The WCM model was also investigated for the estimation of LAI and LWAI crop growth parameters. The retrieval values of LAI and LWAI were found close to the observed values by the inversion of WCM. During the later growth stages, the σ° was found dominated by an increase in LAI. It was observed that the dominant contribution to total σ° comes mainly from volume scattering of vegetation when $LAI > 3$, whereas soil contributes to σ° significantly until LAI

reaches to 2. The dependence of σ° on soil moisture was found to be negligible when LAI > 3. The Sentinel-1A data was found useful for better understanding the scattering behaviour of crop growth parameters at different growth stages.

- The three different types of regression models such as RFR, SVR and ANNR were evaluated for the retrieval of soil moisture covered with the winter wheat, barley and corn crops. The analysis indicated the efficient performance of the SVR and RFR models for the soil moisture retrieval under different crops in comparison to ANNR model at VV and VH polarizations. The results indicated the inferior performance of VH polarization in comparison to VV polarization for soil moisture retrieval using the Sentinel-1A satellite data.

8.1 SCOPE FOR FURTHER WORK

The outcome of the present study may provide the valuable information for the satellites to be launched in the near future for the accurate monitoring of different crops and soil moisture retrieval. In future studies, different combination of LISS-IV and Landsat-8 OLI bands may be used for the classification of crops grown in other regions. The investigation demonstrates the excellent capability of the Sentinel-1A SAR data at C-band for the monitoring of agricultural crops and the soil moisture retrieval. WCM may be useful for the retrieval of crop growth parameters and soil moisture using multi-sensor satellite data-sets.