Determination of planting crops using satellite data at Shonai Plain in Japan

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Abstract. Shonai Plain is famous paddy area in Japan. As a countermeasure overproduction of rice in Japan, there are many other crops not rice in the paddy fields. We try to determination of planted crops using satellite data. Recently, in Asian countries, GIS is spread widely and agricultural field polygon is commonly used. Crop determination using the polygon is becoming popular. Normally, fields are used without changing, but sometimes, one field is divided two or three fields, and two or three fields are integrated one field. It is necessary to overlay satellite image and the polygon, and to check with fitting or not. In case of mismatch, field polygon must be corrected. Simultaneously with this confirmation work for each field polygon, the optical satellite data were classified as water surface ‘water’, vegetation as ‘vegetation’, bare soil as ‘soil’ and ‘cannot determination’. In the SAR image, we classify 4 degrees, as small scattering of the water surface '0', scattering slightly larger than the water surface '1', larger than the water surface '2', and large scattering '3’. The crop determination is performed according to the following standard using to the time series data. (a) Rice: Almost water surface at rice planting time and following several weeks. In summer, there is large vegetation. (b) Wheat: There is large vegetation at rice planting time, and small vegetation at summer. (c) Soybean: There is small vegetation at rice planting time, and large vegetation in summer. Using this evaluation criteria, we performed the crop classifications in Shonai Pain by ALOS2 and Sentinel2 data, and the correct answer rates are more than 95% at both satellite data.

1. Introduction

There are many satellite sensors for crop identification, and optical sensors has long history for this purpose. Crop determination using SAR data was studied at JERS-1, but resolution was not enough for each field [1]. High resolution ability of ALOS2/PALSAR2 (written as ALOS 2) is tested by determination of planted crops in each agricultural field at Shonai Plain. Recently, in Asian countries, GIS is in use widely, and agricultural field polygons are commonly used. Crop identification using the

polygons are becoming popular. Normally, fields are used without changing, but sometimes, one field is divided into two or three fields, and two or three fields are integrated one field. Using existing field polygon, we must check the polygon shape is correct or not using satellite data. In this process, visual interpretation is easy and correct way [2 -5].

2. Procedure

Using ArcGIS, satellite image and field polygon are overlaid. In the case of mismatch, we changed the polygon shape. Simultaneously with this confirmation work, by visual interpretations for each field polygon were performed.

At the SAR image, we use ALOS2. At the ranking method, scattering of water surface is 0, scattering slightly larger than the water surface is 1, scattering which is clearly larger than the water surface is 2, and large scattering is 3.

At the optical sensor data, the resolutions of Landsat8 colour bands are 30m times 30m, and we perform pan-sharpen treatment using panchromatic band (resolution is 15m times 15m). As the result, we get the colour bands that resolutions are 15m times 15m. The resolutions of Sentinel2 at visible and near infra-red bands are 10m times 10m, and SWIR and Red Edge bands are 20m times 20m. We made natural colour composite images (R=red band, G=green band, and B=blue band). At the images, very dark colour (water surface and wet bare soil) is 0, the dark colour lighter than the dark is 1, white or light brown (dry bare soil) is 2, and green (large vegetation) is 3. The SWIR bands are used water detection under the rice bodies and the detail is mentioned at '3 Results and Discussions'.

The crop determinations were performed according to the following standard according to the time series data.

Rice: Almost water surface at rice planting time and following several weeks. In summer, there is large vegetation.

Wheat: There is large vegetation at rice planting time and small vegetation at summer.

Soybean: There is small vegetation at rice planting time and large vegetation in summer.

Grasses: There is large vegetation at rice planting time and at summer.

Four target fields were selected paddy fields area of main flat parts in Shonai Plain. The target points were Skata_East, Sakata_West, Tsuruoka_Mizusawa, and Mikawa. At the four target points, we used 116 field polygons at Skata_East, 112 field polygons at Skata_West, 140 field polygons at Tsuruoka_Mizusawa, and 292 field polygons at Mikawa.

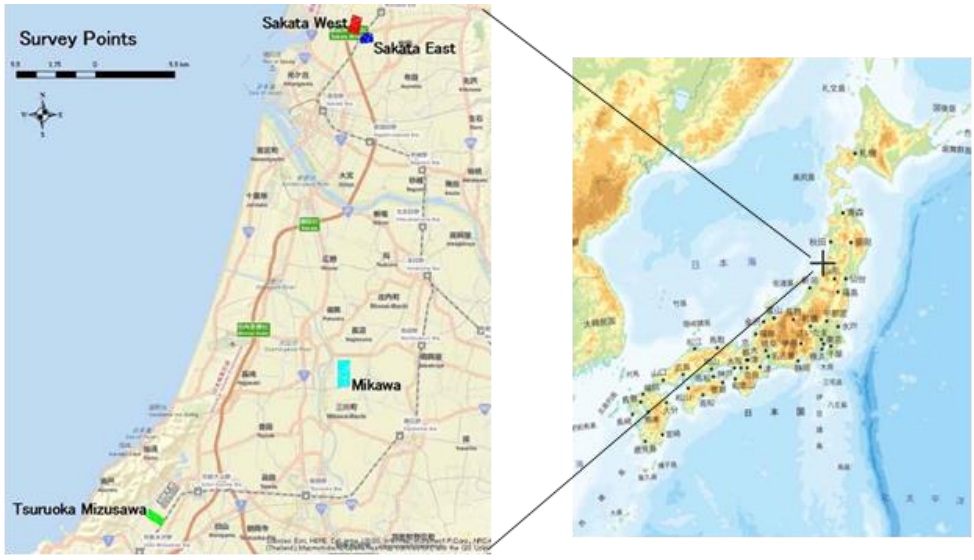


Figure 1. Map of Japan and Target points in Shonai Plain.

3. Results and Discussions

The ranking scores of each field condition at the satellite image were filled in the excel tables, and we judged using ranking method that mentioned at "2 Procedure". The water surface meant low backscatter at SAR and dark at optical data. At high vegetation, there were some backscatters in SAR image, and green colour at the natural colour composite of optical data. In 2016, we listed ALOS2 images of observing at 2016.05.31at end of trans-planting rice period, and at 2016.08.02 of maximum growth stage of rice. We also listed Landsat8 data of observing at 2016.06.12 and 2016.07.30 that were between two ALOS2 data. We mentioned about the results using these 2 ALOS2 data and 2 Landsat8 data. We performed crop identification and made confusion matrixes and calculated user's accuracy (UA), producer's accuracy (PA), and overall accuracy (OA).

At 2017, we used ALOS2 data only and 4 ALOS2 data at 2017.05.16, 2017.05.23 (rice planting time), 2017.07.13(growing time) and 2017.08.01(Vegetated time). Same as 2016, we performed crop identification and made confusion matrixes.

At 2018, Sentinel 2 data and ALOS2 data were tested. Sentinel 2 is optical sensor, and that observes every 5 days. The resolution is 10m at visible and NIR, and 20m at SWIR and Vegetation Red Edge. We used Sentinel 2 data at 2018.06.07 and 2018.07.27. We used ALOS2 data at 2018.05.22, 2018.07.12 and 2018.07.31. Mainly used data were at 2018.05.22 (rice planting time), 2018.07.12(growing time), 2018.07.31(vegetated time), Same as 2016 and 2017, we performed crop identification and made confusion matrixes.

Table 1. Excel Table for Classification.

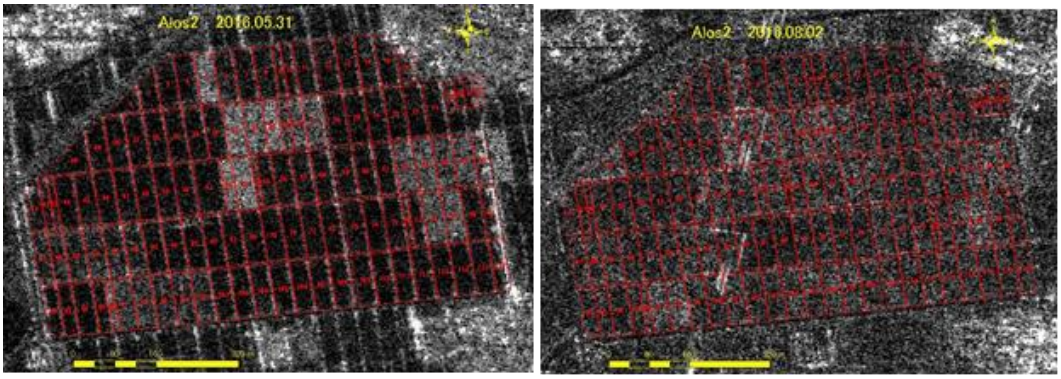
Sakata East		2016										
	Alos2 5/31	Alos2 5/24	S1 p141 5/25	S1 p46 5/30	Alos2 8/2	S1 p141 8/5	S1 46 8/10	Classify1	L8 6/12	L8 7/30	Classify2	Ground Truth
1	0	0	0	0	3	1	1	paddy rice	0	1	paddy rice	y
2	0	0	0	0	2	1	1	paddy rice	0	1	paddy rice	y
3	0	0	0	0	2	2	1	paddy rice	0	1	paddy rice	y
4	0	0	0	0	2	2	1	paddy rice	0	1	paddy rice	y
5	2	2	2	1	3	3	3	soy bean	1	2	soy bean	y
6	0	0	0	0	2	1	1	paddy rice	0	1	paddy rice	y
7	0	0	0	0	2	1	1	paddy rice	0	1	paddy rice	y
8	0	0	0	0	2	1	1	paddy rice	0	1	paddy rice	y
9	0	0	0	0	2	1	1	paddy rice	0	1	paddy rice	y
10	0	0	0	0	2	1	1	paddy rice	0	1	paddy rice	y
11	0	0	0	0	2	2	1	paddy rice	0	1	paddy rice	y
12	0	0	0	0	2	1	1	paddy rice	0	1	paddy rice	y
13	0	0	0	0	2	1	1	paddy rice	0	1	paddy rice	y
14	0	0	0	0	2	1	1	paddy rice	0	1	paddy rice	y
15	0	0	0	0	3	1	1	paddy rice	0	1	paddy rice	y
16	0	0	0	0	3	1	1	paddy rice	0	2	paddy rice	y
17	2	1	1	1	2	3	2	soy bean	1	3	soy bean	y
18	0	0	0	0	3	2	2	paddy rice	0	3	paddy rice	y
19	0	0	1	0	3	2	1	paddy rice	0	1	paddy rice	y
20	2	1	2	0	3	2	2	soy bean	0	3	paddy rice	y
21	0	0	0	0	2	1	1	paddy rice	0	2	paddy rice	y
22	0	0	0	0	3	1	1	paddy rice	0	1	paddy rice	y
23	0	0	1	1	3	2	1	paddy rice	0	2	paddy rice	y
24	0	0	1	0	2	2	1	paddy rice	0	2	paddy rice	y
25	0	0	1	0	3	2	2	paddy rice	0	2	paddy rice	y
26	0	0	0	0	3	2	2	paddy rice	0	2	paddy rice	y
27	2	1	2	1	3	3	2	soy bean	0	2	paddy rice	y
28	2	1	2	1	3	3	1	soy bean	0	2	paddy rice	y
29	2	1	2	1	3	3	1	soy bean	0	2	paddy rice	y
30	2	2	2	1	3	3	2	soy bean	0	2	paddy rice	y
31	2	2	2	2	3	3	3	soy bean	1	3	soy bean	y
32	2	2	2	1	3	1	3	soy bean	1	3	soy bean	y
33	0	0	0	1	3	1	2	paddy rice	0	3	paddy rice	y
34	0	0	0	0	2	1	1	paddy rice	0	3	paddy rice	y
35	0	0	0	0	2	1	1	paddy rice	0	2	paddy rice	y

3.1. Sakata East

3.1.1. At 2016

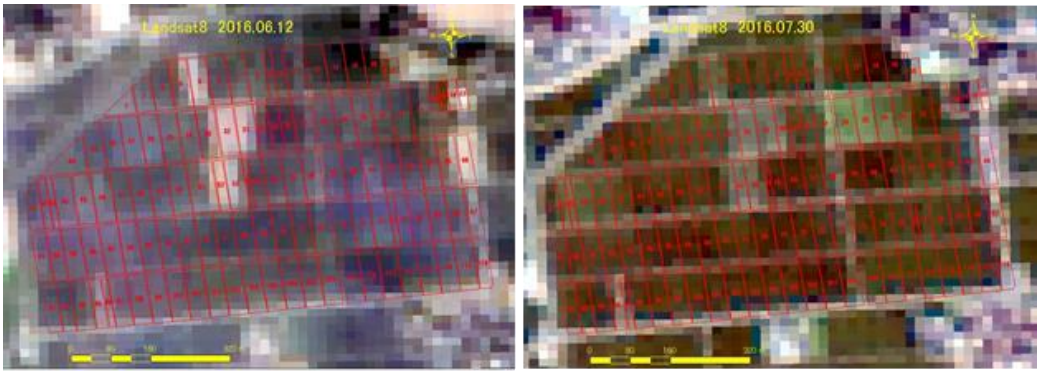
At the target fields of Sakata East, there were some mistakes of rice to soybean. The reason of the mistake was there was no water in the rice paddy fields at May 31. At the forage rice, farmers performed direct seeding instead of trans-planting, and there were no flooding water in the paddies at May 31. In

the case, flooding paddy was maybe at early June. Using Landsat8 data that acquired June 12, the mistake was corrected. Using SAR and optical data, one mistake was very narrow field



(a) 2016.05.31 (b) 2016.08.02

Figure 2. ALOS2 images and field polygon at Sakata East.



(a) 2016.06.12 (b) 2016.07.30

Figure 3. Landsat8 images and field polygon at Sakata East.

Table 2. Confusion matrix for crop identification using SAR data at Sakata East.

		Ground Truth			
		Rice	Soybean	Total	UA %
Classify1	Rice	92	0	92	100.0
	Soybean	15	9	24	37.5
	Total	107	9	116	
	PA	86.0	100.0		OA=87.1

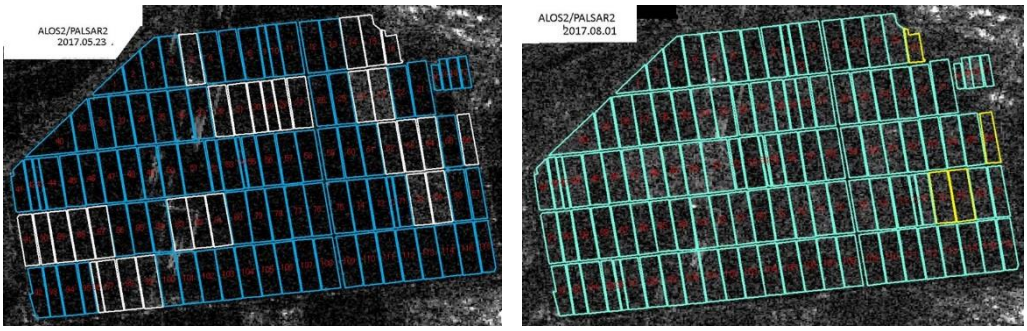
UA: User's accuracy, PA: Producer's accuracy, OA: Overall accuracy

Table 3. Confusion matrix for crop identification using SAR and Optical data at Sakata East.

		Ground Truth			
		Rice	Soybean	Total	UA %
Classify2	Rice	106	0	106	100
	Soybean	1	9	10	90
	Total	107	9	116	
	PA %	99.1	100.0		OA=99.1

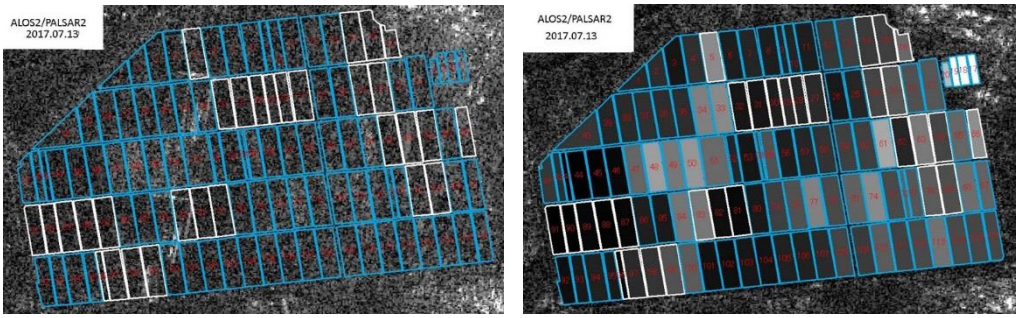
3.1.2. At 2017

In the first discrimination using the ALOS2 data of rice trans-planting time (May 23) and maximum growing season (August 1), there were a lot of mistakes in paddy rice and soybean, same to results in 2016. This mistake was greatly improved by using the ALOS2 data on July 13 in the middle of May 23 and August 1. However, July 13 was slightly too late, it was judged as soybean at the first time and it was difficult to identify the rice from the judged soybean fields. For this reason, average values in field polygons were calculated and displayed, it was easy to identify. Using ALOS2 data on July 13, the overall accuracy was greatly improved.



(a) 2017.05.23 (b) 2017.08.01

Figure 4. ALOS2 images and field polygon at Sakata East at end of May and early August.



(a) 2017.1007.13 (b)2017.107.3 Mean values of each field polygon

Figure 5. ALOS2 images and field polygon at Sakata East at middle of July.

Table 4. Confusion matrix for crop identification using SAR data at Sakata East.
(SAR data: 2017.05.23 and 2017.08.01)

			Ground Truth		
		Rice	Soybean	Total	UA %
Classify1	Rice	83	0	83	100.0
	Soybean	29	4	33	12.1
	Total	112	4	116	
	PA	74.1	100.0		OA=75.0

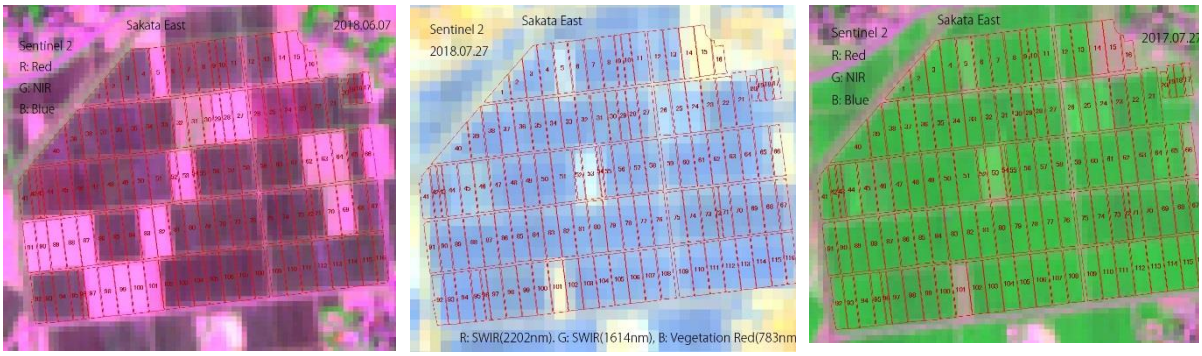
Table 5. Confusion matrix for crop identification using SAR data at Sakata East.
(SAR data: 2017.05.23, 2017.08.01 and 2017.07.13)

			Ground Truth		
		Rice	Soybean	Total	UA %
Classify2	Rice	111	0	111	100.0
	Soybean	1	4	5	80.0
	Total	112	4	116	
	PA	99.1	100.0		OA=99.1

3.1.3. At 2018

3.1.3.1. Sentinel 2

Sentinel 2 data of 2018.06.07 are listed at figure 6(a) and that of 2018.07.27 were listed at figure 6(b) and (c). The images are false color composite, (a) and (c) are RGB = Red: NIR: Blue, and resolution is 10m, and (b) is RGB= SWIR2: SWIR1: Vegetation Red Edge. At Figure 6 (b), regardless of the rice vegetation, we can easily understand water conditions using SWIR. Filled with water area of 2018.07.27 was larger than at 2018.06.07. At the forage rice, farmers performed direct seeding instead of trans-planting, and there was no flooding water in the paddies at 07 June. Good result was obtained.



(a) 2018.06.07 RGB=R:NIR:B (b) 07.27 RGB=SWIR2:SWIR1:RE (c) 07.27 RGB=R:NIR:B

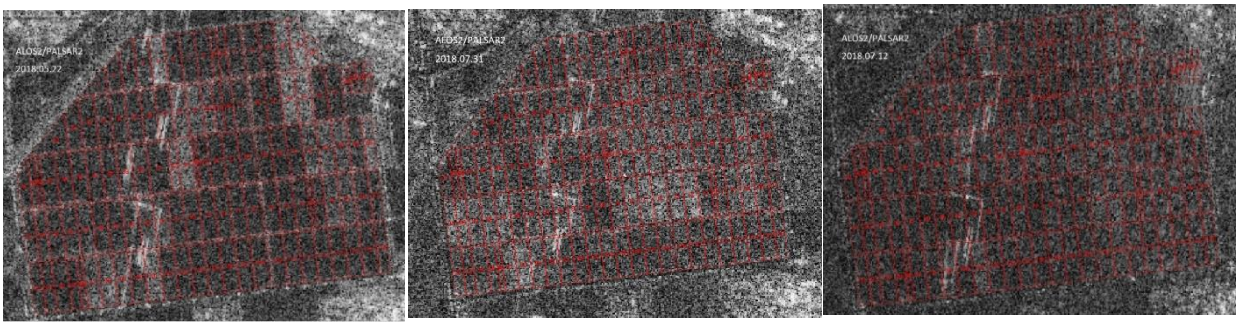
Figure 6. Sentinel 2 images and field polygon at Sakata East (RE=Red Edge).

Table 6. Confusion matrix for crop identification using Sentinel 2 at Sakata East (2018.06.07 and 2018.07.27).

		Ground Truth			
		Rice	Soybean	Total	UA %
Classify	Rice	106	1	107	99.1
	Soybean	0	9	9	100.0
	Total	106	10	116	
	PA	100.0	90.0		OA=99.1

3.1.3.2. ALOS2

At ALOS2 images and field polygon of Sakata East at 2018.05.22, 2018.07.31 and 2018.07.12 were indicated at figure 7. There were some mistakes of rice and soybean in the first classification using the ALOS2 data at rice trans-planting time (May 22). These mistakes were improved using the ALOS2 data on July 12. The fields of high back scattering at May 22, and the fields of small back scatter at July 12 were added to paddy rice.



(a) 2018.05.22 (b) 2018.07.31 (c) 2018.07.12

Figure 7. ALOS2 images and field polygon at Sakata East.

Table 7. Confusion matrix for crop identification using SAR data at Sakata East.
(SAR data: 2018.05.22)

		Ground Truth			
		Rice	Soybean	Total	UA %
Classify1	Rice	92	0	106	100.0
	Soybean	15	9	24	37.5
	Total	107	9	116	
	PA	86.0	100.0		OA=95.6

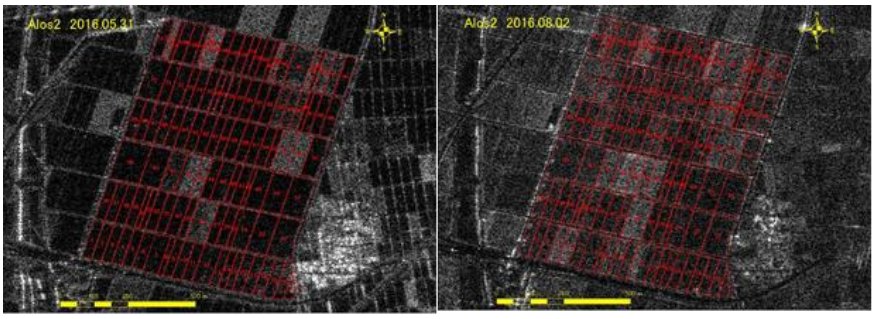
Table 8. Confusion matrix for crop identification using SAR data at Sakata East
(SAR data: 2018.05.22 and 2018.7.12).

		Ground Truth			
		Rice	Soybean	Total	UA %
Classify2	Rice	107	1	108	99.1
	Soybean	0	8	8	100.0
	Total	107	9	116	
	PA	100.0	88.9		OA=99.1

3.2. Sakata West

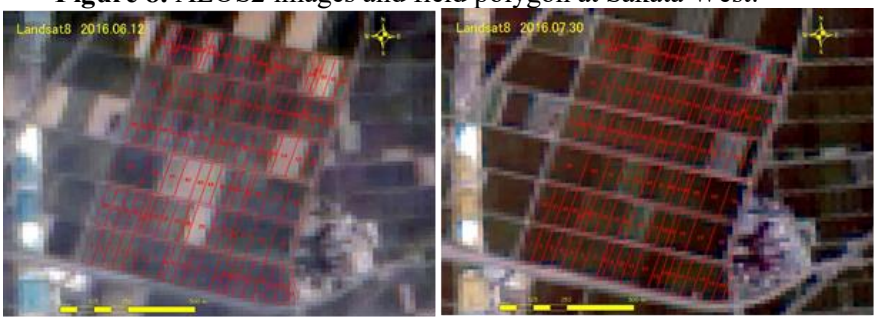
3.2.1. At 2016

At the target fields of Sakata West, there were 6 fields mistaken of rice to soybean same as Sakata East. Using Landsat8 data acquired June 12, the mistakes were corrected, but some mistakes were not corrected. At ALOS2 SAR image (figure 8), Central 2 fields in 4 fields of center parts were soybean field and some backscattering observed at both rice paddies, and rice field mistakes to soybean field. The field shapes of the fields are long and narrow, and it was very difficult to determined flooding or not at 15m resolution of Landsat8 data. One error of upper side, the field was vegetable, and error reason was that of no making class as vegetable. The overall accuracy between using SAR and optical data was a little higher than using only SAR data.



(a) 2016.05.31 (b) 2016.08.02

Figure 8. ALOS2 images and field polygon at Sakata West.



(a) 2016.06.12 (b) 2016.07.30

Figure 9. Landsat8 images and field polygon at Sakata West.

Table 9. Confusion matrix for crop identification using SAR data at Sakata West.

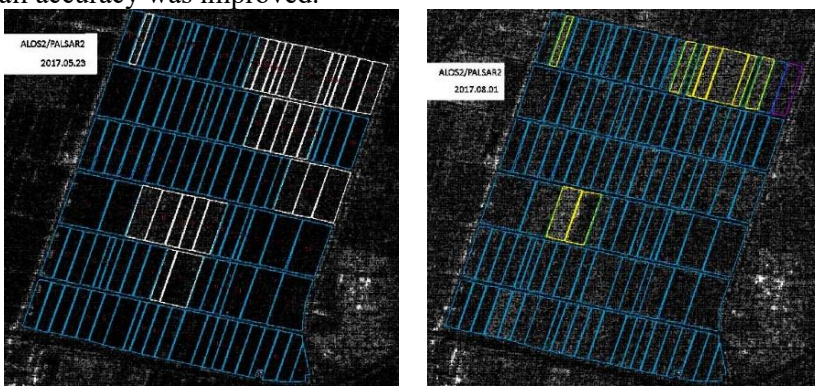
			Ground Truth				
		Rice	Soybean	Grasses	Vegetable	Total	UA
	Rice	96	0	0	0	96	100.0
Classify1	Soybean	6	12	0	0	18	66.6
	Grasses	0	0	0	1	1	0.0
	Vegetable	0	0	1	0	0	0.0
	Total	102	12	1	1	115	
	PA	94.1	100.0	0.0	0.0		OA=93.9

Table 10. Confusion matrix for crop identification using SAR and Optical data at Sakata West.

			Ground Truth			
		Rice	Soybean	Vegetable	Total	UA %
	Rice	97	1	0	98	99.0
Classify2	Soybean	4	12	1	17	70.6
	Vegetable	0	0	0	0	0.0
	Total	101	13	1	115	93.9
	PA %	96.0	92.3	0.0		OA=94.8

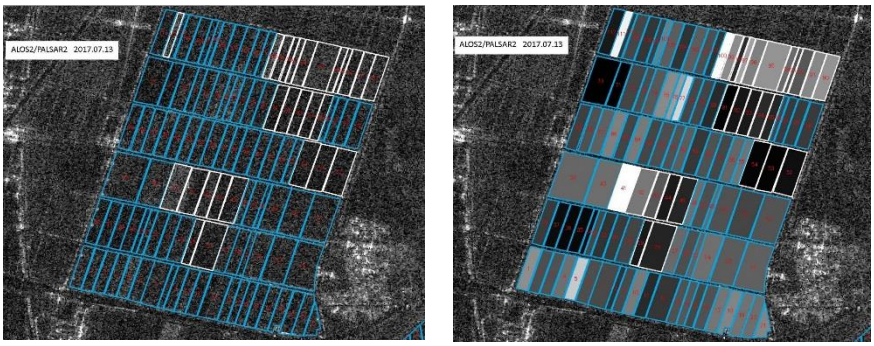
3.2.2. At 2017

In the first discrimination using the ALOS2 data of rice trans-planting time (May 23) and maximum growing season (August 1), there were some mistakes in paddy and soybean, same to results in 2016 and Sakata East in 2017. This mistake was greatly improved by using the ALOS2 data on July 13 in the middle of May 23 and August 1. However, July 13 was slightly too late, it was judged as soybean at the first time and it was difficult to identify the rice from the judged soybean fields. For this reason, average values in field polygons were calculated and displayed, it was easy to identify. Using ALOS2 data on July 13, the overall accuracy was improved.



(a) 2017.05.23 (b) 2017.08.01

Figure 10. ALOS2 images and field polygon at Sakata West at end of May and early August.



(a) 2017.07.13 (b) 2017.107.3

Mean values of each field polygon

Figure 11. ALOS2 images and field polygon at Sakata West at middle of July.

Table 11. Confusion matrix for crop identification using SAR data at Sakata West (SAR data: 2017.05.23 and 2017.08.01)

		Ground Truth				
		Rice	Soybean	Vegetable	Total	UA %
	Rice	97	0	0	97	100.0
Classify1	Soybean	6	9	1	16	66.6
	Vegetable	0	0	0	0	0.0
	Total	103	9	1	113	
	PA %	94.1	100.0	0.0		OA=93.9

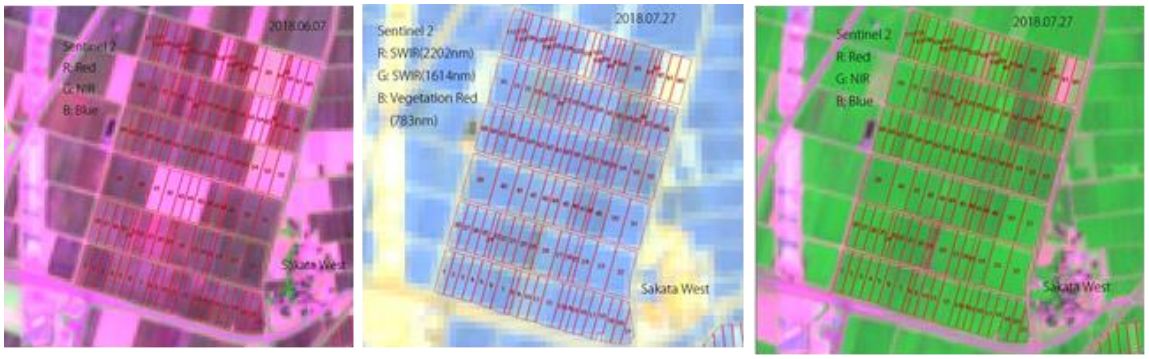
Table 12. Confusion matrix for crop identification using SAR data at Sakata West (SAR data: 2017.05.23, 2017.08.01 and 2017.07.13)

		Ground Truth				
		Rice	Soybean	Vegetable	Total	UA %
	Rice	102	0	0	102	100.0
Classify2	Soybean	1	9	1	11	81.8
	Vegetable	0	0	0	0	0.0
	Total	103	9	1	113	
	PA %	99.0	100.0	0.0		OA=98.2

3.2.3. At 2018

3.2.3.1. Sentinel 2

Same as Sakata East, Sentinel 2data of 2018.06.07 were listed at figure 12 (a) and that of 2018.07.27 are listed at figure 12(b) and (c). The images are false colour composite, (a) and (c) are RGB = Red: NIR: Blue, and resolution is 10m, and (b) is RGB = SWIR2: SWIR1: Vegetation Red Edge. At figure 12 (b), regardless of the rice vegetation, we can easily understand water conditions using SWIR. Filled with water area of 2018.07.27 is larger than at 2018.06.07. At the forage rice, farmers did direct seeding instead of trans-planting, and there were no flooding water in the paddies at 07 June,



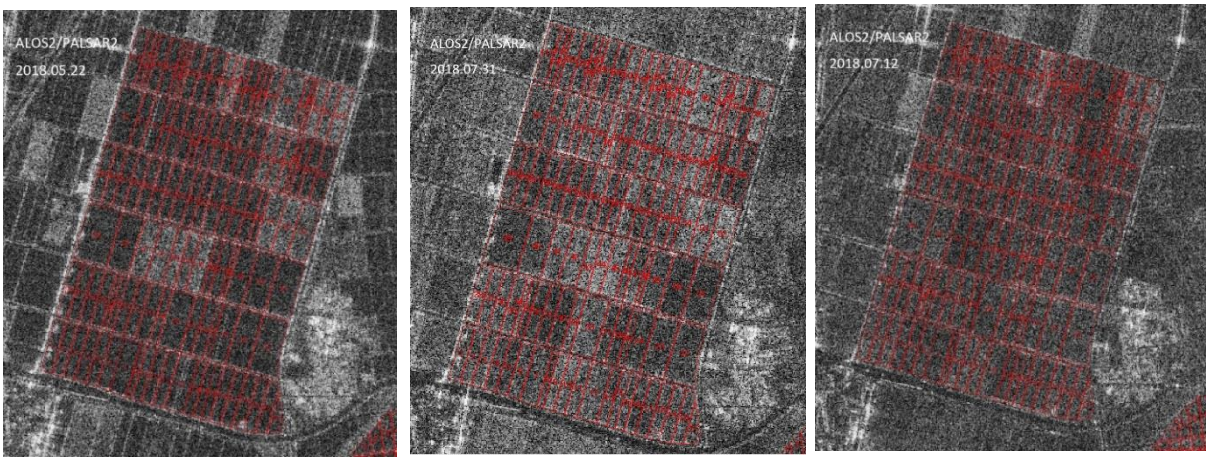
(a) 2018.06.07 RGB=R:NIR:B (b) 07.27 RGB=SWIR2:SWIR1:RE (c) 07.27 RGB=R:NIR:B
Figure 12. Sentinel 2 images and field polygon at Sakata East RE=Red Edge

Table 13. Confusion matrix for crop identification using Sentinel 2 at Sakata West (Sentinel 2 data: 2018.06.07 and 2018.07.27)

		Ground Truth				
		Rice	Soybean	Vegetable	Total	UA %
	Rice	107	0	0	107	100.0
Classify	Soybean	0	4	0	4	100.0
	Vegetable	0	0	1	0	100.0
	Total	107	4	1	112	
	PA %	100.0	100.0	100.0		OA=100

3.2.3.2. ALOS2

At ALOS2 images and field polygon of Sakata East at 2018.05.22 2018.07.31 and 2018.07.12 were indicated at figure 13. Same as Sakata East, there were some mistakes of rice and soybean in the first classification using the ALOS2 data of rice trans-planting time (May 22), these mistake were improved using the ALOS2 data on July 12. The fields of high back scattering at May 22, and the fields of small back scatter at July 12 were added to paddy rice. We got 100% accuracy using three times ALOS2 data that were 2018.05.22 2018.07.31 and 2018.07.12.



(a) 2018.05.22 (b) 2018.07.30 (c) 2018.07.12

Figure 13. ALOS2 images and field polygon at Sakata West

Table 14. Confusion matrix for crop identification using ALOS2 at Sakata West (SAR data: 2018.05.22 and 2018.07.31).

		Ground Truth				
		Rice	Soybean	Vegetable	Total	UA %
	Rice	88	0	0	88	100.0
Classify	Soybean	19	4	1	24	16.7
	Vegetable	0	0	0	0	0.0
	Total	107	4	1	112	
	PA %	100.0	100.0	0.0		OA=90.2

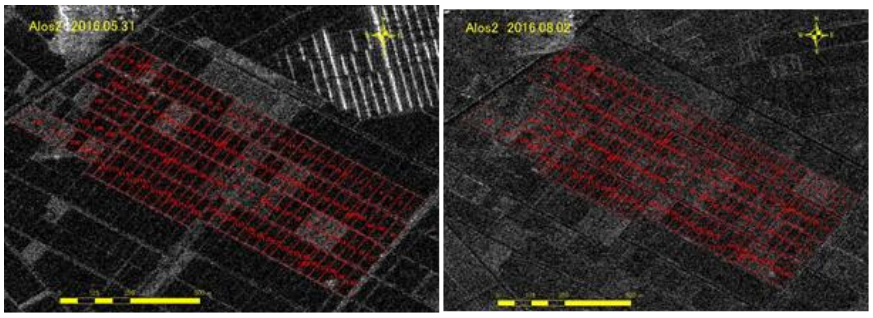
Table 15. Confusion matrix for crop identification using Sentinel 2 at Sakata West (SAR data: 2018.05.22, 2018.07.31 and 2018.07.12).

		Ground Truth				
		Rice	Soybean	Vegetable	Total	UA %
	Rice	107	0	0	107	100.0
Classify	Soybean	0	4	0	4	100.0
	Vegetable	0	0	1	0	100.0
	Total	107	4	1	112	
	PA %	100.0	100.0	100.0		OA=100

3.3. Tsuruoka Mizusawa

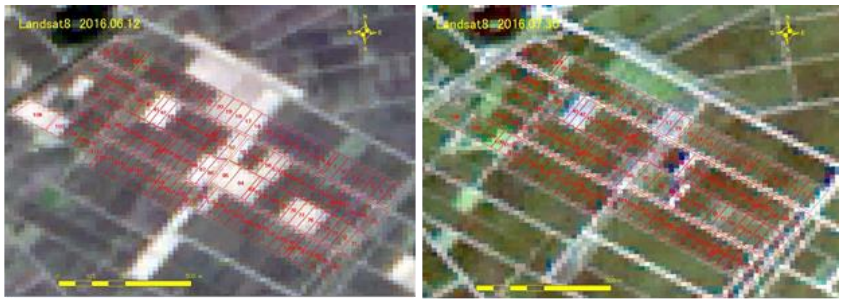
3.3.1. At 2016

At the target point of Tsuruoka Mizusawa, we got very high accuracy using only SAR data. Only using SAR data, rice fields were perfectly extracted. There was no the forage rice, direct seeding. In the area, there were vegetable field and non-crop field that were no class at the determination. In vegetable field, there were pumpkins with many weeds, and it was difficult to determine vegetable, grasses, or non-crops. Overall accuracies were same to using SAR data and using SAR and optical data.



(a) 2016.05.31 (b) 2016.08.02

Figure 14. ALOS2 images and field polygon at Tsuruoka Mizusawa.



(a) 2016.06.12 (b) 2016.07.30

Figure 15. Landsat8 images and field polygon at Tsuruoka Mizusawa.

Table 16. Confusion matrix for crop identification using SAR data at Tsuruoka Mizusawa.

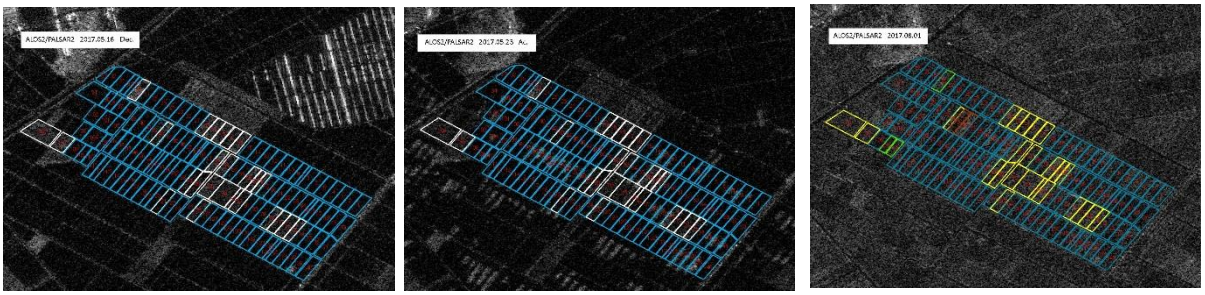
		Ground Truth					
		Rice	Soybean	Vegetable	Non_Crop	Total	UA
	Rice	111	0	0	0	111	100.0
Classify1	Soybean	0	26	2	1	29	89.7
	Vegetable	0	0	0	0	0	0.0
	Non_Crop	0	0	0	0	0	0.0
	Total	111	26	2	1	140	
	PA	100.0	100.0	0.0	0.0		OA=97.9

Table 17. Confusion matrix for crop identification using SAR and Optical data at Tsuruoka Mizusawa.

		Ground Truth						
		Rice	Soybean	Grasses	Vegetable	Non_Crop	Total	UA
	Rice	111	0	0	0	0	111	100.0
Classify2	Soybean	0	26	0	0	0	26	100.0
	Grasses	0	0	0	2	1	3	0.0
	Vegetable	0	0	0	0	0	0	0.0
	Non_Crop	0	0	0	0	0	0	0.0
	Total	111	26	0	2	1	140	
	PA	100.0	100.0	0.0	0.0	0.0		OA=97.9

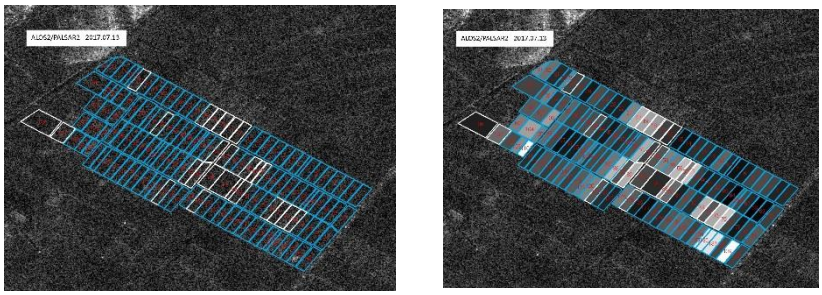
3.3.2. At 2017

The target point of Tsuruoka Mizusawa, we obtained very high accuracies using only SAR data. Using only SAR data, paddy rice fields were completely extracted. There was not direct seeding for livestock feed rice. In this area there were vegetable fields and bare soil fields, vegetable fields had mainly weedy and small pumpkins, it was difficult to identify vegetables, grasses or bare soil fields. It was the same overall accuracy as SAR data only case and when using SAR and optical data. Using 2017.07.13 data or not using the data, the confusion matrixes were exactly same.



(a) 2017.05.16 (b) 2017.05.23 (c) 2017.08.01

Figure 16. ALOS2 images and field polygon at Tsuruoka Mizusawa at end of May and early August.



(a) 2017.07.13 (b) 2017.07.13 Mean values of each field polygon

Figure 17. ALOS2 images and field polygon at Sakata East at middle of July.

Table 18. Confusion matrix for crop identification using SAR data at Tsuruoka Mizusawa (SAR data: 2017.05.16 and 2017.08.01).

		Ground Truth					
		Rice	Soybean	Grasses	Non_Crop	Total	UA %
	Rice	111	0	2	1	114	97.3
Classify1	Soybean	1	23	1	1	26	88.5
	Grasses	0	0	0	0	0	0.0
	Non_Crop	0	0	0	0	0	0.0
	Total	112	23	3	2	140	
	PA %	99.1	100.0	0.0	0.0		OA=95.7

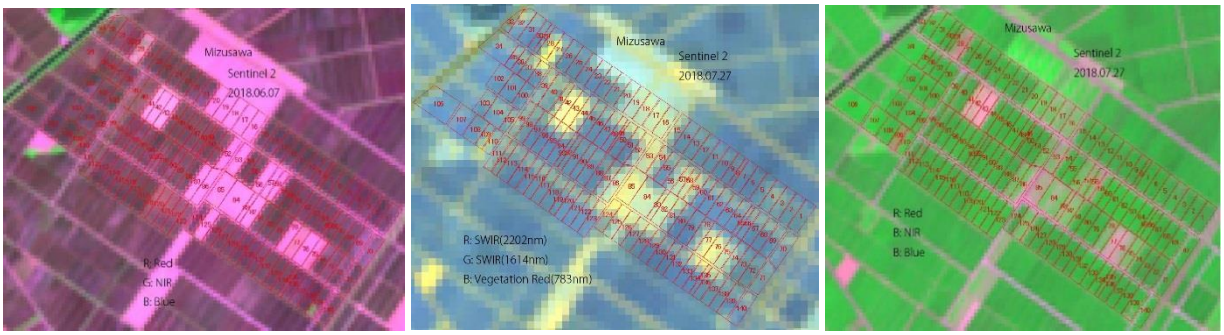
Table 19. Confusion matrix for crop identification using SAR data at Tsuruoka Mizusawa (SAR data: 2017.05.23, 2017.08.01 and 2017.07.13).

		Ground Truth					
		Rice	Soybean	Grasses	Non_Crop	Total	UA %
	Rice	111	0	2	1	114	97.3
Classify2	Soybean	1	23	1	1	26	88.5
	Grasses	0	0	0	0	0	0.0
	Non_Crop	0	0	0	0	0	0.0
	Total	112	23	3	2	140	
	PA %	99.1	100.0	0.0	0.0		OA=95.7

3.3.3. At 2018

3.3.3.1. Sentinel 2

Same as Sakata East, Sentinel 2data of 2018.06.07 are listed at figure 18 (a) and that of 2018.07.27 were listed at figure 18 (b) and (c). The images were false color composite, (a) and (c) are RGB = Red: NIR: Blue, and resolution is 10m, and (b) is RGB = SWIR2: SWIR1: Vegetation Red Edge. At figure 19 (b), using SWIR, we can easily understand water conditions regardless of the rice vegetation. Filled with water area of 2018.07.27 and that of 2018.06.07 were almost same. At the area, there were no late planting rice after June 07.



(a)2018.06.07 RGB=R:NIR:B (b)2018.07.27 RGB=SWIR2:SWIR1:RE (c)2018.07.27 RGB=R:NIR:B

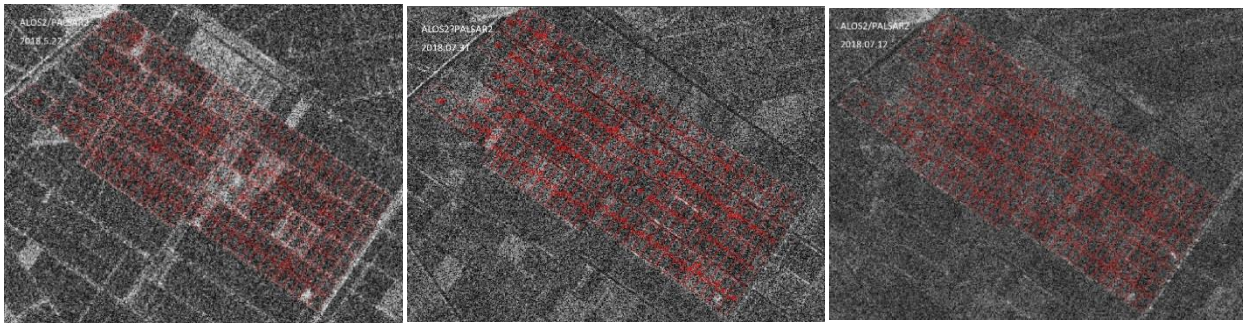
Figure 18. Sentinel 2 images and field polygon at Tsuruoka Mizusawa at 2018 (RE=Red Edge).

Table 20. Confusion matrix for crop identification using Sentinel 2 at Tsuruoka Mizusawa (Sentinel 2 data: 2018.06.07 and 2018.07.27).

		Ground Truth					
		Rice	Soybean	Vegetable	Non	Total	UA %
	Rice	111	0	0	2	113	98.2
Classify	Soybean	0	26	0	0	26	100.0
	Vegetable	0	1	0	0	1	0.0
	Non	0	0	0	0	0	0.0
	Total	111	27	0	2	140	
	PA %	100.0	96.3	0.0	0.0		OA=97.9

3.3.3.2. ALOS2

At ALOS2 images and field polygon of Sakata East at 2018.05.22 2018.07.31 and 2018.07.12 were indicated at figure 19. Same as Sakata East, there were some mistakes of rice and soybean in the first classification using the ALOS2 data of rice trans-planting time (May 22). This mistake was improved by using the ALOS2 data on July 12. The fields of high back scattering at May 22, and the fields of small back scatter at July 12 are added to paddy rice.



(a) 2018.05.22 (b) 2018.07.31 (c) 2018.07.12

Figure 19. ALOS2 images and field polygon at Tsuruoka Mizusawa.

Table 21. Confusion matrix for crop identification using Sentinel 2 at Tsuruoka Mizusawa (SAR data: 2018.05.22 and 2018.07.31).

		Ground Truth				
		Rice	Soybean	Non	Total	UA %
	Rice	114	4	3	121	98.2
Classify1	Soybean	9	9	1	19	100.0
	Non	0	0	0	0	0.0
	Total	123	13	4	140	
	PA %	92.7	69.2	0.0		OA=87.9

Table 22. Confusion matrix for crop identification using Sentinel 2 at Tsuruoka Mizusawa (SAR data: 2018.05.22, 2018.07.12 and 2018.07.31).

		Ground Truth				
		Rice	Soybean	Non	Total	UA %
	Rice	123	0	2	125	97.6
Classify2	Soybean	5	9	1	15	60.0
	Non	0	0	0	0	0.0
	Total	128	9	3	140	
	PA %	97.6	100.0	0.0		OA=94.3

3.4. Mikawa

3.4.1. At 2016

At the target point of Mikawa, we got perfect accuracy using only SAR data. The reasons of perfect determination were as follows, (1) In this area, field sizes were large and near square shape and fields are kept well maintenance (2) This area was very flat and only agricultural activities. (3) Cultivating plants were major crops as rice, wheat, and soybean. Using SAR data, we reached perfect score, and we did not perform the analysis using SAR and optical data.

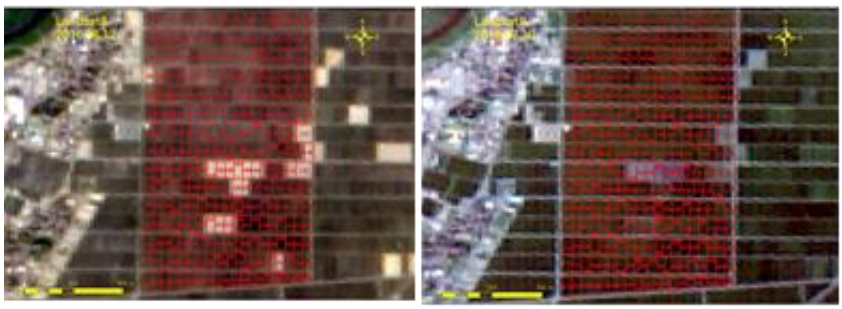


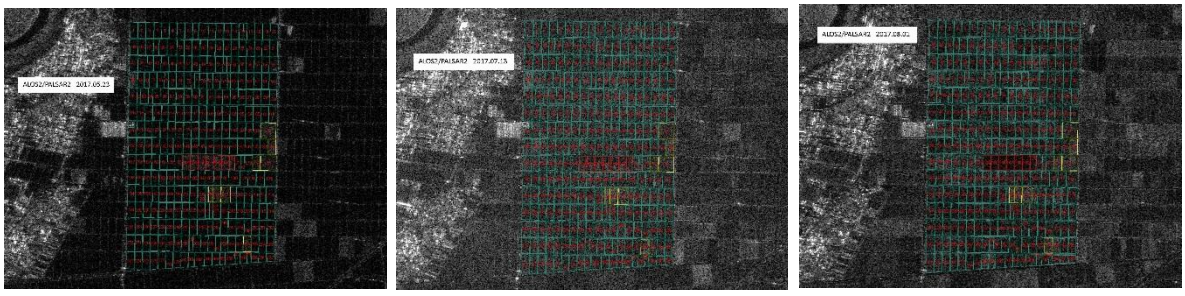
Figure 20. ALOS2 images and field polygon at Mikawa.

Table 23. Confusion matrix for crop identification using SAR data at Mikawa.

		Ground Truth				
		Rice	Soybean	Wheat	Total	UA %
	Rice	273	0	0	273	100.0
Classify1	Soybean	0	12	0	12	100.0
	Wheat	0	0	7	7	100.0
	Total	273	12	7	292	
	PA %	100.0	100.0	100.0		OA=100.0

3.4.2. At 2017

At this target point in Mikawa, 100% accuracy was obtained by the first interpretation by ALOS2 data at rice trans-planting period and maximum growth period. The reason for the perfect judgment was the same reason as in 2016. Since it was 100% accurate once, the second study was not performed.



(a) 2017.05.23 (a) 2017.07.13 (c) 2017.08.01

Figure 21. ALOS2 images and field polygon at Mikawa on end of May, middle of July and early August.

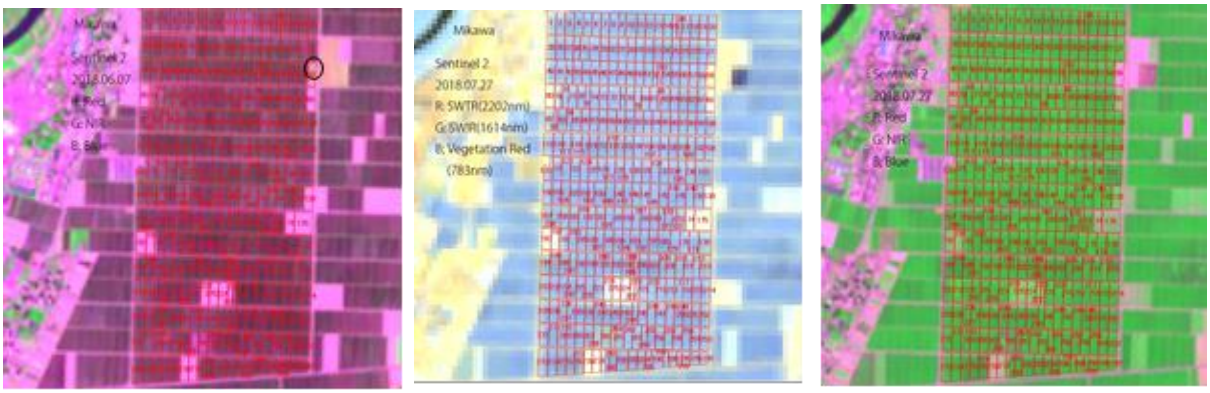
Table 24. Confusion matrix for crop identification using SAR data at Mikawa in 2017 (SAR data: 2017.05.23 and 2017.08.01).

		Ground Truth				
		Rice	Soybean	Wheat	Total	UA %
	Rice	277	0	0	277	100.0
Classify1	Soybean	0	8	0	8	100.0
	Wheat	0	0	7	7	100.0
	Total	277	8	7	292	
	PA %	100.0	100.0	100.0		OA=100.0

3.4.3 At 2018

3.4.3.1 Sentinel 2

Sentinel 2 data of 2018.06.07 were listed at figure 22 (a) and that of 2018.07.27 were listed at figure 22 (b) and (c). The images were false colour composite, and (a) and (c) are RGB= Red: NIR: Blue and resolution is 10m, and (b) was RGB= SWIR2: SWIR1: Vegetation Red Edge and resolution is 20m. At figure 22 (b), we can easily understand water conditions using SWIR regardless of the rice vegetation. Filled with water area of 2018.07.27 and that of 2018.06.07 were almost same. At the area, there were no late planting rice after June 07. We can distinguish wheat field (black cycle marker at figure 21 (a)). There is same vegetation at June 22 and no vegetation at July 27 in wheat filed. Soybean field is no vegetation at June 22 and some vegetation at July 27.



(a) 2018.06.07 RGB=R:NIR:B (b)2018.07.27 RGB=SWIR2:SWIR1:RE (c)2018.07.27 RGB=R:NIR:B

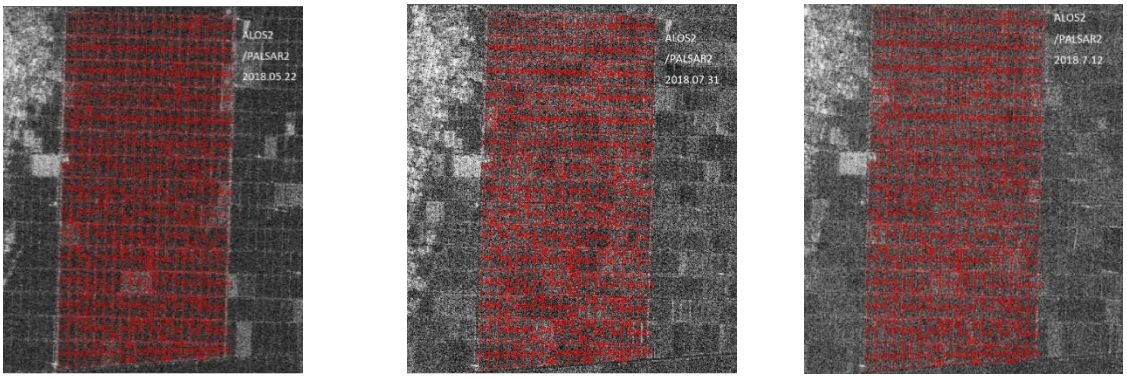
Figure 22. Sentinel 2 images and field polygon at Mikawa (RE: Red Edge)

Table 25. Confusion matrix for crop identification using Sentinel 2 at Mikawa (Sentinel 2 data: 2018.06.07 and 2018.07.27)

		Ground Truth				
		Rice	Soybean	Wheat	Total	UA %
	Rice	278	0	0	278	100.0
Classify	Soybean	0	13	0	13	100.0
	Wheat	0	0	1	1	100.0
	Total	278	13	1	292	
	PA %	100.0	100.0	100.0		OA=100.0

3.4.3.2 ALOS2

At ALOS2 images and field polygon of Sakata East at 2018.05.22, 2018.07.31 and 2018.07.12 were indicated at figure 23. Only back scatter value of June 07, we could not distinguish soybean and wheat. At wheat field, back scatter value of June 07 was larger than that of July 31. At soybean field, the back scatter value of June 07 was smaller than that of July 31. Using 2018.05.22 and 2018.07.31 data, we reached perfect score, and we did not perform the analysis using 2018.07.12 data.



(a) 2018.05.22 (b) 2018.07.30 (c) 2018.07.12

Figure 23. ALOS2 images and field polygon at Mikawa.

Table 26. Confusion matrix for crop identification using ALOS2 at Mikawa (SAR data: 2018.06.07and 2018.07.31).

		Ground Truth				
		Rice	Soybean	Wheat	Total	UA %
	Rice	278	0	0	278	100.0
Classify	Soybean	0	13	0	13	100.0
	Wheat	0	0	1	1	100.0
	Total	278	13	1	292	
	PA %	100.0	100.0	100.0		OA=100.0

3.5. Total Calculations

3.5.1. At 2016

At the total calculation, over all accuracy using two times of ALOS2 data was 96.2%, and over all accuracy using two times of ALOS2 data and two times of Landsat8 data was 98.6%. Both over all accuracies were over 95% using visual interpretations. The reason of misjudge was “Rice field of direct seeding”, and Landsat8 data of middle June were useful. Timing is important and both of SAR and Optical data are useful. At the flat plain, the crop determinations can be performed with nearly 100% accuracy.

Table 27. Confusion matrix for crop identification using SAR data at total Area.

		Ground Truth							
		Rice	Soybean	Wheat	Grasses	Vegtable	Non Crop	Total	UA %
	Rice	572	0	0	0	0	0	572	100.0
	Soybean	21	59	0	0	0	0	80	73.8
	Wheat	0	0	7	0	0	0	7	100.0
Clasify1	Grasses	0	0	0	1	3	1	5	20.0
	Vegtable	0	0	0	0	0	0	0	0.0
	Non Crop	0	0	0	0	0	0	0	0.0
	Total	593	59	7	1	3	1	664	
	PA %	96.5	100.0	100.0	100.0	0.0	0.0		OA=96.2

Table 28. Confusion matrix for crop identification using SAR data and Optical data at total Area.

		Ground Truth							
		Rice	Soybean	Wheat	Grasses	Vegtable	Non Crop	Total	UA %
	Rice	587	1	0	0	0	0	588	99.8
	Soybean	5	59	0	0	0	0	64	92.2
	Wheat	0	0	7	0	0	0	7	100.0
Clasify2	Grasses	0	0	0	0	2	1	3	0.0
	Vegtable	0	0	0	0	0	0	0	0.0
	Non Crop	0	0	0	0	0	0	0	0.0
	Total	592	60	7	0	2	1	662	
	PA %	99	98	100	0	0	0		OA=98.6

3.5.2. At 2017

Continuing from 2016, we could classify with high accuracy. The first classification accuracy was 93.6% and lower than 95% at first classification, which was thought to be the result of increasing number of direct seeding for livestock feeding rice. Because survey at the end of May, we could not catch the direct seeding rice. Observation from middle of June to early July is necessary. In the second classification, total accuracy of 98% was achieved.

Table 29. Confusion matrix for crop identification using SAR data at total area in 2017 (SAR data: 2017.05.23(or 5.16), and 2017.08.01).

		Ground Truth							
		Rice	Soybean	Wheat	Grasses	Vegetable	Non_Crop	Total	UA %
	Rice	568	0	0	2	0	1	571	99.5
Classify1	Soybean	36	44	0	1	1	1	83	53.0
	Wheat	0	0	7	0	0	0	7	100.0
	Vegtable	0	0	0	0	0	0	0	-
	Grasses	0	0	0	0	0	0	0	-
	Non_Crop	0	0	0	0	0	0	0	-
	Total	604	44	7	3	1	2	661	
	PA %	94.0	100.0	100.0	0.0	0.0	0.0		OA=93.6

Table 30. Confusion matrix for crop identification using SAR data at total area in 2017 (SAR data: 2017.05.23 (or 5.16), 2017.08.01 and 2017.07.13).

		Ground Truth							
		Rice	Soybean	Wheat	Grasses	Vegetable	Non_Crop	Total	UA %
	Rice	601	0	0	2	0	1	604	99.5
Classify1	Soybean	3	44	0	1	1	1	50	88.0
	Wheat	0	0	7	0	0	0	7	100.0
	Vegtable	0	0	0	0	0	0	0	-
	Grasses	0	0	0	0	0	0	0	-
	Non_Crop	0	0	0	0	0	0	0	-
	Total	604	44	7	3	1	2	661	
	PA %	94.0	100.0	100.0	0.0	0.0	0.0		OA=97.6

3.5.3. At 2018

3.5.3.1. Sentinel 2

Sentinel 2A was launched at June 2015 and Sentinel 2A was launched at March 2017, and Sentinel 2 has SWIR band. Using SWIR, we can easily understand water conditions regardless of the rice vegetation. Using July data, we can distinguish paddy rice using Sentinel 2 and field polygon data. The resolution of SWIR bands at Sentinel 2 is 20m, and field polygon data are necessary for crop identification.

Table 31. Confusion matrix for crop identification using Sentinel 2 (Sentinel 2 data: 2018.06.07 and 2018.07.27)

		Ground Truth						
		Rice	Soybean	Wheat	Vegetable	Non	Total	UA %
	Rice	602	1	0	0	2	605	99.6
Classify	Soybean	0	52	0	0	0	52	100.0
	Wheat	0	0	1	0	0	1	100.0
	Vegetable	0	1	0	1	0	2	50.0
	Non	0	0	0	0	0	0	0.0
	Total	602	54	1	1	2	660	
	PA %	100.0	98.1	100.0	100.0	0.0		OA=99.4

3.5.3.2. ALOS2

At first classify, we used ALOS2 data at 2018.06.07 and 2018.07.31, and there were some mistakes of rice and soybean. ALOS2 data of rice trans-planting time was June 07 and there was no flooding water some rice fields. This mistake was improved by using the ALOS2 data on 2018.07.12. The fields of high back scattering at June 07, and the fields, which back scatter of July12 is smaller than that of June 07,

are added to paddy rice. At the forage rice, farmers did direct seeding instead of trans-planting, and there was no flooding water in the paddies at June 07.

Table 32. Confusion matrix for crop identification using ALOS2 at total Area (SAR data: 2018.06.07 and 2018.07.31).

		Ground Truth						
		Rice	Soybean	Wheat	Vegetable	Non_Crop	Total	UA %
	Rice	572	4	0	0	0	576	99.5
Classify1	Soybean	43	41	0	1	1	87	88.0
	Wheat	0	0	1	0	0	1	100.0
	Vegtable	0	0	0	0	0	0	0.0
	Non_Crop	0	0	0	0	0	0	0.0
	Total	615	45	1	1	2	664	
	PA %	83.0	81.1	100.0	0.0	0.0		OA=92.4

Table 33. Confusion matrix for crop identification using ALOS2 at total Area (SAR data: 2018.06.07, 2018.07.31 and 2018.07.12).

		Ground Truth						
		Rice	Soybean	Wheat	Vegetable	Non_Crop	Total	UA %
	Rice	615	1	0	0	2	618	99.5
Classify2	Soybean	5	35	0	0	1	41	88.0
	Wheat	0	0	1	0	0	1	100.0
	Vegtable	0	0	0	1	0	1	0.0
	Non_Crop	0	0	0	0	0	0	0.0
	Total	620	36	1	1	3	661	
	PA %	99.2	97.1	100.0	100.0	0.0		OA=98.6

4. Conclusion

At the flat plain, the crop determinations could be performed with nearly 100% accuracy. Over all accuracies were over 95%, this results using visual interpretations, but recently artificial brain technology is developing and deep learning method will be reach at this accuracy. Using ALOS2 data of end of May and early August, there are same mistakes of crop classification. The reason of misjudge is “Rice field of direct seeding”. The direct seeding rice is for feeding to livestock. Using ALOS2 data. It was necessary for observation at late June. Observing timing is important and both of SAR and Optical data are useful. The SWIR data of Sentinel 2 are very useful for Paddy Rice determination. SWIR data can detect flooding of paddy field at growing period of rice. ALOS2 data are observable when planned with all-weather condition, and 3 m resolution is attractive.

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