On the Performance Analysis of Classifier Fusion for Land Cover Classification

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Abstract: We investigate the performance evaluation of merging (fusing) the classification capabilities of classifiers for the land use analysis. For the fusion approach, we select the parametric and non-parametric classifiers. The set used includes: Bayesian Network, Multi-layer Perceptron (MLP), Support Vector Machines (SVM) and Random Forest. These classifiers are selected based on their good over-all performance for the land use analysis and in general for other classification tasks. We evaluate the concept on both the high and low resolution multispectral satellite imagery. The performance of the approach is evaluated using F-score, computation time and accuracy. Based on the experimental evaluation, we advocate the use of classifier fusion for the low resolution satellite imagery. While for high resolution satellite imagery, the fusion shows slight improvement in performance.

I.   INTRODUCTION:

Land cover classification plays an important role in the estimation of land use in agriculture, settlements and irrigation. Today, due to the technological revolution it's possible to deal with such problems. Remote sensing and machine learning techniques are now used to locate the land clusters within the domain of satellite imagery. In machine learning technique, the pixels (bands) from the satellite imagery is extracted and on these pixel based features, the classifier is trained to predict the unknown pixel. Several researches have been carried out to investigate the performance of state-of-the-art supervised classifiers such as: Support Vector Machine (SVM), Bayesian Networks (BN), Multi-layer Perceptron (MLP), Maximum Likelihood (MLE) and Random Forest. MLE is based on the statistical theory and it uses normal distribution for each class to classify the input pattern and thus it is a parametric classifier which requires the prior probabilities before classification of the input pixel. In [1], the author has compared the performance of ANN and MLE on low resolution Landsat imagery and showed that ANN can better locate the various land using simple pixel based features. In [2-4], various approaches have been used for band classification using the ANN. ANN was originally developed for pattern recognition task. ANN computations are different from the traditional statistical computations and hence it is a non-parametric classifier [5]. The main advantage of neural network is parallel computation which makes it more prominent for pattern recognition problem. Recent studies have advocated the use of ANN compared to non-parametric classifier such as MLE [5-6]. In contrast to ANN, SVM is reported to accurately classify the input pattern and hence outperforms state-of-the-art such as MLE, ANN and Decision trees [7]. The advantage of SVM is its non-linear kernels, and hence can model complex problems [8]. Due to the several variants of SVM kernels, it can effectively differentiate between the spectral signatures compared to non-parametric classifiers [9]. Based on the spectral signatures of vegetation, the non-parametric classifiers such as the MLE fails to correctly locate the vegetation categories compared to SVM. Compared to the parametric classifiers such as MLE, the random

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Land Usage Analysis: A Random Forest Approach

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Abstract: Land usage analysis takes advantage of the multi-band imagery for classification and recognition. Multi-bands data contains reliable information compared to the raw image formats e.g. RGB, HIS, HSV and other color spaces. In this paper, we advocate the usage of non-parametric machine learning algorithms for land usage analysis. From the non-parametric algorithms, we propose a random forest approach for land use analysis. Our analysis is concerned with the classification of land into seven classes. We have shown that non-parametric classifier the "Random Forest" is well suited to the task of multi-band land usage analysis. In the experimentation setup, we have compared the random forest with the state-of-the-art classifiers. Based on the SPOT-5 imagery, we have shown that the random forest outperforms the state-of-the-art classifiers including Naïve Bayesian, Mutli-Layer Perceptron, Bayesian Network, SVM, Radial Basis Function Network (RBF) and Ada-boost. We further show that for the land use analysis, increasing the number of trees has no effect on the performance of the random forest and therefore the runtime of the random forest can be reduced compare to all the other classifiers. The best F-score is achieved using 4 trees and 10 Fold Cross Validation.

I. INTRODUCTION

Remote sensing uses satellite imagery for land surface analysis. The common technique used for remote sensing is the pixel based image analysis. The pixels obtained from the Multi bands imagery are modeled using the supervised machine learning classifiers. Supervised classifiers are further divided into parametric and non-Parametric. The parametric classifier requires prior probabilities of the pixel distribution, such as Naïve Bayesian, Bayesian Network Support Vector Machine (SVM) and Maximum Likelihood (MLC). Non parametric classifiers normally are independent of the prior knowledge such as learning algorithms based on the decision trees. The non-parametric algorithms are generally not used for the land usage analysis.

From the parametric set of algorithms, the SVM shows stronger detection performance compared to the MLC, Artificial Neural Network (ANN) and Decision trees [1]. SVM heavily rely on its classification parameters and kernels, hence various kernels are used for classification and land usage analysis [2]. ANN is widely known for its strong detection probability. Comparison between the ANN and MLC shows that ANN outperforms MLC for low resolution satellite imagery analysis and classification [3]. Classifiers like ANN, SVM and MLC have also been used for tropical zone analysis. The results show that SVM can efficiently differentiate between different land clusters [4]. The superiority of SVM for the land use analysis and classification has also been reported in [5][6][7][8][9]. The parametric classier Naïve Bayesian assumes the probability independence of the feature set and hence it is also used for pixel based land usage analysis. In [10], Naïve Bayesian based approach is advocated for the satellite imagery classification into shades, roads and building. From the parametric set of classifiers, the Bayesian Network has also been used for the analysis of storm water modeling using Landsat imagery [11].

In this paper, our objective is twofold: Firstly, we advocate the usage of the non-parametric classifiers for the task of land usage analysis. The non-parametric classifiers were generally not favored for the land use analysis due to the pixel-like data as evident from the state-of-the-art. Secondly, in the shape of the non-parametric classifier, we propose the use of the random forest classifier for the SPOT-5 imagery. In an experimentation setup, using 10-fold cross validation, we show that the random forest outperforms the state-of-

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Performance Analysis of H.265/HEVC (High-Efficiency Video Coding) with reference to Other Codecs

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Abstract—Compression performance of a video codec is very important to enable it to encode high quality videos at low bitrates. Significant progress has been made in the area of video encoding. The latest state of the art video encoding standard, High Efficiency Video Coding – HEVC/H.265 doubles the video quality for the same bitrate compared to other codecs. This paper presents quality & performance comparison amongst H.265, H.264, and Motion JPEG using different video encoding libraries. Alongside the need for high compression efficiency, it is also important to keep in the computational complexity of video codecs. In this regards, although HEVC provides the best compression efficiency, it does so at the expense of significantly more computational cost than H.264.

The results of the conducted experiments show that HEVC produced best quality video followed by H.264. However Motion JPEG encoding produced fastest encoding times followed by HEVC. Videos encoded with Motion JPEG using OpenJPEG library produced the worst results in terms of quality. H.264 was the slowest among the video codecs and often produced video quality comparable to videos encoded with Kakadu (Motion JPEG). This work is meant to provide insights regarding choice of the video encoding suite & future development of the codecs.

Index Terms—HEVC/H.265; H.264; Kakadu; Open JPEG 2000; PSNR; SSIM

I. INTRODUCTION

Computing power doubles every year according to Moore's law & the devices get cheaper & efficient, however the desire for squeezing every ounce of performance out of the hardware is ever growing. Super computers of the past the smart phones of today & smart phones of today will be the wearables of tomorrow but the limitation comes in terms of power consumption. As the devices get smaller, the capacity of the battery power reduces. The balance between functionality & power consumption can be maintained by efficiently utilizing the system resources [1]. Most of the consumer devices are used as a multimedia gadget; therefore the need for providing visually appealing multimedia content at lowest bitrate & power consumption is the top priority. In this pursuit, video codecs are always evolving, trying to create the perfect balance between quality & performance. Many codecs have been released, however few of them managed to acquire the attention of content producers. From 1994 to 2013, video compression techniques changed a lot. The streaming

videos improved by current HEVC in different aspects namely lesser storage memory, lesser decoding time and lesser bitrates [2], [3].

HEVC is able to achieve twice the compression performance relative to H.264, whilst maintaining the same level of video quality. HEVC achieves this by relying upon enhanced intra prediction, de-correlating transforms, de-blocking filters, motion estimation & variable length entropy coding to produce good quality at high compression ratios [2], [4].

Work on developing a codec which can produce substantially good quality videos with high compression ratios & respectable performance was started as early as 2004. The ITU-T VCEG (video coding experts group) started the study of various potential techniques that the successor of H.264/AVC will assimilate. KTA a software code base, supported by Joint Model (JM) which was developed by VCEG & MPEG Joint Video Team for H.264/AVC was established to evaluate such a joint Call for Proposals (CfP). In 2010, it was standardized into HEVC joint project with MPEG. The first version of HEVC was completed & published in 2013 [5].

With the need of achieving high compression ratios, computational performance of the codec is also of great importance considering the most common usage of these codecs & the targeted devices which have usually very low reserves of battery power to sustain & maintain longer usage of the device. Disinterment of the codec in terms of high compression ratio, higher performance & low power consumption is the main purpose of this paper.

II. VIDEO CODECS & LIBRARIES

This section will briefly shed some light on the selected codecs and their respective software libraries used for video encoding.

A. HEVC (High Efficiency Video Codec)

HEVC is the successor to H.264/MPEG-4 AVC (Advanced Video Coding). Goals of HEVC include easiness of transport system integration, coding efficiency, implementation using parallel processing architectures and data loss resilience. HEVC includes Inter Prediction, Intra

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Parallelepiped and Mahalanobis Distance based Classification for Forestry Identification in Pakistan

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Abstract—Rapid deforestation has been witnessed in Pakistan over the past few years. It is taking its toll on Pakistan economy, infrastructure, and environment in the form of frequent floods. In order to keep the numbers steady frequent surveys need to be conducted. Identifying lush green forests through remote sensing is quite effective when it comes to collecting ground truth reality through extensive ground surveys. In the following study two pixels based supervised classification algorithms i.e. Parallelepiped and Mahalanobis Distance Classification Algorithms are compared for classifying forests in Pakistan. For that purpose High Geometric Resolution Imagery of SPOT-5 (2.5m) is used as the base image. According to our results Parallelepiped Classification is proved to be the better one of the two with overall accuracy of 95.4% and kappa coefficient value of 0.937, with reference to the Mahalanobis Distance classifier with overall accuracy of 85.97% and kappa coefficient value equal to 0.8115. On the basis of these findings Parallelepiped Classifier is preferred to be used for the remote sensing of forestry in Pakistan.

Keywords—Normalized Difference Vegetation Index, Kappa Coefficient, Confusion Matrix

I. INTRODUCTION

Forestry is the study of management of significant components of forests, conserving the natural resources for fulfilling the human needs and keeping intact the habitat of all the life forms it supports. For preservation of the forests and its inhabitants information about the area covered by the forests and their types is significant. Acquisition of such information requires space based and aerial based remote sensing techniques. Among the two, space based method is widely used due to its large coverage areas as in this case forests.[1]

Overall forests in Pakistan are limited. About less than 4% of the land mass is covered by forests. Rich in terms of biodiversity they are, the number is very much lower than the optimum value of 25% for a country. In Pakistan forests cover a total area of 5.01 hectares of land mass including both the natural and artificial plantation. Having the deforestation rate of 27,000 hectares per year it is ranked the highest among Asia. Rapid deforestation is taking its toll on Pakistan's economic status, its infrastructure, and environmental conditions in the shape of large scale floods for the past few years. Floods have catastrophic effects particularly in the developing countries lacking the appropriate infrastructure to counter above average water levels. It has been always believed that the native forest cover reduces the risks and severity of catastrophic floods. Due to lack of forests both people and environment are at risk. In order to keep the updated statistics of forests periodic surveys are necessary. However, due to land mafia ground surveys are hard to conduct. Remote sensing thus can be used to identify and delineate the forests and their types [2]. With increased spatial & spectral resolution it is not only accurate but also a lot easier than the ground surveys.

Forest identification based on subsequent multi date imaging over a time period is proved to be beneficial over a single date data. However for a selected region like forest, employing more training samples on single data images for recognizing spectral signature can be used to correctly identify the forestry.

In this study, two simple and fast pixel-based algorithms are compared in terms of accuracy on a high resolution image over a large study area. These algorithms include Parallelepiped classification and Mahalanobis Distance Classification. Pixels are considered to be the smallest unit of the image data and are classified on the basis of their individual spectral values [3] . The high resolution image has been taken by SPOT-5. It was a French satellite and offered greatly enhanced capabilities providing cost effective imaging solutions [4].

The paper is structured as follows. Section II highlights the methodology and briefly describes the pre-processing of the SPOT-5 image and division of data set into testing and training pixels, section III highlights the pixel based classification and covers the brief description of the two classification algorithms, section IV gives an insight of accuracy assessment of the two algorithms in question, section V discusses the results of the two classification algorithms and section VI hence concludes the paper.

II. METHODOLOGY

A. Study Area

Khyber Pakhtunkhwa, the province of Pakistan has almost 40 percent of the country's forest cover. It is embellished with prolific and dense forests covering the major portions of Hazara and Malakand division. Therefore, the location of our study includes forest intensive areas of Abbottabad districts, Khyber Pakhtunkhwa, Pakistan. Approximately 4599 km² area is studied which is a subset of the acquired SPOT5 imagery. It includes densely populated urban as well as rural areas. The

Iterative H.264 Video Decoding Using Mutual Information Exchangeable DSTS and SP Modulation

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Abstract—In this paper we analyze the impact of unequal error protection (UEP) over Data-Partitioned (DP) H.264 video transmission over Correlated Rayleigh fading channel using Recursive Systematic Convolution Codes (RSC). Multi transmit and receive antenna system with Differential Space Time Spreading (DSTS) is employed in combination with Sphere Packing (SP) Modulation to demonstrate the overall BER reduction and PSNR improvement of the received bit-stream. Furthermore, Iterative Soft Bit Source Decoding (SBSD) along with Channel Decoding mechanism is employed, which results in mutual information exchange to correct possible errors and results in the enhanced quality of the final decoded video. Similarly the performance improvement due to additional Exit-Optimized Over-complete Mapping(OM) is also presented. It is important to note that the overall bitrate of all the consider coding schemes is kept constant, while conducting the performance comparison. In UEP important Partitions in H.264 video stream are more error protected compare to less important Partitions. It is observed that using DSTS along with SBSD and Over-complete Mapping results in BER reduction and PSNR improvement of the received H.264 Coded bit-stream.

I. INTRODUCTION

The main goal of H.264 AVC standard is the design of high-compression efficient and Network friendly video transmission system. The H.264 Video Coding Layer (VCL) consists of different levels of elements like block, macro-block and slice and is responsible for significant video compression performance gain [1]. H.264 video coding techniques like multiple reference frames, deblocking filter, 1/4 pixel motion compensation and integer transform resulted in an increase in coding performance [2]. The Network adaptation is achieved through Network Abstraction Layer (NAL). NAL provides header information and represent VCL in a manner appropriate for various wired and wireless networks. The H.264 results in significant bit-rate reduction, compare to all previous standards such as ISO/ IEC JTC1 MPEG4 and ITU-T Rec. H.263 at the same quality level [3]. However due to compression efficiency the generated bit-stream is more vulnerable to transmission errors. Different error resilience mechanisms are incorporated in H.264 to reduce this problem, but they are computationally complex and also negatively effect compression performance. Various robust video communication mechanisms such as layered video coding with unequal error protection are proved to be beneficial for H.264 video stream transmission.

In recent work [4], the error resilient coding schemes of H.264 are exploited and unequal error protection is applied to adaptive macro-block classified slices using Reed Solomon codes. Another approach is presented in [5], which uses data-partitioning mode of H.264/AVC. Unequal Error Protection (UEP) is performed using Adaptive Hierarchical QAM. Similarly data partitioning approach is also used in [6]. Data partitions were Unequal Error Protected based on their relative importance and was compared with non-scalable video coding under similar applications and transmission constraints over mobile channels. UEP to data partitioned H.264 video stream is also performed in [7], using turbo codes. Channel Adaptive Joint Source and Channel coding scheme is proposed in [8], where UEP is applied to different relative important partitions of H.264 using Rate Compatible Punctured Turbo Code (RCPT). In [9] a Joint Source and Channel Decoding method based on Maximum a posteriori probability (MAP) was proposed. The proposed method is applied to decode Motion Vectors in H.264 coded video stream. Similarly in [10] a joint source channel decoding system is proposed, where multidimensional intra-frame correlation is exploited by the receiver for error correction. An application of Iterative Source Channel Decoding for distributed video coding by modeling the video signal with Iterative Horizontal-Vertical Scanline Model (IHVSM) relying on a first-order Markov process is presented in [11].

In this paper we have performed Slice Error Sensitivity of data partitioned H.264 bit-stream. Using this knowledge UEP is performed on the video stream encoded using by employing Recursive Systematic Convolution codes. The resultant bit-stream is modulated using Sphere Packing (SP) modulation and is finally transmitted using Differential Space-Time Spreading (DSTS). The corresponding performance improvement is investigated. The performance improvement gained through SBSD and Over-complete Mapping is also demonstrated.

II. DATA PARTITIONING (DP) EMPLOYED BY H.264

Apart from compression efficiency and network friendliness, H.264 video codec has also considered its support for advanced features resilience to error. In DP H.264, video stream is partitioned into 3 different types of Network Abstraction Layer Units (NALU's) [1].

A. Type A NALU:

It consists of header information of the slice, types of the MB, Quantization parameter and motion vectors. It's the most

A Secure True Edge based 4 Least Significant Bits Steganography

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Abstract—In this paper true edge based data hiding technique is proposed to take advantage of less sensitivity of human visual system to changes in complex regions of the image. This method utilizes edge detection and Steganography techniques. The Canny edge detection technique is used to identify true edge pixels and 4LSB Steganography technique is used to hide a secret message in the 4 least significant bits of edge pixels in the cover image. By hiding data in edges improve the quality of stego-image significantly. The results obtained show that the proposed technique hides large amount secret information in the cover image with better visual image quality than other techniques. The experimental results demonstrate the average hiding capacity of 4%, and the *PSNR* and *MSE* are 45dB and 1.60 respectively.

Keywords—Steganography; Edge detection; 4LSB Steganography; Steganalysis.

I. INTRODUCTION

Data hiding, also called Steganography, is a technique of concealing secret information within other information, thereby hiding the message secretly. In the era of modern communication and development of very fast processing systems, Steganography methods have become very important in several applications. For example, copyright, data integrity and authentication are few well-known applications of Steganography. Many digital images, audio and video now comprise a distinctive yet invisible watermark that help in preventing unauthorized copying of these materials [1, 2]. The digital media, e.g. image, audio and video can be used as a cover, but the media with higher redundancy is considered to be the most suitable cover for data hiding. As digital images have high redundancy that's why the images are mostly adopted for data hiding and lots of research has been carried out in the field of image Steganography.

Several data hiding methods have been reported both in the spatial domain and transform domain. Housinger et al.'s and Fridrich et al.'s proposed Steganography methods in spatial domain by hiding secret information directly in image pixels [3, 4]. VLSB Steganography was introduced by Sahib et al. and they also proposed some algorithms (i.e. MDT and DDDBA), for implementation of VLSB Steganography [5, 6]. In transform domain DCT coefficients are subjected to data hiding instead of pixels. Macq et al. implemented his method by data hiding using transform domain [7]. De Vleeschouwer et al. and Goljan et al. also developed invertible data hiding

techniques, but the data hiding efficiency was very low for the acceptable image quality and the quality of a stego-image dropped severely when the capacity was increased [8, 9]. Sahib et al. proposed a variable data hiding method in DCT domain [10]. Xuan et al.'s method, achieved a quite large hiding efficiency by hiding data in cover media using wavelet transform [11]; however, the image quality was affected significantly.

The main aim of Steganography is to hide more data in the cover image in such manner that the change made in the cover is unperceivable to human visual systems (HVS). As a HVS is more sensitive to variations in the smooth area of cover image than the complex area. Due to this characteristic of the HVS different amount of message data is hidden in smooth and complex regions of cover image. The complex region is subjected to more data hiding than smooth areas of the cover image. As a result the quality of the stego-image increases and the security of hidden information also increases. A lot of techniques, including LSB methods, PVD methods, and side-match methods have been proposed to hide data in complex areas of images [12-18]. However, some of these techniques provided a small hiding efficiency [12, 18], and doesn't comply completely with the rule that the edges can tolerate more changes than smooth region [16, 17]. To increase data hiding capacity Jung et al. [19] presented a new technique that hides data in smooth areas along with edges resulting in more distortion.

In the proposed technique of data hiding, canny edge detection is applied on a cover image to detect true edge pixels and the four least significant bits of each edge pixel are substituted with secret data using 4LSB Steganography.

II. PROPOASED METHOD

The previous methods hide data in the complex region of cover image, but they also hide data in those pixels that doesn't belong to edges. These methods hide data in a noisy or very weak and disconnected edge pixels which are not considered as the edges by most of the nowadays edge detection technique, e.g. Canny etc. In this paper a spatial domain data hiding method is proposed to hide secret information in true edges by substitution of 4 least significant bits of the cover image. The hiding of a secret message in true edges only, decreases the hiding capacity a bit, but the hiding of data in the true edge

Comparing Pixel-based Classifiers for Detecting Tobacco Crops in North-West Pakistan

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Abstract— Pakistan faces heavy revenue losses in terms of one of its major cash crop i.e. Tobacco, due to the unavailability of accurate statistics of the total tobacco production. During the cropping season, there are many competing crops along with tobacco in the neighboring fields – making tobacco identification a challenging task. This study considers a pilot region of interest that spans over 64844 hectares, in the north-western Pakistan, covered through SPOT5 (2.5m) satellite imagery, acquired on June, 28, 2013. Two supervised pixel based classifiers: (1) minimum distance (MD) and (2) Spectral Angle Mapper (SAM) are compared and their overall accuracy discussed. The results show that there is no significant difference in the overall classification accuracy of MD and SAM. However, SAM performs better than MD with overall accuracy and Kappa coefficient of 76.56% and 0.7009 respectively. For the specific case of Tobacco crop, MD classifier has producer's accuracy of 81.7% while SAM has that of 70.44%. The study also finds that Euclidean distance (in case of MD) and angle difference (in case of SAM) has no significant difference in classifying land cover types. It is also learnt that if area estimation is the objective, both of the classifiers will under-estimate tobacco covered area.

Keywords—SPOT5; Crop Monitoring; Spectral Angle Mapper; Minimum Distance Classifier;

I. INTRODUCTION

Information about land covers has significant applications in environmental, developmental, and resource planning. Land cover information and changes in the Earth's surface is also an important consideration for businesses and scientific communities. Image processing and pattern recognition on medium to high spatial resolutions' satellite imagery have been utilized for delineating and estimating area under different crops - including images from SPOT [1, 2], Landsat [3-5], and IRS [6, 7] satellite sources. The idea behind separating one crop from another is the distinguishable appearance of different species based on their maturity, greenness, and planting dates when they are seen from different spectral eyes. Difficulties in using satellite imagery for crop identification are associated with field-to-field inconsistency in reflectance of same crop types, similar reflectance properties of different crops, and spectral and spatial variability within fields [8, 9]. With the increase in spatial and spectral resolution of satellite images, more accurate crop identification is increasingly becoming possible.

Crop identification based on subsequent multi-date imagery within a growing season is proved to have benefits over that on single date imagery [7, 10, 11]. However, for a specific targeted crop, employing more training samples on single date imagery after recognizing its proper cropping calendar and optimum discrimination time can be used to accurately categorize that crop[12, 13].

In this study two supervised pixel based classifiers: (1) minimum distance (MD) and (2) Spectral Angle Mapper (SAM) are compared for a pilot region in the north-western Pakistan. The pilot region spans over 64844 hectares, covered through SPOT5 (2.5m) satellite imagery, acquired on June, 28, 2013. The RS data acquisition time (of June) is ideal for tobacco estimation. The study also examines key pre- and post-classification steps that are essential for achieving better classification and area-estimation results.

The paper is organized as follows: section II briefly explains the pilot region in terms of land properties, section III is about the methodology for acquiring the training and testing pixels, section IV gives the theoretical background of the two classifiers used in this study. Results of the study are discussed in section V and the findings are concluded in section VI.

II. STUDY AREA

The location of our study area includes tobacco intensive area in Mardan and Charsadda districts of Khyber Pukhtunkhwa province, Pakistan. Approximately 1064 km^2 area is studied which is a subset of the acquired SPOT5 imagery. This area has wide arable lands and covers approximately one-fourth tobacco production of Pakistan. It includes densely populated urban as well as rural areas.

III. METHODOLOGY

A. Pre-processing

The fused multispectral and panchromatic, High Geometric Resolution (HRG) SPOT-5 imagery of 2.5m spatial resolution is acquired from Pakistan Space and Upper Atmosphere Research Commission (SUPARCO). The image is CCD normalized for compensating radiometric variations and geometrically corrected to compensate for panchromatic distortion, differences in satellite orbital altitudes, and the Earth's rotation. Afterwards, the image is geometrically

A.