TREND ASSESSMENT OF CROP VIGOUR IN APPLE ORCHARDS USING TIME SERIES HIGH RESOLUTION SATELLITE DATA

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ABSTRACT: Himachal is known as the apple state of India and covers nearly 49 per cent of the total area under fruit crop and 87 per cent of the total fruit production. Though area under apple orchards is growing, the present orchards are not able to meet the requirements of the country. Many orchards have become uneconomic and require rejuvenation practices in order to boost their economic yield. Remote sensing has played a vital role in assessment of orchard inventories in India and around the globe. However, very few studies have been directed in the area that utilizes remote sensing as a tool to keep a track of orchards to be considered for rejuvenation. The present study was conducted in Shimla district of Himachal Pradesh, in an effort to identify such orchards. Apple area was identified using supervised classification of RESOURCESAT-2 LISS IV data (~5 m spatial resolution). LISS III data (~23 m resolution) from RESOURCESAT 1 and 2 over past 10 years (2005 – 2015) were used to study the trend of vigour of the apple orchards. It was done by using regression analysis of the NDVI of the 10 years' data against time represented by the years. Apple orchards of Shimla were characterized based on the analysis. Steady decline in the trend in vigour of apple orchards can indicate need of rejuvenation practices in those areas. But in Shimla, such areas constitute very negligible areas. The result is also validated by the ground observation that the apple farmers take exceptionally good care of their crop. Future scope of studies include impact of global warming, shift in suitable growing degree days and unconventional pest-disease effects. The study can be used to delineate areas requiring rejuvenation practices in other study areas and also for other crops like mango.

1. INTRODUCTION

Apple has brought prosperity to the state of Himachal Pradesh. It is contributing around Rs. 3200 crore to the State Gross Domestic Product (GDP). Himachal Pradesh is also known as 'Apple State of India' and it is the major fruit crop of the State which constitutes about 49% of the total area under fruit crop and about 87% of the total fruit production. Area under apple has increased from 400 hectares in 1950-51 to 3,025 hectare in 1960-61 and 1,06,440 hectares in 2012-13.

Apple has been found to be the most viable and sustainable option for the livelihood of farmers especially the small and marginal farmers. The districts such as Shimla, Kullu, Kinnaur, Chamba, Mandi and Sirmaur are the major apple growing regions in the State. The commercial cultivation of apple dates back to 80-90 years. Many orchards are still having apple trees that dates back to 80 years. Various factors such as overcrowding and unsystematic planting, average age of orchards crossing the prime age for productivity, growth of wild shrubs and grasses, damage due to weather conditions and infestations of pests can lead to orchards becoming less productive. These trees do not get proper sunlight resulting due to decreased production of shoots. New emerging shoots are weak and are unsuitable for flowering and fruiting. As a result, the productivity of the orchards goes down alongwith their profitability to the farmers. Such orchards require rejuvenation practices. The term 'Rejuvenation' means renewal or making new or young again. When applied to orchards it means to restore the productivity and the economic value of orchards. To enhance apple productivity, 'Apple Rejuvenation Project' is being implemented under Rashtriya Krishi Vikas Yojna, under which old apple orchards are being rejuvenated and replaced with the new, improved and regular bearing spur varieties.

Remotely sensed data along with ancillary data and ground truth data have been used extensively for survey of resources like agriculture, horticulture, forestry and to study various physical phenomena. Remote sensing technology proves to be cost effective as well as time effective as it provides a synoptic view of region under study with multispectral information which provides valuable information for various kinds of analysis.

Remote sensing has played a vital role in assessment of orchard inventories in India and around the globe (Gupta and Sharma, 1990, Sharma and Panigrahy, 2007, Usha and Singh, 2013, Warner and Steinmaus, 2005, Zhang et. al., 2007). Studies in the past have shown the use of remote sensing and Geographic information system (GIS) to accurately extract horticulture crops at different scales (Mehta et al., 2006, Panigrahy et al., 2001, Hebbar et al., 2013).

However, as of yet no study has been done using satellite remote sensing data to feed into decision making process to assess when or which orchards has declined in their productivity. The present study is aimed at understanding the utility of remote sensing studies to characterize apple orchards in order to understand the areas that require rejuvenation practices using long term data from Indian Remote Sensing(IRS) satellites.

2. STUDY AREA AND DATA USED

2.1 Study Area

The present study proposes the delineation of apple crop area requiring rejuvenation in the district of Shimla of Himachal Pradesh State. Shimla is located between 76.99^0 E, 31.72^0 N and 78.31^0 E, 30.76^0 N. It receives about 1000 mm of rainfall and the major soil types include Brown hill soil and Alpine Humus Mountain skeletal soil. The location map of the study area is given in Figure1.

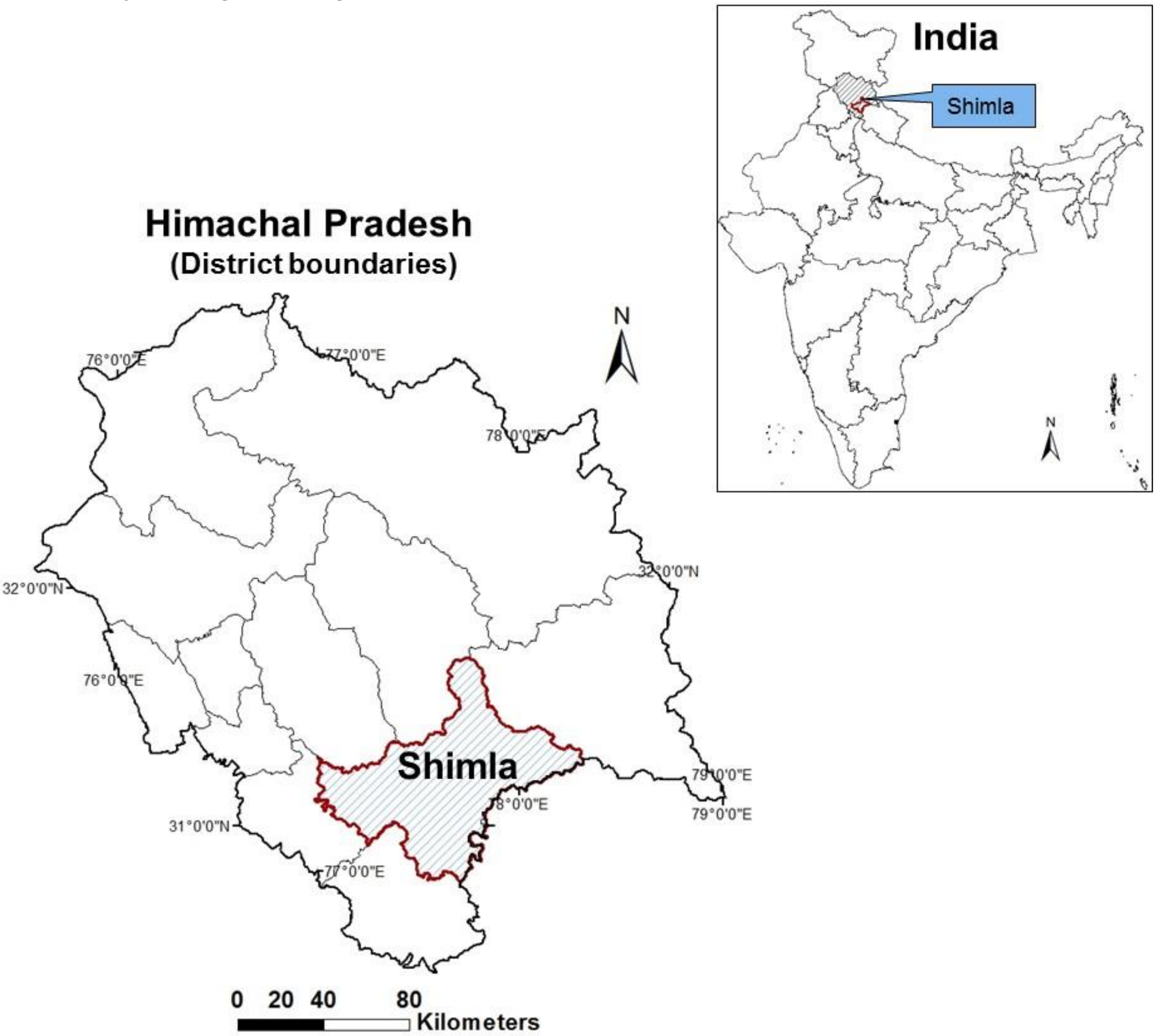

Figure 1. Study area for apple orchard study

2.2 Data used

2.2.1 Satellite remote sensing data

Apple tree is of perennial nature. Six-date LISS-IV sensor data (~5 m spatial resolution) of the year 2015 were used to understand the best date to classify and to study the crop. The study area of Shimla was covered by 2 scenes of LISS IV data as given in table 1. For studying change in vigor over previous years, LISS III data (~23 m spatial resolution) of past 11 years were used, from 2004 – 2015 (table 1). In order to have comparability among data of these 11 years, the time period selected was as closest to each other as possible. The selection of time was based on the evaluation of the best bio window for apple area estimation followed in the study. The period between May and

June was selected for the study because of reasons like maximum divergence of spectral profile of apple from other crops and lesser possibility of cloud cover during that period. LISS III data were chosen due to higher repeativity and regular availability as compared to high resolution LISS IV data.

Table 1. List of LISS IV and III data used from IRS satellites

Sensors	Path	Row	Sub-scene	Dates	Year
LISS-IV	95	49	b	9 April, 27 May, 31 August,	2015
	96	49	a	21 March, 8 May, 29 September	2015
LISS-III	95	49	-	24 May, 12 June, 7 June, 2 June, 22 May, 10 June, 12 May, 30 May, 25 May, 20 May, 8 June	2004, 2005, 2006, 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015 respectively
	96	49	-	29 May, 24 May, 19 May, 7 June, 27 May, 22 May, 10 June, 4 June, 30 May, 25 May, 20 May	2004, 2005, 2006, 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015 respectively

2.2.2 Ground truth data

Ground truth (GT) / field verification is an important component for validation of analysis involving satellite data. Thus meticulous planning was done for the data collection. Based on variation in the spectral signatures in the remote sensing data and available land use data various sample sites were designated for collection of data.
Unsupervised classifications (ISODATA) of the FCCs of the selected dates were carried out to understand the varied classes available. Areas expected to have apple identified with the help of the unsupervised classified data and Google maps were marked on the prints of satellite data of the same time. Other major crops as understood from secondary research about the study area, were similarly marked on the map prints.
Coordinates of the sample sites were used to identify the location during data collection. Global positioning system (GPS), google map prints and transport network visible on the map of the corresponding area was utilized for guiding to the location designated as sample sites. Various details of the sample site along with site description were collected. The ground truth details like type of crop, expected date of harvest, percent canopy cover, crop growth stages, crop health /condition of apple and other existing crops were also recorded.

3. METHODOLOGY

In order to study apple orchards, area under apple orchards needs to be primarily estimated. Based on spectral signature separability tests, apple orchards can be segmented only when the signature separability between apple and competing crops is the highest. Hence, the proposed methodology suggests to identify the bio-window when the vegetation vigour of apple orchard is at its peak and the signature separability of apple with respect to other crops is highest.

3.1 Preprocessing of satellite data

The pre-processing steps consisted of geometric correction followed by radiometric correction in order to minimize geometric and radiometric errors. This was done for both LISS IV and LISS III data.
Geometric correction was carried out in order to minimize geometric distortion, if any, in the image using master/ reference image (Babboo et al., 2011). A nearest neighborhood resampling technique was used during the image registration exercise as it retains the original DN values and does not average them as done by other resampling techniques. The LISS-IV images were resampled to 5 metres and LISS-III images were resampled to 23 metres.
Radiometric normalization was carried out to minimize radiometric error. Initially the digital numbers were converted to radiance as per equation (1) followed by conversion to Top of the Atmosphere (TOA) reflectance or apparent reflectance images (ρ_λ) using equation (2).

$$\textbf{Radiance } (L_\lambda) = (DN/DN_{max})(L_{max} - L_{min}) + L_{min} \quad \text{......} (1)$$

L_{min} = Minimum Radiance, L_{max} = Saturation Radiance, DN_{max} =Radiometric Resolution

$$\textbf{TOA } (\rho_\lambda) = (\pi * L_\lambda * d^2) / (E_o * \cos(\Theta)) \quad \text{......} (2)$$

L_λ = Spectral Radiance (mW cm^{-2} sr^{-1} μm^{-1})
d^2 = Sun distance in astronomical unit (AU)
Θ = Sun zenith angle in radians.
Eo = Mean solar exoatmospheric irradiance (mW cm^{-2} μm^{-1})

For each of the scenes, after geometric and radiometric correction of the LISS III images of all dates, Normalized Difference Vegetation Index (NDVI) was computed for all the dates. NDVI indicates the vigour of vegetation and is higher for dense healthy vegetation and lower for sparse vegetation. NDVI of non-vegetation classes are generally lower than vegetation classes. Vegetation has a distinctive spectral signature that is characterized by low reflectance in visible region of solar optical spectrum and high reflectance in infrared (IR) spectrums. The combination of these two spectral regions allows classification of vegetation. In the present study, Normalized Difference Vegetation Index (NDVI), which is widely used Vegetation Index, is used and is defined as:

$$NDVI = (NIR - R) / (NIR + R) \quad (3)$$

Where, NIR is the reflectance in near infrared band and R is the reflectance in red band of satellite data.

3.2 Extraction of Bio-window

For estimating area under apple orchards, it is primary to be able to distinguish apple from other land uses. Unsupervised classification (ISODATA) was performed on the LISS IV images to get an overall idea about the various land covers of the study area. On the basis of that, ground truth points were decided covering all major classes. Thus, the major classes were determined from the ground truth data. NDVI was estimated for all the dates of the year 2015 of LISS IV data. Region of interest (ROI) polygons from 3 x 3 pixels were made around the GT points. The mean of each ROIs on the NDVI images of each date indicated the NDVI profile of that land use class. NDVI data were used to generate representative trends for the various land uses. Temporal NDVI profile was generated based on GT points and those dates were considered where the divergence of NDVI for the competing crops and apple orchards was maximum. Extraction of bio-window was then followed by generation of training sites and supervised classification.

3.3 Classification and characterization of apple area

Classification of apple orchards was done separately for 2 different scenes, viz. scenes 95 – 49 B and 96 – 49 A. Crops were identified on the false colour composite (FCC) image based on the GT data collected along with their GPS measurements. The training signatures contain multi-band statistics such as mean, standard deviation, and variance-covariance matrix for each class, which is used in supervised classification. Forest class was masked out from the FCC based on Land Use Land Cover (LULC) data derived at 1:50,000 scale (NRDB 2006-07). Thus, only three major signature classes were developed corresponding to the major types of land cover classes of the study area i.e. apple, agricultural crops and wasteland/shrubland.
The pixel-based classification was undertaken on the data which was derived based on bio-window of apple orchards. Supervised classification was carried out on LISS IV datasets of the study area based on the maximum likelihood classifier algorithm (Jensen, 1996; Lillesand and Kiefer, 2000). This involved the selection of training areas representative of the three major land cover classes viz. apple, agricultural crops and wasteland. The training signatures of various crops and other land-use classes were generated with reference to the Ground Truth (GT) sites. A number of training areas were selected to represent each class. Following classification of the imageries, majority filter was implemented in order to remove single pixels which were misclassified as apple based on the majority values within kernel. Classified data of two scenes were then mosaiced to get apple crop acreage. The methodological flow for extraction of apple areas of Shimla region is given in figure 2a. Classification of apple areas was followed by characterization of the apple area using CARTOSAT DEM data. Accuracy assessment of the classified image was carried out based on kappa statistics and GCPs taken during field visit as reference points.

3.4 Trend analysis

Ten years NDVI data, 2005 to 2015, were used (2008 data was missing) for analysing vegetation trend of apple orchards.

Unsupervised classification (ISODATA) was performed on each year's NDVI data. The class(es) with cloud data was masked out. Since NDVI lesser than or equal to 0.09 is essentially not vegetation class, those pixels were also masked out.
Trend analysis of remote-sensing time series has been used to effectively describe a 'slow' or gradual change of vegetation cover (Sonnenschein, et al. 2011) and agricultural ecosystems (Tottrup and Rasmussen 2004; Fuller 1998). This was calculated for each pixel to minimize the sum of least squares between given and estimated values for each fix point (i.e. date available in the time series), yielding a function of the type:

$$y_t = g.\ t + o \quad (4)$$

where,
y_t = vegetation vigour in the form of NDVI at date t
t= date of image acquisition
g= regression coefficient (gain)
o= regressions constant (offset)

The gain describes the direction and magnitude of the development over the monitoring period. Pixels with patches where NDVI is less than 0.09, like the cloud patches, in a particular year would be considered as missing data. Thus, while calculation regression coefficient, care was taken to accommodate such loss of data. As these regression parameters are calculated on a per-pixel basis, the temporal development can be illustrated in a spatially differentiated way. To assess the statistical robustness of the trend, one-sided t-test at 95% significance level (since we are concerned with the decreasing trend only) was calculated. The schematic flow of the methodology followed is depicted in figure 2b.

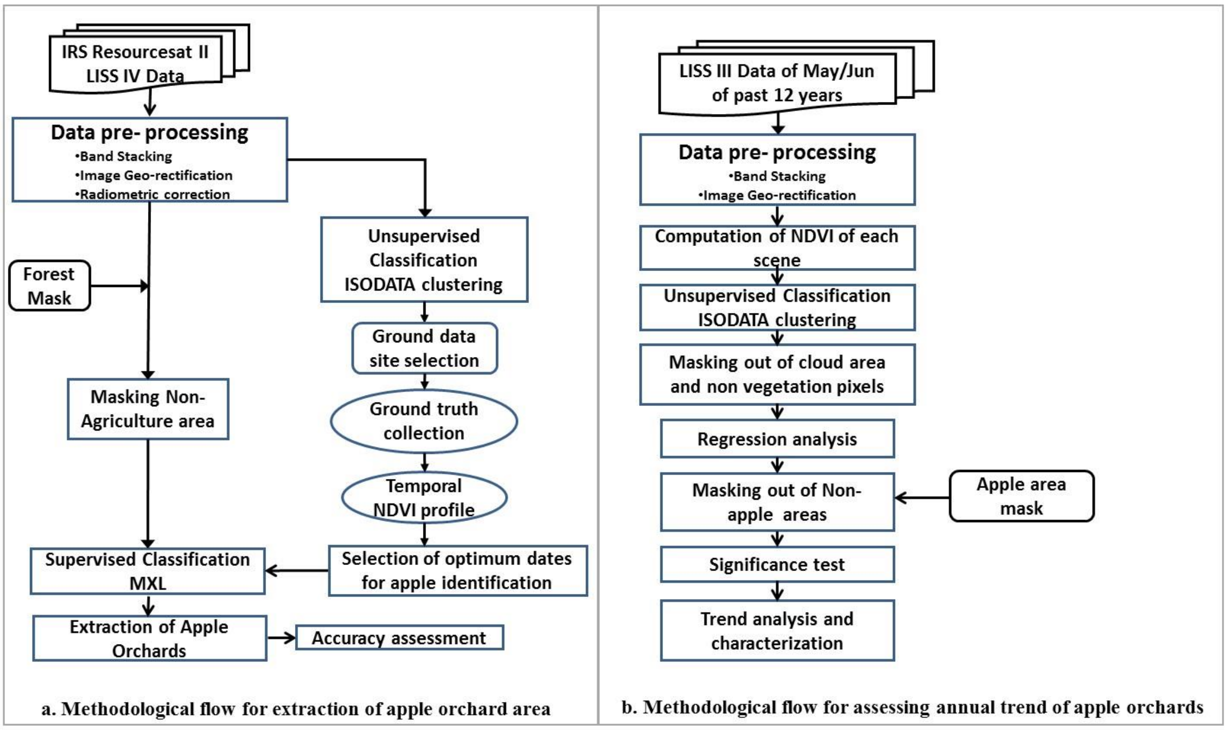

Figure 2.Schematic flow of methodology for estimation of (a) area and (b) annual trend of apple orchards

4. RESULTS AND DISCUSSION

4.1 Bio-window for apple discrimination

The NDVI data for the period March to September 2015 from LISS-IV sensor were used to generate temporal spectral crop growth profiles of apple and major land use classes. The temporal variation of spectral signatures of apple is shown in figure 4 and the visual representation of the crop spectral growth curves is given in the figure 5. In case of apple, the orchards undergo distinct phenological changes in a year that ranges over flowering, vegetative and fruiting season. It is observed that data acquired during fruit set and development period are the most suitable, as the trees are fully vegetated (June to September), to identify apple orchards and derive vegetation vigour (figure 4). It can be observed from figure 4 and 5 that NDVI of apple is maximum in August. However, due to cloud cover it is difficult to obtain optical data from July to September. Maximum divergence of apple NDVI profile is during the months of May, when apple's NDVI is higher than other land use classes, there are no agricultural crops during that time and it shows maximum divergence from shrub or wastelands also. Thus, data acquired during May-June were used in this and further studies.

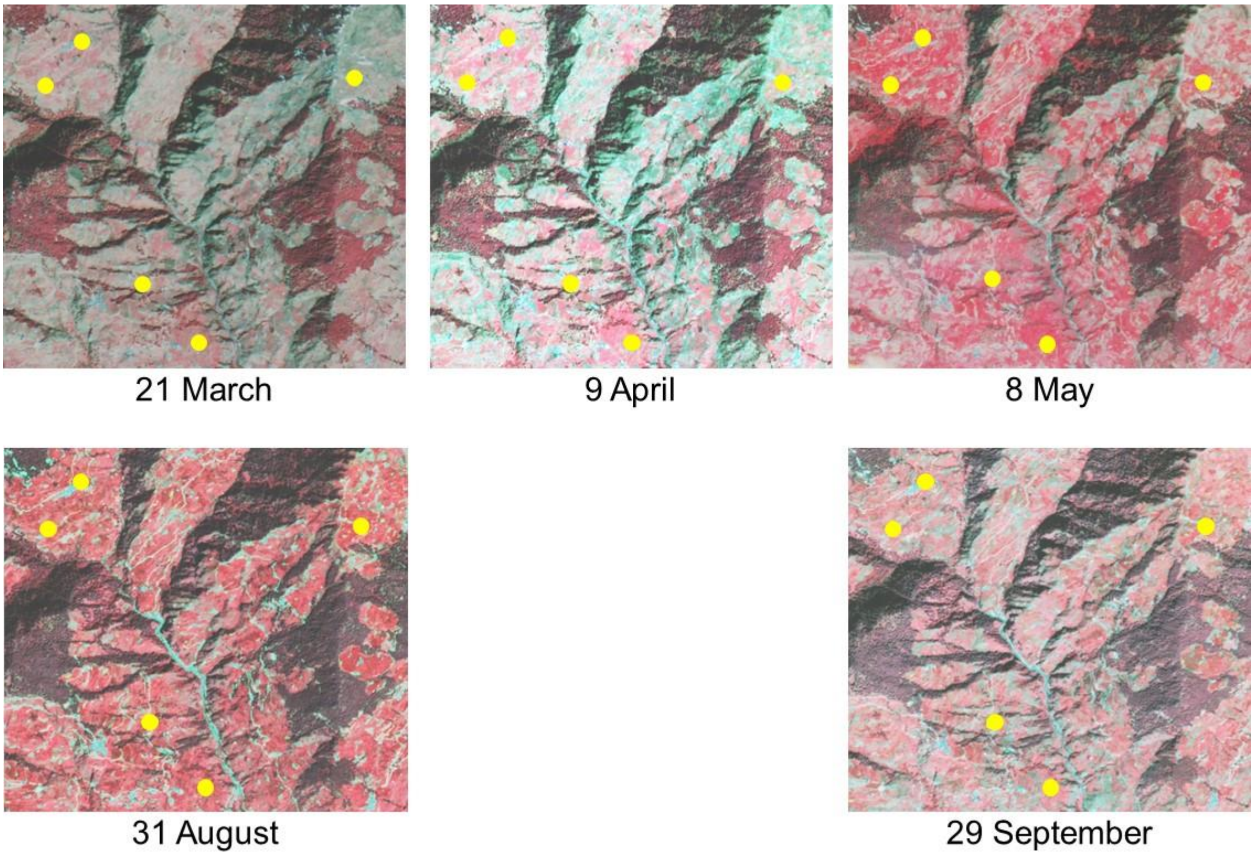

Figure 3. Temporal variation of spectral signature of apple using IRS LISS IV data

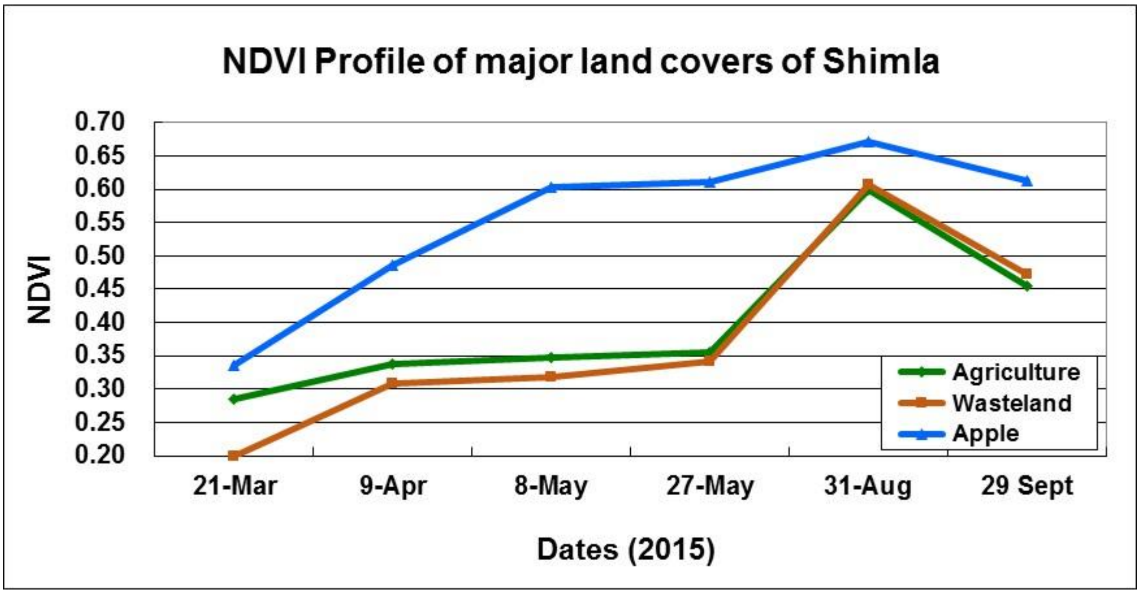

Figure 4: Bio-window estimation for segmentation of apple orchards

4.2 Assessment of apple area

The classification revealed that apple orchards occupy 42170 ha of Shimla district. It was found that Rohru had the maximum area of apple orchards followed by Rampur and Kotkhai taluka (table 2). As per the statistics of state department of horticulture, 2003 - 04, Jubbal – Kotkhai had the maximum area followed by Rohru and Narkanda. It must be noted that the reference statistics used by the state horticulture department is very old and there has been several changes in the block boundaries, including many exclusions and inclusions of areas. These are used for having a rough estimate and comparison of the distribution of apple area over the district.

Table 2. Distribution of apple area over talukas of Shimla district

Blocks	Area (ha)	% area of total apple area	Blocks	State Dept. of Horticulture estimates (2003 - 04)	% area of total apple area
Rohru	11990	28%	Jubbal - Kotkhai	7638.61	21%
Rampur	9705	23%	Rohru	6077.47	16%
Kotkhai	5170	12%	Narkanda	5434.21	15%
Jubbal	5091	12%	Theog	4464.24	12%
Narkanda	3568	8%	Rampur	3993.42	11%
Theog	3362	8%	Chaupal	3679.69	10%
Chaupal	2858	7%	Chirgaon	3520.12	10%
Chirgaon	221	1%	Mashobra	2217.92	6%
Mashobra	157	0.4%			
Basantpur	38	0.1%			
Disputed	9.24	0.0%			
Total apple area	**42170**		**Total apple area**	**37026**	

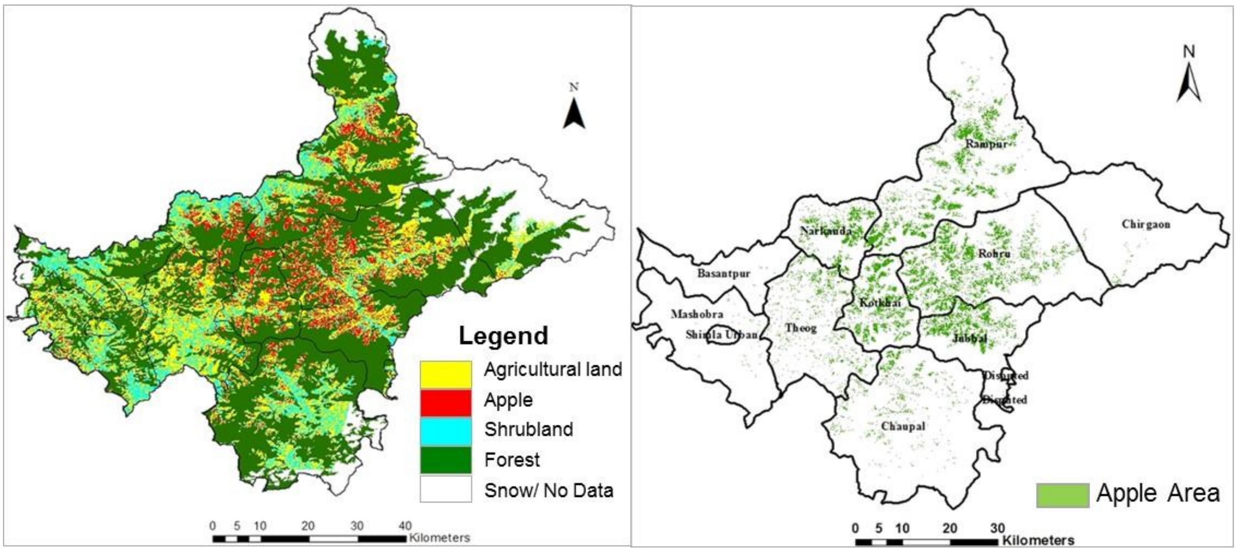

Figure 5. Major land use classes and Apple of Shimla district using LISS IV data

4.3 Estimation of inter annual trends of apple orchard

Inter annual trend of apple orchards was analyzed using linear regression on 10 years' NDVI data from 2005 to 2015 (year 2008 data missing). For each pixel in the map, the retained value was the slope or gain of the fitted linear regression between NDVI and time. We classify the linear trend regression slope value as five levels: severely degraded (-0.05 to -0.007 yr^{-1}); remains stable (-0.007 to 0.007 yr^{-1}); mild degradation (0.007 to 0.056 yr^{-1}); improved (>0.057 yr^{-1}). The results are shown in Figure 4. It was observed that about 60% orchards show positive trend while 37% showed neutral behavior, whereas only about 5% orchards shows a declining trend (figure 7).

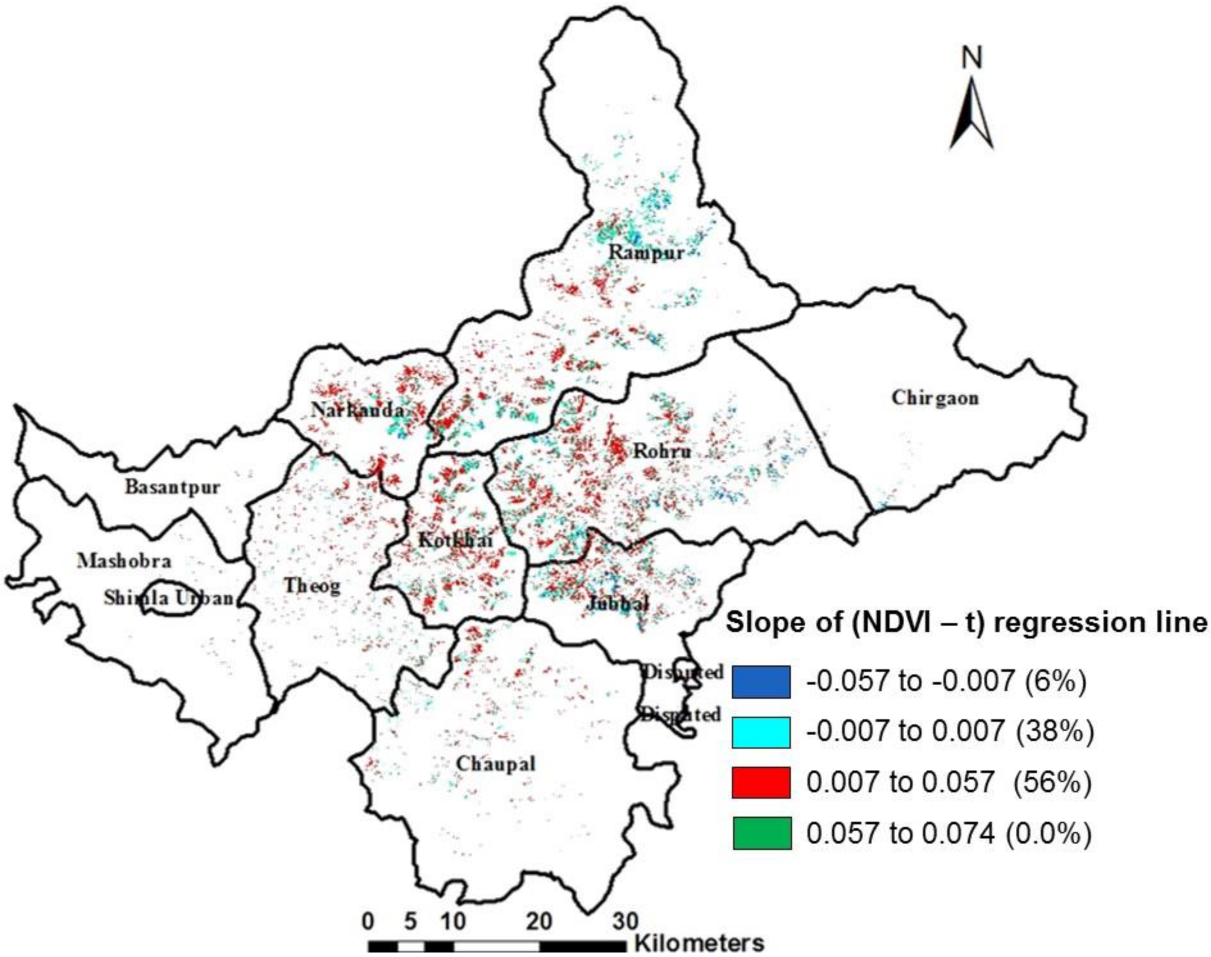

Figure 6. NDVI based regression trend over apple orchards during 2005 – 2015

Temperate horticultural crops such as apple, are concentrated in hilly terrain of higher elevations due to the physiological requirement of cool temperature. Thus, slope and elevation are some of the influencing factors for orchard condition and productivity. It has been already established that apple prefers an elevation of about 1500 – 2700m. Same is also reflected in this study, where apple orchards are concentrated at the height of 1500 – 2500 m (table 3a). Out of them, about 6% showed a negative trend over the years, with slope of trend line ranging from -0.075 to -0.007, 38% orchards showed a steady pattern, denoted by the slope range of -0.007 and 0.007, and 56% orchards showed a positive NDVI trend (figure 7). There has not been any improvement (0%) in the whole area under apple orchards. The result has been validated by the State Remote Sensing Centre, Shimla. The negligible area under severely degraded orchards is because of the fact that, the apple farmers take extremely good care of their orchards. Thus, each tree receives considerable attention, and when they require rejuvenation practices are immediately attended. The general practice is to replace single tree rather than the orchard as a whole. Thus estimation of such areas through remote sensing is not possible in this study area.

The proportion of apple orchards with severely degraded and stable trend of NDVI are increasing, whereas proportion of orchards with mild degradation vegetation is decreasing with height (table 3b). At each class height, area having mild degradation of NDVI is more than other 2 types except for the orchards situated at more than 3000 m of height.

Table 3. Areal statistics of apple orchards showing trend of NDVI over ten years across different heights

(a)

Height(m)/ gain	Area (ha)				
	Severely degraded	Stable	Mild degradation	Improved	Total
0-1500	0.1%	0.8%	1.8%	0.0%	3%
1500-2000	1.3%	12.5%	20.7%	0.0%	34%
2000-2500	3.5%	22.1%	31.1%	0.0%	57%
2500-3000	0.6%	2.7%	2.7%	0.0%	6%
>3000	0.1%	0.1%	0.0%	0.0%	0.2%
Total	**6%**	**38%**	**56%**	**0%**	**100%**

(b)

Height(m)/ gain	Area (ha)				
	Severely degraded	Stable	Mild degradation	Improved	Total
0-1500	3%	29%	68%	0.00%	100%
1500-2000	4%	36%	60%	0.01%	100%
2000-2500	6%	39%	55%	0.00%	100%
2500-3000	10%	45%	45%	0.00%	100%
>3000	45%	50%	6%	0.00%	100%
Total	**6%**	**38%**	**56%**	**0%**	

When the trend of NDVI was observed at different slopes, it was found that overall 42% of orchards are situated at the slope of 20 -30 degrees (tab 4a) closely followed by slope of 0 -20 degrees. Out of that, 6% accounted for severely degraded orchards over the years, 38% showed a stable growth, whereas, 56% orchards underwent mild degradation. Here also, more number of area is under stable and mild degraded orchards.

Table 4. Areal statistics of apple orchards showing trend of NDVI over ten years across different slopes

(a)

Slope (deg)/ gain	Area (ha)				
	Severely degraded	Stable	Mild degradation	Improved	Total
0 - 20	2%	12%	19%	0%	33%
20 - 30	2%	16%	23%	0%	42%
30 - 40	1%	8%	11%	0%	21%
40 - 60	0.33%	2%	2%	0%	4%
> 60	0.01%	0.02%	0.03%	0%	0.06%
Total	6%	38%	56%	0%	100%

(b)

Slope (deg)/ gain	Area (ha)				
	Severely degraded	Stable	Mild degradation	Improved	Total
0 - 20	5%	36%	58%	0%	100%
20 - 30	5%	39%	56%	0%	100%
30 - 40	6%	40%	54%	0%	100%
40 - 60	8%	40%	52%	0%	100%
> 60	12%	44%	44%	0%	100%
Total	6%	38%	56%	0%	

5. CONCLUSION

The steady trend indicates mature orchards. Declining trend can be due to more than one reason – it may indicate senile orchards or unattended orchards infested by pest and diseases or effect of weather parameters. Fluctuation of NDVI can also be due to atmospheric noises in data, or changes in sensor calibration. In view of this, it is recommended to have time composite NDVI data for analysis instead of single day data, which can avoid such noise to a greater extent. Future course of work would include study of the NDVI trend in relation to various factors affecting it, such as, climatic and anthropogenic factors, such as, fire, cyclic replantation, etc. that can possibly affect the trendline.

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