Spectral Reflectance Signatures of Major Upland Crops at OSMI Bands

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ABSTRACT

Spectral reflectance signatures of upland crops at OSMI bands were collected and evaluated for the feasibility of crop discrimination knowledge-based on crop calendar. Effective bands and their ratio values for discriminating corn from two other legumes were defined with OSMI equivalent bands and their ratio values. June 22 among measurements dates was the best date for corn discrimination from two other legumes, peanut and soybean, because all OSMI equivalent bands and their ratio values in June 22 were highly significant for corn separability.

Phenological growth stage of a silage corn (rs510) could be estimated as a function of spectral reflectance signatures in vegetative stage. Five growth stage prediction models were generated by the SAS procedures REG and STEPWISE with OSMI equivalent bands and their ratio values in vegetative stage.

Keywords : OSMI bands, spectral reflectance signature, upland crops, crop discrimination

INTRODUCTION

Image interpretation for land surface cover is basic technology in remote sensing. The same may be said of crop discrimination in agricultural remote sensing(秋山 *et al.*, 1996). In general, spectral reflectance signatures in agricultural fields are shown to be different from crop species, developmental stage, cropping pattern, and cropping environment. For crop classification with remotely sensed data, spectral separability assessment based on time-series spectral reflectance and crop calendar have to be carried out as a basic study.

Panigrahy and Chakraborty(1998) used temporal remote sensing data, along with soil, physiographic rainfall and temperature information to model to derive a potato-growing environment index. Jenssen and Middelkoop(1992) revealed that the accuracy of the knowledge-based classification was 6 to 20 per cent better compared with a maximum likelihood classification, depending on the spectral class discrimination.

On the other hand, population of Korea has been concentrated to the specific area and the landuse is subdivided extremely. Especially agricultural unit of upland crop is very small. Crop inventory with satellite data would be hindered by the small, irregularly shaped fields, and the lack of continuous crop canopy. With the spatial resolution of OSMI, it is still impossible to discriminate crops in Korea. But there are many schedule to launch commercial satellite such as IKONOS, Quick Bird, Orbview loaded with a high resolution and multispectral sensor within a or two years(Yeo, 1998). And also, many countries including America, Russia, Japan, Brazil, China, India, and Korea are involved in launching new satellites.

The study described herein evaluated for the feasibility of crop discrimination knowledge-based on crop calendar and spectral reflectance signatures of upland crops at OSMI equivalent bands. And also, regression models were prepared for estimaing deveolpmental the stage of a corn by using OSMI equivalent bands and their ratio values in vegetative stage.

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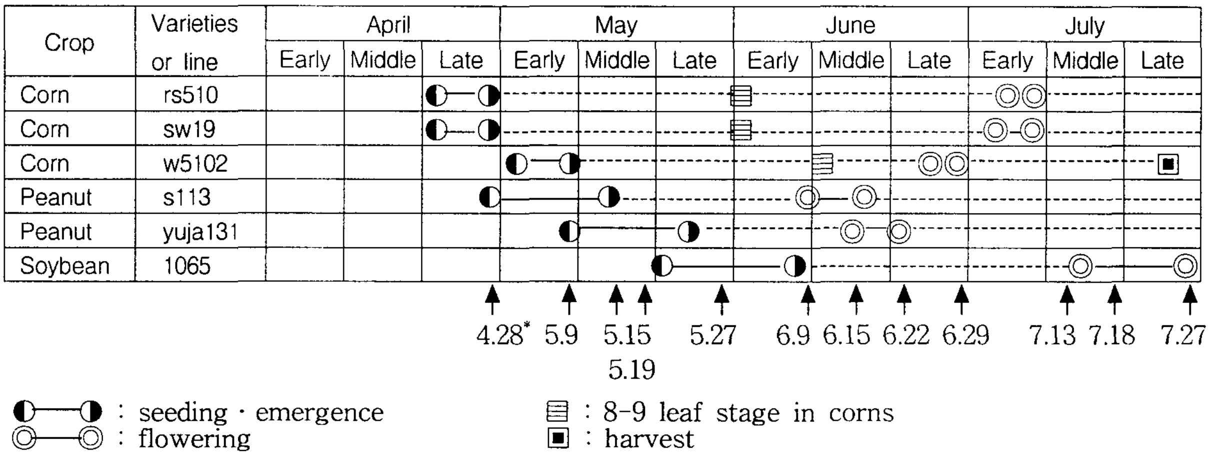
METHODS

1. Crops and their developmental stages

Major upland crops, 3 corn varieties, 1 soybean line, 2 peanut varieties, were grown for the measurement of spectral reflectnce at the field of Crop Experimental Station(Suwon) in 1998. Varieties or lines used in measurement and their developmental stages are shown in Figure 1. In corns varieties, rs510 and sw19 are for silage and w5102 is for grain.



* : dates for reflectance mesurement

Figure 1. Crops and their developmental stage.

2. Measurement condition for spectral reflectance

Radiance measurements, used to determine per cent reflectance of canopies, were acquired with a spectroradiometer (Li-1800, 330-1100 ㎚) *in situ* with 5 ㎚ spectral interval at 10:00 to 11:00 in the morning. The LI-1800 measures the spectral distribution of radiation by dispersing the radiation with a diffraction grating monochromator, and measuring the energy in the various wavebands of the resulting spectrum with a silicon detector(Instruction manual, 1984). Measurements were made throughout each growing season at approximately weekly intervals. The spectroradiometer was elevated 50 ㎝ above the crop canopies. Data were taken only when there were no clouds in the vicinity of the sun and when the solar elevation was at least 51° . Measurements of incident solar radiance and reflective radiance from canopies were made after the instrument was leveled for a nadir view angle. The spectroradiometer has a 60° field of view. Percent spectral reflectance was calculated as the ratio of canopy radiance to the incident solar radiance.

3. Growth index induction of corn and data analysis

The index of phenological growth stage by Hanway(1971) was used for estimating deveolpmental stage of a corn by using OSMI equivalent bands and their ratio values in vegetative stage. SAS statistics procedures were used for general linear models and regression models.

RESULTS AND DISCUSSIONS

1. OSMI bands preparation with spectroradiometer channels

OSMI equivalent bands were selected in spectral wavebands obtained with spectroradiometer ranged from 330 to 1100 ㎚ (5 ㎚ interval), those are 445 ㎚, 490 ㎚, 510 ㎚, 555 ㎚, 670 ㎚, and 865 ㎚ as bands 1, 2, 3, 4, 5, and 6, respectively. Band width of OSMI is 20 ㎚ in bands

1, 2, 3, 4, and 5, and 40 nm in band 6. In this study, however, single bands were used for data analysis because data were taken with 5 nm interval spectroradiometer not an OSMI simulated sensor. Unpublished results showed no critical differnces between single bands and averaged (20 nm) multibands(no data were shown in this paper). The values of averaged multibands were just smoother than those of single bands.

Ratio value (RV) 1, 2, 3, 4, and 5 were derived from the OSMI equivalent band ratios as band 6 : band 1, band 6 : band 2, band 6 : band 3, band 6 : band 4, and band 6 : band 5, respectively.

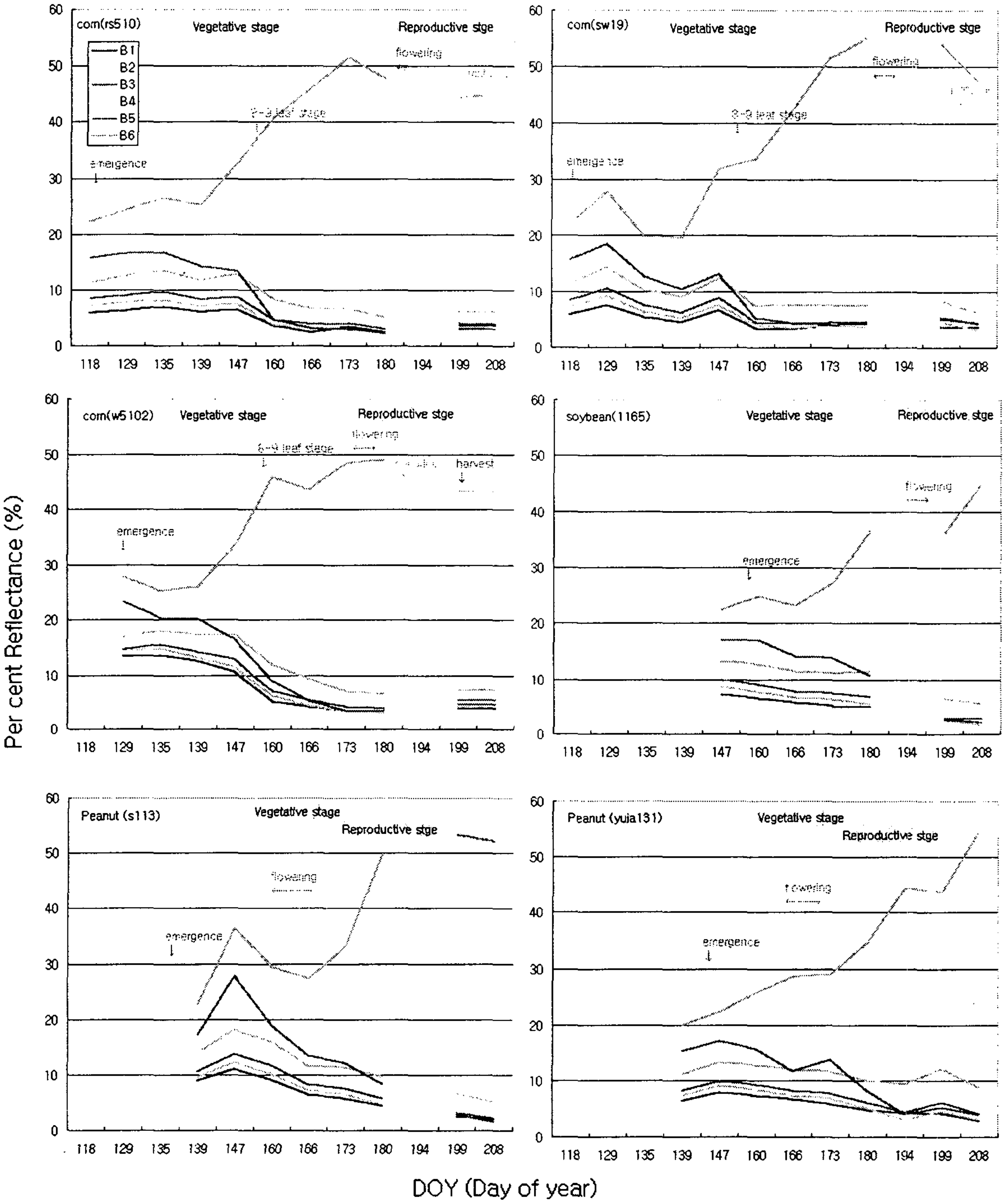


Figure 2. Spectral reflectance profile at OSMI equivalent bands of corns, peanuts, and soybean based on day of year (DOY).

2. Time-series spectral reflectance signatures of corn, peanut, and soybean

Spectral reflectance profiles of corns, peanuts, and soybean based on day of year (DOY) are shown in Figure 2. In corns, for vegetative and reproductive stages are distinct and flowering period is short, corn stops vegetative growth soon after flowering. Spectral reflectances of OSMI equivalent bands 1, 2, 3, 4, and 5 at visible wavelengths had a trend to decrease continually because canopy maintained greeness until harvest. But spectral reflectance of OSMI equivalent band 6 had a maximum value around flowering stage. And then it was decreased on maturing.

On the other hand, spectral reflectances of OSMI equivalent bands 1, 2, 3, 4, and 5 at visible wavelengths in peanuts and soybean were decreased as well. However, per cent reflectance values of OSMI equivalent band 6 in peanuts and soybean were increased even after flowering. That is unique signature of peanuts and soybean, although they have different growth type. Peanuts are indeterminate growth type, while soybeans are determinate growth type.

In general, per cent reflectance value of OSMI equivalent bands 1, 2, 3, 4, and 5 were in upward order at the early stage of vegetative growth in corns, peanuts, and soybean. As crop grows, per cent reflectance value of OSMI equivalent band 5 was lower and lower to the lowest. What was interesting was that crossing point (per cent reflectance value of OSMI band 5 is lower than that of band 4, 3, 2, and 1) between bands of every crop were different form their developmental stages. While this crossing point of band 4 and 5 was at 7 to 9 leaf stage far before flowering in corns, it was at flowering stage in soybean and at after flowering in peanuts. This phenomenon is concerned with canopy covering and development, because 670 ㎚ is chlorophyll absorption wavelength. And also, time difference of crossing points between spectral reflectances of bands could be a parameter to discriminate crops knowledge-based on developmental stages.

3. Crop separability with OSMI equivalent bands at different dates

General linear model(GLM) procedures of SAS statistics package were carried out to find out the appropriate date for crop discrimination by using OSMI equivalent bands(table 1) and their ratio values(table 2). Corn and two other crops were discriminated from band 1 and 5 in June 9, band 1, 2, 3, 5, and 6 in June 15, band 1, 2, 3, 4, 5, and 6 in June 22, and band 4 and 5 in June 29 (Table 1). Peanut and soybean could not be separable from each other only by

Table 1. Spectral reflectance signatures of corn, peanut, and soybean at OSMI equivalent bands.

June 9	B[1]1	B2	B3	B4	B5	B6	**June 15**	B1	B2	B3	B4	B5	B6
Corn	4.03 $^{b[2]}$	4.53 ^{b}	5.44 ^{a}	9.22 ^{a}	6.27 ^{b}	40.14 ^{a}	*Corn*	3.27 ^{b}	3.62 ^{b}	4.51 ^{b}	7.83 ^{b}	4.20 ^{b}	43.94 ^{a}
Peanut	8.16 ^{a}	9.24 ^{a}	10.44 ^{a}	14.30 ^{a}	17.28 ^{a}	27.67 ^{a}	*Peanut*	6.61 ^{a}	7.31 ^{a}	8.33 ^{a}	11.88 ^{a}	12.63 ^{a}	28.08 ^{b}
Soybean	6.31 ^{ab}	7.60 ^{ab}	9.07 ^{a}	12.67 ^{a}	16.96 ^{a}	24.77 ^{a}	*Soybean*	5.60 ^{ab}	6.61 ^{a}	7.65 ^{a}	11.38 ^{ab}	14.05 ^{a}	23.21 ^{b}
Mean	5.79	6.62	7.71	11.49	11.72	33.42	Mean	4.77	5.35	6.31	9.77	8.65	35.20
C.V.(%)	17.33	18.71	18.93	20.30	19.53	15.69	C.V.(%)	14.10	8.83	8.75	11.50	12.73	4.70
F value	10.34 *	9.06	7.56	3.00	17.02 *	5.02	F value	15.74 *	40.94 **	32.41 **	8.99	49.52 **	86.74 **
June 22	B1	B2	B3	B4	B5	B6	**June 9**	B1	B2	B3	B4	B5	B6
Corn	3.59 ^{b}	3.48 ^{b}	4.26 ^{b}	7.03 ^{b}	3.46 ^{b}	50.46 ^{a}	*Corn*	3.07 ^{b}	2.93 ^{b}	3.81 ^{b}	6.42 ^{b}	3.35 ^{b}	50.70 ^{a}
Peanut	5.77 ^{a}	6.69 ^{a}	7.71 ^{a}	11.53 ^{a}	12.97 ^{a}	31.11 ^{b}	*Peanut*	4.60 ^{ab}	4.85 ^{ab}	5.92 ^{ab}	9.89 ^{ab}	8.33 ^{a}	42.42 ^{a}
Soybean	5.12 ^{a}	6.18 ^{a}	7.41 ^{a}	11.21 ^{a}	13.80 ^{a}	27.22 ^{b}	*Soybean*	4.96 ^{a}	5.28 ^{a}	6.75 ^{a}	11.46 ^{a}	10.69 ^{a}	36.51 ^{a}
Mean	4.57	5.00	5.94	9.23	8.35	40.14	Mean	3.90	3.96	5.00	8.42	6.23	45.57
C.V.(%)	5.20	7.36	3.99	4.21	9.67	5.47	C.V.(%)	12.92	16.21	13.73	11.95	13.78	15.54
F value	53.63 **	51.83 **	150.48 **	95.94 **	110.63 **	67.41 **	F value	8.20	7.84	9.53	12.62 *	36.37 **	1.80

[1] : OSMI equivalent band
[2] : Duncan's multiple range test (α =0.05)
*= *0.05>p>0.01*, **= *0.01>p>0.001*, ***= p<0.001

Table 2. Ratio values of OSMI equivalent bands in corn, peanut, and soybean.

June 9	RV1[1)]	RV2	RV3	RV4	RV5
Corn	10.06 [a2)]	9.07 [a]	7.51 [a]	4.43 [a]	6.76 [a]
Peanut	3.41 [b]	3.01 [b]	2.67 [b]	1.95 [b]	1.61 [b]
Soybean	3.92 [b]	3.26 [b]	2.73 [b]	1.95 [b]	1.46 [b]
Mean	6.82	6.08	5.10	3.19	4.16
C.V.(%)	12.74	21.42	17.12	14.28	35.23
F value	41.87 **	15.84 *	22.92 *	22.35 *	9.46

June 15	RV1	RV2	RV3	RV4	RV5
Corn	14.15 [a]	12.36 [a]	9.91 [a]	5.74 [a]	10.98 [a]
Peanut	4.25 [a]	3.84 [b]	3.37 [b]	2.37 [b]	2.24 [a]
Soybean	4.14 [a]	3.51 [b]	3.03 [b]	2.04 [b]	1.65 [a]
Mean	9.18	8.05	6.59	4.00	6.51
C.V.(%)	38.85	21.58	22.18	23.65	41.10
F value	5.82	18.55 *	15.60 *	10.20 *	8.38

June 22	RV1	RV2	RV3	RV4	RV5
Corn	14.09 [a]	14.62 [a]	11.86 [a]	7.19 [a]	14.83 [a]
Peanut	5.40 [b]	4.67 [b]	4.04 [b]	2.71 [b]	2.42 [b]
Soybean	5.32 [b]	4.40 [b]	3.67 [b]	2.43 [b]	1.97 [b]
Mean	9.73	9.60	7.89	4.90	8.55
C.V.(%)	7.66	12.86	6.94	8.19	21.12
F value	102.60 **	49.70 **	158.27 ***	97.56 **	36.32 **

June 29	RV1	RV2	RV3	RV4	RV5
Corn	16.75 [a]	17.90 [a]	13.57 [a]	8.01 [a]	16.02 [a]
Peanut	9.32 [b]	8.85 [a]	7.23 [ab]	4.31 [ab]	5.09 [a]
Soybean	7.36 [b]	6.92 [a]	5.41 [b]	3.19 [b]	3.41 [a]
Mean	12.71	13.05	10.10	5.97	10.27
C.V.(%)	19.80	26.67	20.29	18.26	34.82
F value	7.94	5.92	8.90	10.84 *	7.81

[1)] : RV1=Band6/Band1, RV2=Band6/Band2, RV3=Band6/Band3, RV4=Band6/Band4, RV5=Band6/Band5,
[2)] : Duncan's multiple range test (α =0.05)
*= 0.05>p>0.01, **= 0.01>p>0.001, ***= p<0.001

using spectral reflectance signatures measured during May to July.

Effective ratio values for discriminating corn from 2 other legumes were RV 1, 2, 3, and 4 in June 9, RV 2, 3, and 4 in June 15, RV 1, 2, 3, 4, 5, and 6 in June 22, and RV 4 in June 29(Table 2). Peanut and soybean could not be separable with each other by ratio values as well. We need more spectral data collected during flowering to maturing stage and another parameter to discriminate peanut and soybean including vinyl mulching and cropping pattern. Around June 22 was the best date for corn discrimination from 2 other legumes (no significance were shown in measurement dates other than June) because all OSMI equivalent bands and ratio values in June 22 were highly significant for corn separability.

4. Estimation of vegetative growth stage in corn variety (rs510) as a function of spectral reflectance signatures

Hanway(1971) described the phenological growth stage of a corn plant as stage index from seeding (0.0) to physiological maturity(10.0). In this study, vegetative stage from seeding(0.0) to flowering(5.0) was examined for estimating developmental stage of a corn(rs510 variety) by using OSMI equivalent bands and their ratio values. Four kinds of variable set, which were OSMI equivalent bands(B), logB, ratio values(RV) of OSMI equivalent bands, and logRV, were prepared for multi-regression and stepwise-regression model. As results, five significant models, 2 multi-regression model with RVs(1, 2, 3, 4, and 5) and logRVs(1, 2, 3, 4, and 5)

Table 3. Best growth stage prediction models generated by the SAS procedures REG and STEPWISE with OSMI equivalent bands and their band ratios.

Model name	R^2	Prob>F	Complete model
MR[1)]1	0.97	0.0044	-1.461 - 0.073*RV[3)]1 - 0.155*RV2 + 0.482*RV3 + 1.420*RV4 - 0.493*RV5
MR 2	0.97	0.0039	-0.98 - 5.68*log[4)]RV1 - 16.48*logRV2 + 32.84*logRV3 + 5.61*logRV4 - 7.10*logRV5
SR[2)]1	0.94	0.0005	6.43 + 1.66*B[5)]1 + 3.27*B2 - 4.59*B3
SR 2	0.94	0.0004	12.18 + 10.20*logB1 + 23.06*logB2 - 41.65*logB3
SR 3	0.97	0.0001	-2.000 + 2.066*RV4 - 0.617*RV5

[1)] MR : Multi-regression model, [2)] SR : Stepwise-regression model
[3)] RV1=Band6/Band1, RV2=Band6/Band2, RV3=Band6/Band3, RV4=Band6/Band4, RV5=Band6/Band5,
[4)] log=$\log_{10}$
[5)] B : OSMI eqivalent band

and 3 spepwise-regression model with B(1, 2, and 3), logB(1, 2, and 3), and RV(4 and 5), were obtained from the SAS procedures REG and STEPWISE(Table 3).

Corn (rs510) was about 2.5 meter tall at the end of vegetative stage. It almost stops its vegetative growing after flowering. It means no difference in plant height after flowering in corn, while canopies of peanut and soybean are still growing even after flowering. Therefore, it is worth while estimating developmental stage of a corn(rs510) with OSMI equivalent bands and their ratio values at vegetative stage.

CONCLUSION

Time-series spectral reflectance data of major upland crops, corns, peanuts, and a soybean, were collected by using spectroradiometer and analyzed to use for spectral separability assessment and estimation of vegetative growth stage in a corn, depending on crop phenology.

Spectral reflectance behavior of OSMI equivalent band 5 had a unique characteristic, which was that crossing point of band 4 and 5 was at 7 to 9 leaf stage far before flowering in corns, it was at flowering stage in soybean and at after flowering in peanuts. This phenomenon is concerned with canopy cover and development, because 670 ㎚ is chlorophyll absorption wavelength. And also, time difference of crossing points between spectral reflectances of bands could be a parameter to discriminate the crops knowledge-based on developmental stages. Unpublished results showed no critical differnces between single bands and averaged (20 ㎚) multibands(no data were shown in this paper). Values of averaged multibands were just smoother than those of sigle bands.

Corn was clearly discriminated with two other legumes, peanut and soybean in late June, according to the SAS procedure GLM with OSMI equivalent bands and their ratio values (RVs). And also, growth stage of a corn coule be estimated as a function of OSMI equivalent bands and their ratio values in vegetative stage.

No remarkable difference of spectral reflectance signatures was shown between peanut and soybean by July, although their seeding and flowering periods were different with each other. It needed more study and spectral reflectance data to screen another parameters such as vinyl mulching and cropping pattern to discriminate peanut from soybean and to find out the appropriate time for classification.

This kind of approach method for spectral data interpretation may be theoretical because it considered only spectral reflectance signatures but Korean field unit and spatial resolution of OSMI sensor. But we do say crop calendar and spectral reflectance signatures can be used as a strong ancillary and reference data for crop identification and area estimation, even though interpretation direction may be changed.

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