LAND COVER MAPPING USING INTEGRATION OF SAR AND OPTICAL REMOTELY SENSED DATASETS

Manh Van Nguyen
Institute of Geography – Vietnam Academy of Science and Technology

ABSTRACT

Land cover mapping from remotely sensed datasets is of great interest since they allow every country not only to monitor deforestation, water resources reduction as well as urban growth with up-to-date accurately information, but also lowest charge. In last decades, most of the researchers performed land cover maps using Optical satellite sensors with various spatial resolutions ranging from 1 meter to 30 meters. However, with the high frequently covered by cloud, Optical imagery would not be useful in some areas, such as tropical areas. On the other hand, at present, Synthetic Aperture Radar (SAR) has become a key remote sensing technique due to its advantage of all-weather capability, independence of daylight and cloud penetration capability.

Prime focus of this study was to explore the potential and find out suitable fusion methods using SAR and Optical datasets. Both the data (Sentinel-1A and Sentinel-2) used in this research were provided by European Space Agency (ESA). To process and extract information from SAR imagery, pre-processing that removes radiometric and geometric distortions unique to SAR data is necessary and few of them are multi-looking, radiometric calibration, speckle filtering etc… Firstly, Gamma map 7x7 is selected to reduce speckle noise of SAR image. Secondly, the despeckled image was converted into sigma nought (σ^0) backscattered image, finally, geocoding. The 2016 Sentinel-2 multispectral and the Sentinel-1A C-band VH images were used to generate a new fuse multispectral image with spatial resolution of 10m by the three well-known fusion techniques including Principal Component Analysis (PCA), Intensity-Hue-Saturation (IHS) and Wavelet. The same training and test samples for data classification by Maximum Likelihood and Support Vector Machine were used. Finally, this proposed approach is compared with the classified imagery generated from Optical dataset.

KEYWORDS: land cover maps, fusion, IHS, PCA, Wavelet, Sentinel-1A, Sentinel-2, SVM

I. INTRODUCTION

Land cover classification mapping from remotely sensed datasets is of great interest since they allow every country to monitor deforestation, water resources reduction as well as urban growth. Maintaining up-to-date, Land-cover information is both costly and time consuming using traditional methods such as surveying and air photo methods. At present, remote sensing is an alternative way, a great many researches proved the applicability of optical satellite data for land-use/land-cover mapping (Gao & Skillcorn 1998; Shackelford & Davis 2003; Chou et al. 2005; Carleer & Wolff 2006). Most of the researchers performed land cover maps using Optical satellite sensors which usually detected reflection from ground objects in the visible and infrared part of the electromagnetic spectrum with various spatial resolutions. However, in some areas, with the frequently covered by cloud, Optical imagery would not be useful such as tropical areas.

In contrast, Synthetic Aperture Radar (SAR) has not only ability to cloud penetration, but also all-weather capability, independence of daylight. These advantages make SAR become a key remote sensing technique and one of the most attractive data source for land-use/land-cover mapping, especially when optical data is not available due to some its limitations. SAR images represent the backscattered energy of the different targets which depend on the properties the surface, such as slope, roughness, humidity, textural in homogeneities and dielectric constant. These dependencies allow SAR imagery to be used to separate among various objects on the earth's surface, such as urban area, vegetation and topography (M.R. Inggs and R.T. Lord). Nowadays, there are many SAR space borne satellites like Sentinel-1A (ESA), ALOS PALSAR – 2 (Japan), RADARSAT - 2 (Canada) and so on. Along with these advantages, SAR images also has some limitations, it is only appeared in gray scale color thus may be more difficult for visualization and interpretation and the pre-processing of SAR is required a lot works to user before using to extract properly information of various objects on the Earth.

In practice, the truth is that nothing is perfection, multispectral images produced by optical sensors played a vital role in numerous applications in last few decades, most of the objects on the Earth's surface can be classified but for some classes, spectral response in the visible and infrared wavelength parts are similar, such as dry river and settlement, etc… For SAR data, the different responses is very sensitive to varied terrain, roughness and structure, moisture content, for example, settlement showed very high backscattering coefficient value but low value represented by dry river, however, to separate between agriculture and forest is a difficult mission in SAR but can do easily in multispectral images.

The objective is to generate land cover mapping using Synthetic Aperture Radar (SAR) & Optical remotely sensed datasets through fusion techniques. To achieve the main objective, the following sub objectives are:

- Exploring the potential and find out suitable fusion methods using SAR and Optical datasets.
- Generating the land cover maps using PCA, IHS and Wavelet based on fusion methods by using 2 different approaches: Maximum Likelihood and Support Vector Machine.
- Comparison of different image fusion techniques and classification approaches.

II. STUDY AREA AND DATA ACQUISITION

II.1. STUDY AREA

The study area for the study is Dehradun; which is located between $29^0$58’53.84”N to $30^0$30’46.66”N latitude and $77^0$36’59.08”E to $78^0$11’9.55”E longitude of the southern and western part of Dehradun district and state capital city of Uttarakhand, India. The city is located at altitude of 600m above Mean Sea Level. In Dehradun, paddy is one of the most important food crops cultivated in the district, also many kinds of rice are sown in the area.

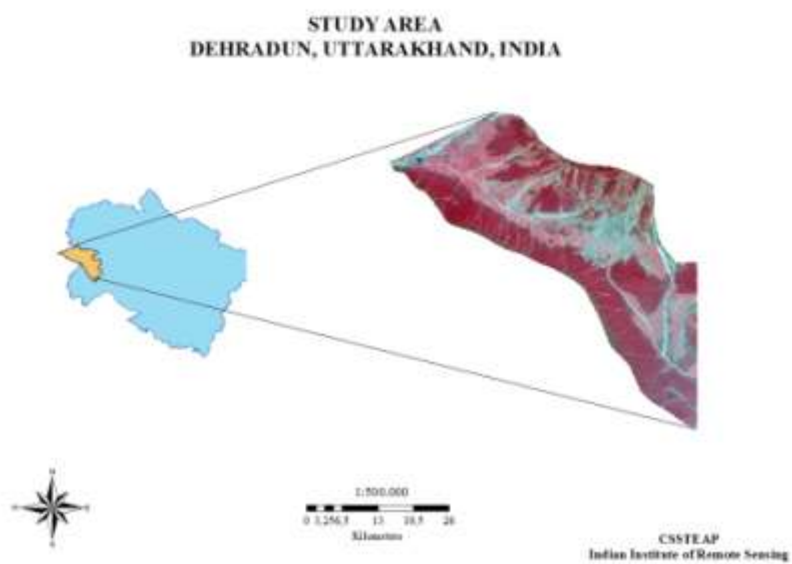


Figure 1: The study area – Dehradun

Dehradun is India’s wettest State capital this monsoon with 2,865 mm of rainfall between 1 June and 30 September, according to Director of the Dehradun Meteorological Centre Anand Sharma. With 2,365 mm, Mumbai received the second highest rainfall during this monsoon season.

The climate of Dehradun is humid continental, although it varies from tropical: from hot in summers to severely cold, depending upon the season and the altitude. The nearby hilly regions often get snowfall during winter.

II.2. DATA ACQUISITION

In this project, both the datasets (Sentinel-1A and Sentinel-2) were provided by European Space Agency (ESA).

II.2.1. SENTINEL-1A

Sentinel 1A is the SAR space borne satellite with the prime objectives of Land and Ocean monitoring. The goal of the mission is to provide C-Band SAR data continuity following the retirement of ERS-2 and the end of the Envisat mission. It carries a C-SAR sensor (5.405 Ghz), which offers medium and high resolution imaging in all weather conditions. The C-SAR is capable of obtaining night imagery and detecting small movement on the ground, which makes it useful for land and sea monitoring. The Sentinel-1A image scene details used in this study are shown in table 3.1

Table 1: Scene description of Sentinel-1A imagery

Product	Data Detail
Instrument name	Synthetic Aperture Radar (C-band)
Instrument mode	IW
Pass Direction	ASCENDING
Date	02 November.2015
Time	00:47:03.242
Orbit Number	8426
Polarisation	VV; VH
Resolution	10m
Product level	L1
Product type	GRD
Incidence Angle	39.3259109013725
Ellipsoid	WGS-84
Datum	WGS-84

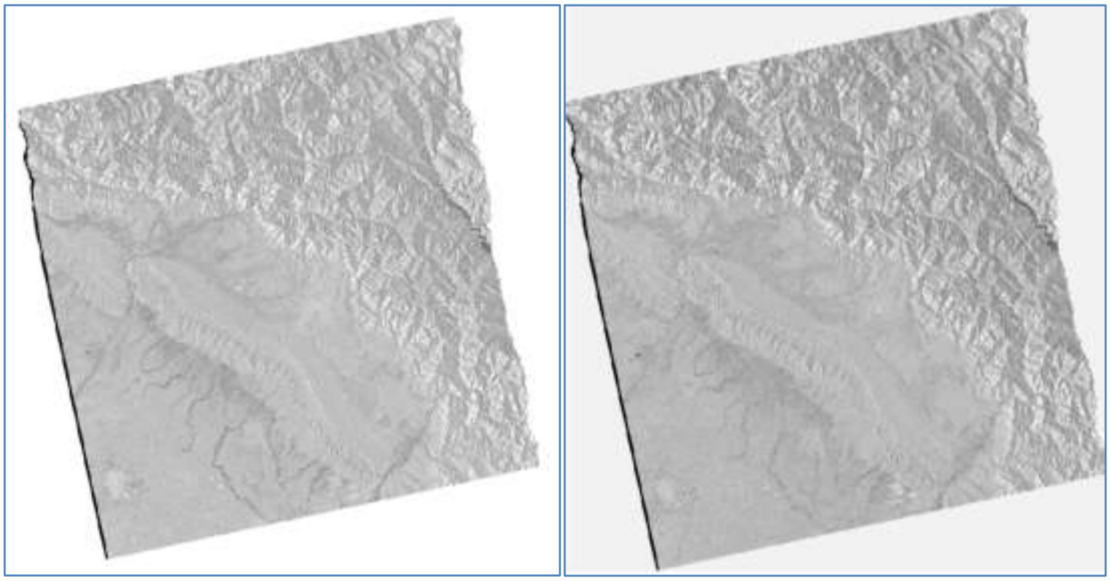


Figure 2: Sentinel-1A Images of the Study Area (VH band-left; VV band-right)

II.2.2. SENTINEL 2A

The Sentinel-2 mission is a land monitoring constellation of two satellites that provide high resolution optical imagery and provide continuity for the current SPOT and Landsat missions. The mission provides a global coverage of the Earth's land surface every 10 days with one satellite and 5 days with 2 satellites, making the data of great use in on-going studies. The satellites are equipped with the state-of-the-art MSI (Multispectral Imager) instrument that offers high-resolution optical imagery (10m, 20m and 60m).

Table 2: Scene description of Sentinel 2A imagery

Product	Data Detail
Instrument name	Multi-Spectral Instrument (MSI)
Pass Direction	DESCENDING
Orbit number	2390
Processing level	Level 1C
Date	05 February.2016
Time	05:36:25.455Z
Spatial Resolution (m)	10;20;60
Cloud cover %	1

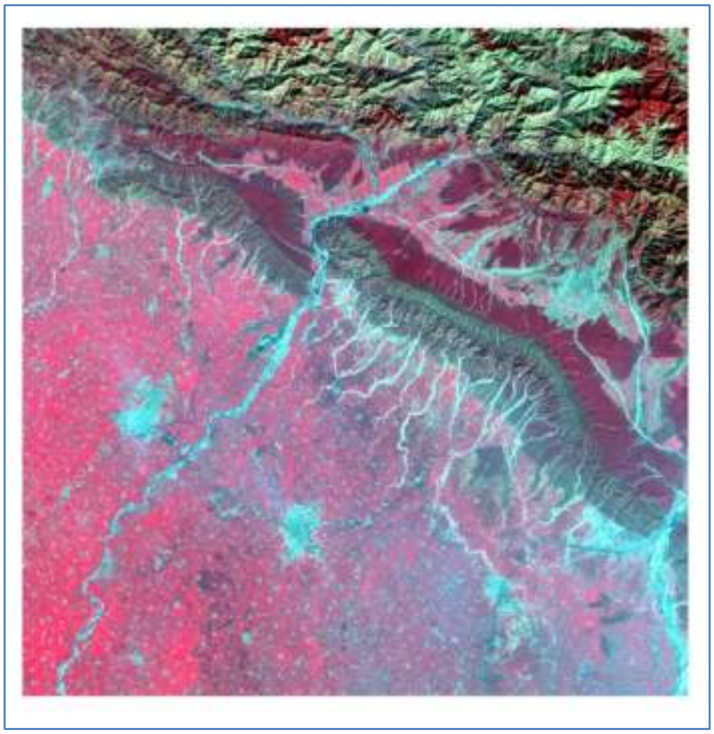


Figure 3: Sentinel-2 image of the Study Area

III. METHODOLOGY

The methodology of this study is followed by the workflow diagram in figure 4.

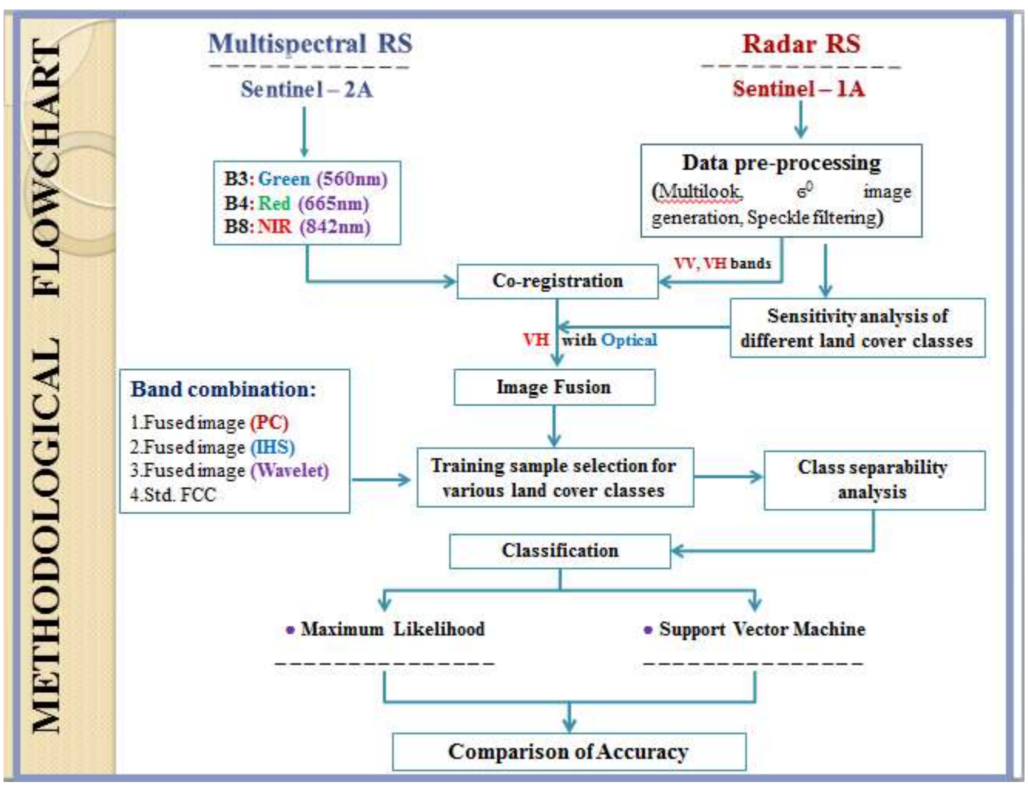


Figure 4: The methodology of this project

IV. RESULTS

In this study, the images was classifed into 6 main classes:

- Forest
- Agriculture
- Built-up
- Dry River bed
- Water
- Wasteland

Table 3: Training sample selection for different images

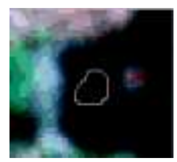
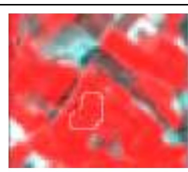
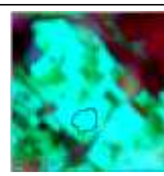
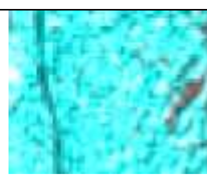
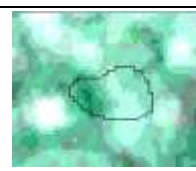
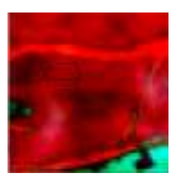
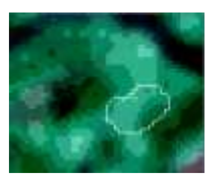
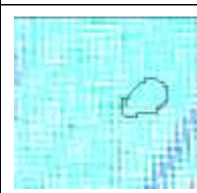
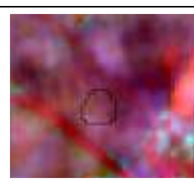
Classes	TRAINING SAMPLES			
	Std. FCC	IHS	PCA	Wavelet
Forest				
Water				
Agriculture				
Built-up				
Dry river bed				
Wasteland				

Table 4: Separability analysis for various land cover classes in different images

Class Pairs	SEPARABILITY			
	NIR-R-G	IHS	PCA	WAVELET
Forest - Agriculture	1.99	1.65	1.84	1.98
Forest - Fallow	1.94	1.93	1.94	1.95
Agriculture - Fallow	1.91	1.94	1.96	1.97
Built up - Dry River	1.10	1.40	1.61	1.45
Built up - Fallow	1.96	1.98	1.98	1.94
Fallow - Dry River	1.88	1.81	1.88	1.98

As can be seen that, the separability value is quite good in almost class pairs, except the pair between built-up and Dry river, 1.10. However, after fusion, this value is slightly increased, 1.4 for HIS, 1.61 for PCA and 1.45 for Wavelet.

IV.1. LAND COVER MAPS GENERATED BY USING MAXIMUM LIKELIHOOD CLASSIFICATION.

IV.1.1 OPTICAL DATASET

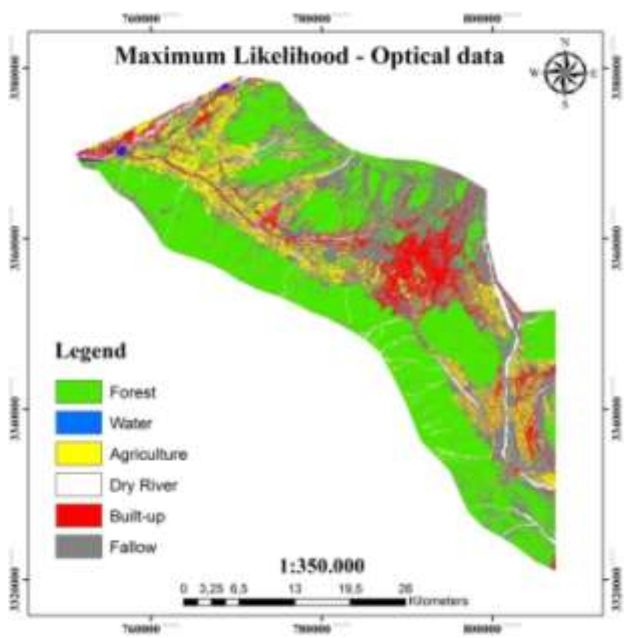


Figure 5: The land cover map generated from Optical data using MLC

For land cover map generated by Optical data, the accuracy of the forest is the best in comparision to the other classes. Among 6 classes, Built-up, Dry river bed and Fallow is the three classes had the low user accuracy, 66.6%, 70% and 66.7%, respectively.

LU/LC Classes	F	W	Agri	Dry R	S	Fallow	Row Total	UA (%)
F	29	0	1	0	0	0	30	96,67
W	1	24	0	0	2	3	30	80,00
Agri	1	0	26	0	1	2	30	86,67
Dry R	3	3	0	20	1	3	30	66,67
S	0	1	0	3	21	5	30	70,00
Fallow	5	0	2	1	2	20	30	66,67
Column Total	39	28	29	24	27	33	180	
PA (%)	74,36	85,71	89,66	83,33	77,78	60,61		
Overall accuracy = 77,78%				Kappa coefficient = 0,73				

Table 5: Confusion matrix of the land cover map generated from Optical dataset using MLC

IV.1.2 INTENSITY-HUE-SATURATION BASED FUSION TECHNIQUE

For land cover map generated from fused image by IHS technique. Among 6 classes, Water and Agriculture is the two classes had the low user accuracy, 46,67% and 70% respectively.

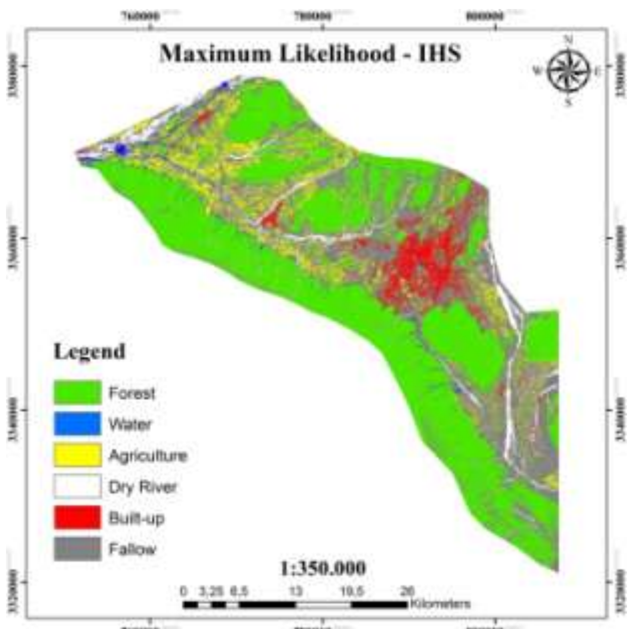


Figure 6: The land cover map generated from IHS fusion technique using MLC

LU/LC Classes	F	W	Agri	Dry R	S	Fallow	Row Total	UA (%)
F	28	0	0	0	0	2	30	93,33
W	3	14	1	1	2	9	30	46,67
Agri	9	0	21	0	0	0	30	70,00
Dry R	0	0	1	24	1	4	30	80,00
S	0	0	0	0	25	5	30	83,33
Fallow	2	0	0	1	1	26	30	86,67
Column Total	42	14	23	26	29	46	180	
PA (%)	66,67	100,00	91,30	92,31	86,21	56,52		
Overall accuracy = 76,67%				Kappa coefficient = 0,72				

Table 6: Error matrix of the land cover map generated from IHS fusion technique using MLC

IV.1.3 Principal Component Analysis based fusion technique

For land cover maps from fused image generated by PCA technique, the accuracy of all six classes is very good.

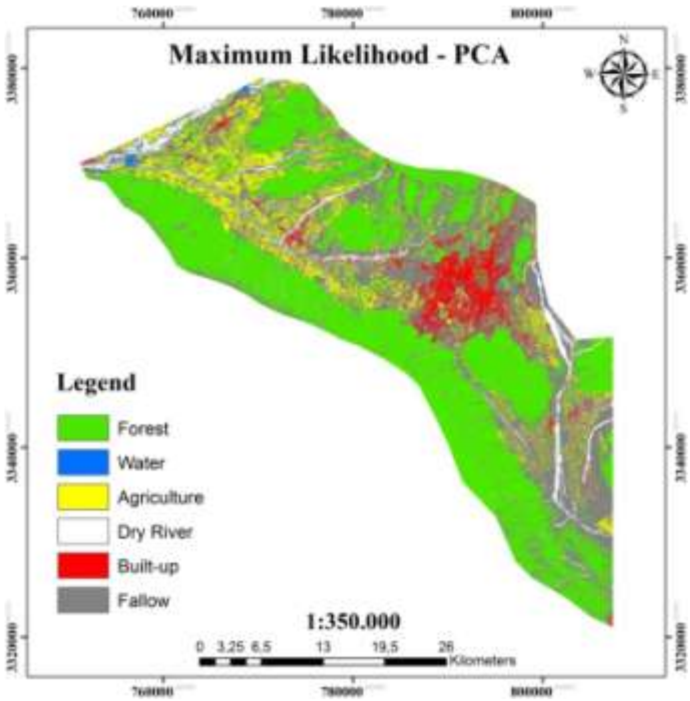


Figure 7: The land cover map generated from PCA fusion technique using MLC

LU/LC Classes	F	W	Agri	Dry R	S	Fallow	Row Total	UA (%)
F	29	0	1	0	0	0	30	96,67
W	0	25	1	0	0	4	30	83,33
Agri	6	0	24	0	0	0	30	80,00
Dry R	1	0	0	28	1	0	30	93,33
S	0	2	0	3	25	2	30	83,33
Fallow	1	0	2	1	2	24	30	80,00
Column Total	37	27	28	32	28	30	180	
PA (%)	78.37	92,59	85,71	87.50	89,28	80,00		
Overall accuracy = 86.11%				Kappa coefficient = 0.83				

Table 7: Error matrix of the land cover map generated from PCA fusion technique using MLC

IV.1.4 WAVELET BASED FUSION TECHNIQUE

In general speaking, for land cover maps from fused image generated by Wavelet technique, the accuracy of all six classes are very good. The overall accuracy and the Kappa coefficient value of this method is the highest among four fusion techniques.

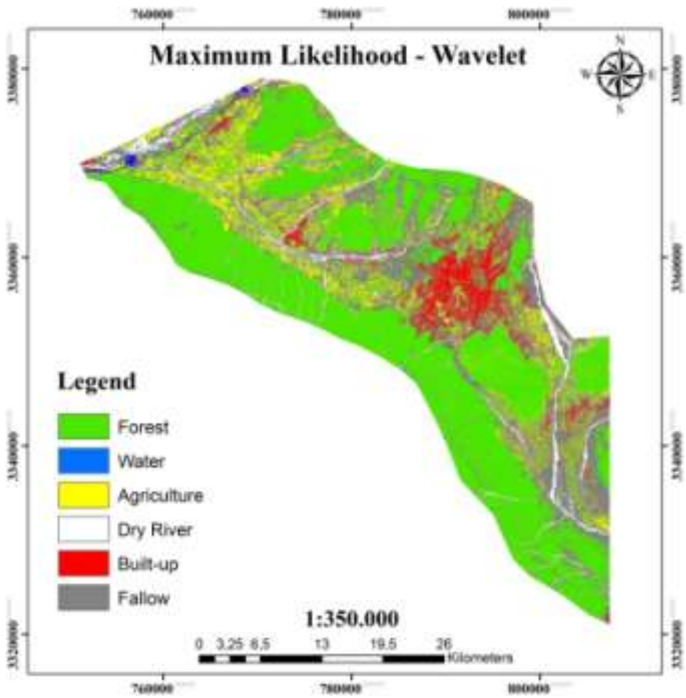


Figure 4.8: The land cover map generated from Wavelet fusion technique using MLC

LU/LC Classes	F	W	Agri	Dry R	S	Fallow	Row Total	UA (%)
F	30	0	0	0	0	0	30	100,00
W	2	19	1	0	0	8	30	63,33
Agri	0	0	29	0	0	1	30	96,67
Dry R	0	0	0	30	0	0	30	100,00
S	0	0	0	1	28	1	30	93,33
Fallow	1	0	1	0	2	26	30	86,67
Column Total	33	19	31	31	30	36	180	
PA (%)	90,91	100,00	93,55	96,77	93,33	72,22		
Overall accuracy = 90,00%				Kappa coefficient = 0,88				

Table 4.7: Error matrix of the land cover map generated from Wavelet fusion technique using MLC

■ **CONCLUSION**:

Based on the confusion matrix, it can be seen that, for Maximum Likelihood classifier, Principal Component Analysis (PCA) and Wavelet is the best two fusion techniques used to generate land cover maps. The overall accuracy is dramatically increased from Optical data to both PCA (9 percentage) and Wavelet (14 percentage), especially the significant accuracy of the dry river and built-up were proven. Additionally, the overall Kappa coefficient is the important index that was also increased.

IV.2. LAND COVER MAPS GENERATED BY USING SUPPORT VECTOR MACHINE

IV.2.1. OPTICAL DATASET

For land cover map generated by Optical data, the accuracy of the agriculture is the best in comparision to the other classes. Among 6 classes, Built-up, Wasteland, Water is the three classes had the low user accuracy, 60%, 66.7% and 56,67%, respectively.

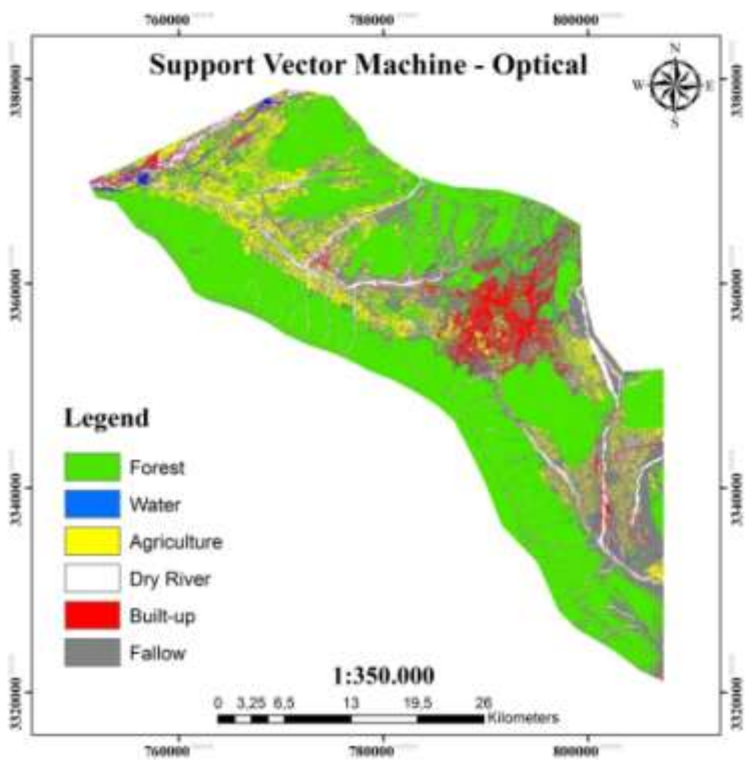


Figure 8: The land cover map generated from Optical using SVM

LU/LC Classes	F	W	Agri	Dry R	S	Fallow	Row Total	UA (%)
F	28	0	1	0	0	1	30	93,33
W	7	17	0	0	3	3	30	56,67
Agri	0	0	28	0	0	2	30	93,33
Dry R	0	0	0	26	2	2	30	86,67
S	0	0	0	6	18	6	30	60,00
Fallow	2	0	2	2	4	20	30	66,67
Column Total	37	17	31	34	27	34	180	
PA (%)	75,68	100,00	90,32	76,47	66,67	58,82		
Overall accuracy = 76,11%				Kappa coefficient = 0,71				

Table 8: Error matrix of the land cover map generated from Wavelet fusion technique using SVM

IV.2.2. INTENSITY – HUE – SATURATION

For land cover map generated from fused image by IHS technique. Among 6 classes, Only Dry River is the class had the low user accuracy by 56,67%

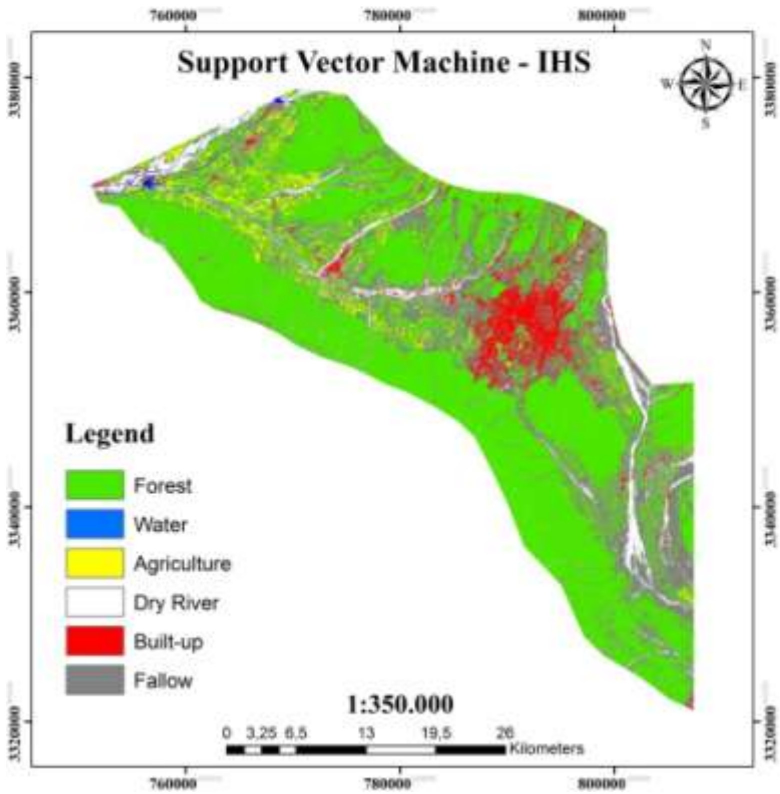


Figure 9: The land cover map generated from lHS fusion technique using SVM

LU/LC Classes	F	W	Agri	Dry R	S	Fallow	Row Total	UA (%)
F	22	0	5	1	1	1	30	73,33
W	4	26	0	0	0	0	30	86,67
Agri	0	0	30	0	0	0	30	100,00
Dry R	1	1	0	17	3	8	30	56,67
S	1	0	0	0	26	3	30	86,67
Fallow	2	0	0	0	4	24	30	80,00
Column Total	30	27	35	18	34	36	180	
PA (%)	73,33	96,30	85,71	94,44	76,47	66,67		
Overall accuracy = 80,56%				Kappa coefficient = 0,77				

Table 9: Error matrix of the land cover map generated from IHS fusion technique using SVM

IV.2.3. PRINCIPAL COMPONENT ANALYSIS

For land cover maps from fused image generated by PCA technique, the accuracy of all six classes are very good, the accuracy of Dry river is good for both user's accuracy and producer's accuracy.

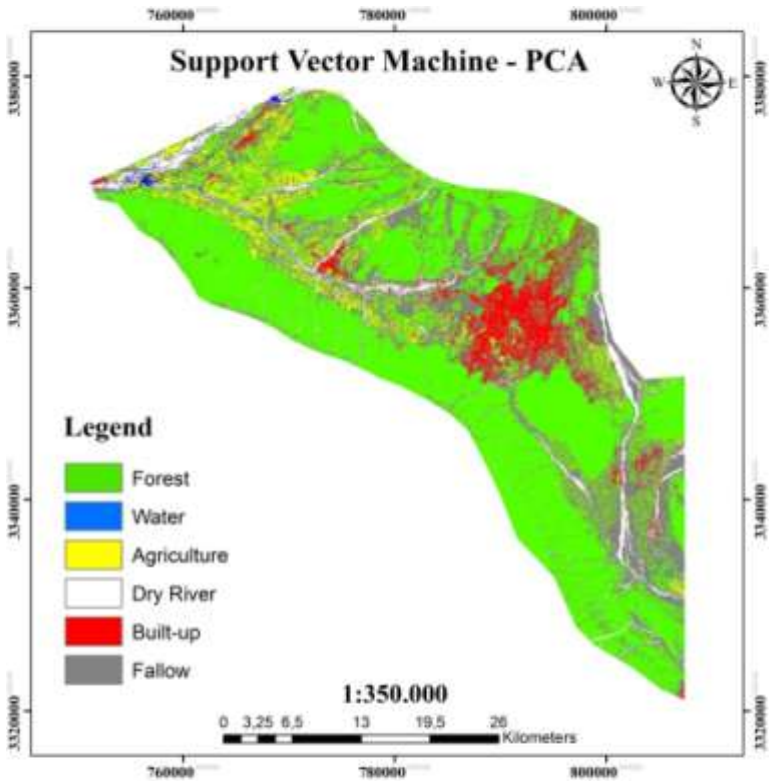


Figure 10: The land cover map generated from PCA fusion technique using SVM

LU/LC Classes	F	W	Agri	Dry R	S	Fallow	Row Total	UA (%)
F	25	0	5	0	0	0	30	83,3
W	3	23	3	1	0	0	30	76,6
Agri	2	0	28	0	0	0	30	93,3
Dry R	1	0	1	24	1	3	30	80,0
S	0	1	0	0	24	5	30	80,0
Fallow	1	1	0	1	2	25	30	83,3
Σ Clm	32	25	37	26	27	33	180	
PA (%)	78,1	92,0	75,6	92,3	88,8	75,7		
Overall accuracy 82,8%				Kappa coefficient 0,79				

Table 10: Error matrix of the land cover map generated from PCA fusion technique using SVM

IV.2.4 WAVELET

In general speaking, for land cover maps from fused image generated by Wavelet technique, the accuracy of all six classes are very good. The overall accuracy and the Kappa coefficient value of this method is the highest among four fusion techniques.

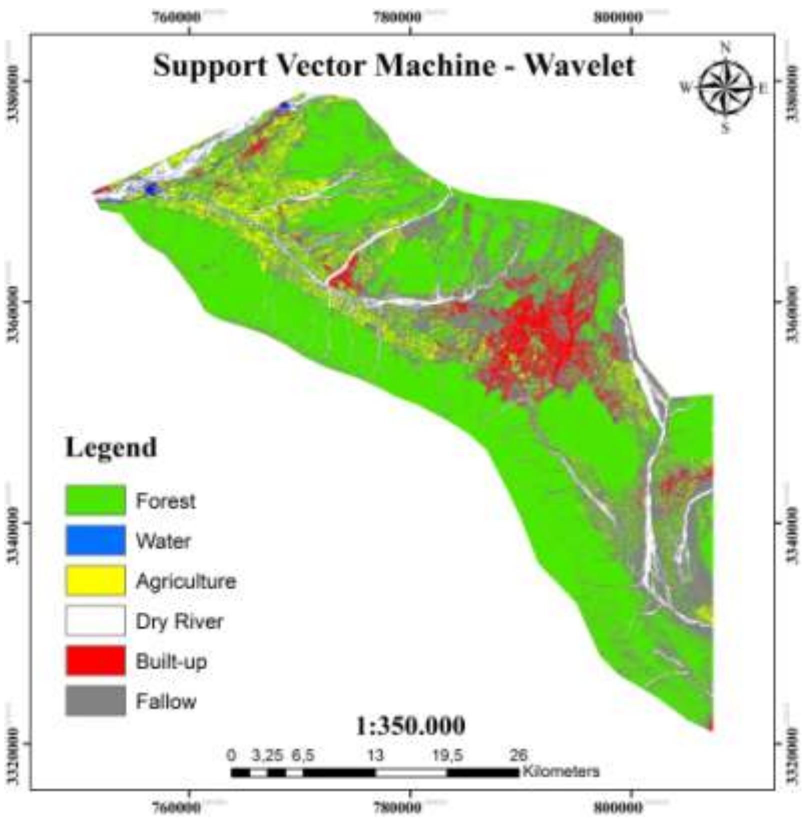


Figure 11: The land cover map generated from Wavelet fusion technique using SVM

LU/LC Classes	F	W	Agri	Dry R	S	Fallow	Row Total	UA (%)
F	26	0	3	0	0	1	30	86,6
W	4	24	0	0	0	2	30	80,0
Agri	0	0	30	0	0	0	30	100,0
Dry R	0	0	0	24	2	4	30	80,0
S	0	0	0	0	28	2	30	93,3
Fallow	2	0	1	0	2	25	30	83,3
Σ Clm	32	24	34	24	32	34	180	
PA (%)	81,25	100,0	88,2	100,0	87,5	73,5		
Overall accuracy 87,2%			Kappa coefficient 0,85					

Table 11: Error matrix of the land cover map generated from Wavelet fusion technique using SVM

■ **CONCLUSION**:

Based on the confusion matrix, it can be seen that, for Support Vector Machine, Wavelet is the best fusion techniques used to generate land cover maps. The overall accuracy is dramatically increased from 76,11 percentage in Optical data to 87,2 percentage in Wavelet, especially the significant accuracy of the dry river and built-up were proven. Additionally, the overall Kappa coefficient is the important index that was also increased.

V. DISCUSSION

Overall, the integration of SAR and Optical datatsets did improve classification performance, the study also indicated the significance of the multi-sensor satellite data for the land cover mapping. The land cover classes like the built up class, dry current fallow or the riverbed show a similar spectral response in the optical data thus resulting in their inseparability.

Even in case of SAR, if utilized in single polarization mode, it does not result in sufficient characterization of the target as was observed during the analysis. Some classes were observed to be overlapping on the VV axis, however due to the addition of the VH channel, the separability among the classes enhanced, thus signifying the importance of multi polarized SAR data.

Out of 3 fusion methods, the fusion of optical and cross polarized (VH) SAR data in Wavelet based fusion technique resulted in highest classification accuracy (90%) with the kappa value of 0.88

in comparison to IHS and PCA, thus exhibiting its potential the multi-sensor approach in land cover characterization.

Two classification approaches SVM and MLC were compared and higher accuracy was achieved through MLC.