Assessing the Ability of Image Processing Methods of Droplets Sprayed on Water Sensitive Papers for Aerial Application

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Abstract. In this study, 33 pieces of WSP were placed along three lines in a paddy. An M-18B Dromader AG aircraft flew and sprayed over the field, and the spray deposits were collected by water sensitive paper. Seven greyscale parameters were used to compare the color depth, deviation and homogeneity of digital water sensitive images. The greyscale images were converted to binary images with five threshold selection methods. The results of recognition of seven greyscale parameters and five threshold methods were compared to analyze the droplets in different scanned images on water sensitive paper. The effects of the threshold on the computation of deposit density and the stain size were evaluated. The most suitable grey scale was found to be luminosity. Finally, a manual validation was performed, and the relationship between the threshold and the stain size of was analyzed.

Keywords: WSP, Image analysis, Aerial application, Droplet identification

1 Introduction

A major concern for environmental conservation and management is the effect of pesticide, fungicide, and herbicide on the environment. A study shows that, the DPI (Drift Potential Index) was mainly influenced by the ground speed of the aerial sprayer. Increasing the ground speed from 3.0 to 6.0 km/h increased the drift potential for 35% on average [1].

Considering drifting, the crop-pesticide aerial spraying is an inefficient process with plenty of the chemicals drifted to air and elsewhere [2]. Some advanced technologies, such as geographic information systems, differential global positioning, electronic-guidance, on-site meteorological monitoring, and remote sensing, can optimize herbicide application for maximum efficacy and environmental protection [3]. Cruz Garcera opened a possibility to estimate the deposition of a plant protection product in field applications from coverage values measured on WSP [4].

WSP (WSP) is widely used for monitoring spray distribution. WSP was a kind of rigid paper with a chemically coated, tinted surface, which would be stained dark by aqueous droplets contacting on it. A linear relationship could be built between droplet and stain diameter on WSP by a spread factor calibration [5]. Generally, WSP is the most important tool for assessing the quality of pesticide, herbicide and fungicide application on crops, but WSP manual analysis is inefficient and inaccurate.

Digital image processing techniques based on scanned WSP was developed recent years. Much commercial and experimental software has been developed and successfully used to evaluate aerially applied pesticide spray deposits [6]. The advance of digital imaging scanning technology has increased the resolution capabilities for spray particle size, amount and distribution analysis from WSP. Software developed specifically for the analysis of WSP can provide an easy, fast, automated, and accurate analysis of the spray quality, minimizing human error [7]. However, there are three limitations so that most of deposits recognizing software were designed for the single WSP analysis and in laboratory experiments. 1, Very low and very high area coverage would cause in accuracy. 2, the assumption of circle droplets caused weak correlations between WSP area coverage measurements and spray deposition. 3, VMD rely on the calculation of the size of single droplet, so the accumulation of errors resulted in inaccurate VMD [8].

The purpose of this work is to evaluate the sensitivity of different greyscale methods for digital WSP images. Some goals were achieved: (1) to compare the detailed resolution and homogeneity of the greyscale methods, (2) to estimate the impact of threshold on recognized droplet size, and (3) to recommend a greyscale parameter and a threshold method for real field experiment.

2 Experiments and Methods

2.1 Sample points and materials

The 33 pieces of Water-sensitive paper (WSP) made by Syngenta Crop Protection were placed along three lines in a paddy field. There were 5 sample points in the east line with10 pieces of WSP. The centerline had 7 sample points with 14 pieces of WSP. The west line had 5 sample points with 9 pieces of WSP. The locations of the sample points were shown in figure 1. The 5 sample points in the east or west lines were located 5, 10, 15, 20 and 25 m from the flight path of. The center line had extra two sample points at 50 m and 100 m from the flight path. For every sample point, WSP was fixed on a compact tripod. The height of tripods was adjusted to 60 cm, the same height of rice canopies. The M18B_Dromader AG aircraft flew through the flight path from west to east over the rice field. The wind direction was 40° to the north with the velocity of 1 m/s. The temperature was 22℃, and the humidity was 76 g/m3.

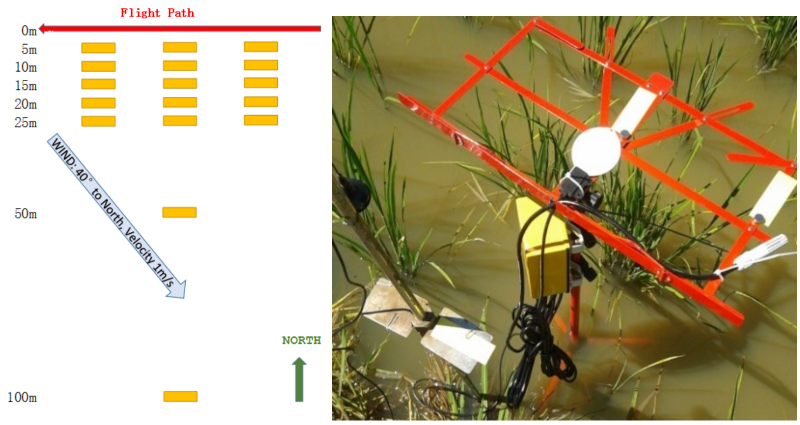


Fig 1 Layout of samples (left) and WSP on the tripod (right)

The Water Sensitive Paper was 76 mm width and 26 mm height, and the samples were scanned by a portable scanner (SKYPIX TN450+A02) with a resolution of 1200 dpi, with 24-bit color images and jpeg format.

2.2 Greyscale conversion method

Seven different greyscale methods were included: Red, Green, Blue, Hue, Saturation, Brightness and Luminosity [9]. Red, Green and Blue were the three components in RGB color model. Hue was one of the main color properties in the HSV color space, and is the degree to which a stimulus can be described as similar to or different from stimuli that are described as red, orange, yellow, green, blue and violet [10]. The saturation was the colorfulness of a stimulus relative to its own brightness. The DepositScan - Portable Scanning System for Spray Deposit Distribution (USDAARS) used saturation as the greyscale parameter [11]. The brightness was average of red, green and blue, in the HSI model called intensity [12].

The luminosity of an object in a given spectral region [13] is related to brightness. In this work, the luminosity was a composed parameter calculated from the RGB model in equation (1) [14].

$$L = 0.21R + 0.72G + 0.07B \qquad (1)$$

Fig 2 shows a scanned WSP which was placed in the centerline and 20 m from the flight path. The image was convert to gray-scale image by 7 methods.

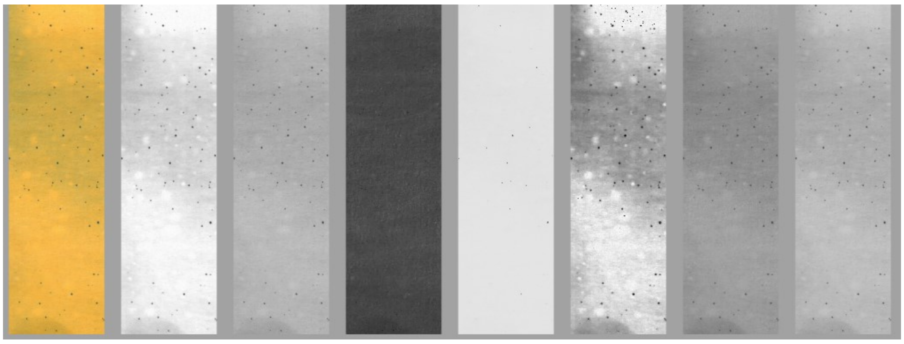


Fig 2 Water-sensitive image and seven grayscale images

This work used three parameters to evaluate the quality of the greyscale methods: (1) the color depth is the number of greyscale levels, indicating the smallest detected change. The standard deviation of greyscales represents the separability of water sensitive images. The homogeneity was standard deviation of color depth from top, middle and bottom of an image, which evaluates the sensitivity of different greyscale methods to the quality of sample.

2.3 Threshold selection method

The following five dynamic threshold selection techniques were implemented and evaluated for computing the threshold values: mean, MeanHist, max-min, median and OTSU's. The mean threshold method simply classified each pixel in the image to binary with the average greyscale of all pixels as the threshold. The MeanHist was the average of the greyscale histogram. The max-min method used the average of minimum and maximum greyscale to separate foreground and background of images. The median threshold compared pixels with the median of greyscale histogram. The OTSU's method is the most popular method of dynamic threshold selection methods [15]. The OTSU's algorithm assumes that the image to be separated contains a bi-modal histogram and then calculates the optimum threshold separating those two classes so that their combined spread is minimal.

To compare the results from different threshold selection methods, the standard deviations were calculated. The less standard deviation means better method, since all WSP was deployed and collected at the same time.

2.4 Manual validation

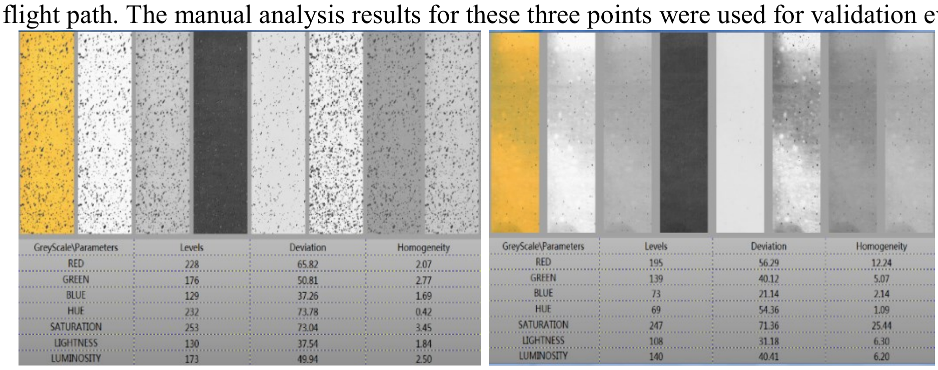
A manual validation was performed for Dv.1, Dv.5, and Dv.9 [16] with continually thresholds. The relationship between the threshold and the stain size of was analyzed. The manual analyses were compared with the computer recognition results.

3 Results and Discussion

The algorithms and methods described in the previous section were applied to the 33 test samples.

3.1 Greyscale parameters

Figures 3a, 3b, 3c show 3 Images of the WSP results in the center line with 5, 20 and 50 m from the flight path. The manual analysis results for these three points were used for validation evaluation.

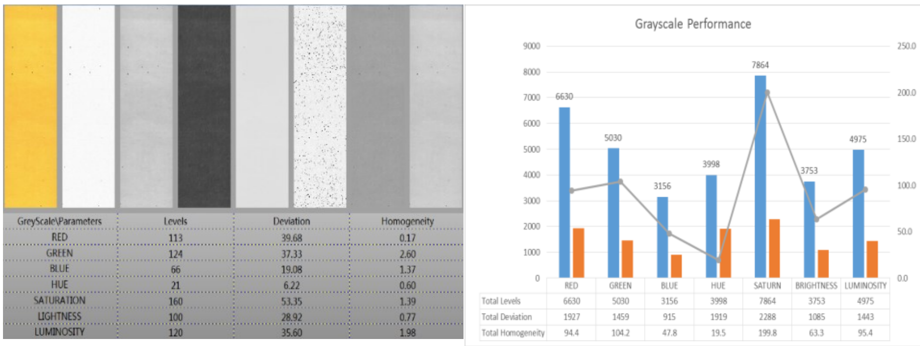


GreyScale\Parameters	Levels	Deviation	Homogeneity
RED	228	65.82	2.07
GREEN	176	50.81	2.77
BLUE	129	37.26	1.69
HUE	232	73.78	0.42
SATURATION	253	73.04	3.45
LIGHTNESS	130	37.54	1.84
LUMINOSITY	173	49.94	2.50

(a)

GreyScale\Parameters	Levels	Deviation	Homogeneity
RED	195	56.29	12.24
GREEN	139	40.12	5.07
BLUE	73	21.14	2.14
HUE	69	54.36	1.09
SATURATION	247	71.36	25.44
LIGHTNESS	108	31.18	6.30
LUMINOSITY	140	40.41	6.20

(b)



(c) (d)

Fig 3 Recognition results for different methods

Figure 3d shows the performance of seven greyscale conversion methods. Saturation parameter got most of greyscale levels, but saturation parameter was easily perturbed by homogeneity. In figure 3b, WSP was 20 m from the fight path, and was quite damp due to high humidity. Thus, the damp print was clear in the saturation image. However, if the coverage was low, saturation greyscale could not be correctly recognized, as shown in figure 3c.

The hue greyscale parameter got the best result for homogeneity and worked well for damped WSP. However, the resolution of hue greyscale was the worst. Compared with luminosity greyscale, the hue greyscale lost about 20% greyscale details.

In Fig 4, the number of total levels, the total homogeneity and the total deviation were uniformed to the same level. According to figure 4, the saturation, the red, the green and the luminosity greyscale parameters were more suitable for the WSP recognition.

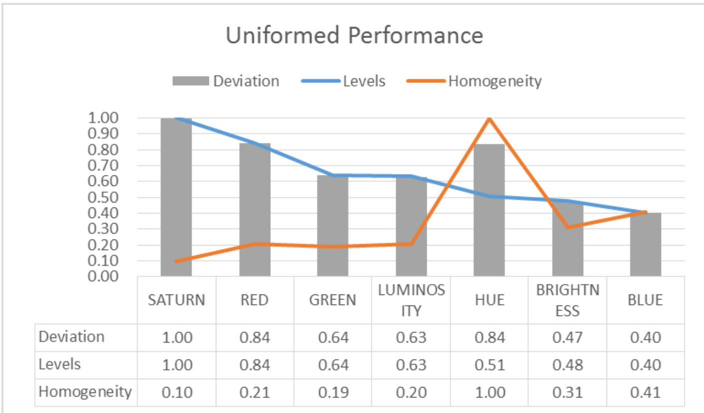


Fig 4 Performance Comparison among 7 grayscale parameters

3.2 Threshold selection method

Fig 5 showed the results from seven greyscale parameters and five Threshold selection methods.

For red, green and luminosity greyscale parameters, the three threshold selection methods from histogram got better results than the OTSU's method. Table 1 showed a comparison among three samples which were 5, 20 and 50 m from the flight path. The OTSU's method was easily influenced by the amount of droplets and damp prints, and therefore, the method was not suitable for high noise environment and low coverage samples.

From table 1, the mean threshold method got higher thresholds than other methods, and was much more sensitive to low coverage samples than the other threshold selection methods.

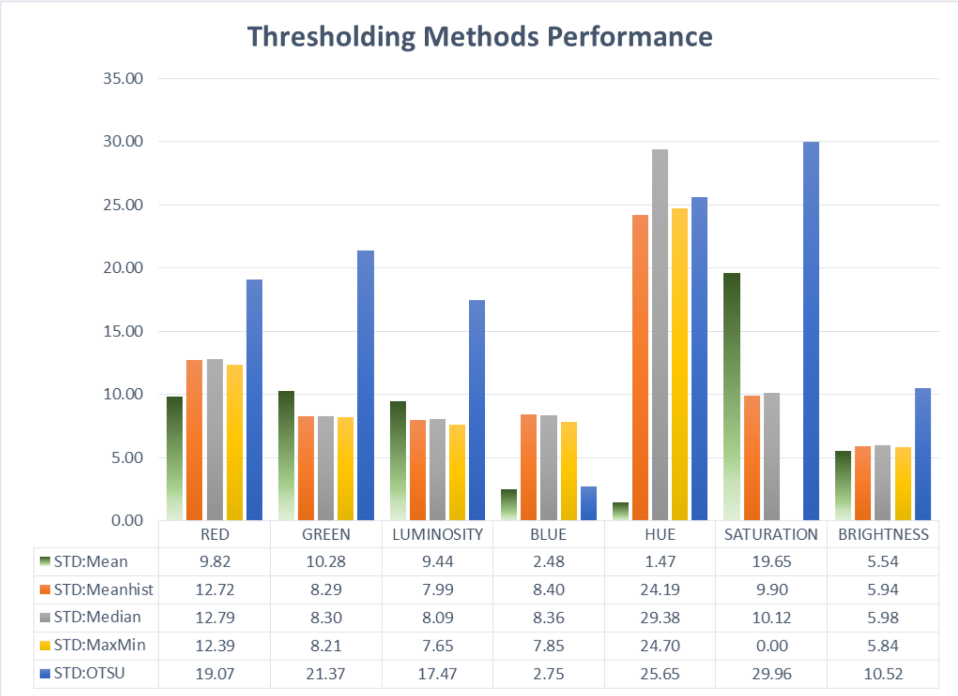


Fig 5 Performance of threshold methods

Table 1 A comparison of threshold methods among three samples

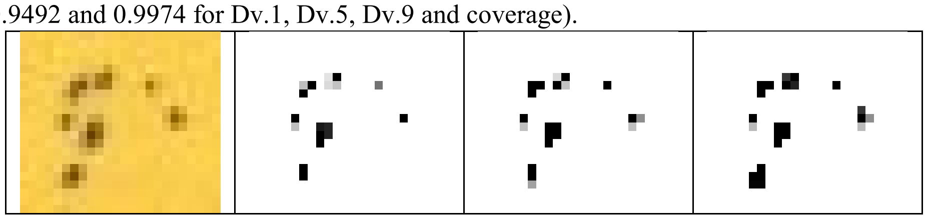
Distance From Flight Path	Greyscale	Mean	MeanHist	Median	Max-Min	OTSU
5m	RED	236	138	138	138	178
5m	GREEN	190	131	132	131	150
5m	LUMINOSITY	192	130	130	130	151
20m	RED	227	154	154	154	224
20m	GREEN	178	135	136	134	177
20m	LUMINOSITY	181	136	136	136	180
50m	RED	250	156	157	154	199
50m	GREEN	203	144	144	144	202
50m	LUMINOSITY	204	143	144	143	203

From table 1 and Fig 5, the red greyscale parameter got worse results than green and luminosity, and it didn't suit low coverage samples.

According to Fig 5, luminosity was the best greyscale parameter, and the Max-Min Threshold selection method was best method with the lowest deviation, and the Max-Min Threshold could be very easily and efficiently calculated.

3.3 Manual validation

Fig 6 shows the relationship among the deposit parameters and the threshold. The image was cropped from fig 3a, and treated by an image segmentation process by the luminosity greyscale parameter. When the threshold increased continually from 120 to 180, the deposit parameters increased with the threshold. Power regressions were calculated between the threshold and Dv.1, Dv.5, Dv.9 and coverage. The coefficient of determination (R2) for the power regression and the statistical significance were presented in figure 6. R2 are high for the luminosity greyscale (0.9966, 0.9863, 0.9492 and 0.9974 for Dv.1, Dv.5, Dv.9 and coverage).



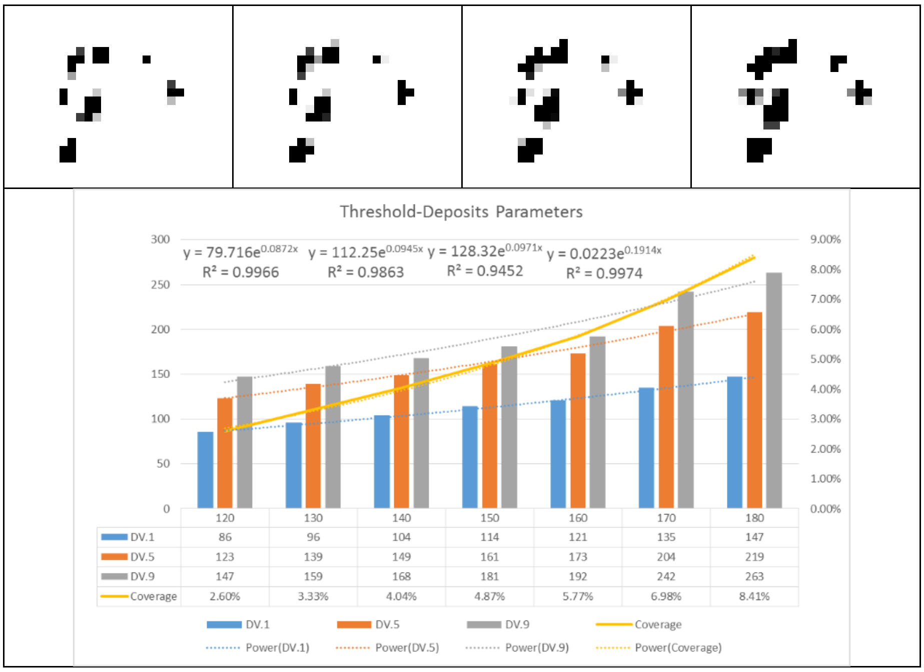


Fig 6 Threshold-Stain Size

According to manual validation, when the coverage was 6.2%, the manual threshold should be 164. All of results which was got by automatically should correct by the manual threshold. The droplet size was not only related to the spread factor of WSP, it also related to the threshold method and grayscale parameters.

5 Conclusions

Image processing of 33 scanned WSP samples was conducted with 7 greyscale parameters (Red, Green, Blue, Hue, Saturation, Lightness and luminosity) and 5 threshold selection methods (Mean, MeanHist, Median, Max-Min and OTSU's methods). A manual validation was performed. The comparison of the greyscale parameters and threshold selection methods was used to evaluate agricultural aerial spraying quality parameters.

Differences in the number and deviation of greyscale levels and homogeneity of collected WSP by different greyscale parameters were analyzed statistically.

These results showed that: 1) the saturation was too sensitive in homogeneity. 2) The hue greyscale parameter worked well with damped WSP, but lost about 20% greyscale details. 3) The red, green and luminosity have high resolution to WSP, and they did fairly well to homogeneity.

Among all 7 greyscale parameters and 5 threshold selection methods, the following conclusions were drawn: 1) The OTSU's method was easily influenced by the amount of droplets and damp prints. 2) The mean threshold method was not suitable for low coverage samples. 3) The red greyscale parameter was also not suitable for low coverage samples. 4) The luminosity greyscale parameter and Max-Min threshold selection method got the best results and should be recommended.

This work shows the relationship among the deposit parameters and threshold. The power regressions were calculated between the threshold and Dv.1, Dv.5, Dv.9 and coverage. The coefficient of determination (R2) for the power regression and the statistical significance were presented. R2 are high for the luminosity greyscale (0.9966, 0.9863, 0.9492 and 0.9974 for Dv.1, Dv.5, Dv.9 and coverage).

Acknowledgment

Funds for this research was provided by The National Key Research and Development Program of China (2017YFD0701004), National Natural Science Fund for Distinguished Young Scholars (31601228) and the 2016 fund from Beijing Academy of Agriculture and Forestry sciences for young scientists (QNJJ201632).

The experiment corporate with BeiDaHuang General Aviation Cooperation. The pilots and engineer was extremely helpful in providing information and implementations of our experiment.

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