**Global Hyperspectral Imaging Spectroscopy of Agricultural-Crops & Vegetation (GHISA)**

**Advances of Last 50 Years of Research**

This webpage showcases the key research advances made in hyperspectral remote sensing of agricultural crops and vegetation over last 50 years. There are three focus areas:

1. **Research conducted over last 20 years (by Dr. Prasad. S. Thenkabail’s group)**

The primary focus is on the seminal research conducted over last 20 years by this group using hyperspectral data of agricultural crops and vegetation, gathered from around the world, from various platforms: ground-based, platform-mounted, drone or unmanned aerial vehicle (UAV)-based, airborne, and spaceborne. The leading world crops studied include wheat, rice, corn, soybeans, barley, cotton, and alfalfa (Table 1). Natural vegetation’s in the African savannas and rainforests were also studied using hyperspectral (or imaging spectroscopy) data. Characteristics of these sensors can be found here (Table 2).

1. **Research conducted over last 50 years (by global remote sensing community)**

The secondary focus is on the compendium of the hyperspectral remote sensing of vegetation and agricultural crops research conducted by a large community of global researchers over last 50 years. This is summarized in a **book on** “hyperspectral remote sensing of vegetation” (Publisher: Taylor and Francis, Inc.):

<https://www.crcpress.com/Hyperspectral-Remote-Sensing-of-Vegetation/Thenkabail-Lyon/p/book/9781439845370>

However, a more comprehensive 4 volumes “**hyperspectral remote sensing of vegetation and agricultural crops**” (Publisher: Taylor and Francis, Inc.) will be published by the end of 2018 or early 2019.

1. **Global hyperspectral imaging spectral-library of agricultural-crops (GHISA)**

The tertiary focus is in establishing global hyperspectral imaging spectral-library of agricultural-crops (**GHISA**) for some of the major crops of the world (Table 1) for various locations of the world and at various growth stages. The crops include wheat, rice, corn, soybeans, barley, and cotton (Table 1). Hyperspectral data for GHISA is gathered from ground-based and speaceborne Hyperion based sensors (see Table 1 for data characteristics of these sensors).

**Hyperspectral Remote Sensing or imaging spectroscopy** (see the definition here), originally used for detecting and mapping minerals, is increasingly needed for to characterize, model, classify, and map agricultural crops and natural vegetation, specifically in study of:

1. Species composition (e.g., *chromolenea odorata vs. imperata cylindrica*);
2. Vegetation or crop type (e.g., soybeans vs. corn);
3. Biophysical properties (e.g., LAI, biomass, yield, density);
4. Biochemical properties (e.g, Anthrocyanins, Carotenoids, Chlorophyll);
5. Disease and stress (e.g., insect infestation, drought),
6. Nutrients (e.g., Nitrogen),
7. Moisture (e.g., leaf moisture),
8. Light use efficiency,
9. Net primary productivity and so on.

**The goal of using hyperspectral narrowband (HNB) data, as opposed to multispectral broadband (MBB) data**, is to increase accuracies and reduce uncertainties in study of various vegetation and agricultural crop classification outcomes, and in modeling and mapping these quantities.

Advances made in using **hyperspectral narrowband (HNB) data, relative to multispectral broadband (MBB) data**, include: (a) significantly improved characterization and modeling of a wide array of biophysical and biochemical properties of vegetation, (b) ability to discriminate plant species and vegetation types with high degree of accuracy, (c) reducing uncertainties in determining net primary productivity or carbon assessments from terrestrial vegetation, (d) improved crop productivity and water productivity models, (e) ability to assess stress resulting from causes such as management practices, pests and disease, water deficit or water excess, and (f) establishing more sensitive wavebands and indices to study vegetation characteristics.

A wide range of **hyperspectral research topics** are covered, such as: (1) hyperspectral sensors and their characteristics, (2) methods of overcoming the Hughes phenomenon, (3) characterizing biophysical and biochemical properties, (4) advances made in using hyperspectral data in modeling evapotranspiration or actual water use by plants, (5) study of phenology, light use efficiency, and gross primary productivity, (5) improved accuracies in species identification and land cover classifications, and (6) applications in precision farming.

One of the first goal of any hyperspectral data analysis is in **dimensionality reduction to overcome data redundancy** and to optimize most valuable data for a given application. This requires data mining. Feature selection is necessary in any data mining effort. Feature selection reduces the dimensionality of data by selecting only a subset of measured features (predictor variables). Feature selection methods recommendation based on: 1. Information Content (e.g., Selection based on Theoretical Knowledge, Band Variance, Information Entropy), 2. Projection-Based methods (e.g., Principal Component Analysis or PCA), 3. Independent Component Analysis or ICA), 4. Divergence Measures (e.g., Distance-based measures), 5. Similarity Measures (e.g., Correlation coefficient, Spectral Derivative Analysis), and 6. Other Methods (e.g., wavelet Decomposition Method).

**Hyperspectral narrowband (HNB)** data is known to **provide significant advances in modelling, mapping, and monitoring agricultural crop and vegetation** **biophysical and biochemical quantities. Biophysical characteristics** that are, typically studied are: 1. Biomass: wet and dry; (kg\m2); 2. Leaf area index (LAI), 3. Green LAI; (m2\m2); 4. Plant height; (mm); 5. Vegetation fraction; (%); 6. Fraction of PAR absorbed by photosynthetically active vegetation (fAPAR); (MJ\m2); 7. Total crop chlorophyll content; (g\m2),and 8. Gross primary production. (g C\m2\yr). **Biochemistry** (e.g., plant pigments, water, and structural carbohydrates): Leaf reflectance in the visible spectrum is dominated by absorption features created by plant pigments, such as: 1. chlorophyll a (chl-a): absorbs in 410-430 nm and 600-690 nm; 2. chlorophyll b (chl-b): absorbs in 450-470 nm; 3. carotenoids (e.g., β-carotene and lutein): peak absorption in wavebands <500 nm; 4. anthocyanin’s, 5. lignin, cellulose, protein, and 6. Nitrogen: relatively low reflectance and strong absorption in SWIR bands by water that masks other absorption features. However, dry leaves do not have strong water absorption and reveal overlapping absorptions by carbon compounds, such as lignin and cellulose, and other plant biochemical, including protein, nitrogen, starch, and sugars.

**Hyperspectral vegetation indices (HVIs)** (e.g., Table 3) provide opportunity to study specific biophysical and biochemical quantities more precisely than multispectral broadband derived indices. HVIs are either two-band or multi-band types. Novelty of HVIs include: 1. physically meaningful indices (e.g., Photochemical reflective index (PRI) as proxy for light use efficiency (LUE)), 2. significant improvement in sensor saturation relative to broadbands, 3. providing greater sensitivity (e.g., an index involving NIR reflective maxima @ 900 nm and red absorption maxima @ 680 nm); 4. new indices not sampled by broadbands such as water-based indices (e.g., involving 970 nm or 1240 nm along with a non-absorption band, and 5. multi-linear indices involving more than 2 bands.

The research also recommends, through comprehensive research, optimal hyperspectral narrowbands (see Table 4) and the best incremental bands (see Table 5) in study of agriculture and vegetation.

This research is led by **Dr. Prasad S. Thenkabail**, Research Geographer @ the United States Geological Survey (USGS) and his team of researchers at various time periods: **Dr. Michael Marshall** (2013-2016) who is currently with the International Institute for Geo-Information Science and Earth Observation (ITC), Netherlands, **Dr. Isabella Mariotto** (2012-2014) wo is currently with the University of New Mexico, **Dr. Itiya Aneece** (2016-present), **Dr. Pardhasaradhi Teluguntla**, of Bay Area Environmental Research Institute (BAERI) @ United States Geological Survey, and **Dr. Muralikrishna Gumma** of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). A number of other have made important contributions and they are acknowledged as co-authors in relevant manuscripts and\or as partners\collaborators in the people biographies.