Chapter 16
Inventory and Phenological Assessment of Apple Orchards Using Various Remote Sensing Techniques for Shopian District of Jammu and Kashmir State, India

Arvind Pandey, R. Hebbar, Sarita Palni, Jiwan Singh Rawat, and Uday Raj

Abstract Horticultural crops are one of the vital role players in the field of economic development in Indian hilly regions. Among all, apple is one of the important horticulture crop in the North-West Himalaya, and 60% of apple production comes from Kashmir state in India. The identification and monitoring of apple becomes essential for proper assessment and planning for large production of apple. Now-a-days, Remote Sensing and GIS have been emerging as the newest and more advanced technique for crop monitoring, crop inventory and the assessment of its production. Keeping in view, the present work deals with the identification of apple-producing areas and assessment of phenology patterns of apple trees in Shopian district of Jammu and Kashmir which is a leading producer of apple in the whole world. The IRS-P6 LISS-IV, Cartosat-1 and LANDSAT-8 data were used for phenology and classification. Top of Atmospheric (TOA) correction and various digital classification algorithms viz., supervised MXL, Unsupervised ISODATA and NDVI threshold were used for estimation of the apple orchard area and NDVI profile for phenology pattern across the years. In comparison to other classification techniques, Supervised classification technique was found most suited with having accuracy ranging between 90 and 95% for all stages of apple trees. On the basis of spectral response and NDVI response, apple orchards were distinguishable amidst the other crops/vegetation types. Generated normalized difference vegetation index value was found to be 0.65 for apple orchards for LISS-IV and the results are used for finding the phenology of apple tree. Using the above NDVI threshold value, the apple orchards are classified with an accuracy range of 75–80%. It shows the unique spectral and phenology feature of apple and highlighted the seasonal change. This method is also very useful for other

A. Pandey (✉) · S. Palni · J. S. Rawat
Department of Remote Sensing and GIS, Soban Singh Jeena University, Almora, Uttarakhand, India

R. Hebbar · U. Raj
Regional Remote Sensing Centre, NRSC/ISRO, ISITE Campus, Marathahalli, Bengaluru 560037, India
e-mail: hebbar_kr@nrsc.gov.in

U. Raj
e-mail: udayraj@nrsc.gov.in

orchard inventory and estimation of productivity. Besides, this also provides a trend in any abnormal seasonal change on horticulture area which may help in providing pre-information about health and effect on overall production of orchard.

Keywords Remote sensing · Apple orchards phenology · supervised and unsupervised classification · NDVI

16.1 Introduction

The scenario of horticultural activities in the country has been changing rapidly both in terms of production and productivity. India stands at the second position in terms of fruits and vegetables production in the whole world and is the leader in several horticultural crops such as mango, papaya, banana, cashew nut, areca nut, potato (Kaul 1997). Proper planning of these crops basically requires reliable and precise data depicting area under production and total production at different spatial hierarchies (block, tehsil, district and state) (Tompkins et al. 2010). Hence, availability of reliable statistical database at micro level is one of the most critical requirements for efficient policy planning for proper development and management of resources (Sadoulet and Janvry 1995). In Asia and Europe, the history of growing apples dates back to over thousand years (Sadoulet and Janvry 1995). Origin of apple is known to be from Central Asia, where its wild ancestor, ***Malus sieversii***, can still be found till today (Harris et al 2002; Way et al. 1991). Apple tree (***Malus domestica***) is a type of deciduous tree (family—Rosaceae), mainly known for its sweet, pomaceous fruit (Ramírez and Davenport 2013). Apple is cultivated in the whole world as a fruit tree, and it is the most widely grown species among the genus ***Malus***. Apple trees do not attain much height and remain small if grafted onto roots (rootstock) but can grow hugely if they are grown from seeds. There are more than 7,500 known varieties of apples worldwide, which result in a range of desired characteristics (Suresha et al. 2012). Different cultivars are usually bred for different purposes and tastes, including cooking, eating uncooked and production of cedar and apple vinegar. In 2010, about 69 million tons apples were grown worldwide and almost half of this total was produced alone by China (Lima et al. 2010). The United States is the second-leading producer, with more than 6% of world production. Turkey, Italy, India and Poland follow the lead after US, respectively, in terms of apple production.

At present, satellite data with medium resolution is being operationally used for mapping and monitoring of agricultural crop (Becker-Reshef et al 2010). Many research works on remote sensing and geospatial technological applications for site-specific management of fruit and nut crops, guidelines for their phenological observation have been carried out by various scholars (Panda et al. 2010; Koch et al. 2007; Polgar and Primack 2011). However, in Himalayan areas, systematic examinations for investigating the utility of Remote Sensing data for horticultural fruit and crops grown by plantation techniques are restricted (Usha and Singh 2013). Advanced object-based classifiers have indicated promising outcomes for differentiation of

high-resolution information for monitoring, mapping and planning of nature-based resources. Object-based image classification technique is an incredible and promising strategy for grouping of high-resolution satellite images by changing image pixels into objects using both textural and logical data (Hebbar et al. 2014). Johansen et al. (2009) demonstrated the use of high-resolution data for depiction of banana plantations utilizing a combination of object-based classification and post-classification visual editing. With progression in space innovation, accessibility of high-resolution information and advanced classifiers, Remote Sensing can play a crucial part in the inventory of horticultural crops. In this context, this current investigation was proposed to investigate the expected utilization of high-resolution data for identifying and outlining horticultural crop types by using semi-automatic classification method *vis-à-vis* conventional visual interpretation techniques.

The major objectives of the study were (i) to study the phenology of apple orchards using temporal data, (ii) to study the inventories of apple orchards using multi-sensor data and (iii) accuracy deviation of classified data.

16.2 Study Area

Shopian was initially known as 'Sheen-e-van' which means 'forest of snow' is a historical town located within 33°42′37.27″ N to 74°56′28.77″ E (Fig. 16.1). It has remained a very important city from the time period of Mughal rulers (Schofield, 2000). The total area of this subdivision is 307.42 km^2 of which 196.93 km^2 area of cultivable nature. From 1872 to 1892 A.D onwards, Shopian was one among 6 Wazarat headquarters in Kashmir. Shopian district is positioned in the foothills of Pir Panjal mountain range and most of its terrain is hilly. The district is also recognized as 'Apple Bowl' of the state as it is famous for horticulture sector. Fruit production in this district is estimated to be 2 lakhs metric tons per annum. Shopian is also home for walnuts (Bhat and Lone 2017).

16.3 Data Used

Cartosat-1 data with 2.5 m PAN and LISS-IV data with 5.8 m resolution multiple data with three band (Green, Red and NIR band) are used for classification of apple orchards. Landsat-8 multiple temporal data with 30 m multiple, 15 m PAN and 30 m thermal data with 11 bands were used for temporal change assessment from June to January. Temporal data are used for determination of phenology of apple orchards and classification of apple orchards (Table 16.1, Fig. 16.2).
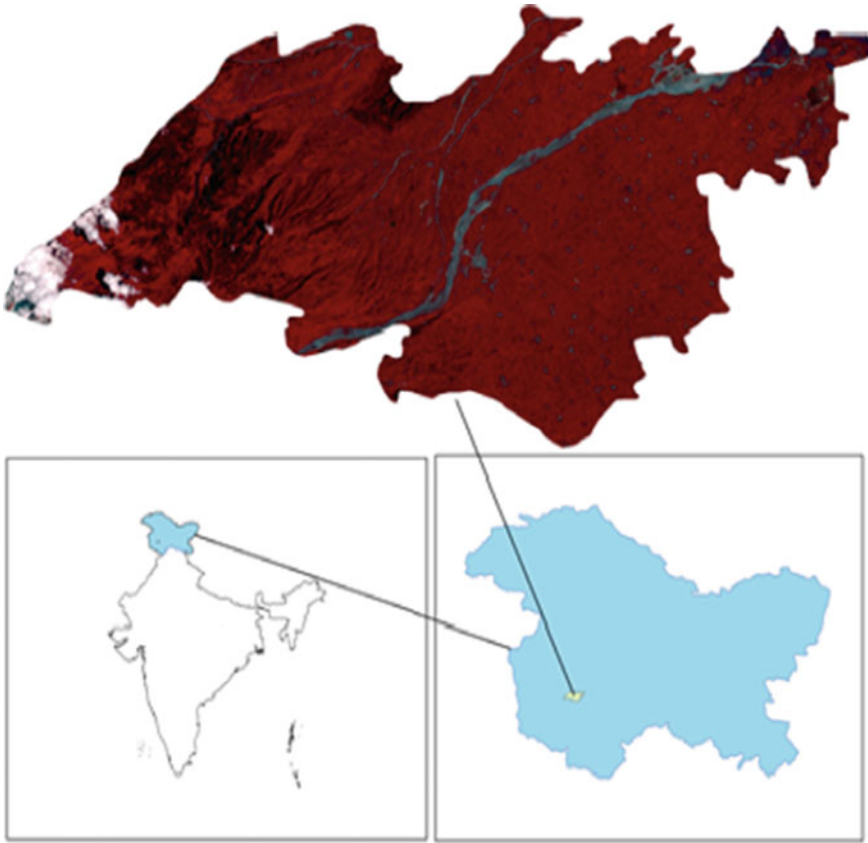
Fig. 16.1 Study area

Table 16.1 Characteristics of satellites data

Satellite	Resolution	Sensor	Revisit time (days)
Cartosat-1 IRS-P5	2.5 M (PAN)	PAN-AFT	5
LISS-IV (IRS-R2)	5.8 m (multi)	L4FX	5
Landsat-8	30 m (multi and thermal)15 m (PAN)	OLI and TIRS	16

16.4 Methodology

Methodology adopted in this study aims to determine the phenology of apple orchards using Landsat-8 multi-temporal data, inventory of apple orchards using multi-sensor data and consoled accuracy of classified data with high-resolution satellite imagery (Fig. 16.3).
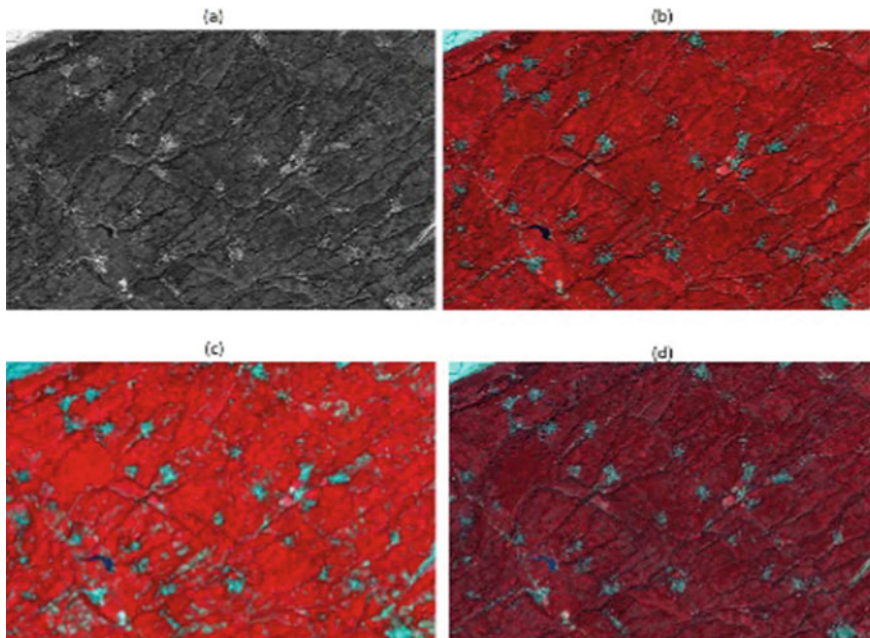
Fig. 16.2   Satellite images used for the study. **a** Cartosat-1 (2.5 m PAN data). **b** LISS-IV multiple data (5.8 m). **c** Landsat-8 multiple data (30 m). **d** Fused Image of Cartosat-1 PAN and LISS-IV multiple data

Three datasets i.e., Landsat-8, Cartosat-1 and LISS_IV have been used to carry out this work. The data of Landsat-8 have been pre-processed by calculating the ToA. It is then layer stacked so that a particulate image can be used. After this, the study area is subset from the layer-stacked image. The subset image is then used for doing the supervised and unsupervised classification to create NDVI spectral profiles for determining the apple orchard phenology profile.

Similarly, Cartosat-1 and LISS-IV images are also pre-processed by ortho-rectifying the both images and then fusing them together. The fused image is then classified by using the methods of supervised as well as unsupervised classification. NDVI is also calculated from the fused image. The supervised and unsupervised images of all the three datasets are then used to validate the output results so that the final classified map can be produced.
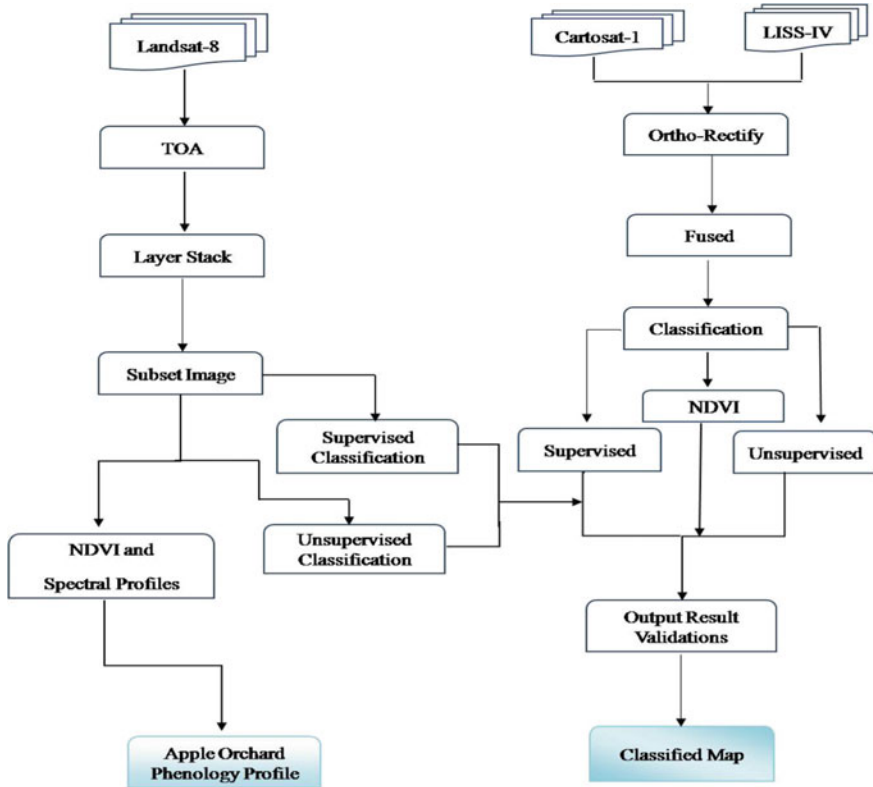
Fig. 16.3 Methodology used for phenology and classification of apple orchards

16.5 Results and Discussions

16.5.1 Spectral Profile of Apple Orchards, Forests and Agriculture Area in NIR Band

Spectral profiles have taken after Top of Atmospheric (TOA) correction of Landsat-8 data. The profile considered here indicates the spectral reflectance in NIR band. In NIR band, the green color reflects maximum; hence, NIR band is used for comparison of Apple, Forest and Agriculture reflectances. Figure 16.4 shows the various reflectance value across the months in Apple orchards, Forests and Agriculture. The following graph was drawn for above figure to describe the temporal changes in terms of spectral reflectance. It is observed from the graph that the spectral profile of apple is different from the spectral profile of forest and agriculture due to high density of orchards.
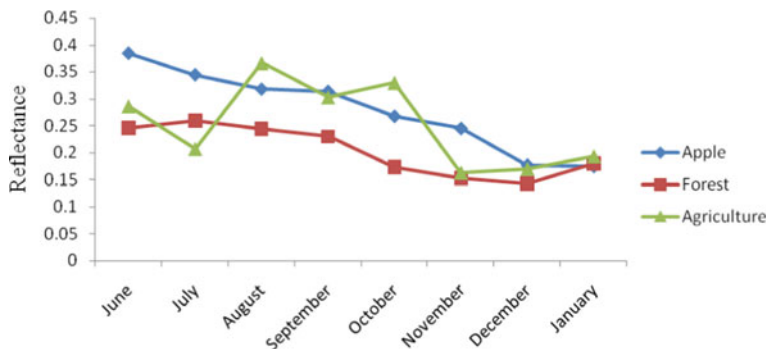
Fig. 16.4 NIR reflectance of the Apple orchards, forests and agriculture (June 2014 to January 2015)

16.5.2   NDVI

Most of vegetation indices (VI) incorporate the information accommodated in two spectral bands i.e., Red and Near-infrared. These indices are set up so as to limit the impact of outer components on spectral data and to determine the characteristics of canopy, for example, leaf area index (LAI) and portion of absorbed photosynthetic active reflectance (Xu and Guo 2014).

NDVI value differs across the months (Fig. 16.5), where red color indicates the distribution of apple orchards. These images show the monthly changes of vegetation in the area. In the month of June, we can see the maximum red color in image and after that it is decreasing continuously. From June to August, monsoon period prolongs hence the proportion of green leaves is maximum and after that it decreases continuously.

16.5.3   NDVI Difference in Among Months

The below Fig. 16.6 indicates the NDVI profile of apple forest and agriculture. The graph indicates that the NDVI response of apple is different from the forest and agriculture. Classification of apple can be done easily with the help of NDVI response.
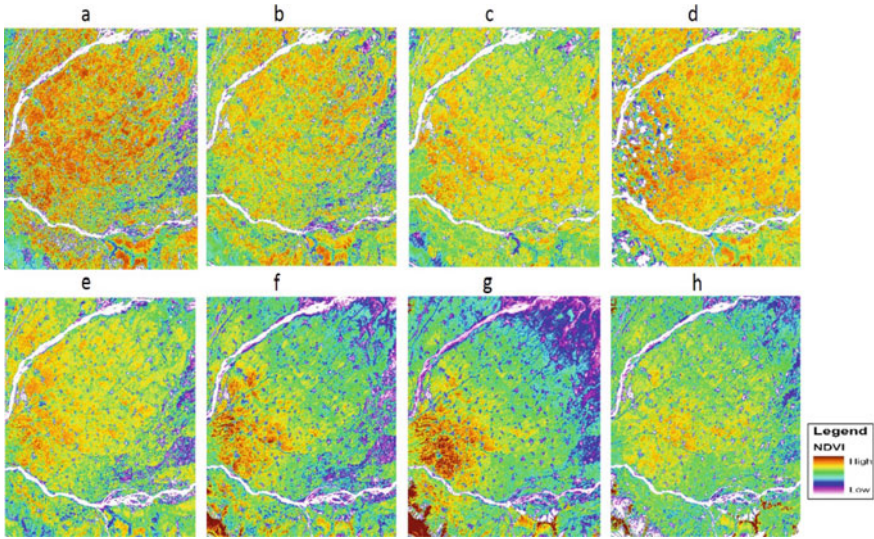
Fig. 16.5 NDVI Changes (temporal change of NDVI (**a**) June, (**b**) July, (**c**) August, (**d**) September,(**e**) October, (**f**) November, (**g**) December and (**h**) January month NDVI)
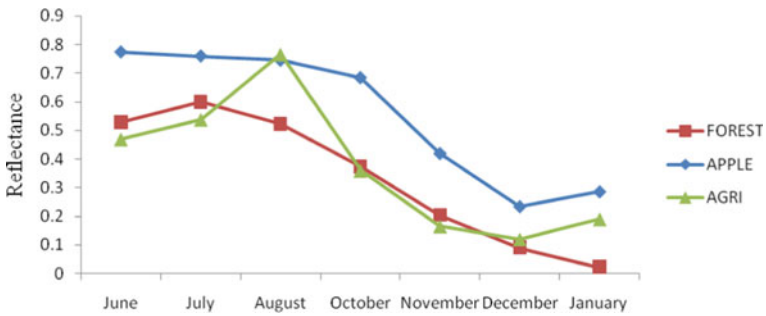

Fig. 16.6 NDVI difference in the month June to January

16.6 Classified Image Result

After spectral profile, we did the classification of the fused image (Cartosat-1 and LISS-IV), Landsat-8 image and NDVI images. With the help of classification, we get the following result.

16.6.1   Classification

For the assessment of phenological pattern and vegetation classification, three different satellite imageries, Cartosat-1, LISS-IV and Landsat-8 were used. Landsat-8 images were used for assessment of phenological pattern with the help of spectral reflectance of apple trees. Fused images of Cartosat-1 and LISS-IV were used for classification of apple orchards, whereas LISS-IV images were used for calculation of NDVI classification, based on threshold values. In this study, we have five classified images which are LISS-IV fused image, Landsat-8 layer stack image and NDVI image. To find out high accuracy in classification, three different methods, e.g., Supervised classification, Unsupervised classification and NDVI Threshold value classification were used (Fig. 16.7).

16.7   Classification Result

In this study, the apple orchards were classified into three age classes viz., Young age, Middle age and Mature age trees.

i.   Young apple trees—young apple trees are 0–3 years trees which are young plantations.
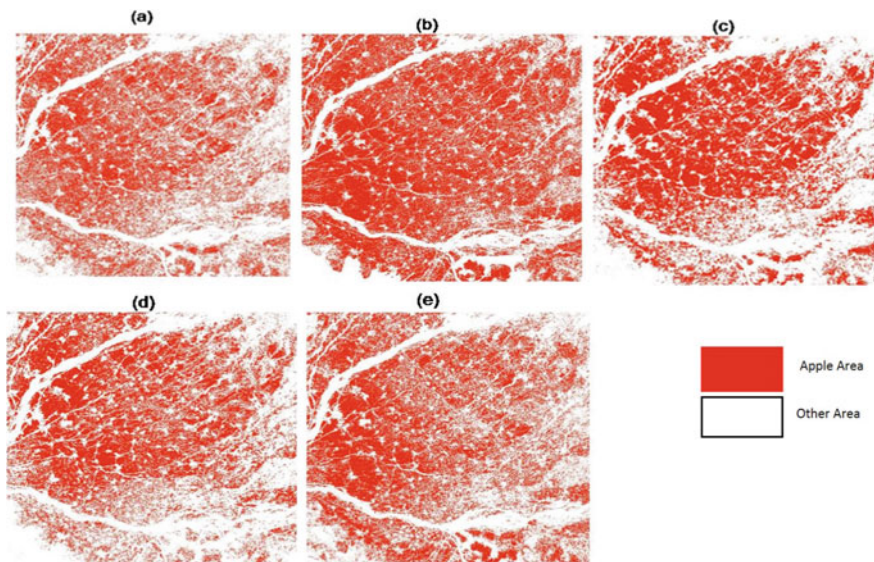

Fig. 16.7   Result of classification images. **a** Supervised classification (Cartosat-1 and LISS-IV fused image). **b** Unsupervised classification (Cartosat-1 and LISS-IV fused image). **c** Supervised classification (Landsat-8). **d** Unsupervised classification (Landsat-8). **e** NDVI classification

ii.   .Middle apple trees—middle apple trees are 3–5 years trees.
iii.   Mature apple trees—mature apple trees are above 5 years.

16.7.1   Classification of Mature Age Trees

With the help of very high-resolution imagery, we take some area of apple mature trees and compare with the classified image.

In Table 16.2, the area of 41.13 hectare is the area of young age apple tree which is identified from the very high-resolution imagery for shape file area. LISS-IV and Cartosat-1 fused image data for Supervised and Unsupervised classification give 37.64 hectare and 34.47 hectare area, respectively, which are 0.91% and 0.83% classified. After that Landsat-8 data are used for supervised and unsupervised classification and it resulted in 35.38 hectare and 32.07 hectare areas which are 0.86% and 0.77% area of classified image in comparison with the very high-resolution imagery area. NDVI image data used for classification with the help of threshold value, and nearly 33.89 hectare areas are resulted which are 0.82% of classified with the very high-resolution imagery area.

16.7.2   Classification of Middle Age Trees

With the help of very high-resolution imagery, we get some random area of middle age apple trees and compared it with the classified image.

In Table 16.3 shows the 31.1 hectare area of young age apple tree which is identified from the very high-resolution imagery. With the help of LISS-IV and Cartosat-1 fused image data for supervised and unsupervised classification area of 29.6 hectare and 28.1 hectare area fall under classified, which are 0.95% and 0.90%. The Landsat-8 data are used for supervised and unsupervised classification and got 24.03 hectare and 25.72 hectare areas which are 0.77% and 0.82% of classified in comparison with the very high-resolution imagery area. Finally, NDVI image data are used for classification with the help of threshold value and 24.47 hectare areas, which are 0.78%, classified with the very high-resolution imagery area.

Table 16.2 Apple mature age trees classification result

S. No	Classification images	Shape file area (mature age) (Ha.)	Classified area (Ha)
1	LISS-IV (supervised)	41.13	37.64
2	LISS-IV (unsupervised)	41.13	34.47
3	Landsat-8 (supervised)	41.13	35.38
4	Landsat-8 (unsupervised)	41.13	32.07
5	NDVI	41.13	33.89

Table 16.3 Apple middle age trees classification result

S. No	Classification Images		shape file area (middle age) (Ha)	Classified area (Ha)
1		LISS-IV (supervised)	31.1	29.6
2	LISS-IV (unsupervised)		31.1	28.1
3	Landsat-8 (supervised)		31.1	24.03
4	Landsat-8 (unsupervised)		31.1	25.72
5	NDVI		31.1	24.47

16.7.3 Classification of Young Age Trees

With the help of very high-resolution imagery, we got some random area of young-aged apple trees and compared it with the classified image.

In Table 16.4, the 26.21 hectare area of young age apple tree which is identified from the very high-resolution imagery. With the help of LISS-IV and Cartosat-1 fused image data for supervised and unsupervised classification and 17.01 hectare and 19.29 hectare area, which are 0.64% and 0.73% classified. The Landsat-8 data are used for supervised and unsupervised classification and got 14.11 hectare and 11.59 hectare areas which are 0.53% and 0.44% are classified compared with the very high-resolution imagery area. The NDVI image data are used for classification with the help of threshold value and got 10.68 hectare areas which are 0.40% classified with the very high-resolution imagery area. The accuracy assessment achieved through classification is 0.91% and by Kappa Coefficient is 0.81.

16.8 Accuracy Assessment

LISS-IV supervised classification gives the better classified image in comparison with other classifications. LISS-IV fused data showed the 0.64 to 0.95% classification accuracy in Mature, Middle and Young age apple orchards. Supervised classification gives better result for Middle age apple orchards. The Table 16.5 showing the

Table 16.4 Apple young age trees classification result

S. No	Classification of images	Shape file area (young age) (hectare)	Classified area (hectare)
1	LISS-IV (supervised)	26.21	17.01
2	LISS-IV (unsupervised)	26.21	19.29
3	Landsat-8 (supervised)	26.21	14.11
4	Landsat-8 (unsupervised)	26.21	11.59
5	NDVI	26.21	10.68

Table 16.5 LISS-IV supervised classification in different age

S. No	Classification of images (LISS-IV supervised)	Shape file area (young) (hectare)	Classified area (hectare)	Accuracy %
1	Mature age (above 5)	41.13	37.64	0.91
2	Middle age (3–5)	31.1	29.6	0.95
3	Young age (0–3)	26.21	17.01	0.64

Table 16.6 LISS-IV Unsupervised classification in different age

Sl. No	Classification of (LISS-IV unsupervised)	Shape file area (young) (hectare)	Classified area (hectare)	Accuracy %
1	Mature age (above 5)	41.13	34.47	0.83
2	Middle age (3–5)	31.1	28.1	0.90
3	Young age (0–3)	26.21	19.29	0.73

classification result of supervised classification of Mature, Middle and Young age apple orchards.

LISS-IV unsupervised classification gives the better classified image in comparison with Landsat-8 and NDVI classifications. LISS-IV fused data are given a range of 0.73 to 0.83% of classification accuracy in Mature, Middle and Young age apple orchards. Unsupervised classification gives better result for Middle age apple orchards. In the Table 16.6, the classification result of unsupervised classification of Mature, Middle and Young age apple orchards is shown.

16.8.1 Landsat-8 Supervised Classification

Landsat-8 supervised classification gives the good classified image for mature age apple orchards compared with other classifications. Landsat-8 data are given 0.53–0.86% classification accuracy in Mature, Middle and Young age apple orchards. Supervised classification gives better result for mature age apple orchards. The Table 16.7 shows the classification result of supervised classification of Mature, Middle and Young age apple orchards.

Table 16.7 Landsat-8 Supervised classification in different age

Sl. No	Classification of landsat-8 (spervised)	Shape file area (young) (hectare)	Classified area (hectare)	Accuracy %
1	Mature age (above 5)	41.13	35.38	0.86
2	Middle age (3–5)	31.1	24.03	0.77
3	Young age (0–3)	26.21	14.11	0.53

Table 16.8 Landsat-8 unsupervised classification in different age

Sl. No	Classification of landsat-8 (unsupervised)	Shape file area (young) (hectare)	Classified area (hectare)	Accuracy %
1	Mature age (above 5)	41.13	32.07	0.77
2	Middle age (3–5)	31.1	25.72	0.82
3	Young age (0–3)	26.21	11.59	0.44

16.8.2   *Landsat-8 Unsupervised Classification*

Landsat-8 unsupervised classification gave good classified image for Middle age apple orchards compared with NDVI classification. Landsat-8 data are given 0.44–0.77% classification accuracy in Mature, Middle and Young age apple orchards. Unsupervised classification gives better result for Middle age apple orchards. The Table 16.8 shows the classification result of unsupervised classification of Mature, Middle and Young age apple orchards.

16.8.3   *NDVI Classification*

NDVI classification has given good classified image for mature age apple orchards compared with Landsat-8 classification. NDVI data are given 0.40 to 0.82% classification accuracy in Mature, Middle and Young age apple orchards. NDVI classification gave better result for mature age apple orchards. In the Table 16.9, the classification result of unsupervised classification of Mature, Middle and Young age apple orchards are shown.

Table 16.9 Landsat-8 NDVI classification in different age

Sl.No	Classification of NDVI	Shape file area (young) (hectare)	Classified area (hectare)	Accuracy %
1	Mature age (above 5)	41.13	33.89	0.82
2	Middle age (3–5)	31.1	24.47	0.78
3	Young age (0–3)	26.21	10.68	0.40

16.9   Discussion

Phenology plays an important role in overall growth and assessment of plant (Sharma and Panigrahy 2007). In this study, we calculated phenology of apple tree and classified the apple orchards with the help of visual interpretation. We have high-resolution image of Cartosat-1 and LISS-IV images which is useful for supervised and unsupervised classification. With the help of spectral profile, we calculated NDVI and after that NDVI threshold values. We used the classified NDVI images. Phenological stages are defined by the Landsat-8 imagery and fused image of Cartosat-1 and LISS-IV data. They are useful for classification of apple orchards. In this study of apple phenological stages which are calculated by Landsat-8 data are then matched with the original natural activity of apple trees. In the NDVI result, the months from June-2014 to October-2014 show the maximum RED colors which indicate apple orchards. In the November month, NDVI and spectral profile show considerable decrease in reflectance values due to falling of leaves. With the help of NIR reflectance, we were able to easily find apple orchard areas. With the help of high-resolution data and fused image, the apple orchards are classified. The results are compared visually and the accuracy is tabulated. From classification techniques, accuracy of the Cartosat-1 and LISS-IV fused image of about 0.91% is produced for mature apple trees, 0.95% for middle apple trees and 0.64% for the young apple trees.

16.10   Conclusion

Remotely sensed data can be utilized successfully in detection, mapping and planning of horticulture crops. In this study, we have proposed a strategy based upon the unique spectral and phenology feature of apple and have focused on the season-wise changes among uncovered leaf falls, ground spread and growing apple plants. To examine the characteristics of apple planning results, supervised classification and unsupervised classification techniques were chosen and compared. The present study was done to investigate the capability of high-resolution LISS-IV and Cartosat-1 data for mapping and Landsat-8 information for phenology of horticultural plantations. Spectral data and NDVI data are utilized for classification of apple plantations. The classification technique was evaluated by very high-resolution images. The results of apple orchards delineation have classification accuracy of 85–92 percent. Other improvement in precision and accuracy could be accomplished utilizing spectral and NDVI threshold value classification of merged data. This study demonstrated potential for spectral, NDVI, Supervised and Unsupervised classification process for delineation of apple orchards. Evaluation and comparison show that inventory of apple orchards by supervised classification method can achieve the highest accuracy. The classification results of apple orchards for satellite data used are in agreement, including the approach of NDVI and spectral reflectance in phenology of apple orchards.

References

Becker-Reshef I, Justice C, Sullivan M, Vermote E, Tucker C, Anyamba A, Small J, Pak E, Masuoka E, Schmaltz J, Hansen M (2010) Monitoring global croplands with coarse resolution earth observations: the global agriculture monitoring (GLAM) project. Remote Sensing 2(6):1589–1609

Bhat TA, Lone TA (2017) Potential and prospects of J&K economy. Educreation Publishing, New Delhi

Harris SA, Robinson JP, Juniper BE (2002) Genetic clues to the origin of the apple. Trends Genet 18(8):426–430

Hebbar R, Ravishankar HM, Subramoniam SR, Uday R, Dadhwal VK (2014) Object oriented classification of high-resolution data for inventory of horticultural crops. Int Arch Photogramm Remote Sens Spatial Inf Sci 40(8):745–749

Johansen K, Phinn S, Witte C, Philip S, Newton L (2009) Mapping banana plantations from object-oriented classification of SPOT-5 imagery. Photogramm Eng Remote Sens 75(9):1069–1081

Kaul GL (1997) Horticulture in India-production, marketing and processing. Ind J Agric Econ 52(3):561–573

Koch E, Bruns E, Chmielewski F-M, Defila C, Lipa W, Menzel A (2007) Guidelines for plant phenological observations. World Climate Data and Monitoring Programme, Geneva

Lima ÁM, Cerqueira MA, Souza BW, Santos ECM, Teixeira JA, Moreira RA, Vicente AA (2010) New edible coatings composed of galactomannans and collagen blends to improve the postharvest quality of fruits–Influence on fruits gas transfer rate. J Food Eng 97(1):101–109

Panda SS, Hoogenboom G, Paz JO (2010) Remote sensing and geospatial technological applications for site-specific management of fruit and nut crops: a review. Remote Sensing 2(8):1973–1997

Polgar CA, Primack RB (2011) Leaf-out phenology of temperate woody plants: from trees to ecosystems. New Phytol 191(4):926–941

Ramírez F, Davenport TL (2013) Apple pollination: a review. Sci Hortic 162:188–203

Sadoulet E, De Janvry A (1995) Quantitative development policy analysis, vol 1. Johns Hopkins University Press, Baltimore

Schofield V (2000) Kashmir in conflict: India, Pakistan and the unending war. IB Tauris, London

Sharma A, Panigrahy S (2007) Apple orchard characterization using remote sensing and GIS in Shimla district of Himachal Pradesh. In Proceedings of remote sensing and photogrammetry annual conference 2007, pp. 11–14.

Suresha M, Shilpa NA, Soumya B (2012) Apples grading based on SVM classifier. Int J Comput Appl 975:8878

Tompkins JA, White JA, Bozer YA, Tanchoco JMA (2010) Facilities planning. Wiley, New York

Usha K, Singh B (2013) Potential applications of remote sensing in horticulture—a review. Sci Hortic 153:71–83

Way RD, Aldwinckle HS, Lamb RC, Rejman A, Sansavini S, Shen T, Watkins R, Westwood MN, Yoshida Y (1991) Apples (Malus). Genetic Resour Temperate Fruit Nut Crops 290:3–46

Xu D, Guo X (2014) Compare NDVI extracted from Landsat 8 imagery with that from Landsat 7 imagery. Am J Remote Sens 2(2):10–14