Image Filtering and Feature Extraction
Following image upload, filtration is necessary to transform the image to a format that can be processed by the classification system. This step also ensures a practical design for Northeast farmers since the system must be capable of processing images taken under different environmental conditions using different cameras and resolutions. The development and testing of algorithms for this step were executed in 2011 and 2012. Each image must be processed through a series of digital image filters to normalize the image and extract key features. For example, a series of algorithms were defined to identify the edges of the white hoop in the image and extract the inner area of the hoop (Figure 2). In system development, it was important to use a hoop to define the sampling area so that the image area in the hoop corresponded to the exact area harvested. However, hoop use is cumbersome and will not be necessary for farmers. Our automated hoop extraction program had an 80% success rate for 2011 and 2012 images. In the remaining images, hoops were extracted manually using the GNU Image Manipulation System (GIMP). The resulting ellipse from each original image was then converted to the gray scale with an emphasis on green pixels (Figure 2). This method was effective in capturing key information about grass composition in the image while minimizing sources of non-composition-related variation arising from lighting and color.

Figure 2 Hoop extraction: a series of algorithms were defined to identify the hoop edges, extract the inner area of the hoop, and convert the resulting image to the gray scale with emphasis on green pixels.

Classification System
Multiple image analysis approaches were tested from 2011 to 2013 during development of the classification system with unsatisfactory results (Table 2). For example, image processing techniques were developed and combined with artificial intelligence approaches to generate stand composition estimates. Early on, the application showing the most potential for success was a tile extraction method with fast Fourier transformation (Polder et al., 2007). This was later combined with support vector machine processing using the LIBSVM open source package (Chang and Lin, 2011). However, estimates generated by the fast Fourier – support vector machine system for single grass species in the mix associated poorly with actual stand composition without additional inputs such as alfalfa maximum height and grass canopy height. Furthermore, the fast Fourier – support vector machine-estimate was inaccurate under diverse conditions of the full 2011 and 2012 datasets. This method was abandoned in spring 2013. The reasons for discarding Naïve Bayes Classifier Artificial Intelligence in 2012 were similar, but the method was less effective. Simpler techniques such as color separation and blob detection were not feasible for this application due to the complexity of mixed stand images. For example, blob detection was infeasible due to broken lines at the pixel resolution level. Thus, blobs (leaves) could not be defined as distinct entities for quantification during image processing. Some techniques were promising with single cameras under similar lighting and field conditions. However, relationships quickly degraded under diverse conditions.