HYPERSPECTRAL REMOTE SENSING FOR TEMPERATE HORTICULTURE FRUIT CROPS IN NORTHERN-WESTERN HIMALAYAN REGION: A REVIEW

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Commission III, WG III/10

KEY WORDS: Hyper spectral remote sensing, spectral library, temperate horticulture, IHR

ABSTRACT:

The North-Western Indian States and the North-Eastern Indian States of Indian Himalayan Region (IHR) are rich of various temperate horticulture fruits such as the Apple, Pear, Peach, Plum, Apricot, Sweet Cherry and Sour Cherry. These horticulture fruits are majorly grown in North-western region comprising of Jammu and Kashmir (J&K), Himachal Pradesh (H.P.) and Uttarakhand (U.K.). These states of IHR share the same type of geographical and climatic condition and having nearly common flora and fauna. Out of the various horticulture temperate fruit crops apple and apricot have the potential to make a positive impact on economy of these states. Hyper-spectral remote sensing due to its capability of identifying the small variations within a particular feature (or land cover) is an important tool for discriminating or mapping the specific land cover among the various existing classes. Contrary to multispectral remote sensing, it is not only capable of mapping the vegetation class among the various classes in the land but also has the potential to discriminate within the different classes of vegetation as well as diseases identification within a class. This specific class level discrimination of vegetation is an important tool for mapping. In hyper-spectral remote sensing this variation is observed through the possible discrimination of spectral signatures of various vegetation classes. Thus, due to its fine spectral bands this type of remote sensing data has the potential to map the horticulture crops. However, the processing of hyper-spectral data always require the in-situ measurements or existing spectral library. Such a type of spectral library is never generated for the horticulture crops of IHR. This can be further useful for identifying the disease affected crops and input for developing model for estimation of biophysical and biochemical parameters. Therefore, in this study, a need for the development of spectral library for temperate horticulture crop has been highlighted. Further, a methodology for the processing of hyperspectral data has also be proposed.

1. INTRODUCTION

Himalaya has more fragile ecosystem. It is more vulnerable and susceptible to the climate change. Himalayas are the rich of various natural resources. Indian Himalayan Region (IHR) is a major source of various resources. The Indian Himalayan region is not too much suitable for the traditional agriculture due to its difficult terrain. However, the frequent variations in altitude and freezing temperature allow the region a limited but unique type of agriculture products and natural vegetation. Due to changing climate, there is a loss of ecosystem and hence the natural resources get affected.

Due to hilly and undulating terrains of IHR, the horticulture crop plays significant role in the food and nutrional security of our country (Sharma and Panigrahy, 2009). The traditional agriculture activities are not economical and sustainable in state like Himachal Pradesh, Uttarakhand and Jammu & Kashmir, especially in hill regions. On the other hand, the climate is much suitable for growing the temperate and subtropical fruits. Therefore, the horticulture crops are (or may be) the major sources of economy of these states. However, due to changing climatic condition there may be a lot of impacts on the production of such crops. The quality, productivity and phenology of crops get affected.

The horticulture crops, especially the temperate horticulture crops are the major source of economy in these states. For example, in Himachal Pradesh the apple is a major horticulture crop and the economy of the state is dependent on it. This particular horticulture crop in this hill State constitutes about 49 per cent of the total area under fruit crops — about 85 per cent of the total fruit production, says the latest Economic Survey of the State. The apple fruit, having an economy of around Rs. 3,500 crore, is grown mainly in the districts of Shimla, Kinnaur, Kullu, Mandi, Chamba and some parts of Sirmaur and Lahaul-Spiti. The average production of apple is around 5 lakh tonnes or 2.5 crore boxes every year but the maximum production was recorded in the year 2010-11 when it crossed 9 lakh tonnes or almost touched 5 crore boxes. In last few decades, lots of changes have been seen in the apple cultivation as well as production. The increasing trend of apple cultivation is seen, comparatively high altitude region such as Lahual and Spitti whereas, decreasing trend in the Theog and Kullu Region of Himachal Pradesh. Further, there is always focus towards the different variety of apple crop such as Royal Delicious, Red Gold, Red Chief and Oregon Spur and later Golden Delicious. These varieties gets a tough challenge in Global market with Chinese Gala and Washington apples from the U.S..

Hyper-spectral remote sensing due to its fine spectral bands has the potential to map the horticulture crops. However, the processing of hyper-spectral data always require the in-situ measurements or existing spectral library. Such a type of spectral library is never generated for the horticulture crops of IHR. Therefore, there is a need for the development of the same.

Since the estimates of biochemical properties such as Chlorophyll and Nitrogen provides the indication of productivity, nutrients and stress in plant. Also, the biophysical properties such as Leaf Area Index (LAI) and plant biomass are important indicator for the quantifying the plant production. Thus, the estimates of biophysical and biochemical properties are important for the study of ecological and meteorological behavior of various plants (Asner, 1998).

2. CAPABILITIES OF HYPER SPECTRAL REMOTE SENSING

Narrow band imaging has the capability of identifying the small variations within a particular feature (Khan, et al., 2013; Khan, et al., 2018) (Figure 1). Since its beginning, hyper-spectral remote sensing has major contribution in the history of narrow band imaging. Further, with the availability of high spatial resolution hyper-spectral data, discrimination of various crop is much easy (Nidamanuri and Zbell., 2011, Whiting et al., 2006; Liang, 2007).

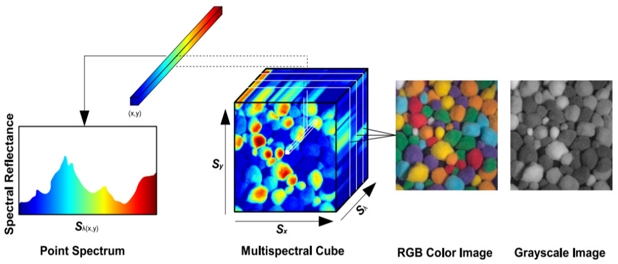

Figure1: A hyperspectral image represented as a 3D cube, S_λ represent number of bands. Derived RGB and grayscale images (Khan, et al., 2013)

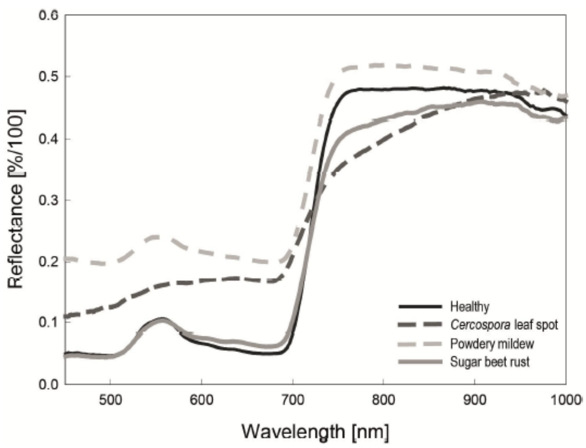

Figure 2: Spectral comparison of healthy and diseased sugar beet leaves (Khan, et al., 2018)

As a wide variety of vegetated land cover exist. A potential applications of hyperspectral remote sensing for the agriculture has been discussed (Xie, Y. et al. 2008; Sahoo et al., 2015). A few studies for the vegetation based land cover are for crop discrimination (Nidamanuri and Zbell., 2011; Shwetank et al. 2012; Arafat et al., 2013; Thenkabail, et al. 2013), Teak (*Tectonagrandis*L.) (Christian et al., 2007), Tobacco plants (Krezhova et al. 2014) and Blueberries (Ahlawat et al., 2011).

Cochrane 2000, studied the potential of reflectance data for the species level classification of hyper spectral data. In this study, the reflectance spectra of 11 species were analysed. It was observed that the different tree species have same nature of spectral reflectance but separable due to high variation in amplitude. Further, for the few categories the sufficient variations within species of the individual tree have also been observed, but not for the all. Thus problem within species has been found more complicated.

Miglani et al., 2008 have studied the EO-1 Hyperion data for the agriculture applications. In their study, apparent reflectance of wheat, sugarcane and potato were compared with the observed spectral reflectance using the field spectroradiometer upto 1075nm. It has been observed that the spectral curves obtained from the atmospherically corrected hyperspectral data were better fitted with those observed on the field.

According to the Xie et al., 2008, hyperspectral sensors are well suited for vegetation studies/discrimination due to possible differentiated reflectance or absorption behaviour by various species. However, the processing of the hyperspectral data always remains challenge. Thus, specialized, cost effective and computationally efficient procedure is require to process these data (Varshney and Arora 2004)

Nidamanuri and Zbell., 2011, classified the airborne hyperspectral image (viz. HyMap with spatial resolution of 5m and 128 spectral bands having spectral resolution of 20nm), using the field spectral reflectance spectra as training data for crop mapping for some of agriculture crops. Mixture tuned matched filtering (MTMF), Spectral feature fitting (SFF) and Spectral angle mapper (SAM) methods were used for the classification of HyMap image. Their study indicated the prospect of using the plant specific spectral signatures for classification of some of the crops. However, for some other crops this prospect fails and the reflectance spectrum of a crop species may closely approximate that of the other similar group and hence possibility of using them in the image classification.

3. IMPORTANCE OF THE STUDY IN CONTEXT OF CURRENT STATUS

The Indian Himalayan region is not too much suitable for the traditional agriculture due to its difficult terrain. However, the frequent variations in altitude and freezing temperature allow the region a limited but unique type of agriculture products and natural vegetation. Due to changing climate, there is a loss of ecosystem and hence the natural resources get affected.

Thus, present scenario is for the mapping and monitoring of the changes of various natural resources & vegetation of this region. Since, different varieties of horticulture fruits especially temperate fruits getting tough challenge from other parts of world in terms of quality as well as per hectare production. Thus, in a way step ahead prime objective of this study is to highlight the need of a digital spectral library for horticulture fruits. The spectral library for the diseases affected crop will be helpful to identify the disease spread on a particular crop in a region. Development of model for the estimation of biophysical and biochemical parameter properties may be helpful for monitoring long time climatic changes in horticulture crops.

4. REVIEW OF METHODOLOGY

This study reviewed a combined methodology for the processing of hyper spectral data for generation of spectral library, identification of diseases and for development of model for the estimation of biophysical and biochemical properties of temperate horticulture fruit crops (Figure 3).

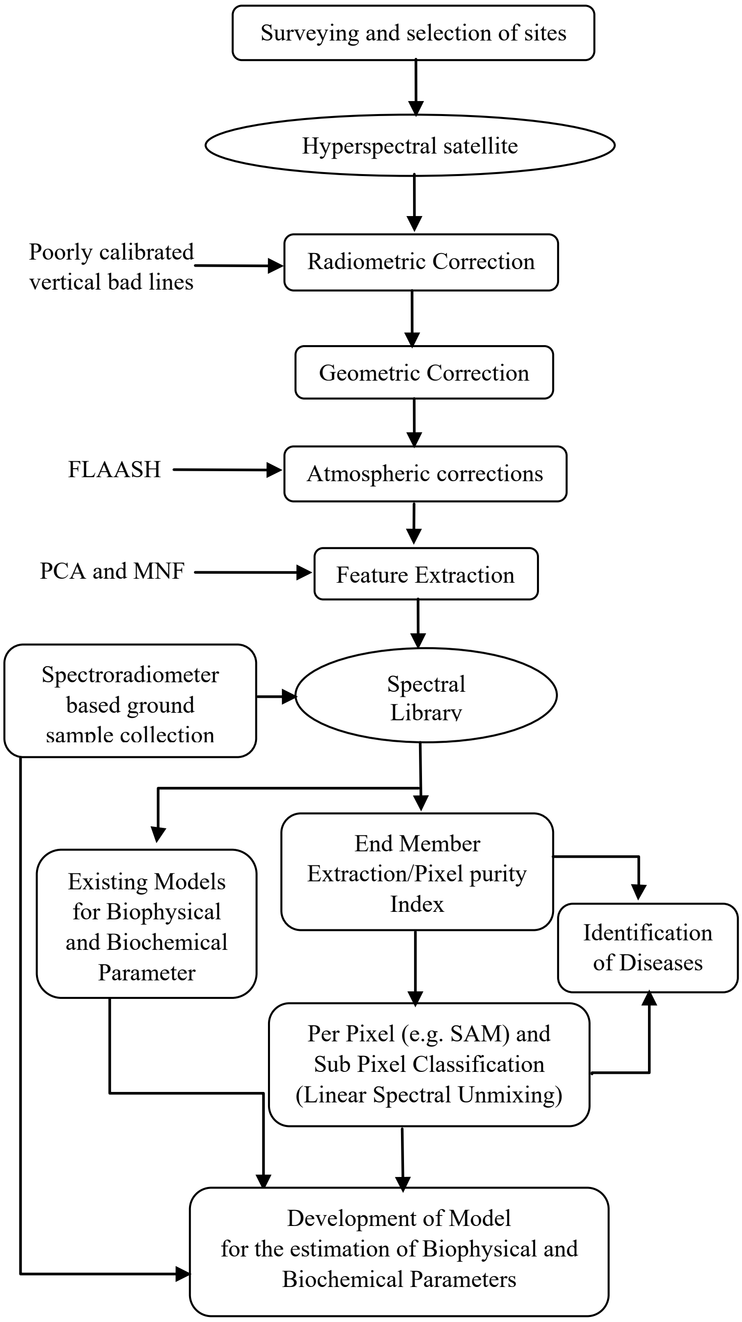

Figure 3: Methodology for the processing of hyperspectral data

At a very first step, to generate the reference data surveying of sites and identification of temperate horticulture crop plots of suitable size is necessary. This will be carried out by selecting appropriate hyper spectral satellite data. Processing of hyper spectral imagery is a challenging task. For poorly calibrated vertical bad lines radiometric correction needs to be applied. For atmospheric correction techniques such as Fast Line-of-sight Atmospheric Analysis of Hypercubes (FLAASH) may be used. Dimensionality reduction or feature extraction can be achieved by the methods such as Principal Component Analysis (PCA) and Minimum Noise Fraction (MNF). The Field Spectroradiometer based ground samples are used for taking the spectral reflectance of different temperate horticulture crop and spectral library generation.

5. REVIEW OF SPECTRAL LIBRARY GENERATION

The problem always arise for the classification of hyper-spectral data due to insufficient training signature, therefore collection of training data and formation of digital library is always a part of interest for the researcher across the world.

Although several researchers are working related to the broad area of hyperspectral remote sensing, yet there is no effort for spectral library generation for the horticulture fruit crops. However, according to a report by Das et al., 2015, some efforts have been made for the spectral library generation for the soil samples. The accurate vegetation identification using the hyperspectral technologies is due to the presence of narrow and contiguous bands that makes it possible to distinguish variations of absorption features on contrary to the multispectral sensors.

Ray et al., 2006 evaluated the hyperspectral indices for Leaf area index (LAI) estimation and the discrimination of potato crop under the different irrigation treatment in an experimental farm of Central Potato Research station located in Jalandhar, Punjab. They have found that the hyperspectral indices are being more efficient than the LAI to detect the difference among crops under the different irrigation scheme. They have also found the optimum spectral bands for the discrimination between different irrigation treatments.

During the previous decade lot of work for the spectral libraries development have been carried out. However, it is basically limited to the reference reflectance spectra of minerals, soils and natural vegetation species (Nidamanuri and Zbell., 2011). Negi H.S., Shekhar C. and Singh S.K., 2015 used hyperspectral data for the snow and glaciers investigation in Northwestern Himalaya of India using the spectroradiometer. The important wavelengths for the snow applications are found to be 440, 550, 590, 660, 860, 1050, 1240 and 1650nm.

Vishnu et al., 2013 reviewed the spectral matching and library search methods for the spectral material mapping using the hyperspectral data. They presented an overall view of literature relevant to the development of library search method, various search algorithm and system available for the development of an automated hyperspectral data analysis system.

Sahoo, Ray and Manjunath, 2015 studied the hyperspectral remote sensing of agriculture. They have discussed the different narrow band spectral properties of vegetation in optical and thermal range of electromagnetic spectrum. Further, different methods for the optimization to reduce the data redundancy as well as potential applications of hyperspectral in crop discrimination and their genotype, quantitative estimation of different biophysical and biochemical parameters have also been discussed.

6. A REVIEW OF HYPERSPECTRAL SATELLITE DATA

In past different type of hyper-spectral satellite data have been explored by the researcher for various applications. Amongst them, EO-1 Hyperion data had been widely used across the globe. The user availability of low price hyper-spectral images with larger swath and high spatial resolution has not been still achieved. After termination of Hyperion mission on the EO-1 satellite the choices are now limited. Further, high quality research in this field needs expensive equipment, hardware and in-situ observations. However, still there are hope for the expecting use of this challenging remote sensing technology for different applications. A list of the current, future and obsolete hyperspectral satellite/ airborne images are given in the table (1).

Table 1: Current status of hyperspectral satellite data of different agencies.

Sensor	Agency/ Country	Spectral bands	Spectral Regions (µm)	Spatial Resolution (m)	Current Status
Hyperion	NASA, USA	242	0.4 to 2.5	30	Mission Terminated
AVIRIS	NASA, USA	224	0.38-2.5	4-20	Data available on user request
HysIS	ISRO, India	60/256	0.4-0.95/0.85-2.4	30	2019-2026
HyMap	Integrated Spectronics Pvt. Ltd./ Australia	128	0.45-2.48	2-10	Data available on user request
CASI	Canada	288	0.38-1.05	0.2-1.5	Airborne/ user demand
AISA	Finland	244	0.4-2.5	2.9	Airborne/ user demand
ROSIS	Germany	115	0.42-0.873	2	Airborne/ user demand
HISUI	Japan	185	0.4-2.5	20-30	2019-2021

Hyperspectral Imaging Satellite (HysIS)
Indian Space Research Organisation (ISRO) has recently launched the Hyperspectral Imaging Satellite (HysIS) successfully. The application areas for this satellite are agriculture, forestry, soil survey, geology, coastal zones, inland water studies and detection of pollution from industries and military surveillances. It has two payloads one in VNIR and another in SWIR range of electromagnetic spectrum.

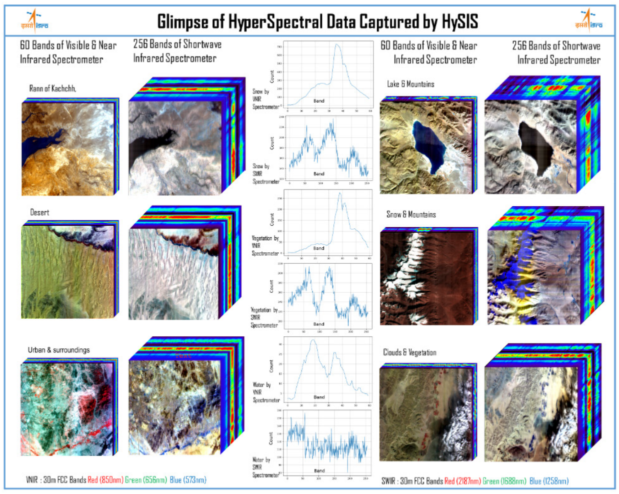

Figure4: Hyperspectral cubes of different terrain conditions & sample spectral plots for different features (https://www.isro.gov.in).

Hyperspectral Image Suiter (HISUI):
It is a space borne hyperspectral earth imaging system being developed by Ministry of Economy, Trade and Industry, Japan. It has a 3 years operation period starting from 2019. The basic aim is to develop a full scale practical application hyperspectral data with high spatial resolution on-board. The spatial resolution for this satellite will be 20meter for cross track and 30 meter for along track with total 185 spectral bands. This satellite has a wide spectral coverage with range to 0.4 to 2.4 µm and spectral resolution is 10nm and 12.nm for VNIR region and SWIR regions respectively.

7. SPECTRO-RADIOMETER DATA FOR FIELD REFERENCE SAMPLES

Due to large variations in spectral characteristics within a land cover, there is always a growing interest of in-situ measurements for the processing of hyper-spectral data (Nidamanuri and Zbell., 2011). Nowadays with the development of advanced field spectro-radiometers having the capability of measuring from ultraviolet (350nm) to the shortwave infrared region (~2500nm) in very small bandwidth, one can easily measure the reflectance characteristics of various features and form the reference data. In previous studies scientists have widely used spectro-radiometer based field spectral data for mapping of mineral (Debba et al., 2005; Swayze et al., 2009), classification of soil (Brown, 2007) as well as for the various urban material discrimination (Herold et al., 2004). However, in the recently studies there is more focus towards the development of spectral library for the vegetation based land cover. Spectro-radiometer based ground collected reference data is not only helpful for the spectral library generation but also an input for the development of estimation of biophysical and biochemical parameters.

8. CONCLUSION

In this study, a need of studying the temperate horticulture fruit crop of IHR through hyperspectral remote sensing was discussed. Importance of this study in the context of current status has also been highlighted. A review of current, future and obsolete missions of hyperspectral satellite mission has also been performed. A methodology for processing of hyperspectral data for spectral library generation and inputs for the development of methodology for estimation of biophysical and biochemical parameter have been proposed. This study will encourage researchers to apply hyperspectral remote sensing not only for horticulture crop but also for other application areas.

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