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Analytical Methods

Integrating satellite images and spectroscopy to measuring green and black tea quality

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ABSTRACT

This study quantifies the effects of green leaf and black tea parameters that influence tea quality in Northeast India. It was motivated by a decline in tea quality that is of concern to tea growers. The rationale of the study is to identify the different parameters that have a significant influence on liquor brightness and other variables measuring tea quality. Here, we investigate several methods for estimating tea quality based on tea quality data, near infrared spectroscopy and remotely sensed data (NDVI). Attention focused on two high yielding clones (TV1 and S3A3). NDVI was obtained from ASTER images. Statistical analysis shows that liquor brightness is affected by the levels of caffeine content, theaflavins and catechins. Relationships exist between quality parameters and remote sensing in particular for the S3A3 clone. NDVI has a positive relation with caffeine, theogallin, EC, and ECG. NIR is negatively related to caffeine, theogallin, and catechins. We conclude that NDVI and Near Infrared (NIR) spectroscopy have a large potential to be used for monitoring tea quality in the future.

1. Introduction

Tea is made from tender shoots of *Camellia sinensis* (L.) O. Kuntze (Hara, Luo, Wickremasinghe, & Yamanishi, 1995; Wright, Mphangwe, Nyirenda, & Apostolides, 2002). It is a leading cash crop in world agriculture (Dutta, Stein, Smaling, Bhagat, & Hazarika, 2010). Its production has increased from 850 million kg between 2000 and 2003 to 980 million kg between 2004 and 2007. Main tea producing countries are China, India, and to a lesser degree Sri Lanka, Kenya, and Indonesia. With the increasing world population, the tea market is expected to grow further (Tea Statistics Annual Report, 2007). In India, however, stagnation in tea production and decline of tea quality are occurring, which are major problems to the tea industry (Dutta, 2006). Several factors attribute, such as old age of tea bushes, declining soil health, and increased incidence of pests and diseases, all resulting in deterioration of tea quality.

Factors like colour, appearance, flavour and mouth feel jointly make up the quality of tea. Formation of orthoquinones, bisflavanols, theaflavins and thearubigins from the catechin precursors takes place during enzymic fermentation (Roberts, 1958a, 1958b). Caffeine plays a vital role in tea quality characteristics such as briskness and other taste properties (Dev Choudhury, Rahman, & Barbora, 1991; Hilton & Ellis, 1972; Roberts, 1962; Sanderson, 1972) and it is an important parameter for quality evaluation (Khokhar & Magnusdottir, 2002; Owuor, Horita, Tsushida, & Murai, 1986; Yao et al., 2006). Liquor brightness and total colour of black tea are critical quality attributes, used in the tea trade to rank and price black teas (Biswas, Sarkar, & Biswas, 1973; McDowell, Feakes, & Gay, 1991). During black tea processing, theaflavins (TF) and thearubigins (TR) and other polymerisation products are formed (Roberts, 1962; Sanderson, Berkowitz, Co, & Graham, 1972). The attractive colour of tea infusion is due to TF which is an important quality index of black tea giving a bright colour and brisk taste of the liquor (Sanderson et al., 1976). TR contributes to total colour i.e. the colour of black tea and possibly also to the liquor brightness. The major tea leaf catechins include epicatechin (EC), epicatechin gallate (ECG), catechin (+C), epigallocatechin (EGC) and epigallocatechin gallate (EGCG) (Obanda, Owuor, & Mang'oka, 2001) contributing to the astringent taste of tea (Ding, Kuhr, & Engelhardt, 1992; Kuhr & Engelhardt, 1991). ECG and EGCG are the main residual catechins in black tea (Obanda, Owuor, & Mang'oka, 2001).

Understanding the spectral characteristics of tea plants is important in monitoring tea plantations by remote sensing (Rajapakse, Tripathi, & Honda, 2002). They developed an empirical model between Normalised Difference Vegetation Index (NDVI) and LAI of the tea canopy and revealed that different tea clones

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have unique spectral characteristics depending on the tea canopy structure, size, greenness and maturity of the leaves. Understanding the spectral characteristics of tea plantations is important for monitoring the growth of plants and estimating tea-yield using remote sensing methods. The spectral characteristics of a plant canopy largely depend on the composite spectral response of leaves and soil background (Richardson & Wiegand, 1977). Reflectance signals of vegetation in the visible and near-infrared are used to detect distribution, health and productivity of plants (Buschmann & Nagel 1993; Rajapakse et al., 2002). Hall, Robertson, & Scotter, 1988 used near infrared (NIR) spectroscopy to determine theaflavins and also to measure the overall tea quality. Near-infrared spectroscopy provides a rapid method for the simultaneous estimation of the moisture content, theaflavin content and overall quality of black tea. NIR spectroscopy also helps monitor tea manufacturing process thus enabling better control of withering, fermentation and drying stages. With the help of available field information, Remote Sensing (RS) and Geographical Information System (GIS) have become powerful and successful for monitoring crop growing status and estimating crop yield in agriculture. At the same time, the demand for monitoring quality has become more urgent. Therefore, attention has been given towards monitoring and estimating crop quality through remote sensing and GIS. In this way, we can relate nitrogen or other bio-chemical contents present in leaves or stems and remotely sensed parameter derived from satellite imagery. Temporal remotely sensed data can also be used to estimate crop quality by retrieving bio-chemical contents in leaves or stems. Correlations between these contents and quality indicator indicate the quality of grains or rootstalks (Pan, Wang, Zhao, Liu, & Huang, 2004).

The important chemical constituents which influence the taste and flavour in tea brew are polyphenols, caffeine, sugars, organic acids, volatile flavour compounds and amino acids. Phenolic compounds of tea, such as theaflavins and thearubigins, are important from an intrinsic quality point of view. These are responsible for the colour, flavour and brightness of tea. Caffeine is responsible for the briskness. The volatile flavour compounds of tea and their variation in composition due to geographical and other process variables are of paramount importance from a quality point of view. It is also known that the chemical and quality variations occur due to the variation in the genetic make-up of the plants, even when they are grown under similar conditions in one environment (Owuor, Obanda, Nyirenda, & Mandala, 2008).

Tea quality should maintain the ISO standards so that the expectations of the consumers are met (Scott, 2004). Methods for sampling tea should follow the ISO 1839 while liquor preparation for use in sensory tests should follow ISO 7516 standards (ISO Focus. Food, 2004). Quality monitoring is usually done through laboratory analysis. Vegetation indices obtained by remote sensing and NIR spectroscopy have not been used in monitoring tea quality.

The present study aims to investigate methods for estimating tea quality based on tea quality data, near infrared spectroscopy and remotely sensed data (NDVI). These methods are then explored when developing an approach to monitor tea quality. The study is applied to a tea estate in the Assam region in India.

2. Materials and methods

2.1. Study area

The study area is located in the Jorhat district, at South Bank region of Assam in India (Figure 1). Jorhat, the second largest town in Assam, is situated in the South Bank at 26.75° N latitude and 94.22° E longitude. It has an average elevation of 116 m. The district spreads over an area of 2851 m^2. Summer temperature ranges between 15 and 28 °C, and winter temperature between 7 and 18 °C. Summers are accompanied by the monsoon showers leading to an average annual rainfall of 2244 mm. There are approximately 135 tea estates including 'out' gardens that occupy an area of

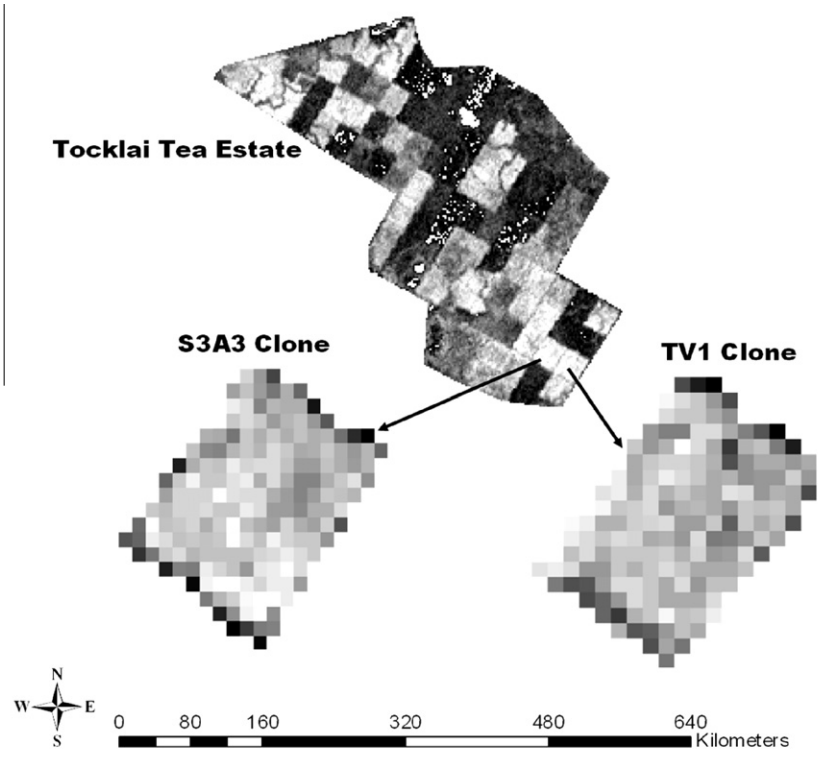

Fig. 1. NDVI map showing the sections of clone S3A3 and TV1 of Tocklai Tea Estate, Assam, Northeast India.