

The price of tea

“The tea industry wants to come up with new technologies to effectively monitor and manage these plantations.”

Rishiraj Dutta

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by Laura Naranjo

“The best tea must have creases like the leather boots of Tartar horsemen, curl like the dewlap of a mighty bullock, unfold like a mist rising out of a ravine, gleam like a lake touched by a zephyr, and be wet and soft like earth newly swept by

rain,” wrote the great Chinese tea sage, Lu Yu. More than 1,200 years since Lu Yu wrote these words, people can still be very serious about the pleasures of tea.

Whether consumed British-style with milk, Moroccan-style with mint, or with yak butter



Assam tea is known for producing a reddish cup of tea with an astringent flavor. It is grown exclusively in the Assam region of India. (Courtesy T. Ducasse)

and salt in Tibet, the basis for tea is simple: nothing more than hot water and the leaves of a shrub. Growing and producing those tea leaves, however, is anything but simple. Much of the industry remains labor intensive, and as plantations age, tea quality and crop yield have declined. In India, the industry has struggled to modernize and remain competitive. A new breed of tea sages is now waxing scientific instead of poetic on the quality of tea.

Aging plantations

Tea production is a relative newcomer to India's agricultural scene, introduced by the British in the early 1800s to compete with China. In less than 200 years, the tea industry has become India's second largest employer and is a mainstay in the country's economy. India is home to nearly 1,600 plantations that grow an extensive variety of black and green teas. Many plantations have been producing tea for 50 to 100 years or more, and their harvesting and production methods are steeped in tradition. Yet their very age may contribute to the problems the industry now faces.

"The big production period for plantations is between 20 and 40 years," said Rishiraj Dutta, one of the researchers who studied ways to modernize India's aging tea industry. "Most of the plantations in India are more than 60 years old. So their productivity levels and tea quality are starting to decline." Plant age, soil depletion, and increasing pest infestations are making it difficult for plantations to continue producing the quality and quantity of tea that they have in the past.

Dutta and his colleagues hoped to use remote sensing to help get the most out of tea plants. Qualities of specific tea varieties, such as Darjeeling's astringent muskiness, or the bold



Most tea leaves are still harvested by hand. Tea trees are pruned to waist height so pluckers can easily reach the leaves. (Courtesy M. Williams)

flavor of Assam tea, rely heavily on specific chemicals within the tea leaves. "The tea industry wants to come up with new technologies to effectively monitor and manage these plantations. That's where this research started," Dutta said. Could multispectral remote sensing permit

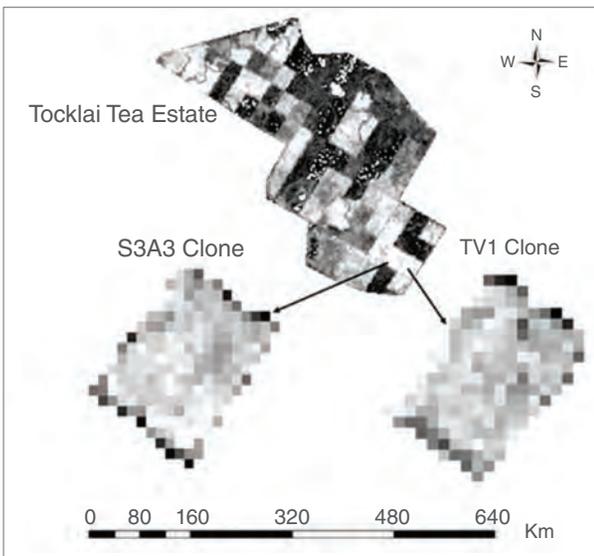
plantation managers to monitor the chemistry of tea leaves from space?

First flush

From the first shoots of spring through the series of summer harvests, called flushes, tea



Tea is the most widely consumed beverage in the world, and is typically grown on massive plantations such as this one in Munnar, India. (Courtesy J. Dohnal)



This Normalized Difference Vegetation Index (NDVI) map shows the sections of two particular tea clones on the Tocklai Tea Estate, in Assam, Northeast India. Researchers observed the two clones to see how certain amounts of chemicals in the leaves, such as caffeine or catechins, affected their spectral reflectance in the image. Data are from the NASA Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). (Courtesy R. Dutta et al., 2011, *Food Chemistry*)

production is tightly controlled to nurture and retain the finest tea qualities. Specific chemicals in the leaves determine tea quality, including the flavor, color, appearance, mouthfeel, and the brightness of the brewed product. A class of compounds called polyphenols has a large influence: Catechins and tannins contribute an astringent taste, and theaflavins play a role in flavor and color. Tannin levels also generate the mouthfeel of tea—whether it feels smooth or rough in the mouth. One of the most well-known compounds, caffeine, helps determine the briskness of tea. Combined, these constituents create a tea’s overall flavor.

The chemical makeup of tea leaves develops as the plants grow, meaning the qualities of each flush differ. The first flush of certain varieties, such as Darjeeling, is highly valued. Yet other varieties are considered best during their second flush. Likewise, the subsequent third and fourth flushes will have slightly different qualities and flavors as each of the chemicals increases or decreases. “We considered the first flush and the second flush for this study. We can see the difference in the chemical parameters in the green leaves, as well as with the black tea,” Dutta said. Ideally, these chemical differences reveal variations in catechins, tannins, and caffeine content of the leaves from flush to flush.

Dutta and his colleagues focused on two particular tea clones on a plantation that is part of the Tocklai Experimental Station in the Jorhat district of Assam, India. They planned to use a satellite instrument to measure the Normalized Difference Vegetation Index (NDVI), which is a visual indicator of vegetation abundance and health. Remotely sensed NDVI reveals how the leaf canopy reflects light at different frequen-

cies across the electromagnetic spectrum, many of which are invisible to the human eye. In this case, Dutta also hoped it would help distinguish the chemical components in the leaves that were responsible for tea quality.

Producing the perfect tea

Remotely sensed NDVI, however, would only work for observing plants in the field. The researchers still needed to analyze the final tea product to make a correlation between satellite and ground data. For the most accurate results, they would have to harvest and process a batch of tea samples under the same rigorous conditions the plantations used. Between April 20 and June 15, 2009, they had one kilogram of tea leaves carefully plucked. “Quality differences also depend on how we collect the leaves,” Dutta said. “So we retained the same sets of pluckers for the entire plucking period to maintain the leaf fineness.” The researchers then reproduced standard tea processing commonly used in the industry.

Once the leaves were processed and graded for quality, they assessed the chemical contents of final black tea and green tea products. For the NDVI analysis, they chose imagery from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), an instrument aboard the NASA Terra satellite. The image captured leaf conditions during the second flush when they had collected the leaves.

By comparing the chemistry of the processed leaves with the NDVI analysis of the plantation fields, Dutta and his colleagues found that they could use remote sensing to detect the changes in caffeine, catechins, and various theaflavins that influenced a tea’s appearance and flavor. Remote

sensing could reduce the amount of hand sampling in the field by monitoring the desired leaf qualities across large sections of tea destined to be harvested in each flush.

Quantifying quality

India produces approximately a quarter of the world's tea, and the tea industry is trying to modernize its practices to keep up with that demand. Plucking tea bushes will likely remain labor intensive, as machine harvesting damages the leaves. Dutta's study proved that satellite imagery can help estate managers track the overall health of the plantations and tea leaf quality. "They want new techniques where it would be cost-efficient for them, and reduce the labor," Dutta said.

Dutta has also applied remote sensing to monitor the replanting of tea. Estate managers cope with not only aging plantations but also the effects of climate change. Tea thrives best in humid, subtropical climates with wet growing seasons. Historically, natural rainfall watered India's plantations, but as climate change shifts rainfall patterns and amounts, some managers must either replant sturdier tea clones or install expensive irrigation systems to water their tea bushes. "These are very old plants, so they are not able to adapt much to the changing environment," Dutta said.

Tracking the growth of replanted tea bushes is an intensive process, but it is critical if a plantation owner wants to continue producing tea. Replanting is completed one section at a time in a process that can take two years or more. Managers must remove old plants, refresh and prepare the soil, and then plant tens of thousands of new seedlings, often alongside other plants that help deter pests. "Once you replant, it takes

About the remote sensing data

Satellite	Terra
Sensor	NASA Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
Data set	ASTER L1B
Spatial coverage	60 x 60 kilometers
Parameter	Reflectance
Data center	NASA Land Processes Distributed Active Archive Center (LP DAAC)

About the scientists



Rishiraj Dutta is a technical officer with the Thailand office of the Asian Disaster Preparedness Center, and has worked with research programs on climate change, agriculture, and food security. He holds a PhD in applied geoinformation and Earth observation. The Tea Research Association supported his research. Read more at <http://goo.gl/fiKvos>. (Photograph courtesy R. Dutta)

almost three to four years to get your first production," Dutta said. Estate managers could employ remote sensing to monitor the leaf qualities from seedling plants to first harvest, and identify sections where crop yield might be highest, or where new growth might be stunted by lack of water or pest infestations.

Applying remote sensing allows plantation managers to track tea quality and plant growth, and is one more tool they can use to reduce costs and remain competitive. "If we can manage the plantations well, then they will sustain and produce tea for more than one hundred years into the future," Dutta said.

To access this article online, please visit <http://earthdata.nasa.gov/sensing-our-planet/price-tea>



References

- Dutta, R. 2013. Monitoring green leaf tea quality parameters of different TV clones grown in northeast India using satellite data. *Food Chemistry* 139: 689–694.
- Dutta, R., A. Stein, and R. M. Bhagat. 2011. Integrating satellite images and spectroscopy to measuring green and black tea quality. *Food Chemistry* 127: 866–874.
- NASA Land Processes DAAC. ASTER L1B data. Sioux Falls, South Dakota USA: USGS/Earth Resources Observation and Science (EROS) Center. https://lpdaac.usgs.gov/products/aster_overview.

For more information

- NASA Land Processes Distributed Active Archive Center (LP DAAC)
<http://lpdaac.usgs.gov>
- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
<http://asterweb.jpl.nasa.gov>
- Tea Research Association
<http://www.tocklai.net>