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Field hyperspectral data analysis for discriminating spectral behavior of tea plantations under various management practices

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ABSTRACT

The quality and yield of tea depends upon management of tea plantations, which takes into account the factors like type, age of plantation, growth stage, pruning status, light conditions, and disease incidence. Recognizing the importance of hyperspectral data in detecting minute spectral variations in vegetation, the present study was conducted to explore applicability of such data in evaluating these factors. Also stepwise discriminant analysis and principal component analysis were conducted to identify the appropriate bands for accessing the above mentioned factors. The Green region followed by NIR region was found as most appropriate best band for discriminating different types of tea plants, and the tea in sunlit and shade condition. For discriminating age of plantation, growth stage of tea, and diseased and healthy bush, Blue region was most appropriate. The Red and NIR regions were best bands to discriminate pruned and unpruned tea. The study concluded that field hyperspectral data can be efficiently used to know the plantation that need special care and may be an indicator of tea productivity. The spectral signature of these characteristics of tea plantations may also be used to classify the hyperspectral satellite data to derive these parameters at regional scale.

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1. Introduction

The tea (*Camellia* sp.) belongs to family Theaceae of plant kingdom and is primarily consumed as beverage around the world. Annually, 2.6 million t of tea worth millions of dollars is consumed in 65 countries where people daily drink some 4 billion cups of tea (Jain, 1999). The tea plant is also used as raw material for medicines, confectionaries, furniture etc. The plant type, age, growth stage, pruning, light conditions, and disease incidence are some of the important factors which govern productivity and quality of tea plantations. A variety of tea represents its genetic makeup and determines quality and quantity of tea (Bandyopadhyay, 2011; Owuor et al., 2010). The tea yield declines with the increase in age of plantation (Dutta, 2011; Kamau et al., 2008). Flowering is considered non-desirous growth in tea plantation as it may reduce crop yield, which could be controlled by suitable pruning or by planting new tea. The pruning is done for vigorous vegetative growth and to maintain the plucking table at desirable height. In unpruned tea the shoot length tends to be shorter than that of the shoot from a pruned section. Also, unpruned section will have increased number of dormant or *Banjhi* shoots leading to yield reduction (Yilmaz et al., 2004). Tea is grown under the shade trees for better quality and productivity (Mukherjee et al., 2008). The unshaded or heavily shaded tea sections are prone to pest attack (Muraleedharan, 2005). The disease incidence due to deficiency of micronutrients such as Magnesium results in loss in tea quality and yield as it regulates photosynthesis and acts as an activator of carbohydrate metabolism and nucleic acid synthesis (Jayaganesh and Venkatesan, 2010). The regular monitoring of tea gardens on a regional scale on the above parameters is expected to help tea growers in identifying the tea sections requiring special cultural practices and farm inputs. Besides, it will also form basis for prediction of the yield.

The multispectral remote sensing data (Sabins, 1997) have been widely used in the study of tea. The acreage and conditions of tea in Nilgiri district of Tamil Nadu state was estimated using Landsat MSS and TM multispectral data (Sharma et al., 1993). The geographical distribution of tea plantations was mapped using LISS II multispectral remote sensing data in the district of Cacher in Assam, India (Ghosh et al., 2000). The evaluation and mapping of tea plantations by other workers, as mentioned above, were carried out using fuzzy knowledge based image interpretation system deploying spectral knowledge of land covers, domain knowledge and field information. The Landsat, LISS III and ASTER multispectral

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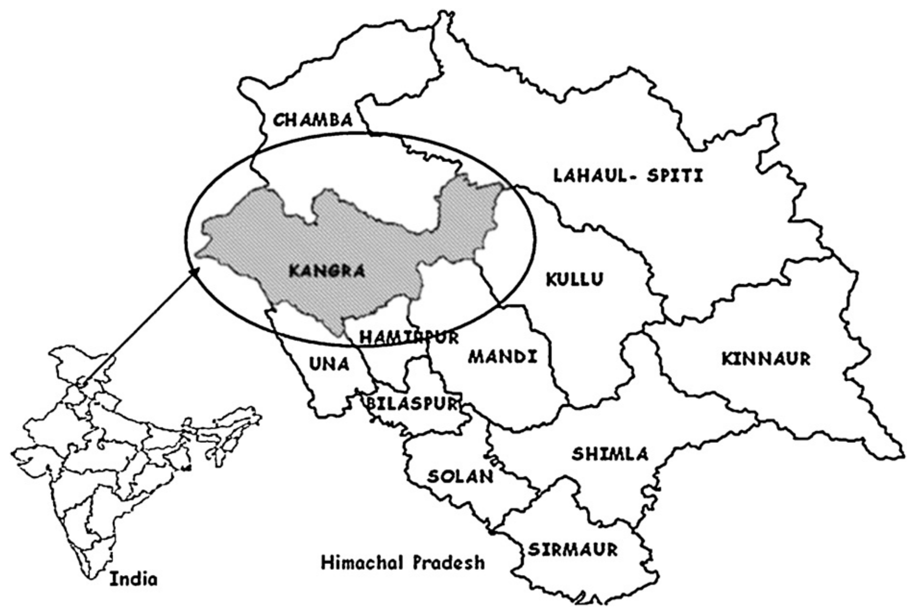

Fig. 1. Study area.

data could delineate tea patches into healthy, moderately infested and infested patches with intermixing of classes at some places in north eastern region of India (Dutta et al., 2008, 2009). The yield of tea was modeled in Nawalapitiya tea state of Sri Lanka using field derived Leaf Area Index (LAI) and Normalized Difference Vegetation Index (NDVI) derived from multispectral satellite data (Rajapakse et al., 2000). The productivity and growth pattern of different types of tea clones for different pruning ages were modeled using LAI and NDVI in Westhall tea estate of Kataboola in Kandy district in Sri Lanka (Rajapakse et al., 2002). A model between laboratory derived chlorophyll content in tea leaf sample and their spectral reflectance was developed to understand its nutritional conditions (Jiewen et al., 2010). It is, therefore, evident that for mapping of tea acreage, and assessment of health and productivity, the multispectral data in isolation is not sufficient and needs field derived information; as multispectral satellite data has limitations in providing biophysical, yield and species level identification (Asner et al., 2000; Carter, 1998; Richardson et al., 1992; Wiegand et al., 1992). The minute variations in the spectral characteristics of tea resulting due to canopy structure, size, greenness and maturity of tea leaves were not prominent in case of multispectral remote sensing (Rajapakse et al., 2002). The hyperspectral data is efficient in differentiating such spectrally similar conditions as it is a collection of narrow and contiguous spectral reflectance from plant foliage (Bajwa et al., 2004; Green et al., 1998; Schmidt, 2003). Therefore, the present work was carried out to explore the potential of hyperspectral data in identifying above mentioned parameters related to tea garden management practices which is solely based on physical appearance and does not need any allied information. Simultaneously, in contrast to broad bands of multispectral data, it consists of large number of bands which are redundant and among which only few bands record spectral variations (Thenkabail et al., 2000). Thus, with the above background the present study was conducted with following objectives.

1. To understand the spectral behavior of tea plantations owing to plant type, age, growth stage, pruning status, light condition, and disease incidence deploying non-destructive approach.
2. To find out suitable bands from field hyper-spectral data for discrimination of tea plantation or section based on above aspects.

2. Materials and methods

The study was conducted in the Kangra district of Himachal Pradesh, India (Fig. 1), located between 31°41′–32°25′ N latitude and 75°39′–76°56′ E longitude. Kangra has ideal terrain and climate for tea cultivation and is also known as Kangra tea valley. Though tea is found in a very limited area (2063 ha) but the quality of Kangra tea is considered to be quite high (Sud, 2007). *Camellia sinensis* (L.) O. Kuntz, commonly known as china hybrid tea, is the main tea species grown in this region. Studies for discriminating the plant type were undertaken on the clones BGP-126, BGP-133 and TV-1, whereas remaining parameters (Table 1) were studied on seed-grown plantation.

The field spectra were recorded from randomly selected three tea bushes representing the test parameters viz., types, age of plant, growth stage, pruning status, light condition, disease incidence, affecting productivity and quality of the tea plantations (Fig. 2). Total 30 reflectances were recorded within 25° field of view for each bush and finally they were averaged to produce a single reflectance spectrum.

The 512-channel ASD handheld spectroradiometer (Fieldspec®Pro 2000) with a range of 325–1075 nm (Fig. 3) was used to record reflectance. Before taking any observation, the spectroradiometer was calibrated with white spectrum in order to minimize the effect of change in sun illumination. In order to maintain the uniformity among the experimental materials, the tea plots having desired homogenous conditions were selected for the study. While recording hyperspectral data for different plant types the sections of the same age, light condition, planting geometry, growth stage, and pruning status were selected to ensure uniformity in the material except the plant type. In case of observations regarding age of the plant, the plant type, light condition, and planting geometry were common to both tea sections. For data on growth stage (flowering/non-flowering), tea sections of same plant type, age of plantation, pruning status, bush surface area, and planting geometry were chosen. While recording data for the pruning status (pruned/unpruned), plant type, age of plantation, light condition, and planting geometry were common. For data on light condition, tea sections of same and healthy plant type, age of plantation, pruning status, bush surface area, and planting geometry were selected. For data on disease incidence,

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