Possibilities of using digital technologies in agriculture in areas with high agrarian fragmentation

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Table 1. Characteristics of the surveyed farms

Area	Number of farms [GUS, 2020]	Production mainly (including exclusively) for own use	Farm structure by size [%]				
			up to 1 ha inclusive	1 - 5 ha	5 - 10 ha	10 - 15 ha	15 ha and more
Poland	1 316 759	15.70	1.87	50.15	21.95	9.91	16.12
Małopolskie voivodeship	126 172	33.93	2.54	78.37	13.24	2.79	3.06
Podkarpackie voivodeship	114 182	39.03	2.30	76.86	13.75	2.96	4.14
Farms surveyed	389	*10.54	x	62.98	20.05	7.20	9.77

Source: **GUS (2020) and own study.

* Production exclusively for own use; **https://stat.gov.pl/

Table 2. Digital technologies used in the surveyed farms – the total group and groups of farms by size [% of responses]

Types of digital technologies	Use of digital technologies in the surveyed household groups [percentage of answers given by respondents]				
	Total	≤2.7 ha	>2.7ha≤4ha	>4ha≤7.8ha	>7.8ha
Decision support applications	18.77	2.83	8.60	12.77	52.08
Plant disease recognition applications	26.22	5.66	15.05	26.60	59.38
Cloud-based farm management systems	7.97	1.89	1.08	1.06	28.13
Precision farming systems	0.26	0.00	0.00	0.00	1.04
Real-time data collection sensors	4.88	0.00	0.00	1.06	18.75
Animal production automation systems	9.25	0.00	0.00	5.32	32.29
Drones monitor the current condition of crops and soils	0.00	0.00	0.00	0.00	0.00
Agricultural robots enabling crop production automation	1.29	0.00	0.00	0.00	5.21
None of the digital solutions are used	65.81	94.34	82.80	63.83	19.79

Source: own study.

Table 3. Characteristics of respondents and surveyed farms in the group in general and depending on farm size [% of responses]

Specification		Farm size				
		Total	up to 2.7 ha	>2.7ha≤4ha	>4ha≤7.8ha	>7.8ha
Age	up to 35	10.80	13.21	9.68	5.32	14.58
	35-50	39.59	28.30	36.56	42.55	52.08
	>50	49.61	58.49	53.76	52.13	33.33
Gender	Female	35.99	53.77	36.56	34.04	17.71
	Male	64.01	46.23	63.44	65.96	82.29
Respondents' education	Elementary	6.43	9.43	9.68	5.32	1.04
	Vocational agricultural	16.71	3.77	15.05	21.28	28.13
	Vocational other than agricultural	26.99	39.62	33.33	28.72	5.21
	Secondary agricultural	14.14	0.94	5.38	13.83	37.50
	Secondary other than agricultural	23.65	29.25	27.96	24.47	12.50
	Higher agricultural	1.80	0.00	0.00	1.06	6.25
	Higher other than agricultural	10.28	16.98	8.60	5.32	9.38
Employment	On the farm exclusively	58.61	40.57	51.61	57.45	86.46
	On and off the farm	41.39	59.43	4839	42.55	13.54
Organizational form	Individual farm	99.74	100.00	97.85	100.00	98.96
	Agricultural enterprise	0.26	0.00	0.00	0.00	1.04
Type of farm	Conventional Farm	96.14	98.11	96.77	97.87	91.67
	Organic farm	2.83	1.89	3.23	2.13	4.17
	Farm with integrated production	1.03	0.00	0.00	0.00	4.17
Dominant production direction	Crop production	79.18	96.23	84.95	7.66	56.25
	Animal production	20.57	3.77	15.05	21.28	43.75
Production directions	Cattle breeding	19.02	11.32	17.20	23.40	25.00
	Pig breeding	13.37	6.60	10.75	9.57	27.08
	Poultry breeding	48.84	67.92	50.54	48.94	26,04
	Sheep/goat breeding	3.08	0.00	5.38	3.19	4.17
	Horse breeding	1.80	0.94	2.15	1.06	3.13
	Creal cultivation	91.52	78.30	96.77	94.68	97.92
	Oil plant cultivation	22.37	7.55	19.35	23.40	40.63
	Legume cultivation	9.77	14.15	9.68	8.51	6.25
	Field vegetable cultivation	45.24	65.09	45.16	40.43	28.13
	Berry cultivation	2.57	2.83	5.38	2.13	0.00
	Fruit growing	15.42	27.36	10.75	10.64	11.46
	Greenhouse production	9.25	15.09	10.75	8.51	2.08
	Fodder plant cultivation	37.79	29.25	43.01	42.55	37.50
	Processing of agricultural products	10.03	1.89	6.45	10.64	21.88
	Provision of agricultural services	5.40	0.94	1.08	7.45	12.50
	Agritourism	1.29	0.00	2.15	3.19	0.00
	Zootherapy	0.26	0.00	0.00	0.00	1.04
	Shop operating at a farm	0.77	0.00	0.00	1.06	2.08
	Others	0.00	0.00	0.00	0.00	0.00

Source: own study.

Table 4. Production in the surveyed farms in general and depending on the use of digital technologies [% of responses]

Production Directions	Total study group	Farms using digital technologies	Farms that do not use digital technologies
Cattle breeding	19.02	26.32	15.23
Pig breeding	13.37	14.29	12.89
Poultry breeding	48.84	29.32	58.98
Sheep/goat breeding	3.08	4.51	2.34
Horse breeding	1.80	2.26	1.56
Creal cultivation	91.52	93.98	90.23
Oil plant cultivation	22.37	39.10	13.67
Legume cultivation	9.77	12.03	8.59
Field vegetable cultivation	45.24	32.33	51.95
Berry cultivation	2.57	0.75	3.52
Fruit growing	15.42	10.53	17.97
Greenhouse production	9.25	8.27	9.77
Fodder plant cultivation	37.79	42.11	35.55
Processing of agricultural products	10.03	22.56	3.52
Provision of agricultural services	5.40	12.78	1.56
Agritourism	1.29	2.26	0.78
Zootherapy	0.26	0.75	0.00
Shop operating at a farm	0.77	2.26	0.00

Source: own study.

Table 5. Use of digital technologies and perception of barriers to their implementation depending on the respondents' age [% of responses]

Specification		**Total**	Up to 50	Over 50
Digital technologies used in ...	Decision support applications	**18.77**	30.61	6.74
	Plant disease recognition applications	**26.22**	41.84	10.36
	Cloud-based farm management systems	**7.97**	13.78	2.07
	Precision farming systems	**0.26**	0.51	0.00
	Real-time data collection sensors	**4.88**	7.14	2.59
	Animal production automation systems	**9.25**	12.76	5.70
	Drones monitoring the current condition of crops and soils	**0.00**	0.00	0.00
	Agricultural robots enabling crop production automation	**1.29**	2.04	0.52
	None of the digital solutions are used	**65.81**	46.94	84.97
Barriers to using precision farming systems	Significant spatial distance of agricultural plots	**11.05**	13.78	8.29
	The terrain on which the agricultural plots are located (slope, uneven surface)	**11.83**	13.27	10.36
	Difficult access to agricultural plots	**5.66**	8.16	3.11
	Limited Internet coverage within agricultural plots	**18.77**	23.47	13.99
	Inability to increase the production area to a level that would ensure the profitability of using this type of solution	**18.77**	26.02	11.40
	Lack of sufficient knowledge regarding the use of these solutions	**25.19**	27.55	22.80
	Financial constraints	**56.30**	61.22	51.30
	Uncertainty regarding the effects of investing in the above systems	**17.74**	19.39	16.06
	Uncertainty related to the shape of EU requirements that may affect changes in the way production is conducted	**24.94**	26.53	23.32
	Negative attitude of the local community towards this type of solution	**0.51**	0.51	0.52
	Lack of institutional support (through consulting, training)	**6.43**	8.16	4.66
	Unpredictable profitability of investments in digital systems caused by the impact of climate change on the condition of crops	**9.25**	9.69	8.81
	In the case of the production profile and its scale that I run, there is no need to introduce this type of solution	**46.53**	32.14	61.14
	I do not trust systems based on artificial intelligence	**8.74**	2.04	15.54
	I do not see any barriers	**0.77**	1.53	0.00
Barriers to using AI-based plant production automation ...	Significant spatial distance of agricultural plots	**9.77**	11.22	8.29
	The terrain on which the agricultural plots are located (slope, uneven surface)	**13.88**	17.35	10.36
	Difficult access to agricultural plots	**6.17**	9.18	3.11
	Limited Internet coverage within agricultural plots	**17.99**	21.94	13.99
	Inability to increase the production area to a level that would ensure the profitability of using this type of solution	**20.05**	26.53	13.47
	Lack of sufficient knowledge regarding the use of these solutions	**24.94**	26.02	23.83
	Financial constraints	**56.30**	60.20	52.33
	Uncertainty regarding the effects of investing in the above systems	**15.17**	15.82	14.51
	Uncertainty related to the shape of EU requirements that may affect changes in the way production is conducted	**24.42**	26.53	22.28
	Negative attitude of the local community towards this type of solution	**0.51**	1.02	0.00
	Lack of institutional support (through consulting, training)	**5.14**	5.10	5.18
	Unpredictable profitability of investments in digital systems caused by the impact of climate change on the condition of crops	**8.74**	9.18	8.29
	In the case of the production profile and its scale that I run, there is no need to introduce this type of solution	**45.50**	33.67	57.51
	I do not trust systems based on artificial intelligence	**10.80**	3.57	18.13
	I do not see any barriers	**0.77**	1.53	0.00

Source: own study.

Table 6. Use of digital technologies and perception of barriers to their implementation depending on the respondents' level of education [% of responses]

	Specification	**Total**	Elementary	Vocational	Secondary	Higher
Digital technologies used in the surveyed farms	Decision support applications	**18.77**	0.00	7.65	26.53	44.68
	Plant disease recognition applications	**26.22**	0.00	13.53	36.73	53.19
	Cloud-based farm management systems	**7.97**	0.00	1.18	13.61	19.15
	Precision farming systems	**0.26**	0.00	0.00	0.00	2.13
	Real-time data collection sensors	**4.88**	0.00	1.18	8.16	10.64
	Animal production automation systems	**9.25**	0.00	5.29	15.65	8.51
	Drones monitoring the current condition of crops and soils	**0.00**	0.00	0.00	0.00	0.00
	Agricultural robots enabling crop production automation	**1.29**	0.00	0.00	2.04	4.26
	None of the digital solutions are used	**65.81**	100.00	81.76	50.34	38.30
Barriers to using precision farming systems	Significant spatial distance of agricultural plots	**11.05**	0.00	10.59	12.93	12.77
	The terrain on which the agricultural plots are located (slope, uneven surface)	**11.83**	4.00	12.35	11.56	14.89
	Difficult access to agricultural plots	**5.66**	0.00	6.47	4.08	10.64
	Limited Internet coverage within agricultural plots	**18.77**	0.00	17.06	23.81	19.15
	Inability to increase the production area to a level that would ensure the profitability of using this type of solution	**18.77**	0.00	12.94	29.25	17.02
	Lack of sufficient knowledge regarding the use of these solutions	**25.19**	12.00	27.06	27.21	19.15
	Financial constraints	**56.30**	4.00	54.12	70.07	48.94
	Uncertainty regarding the effects of investing in the above systems	**17.74**	4.00	16.47	21.77	17.02
	Uncertainty related to the shape of EU requirements that may affect changes in the way production is conducted	**24.94**	0.00	24.71	30.61	21.28
	Negative attitude of the local community towards this type of solution	**0.51**	0.00	0.59	0.68	0.00
	Lack of institutional support (through consulting, training)	**6.43**	0.00	5.88	8.84	4.26
	Unpredictable profitability of investments in digital systems caused by the impact of climate change on the condition of crops	**9.25**	0.00	9.41	8.84	14.89
	In the case of the production profile and its scale that I run, there is no need to introduce this type of solution	**46.53**	92.00	52.94	34.01	38.30
	I do not trust systems based on artificial intelligence	**8.74**	24.00	14.12	2.04	2.13
	I do not see any barriers	**0.77**	0.00	0.00	0.68	4.26
Barriers to using AI-based plant production automation technologies	Significant spatial distance of agricultural plots	**9.77**	0.00	10.00	10.88	10.64
	The terrain on which the agricultural plots are located (slope, uneven surface)	**13.88**	4.00	12.35	15.65	19.15
	Difficult access to agricultural plots	**6.17**	0.00	6.47	6.12	8.51
	Limited Internet coverage within agricultural plots	**17.99**	0.00	17.65	21.09	19.15
	Inability to increase the production area to a level that would ensure the profitability of using this type of solution	**20.05**	0.00	13.53	29.93	23.40
	Lack of sufficient knowledge regarding the use of these solutions	**24.94**	16.00	26.47	26.53	19.15
	Financial constraints	**56.30**	4.00	55.88	64.63	59.57
	Uncertainty regarding the effects of investing in the above systems	**15.17**	4.00	14.12	19.73	10.64
	Uncertainty related to the shape of EU requirements that may affect changes in the way production is conducted	**24.42**	0.00	23.53	29.93	23.40
	Negative attitude of the local community towards this type of solution	**0.51**	0.00	0.00	1.36	0.00
	Lack of institutional support (through consulting, training)	**5.14**	0.00	5.88	6.12	2.13
	Unpredictable profitability of investments in digital systems caused by the impact of climate change on the condition of crops	**8.74**	0.00	9.41	9.52	8.51
	In the case of the production profile and its scale that I run, there is no need to introduce this type of solution	**45.50**	88.00	50.59	33.33	42.55
	I do not trust systems based on artificial intelligence	**10.80**	32.00	14.71	5.44	2.13
	I do not see any barriers	**0.77**	0.00	0.00	0.68	4.26

Source: own study.

Table 7. Barriers to the implementation of precision farming technology and plant production automation systems based on the use of AI in the surveyed farms in general and depending on the size of the farm [% of responses]

Type of technology	Group of farms	Financial constraints	There is no need to introduce such solutions	Lack of sufficient knowledge	Uncertainty related to the shape of EU requirements that may affect changes in the method of production	Limited Internet coverage within agricultural plots	Inability to increase the production area to a level that would ensure the profitability of using such solutions	Uncertainty as to the effects of investing in the above-mentioned systems	The terrain on which the agricultural plots are located (slope, uneven surface)	Significant spatial distance of agricultural plots	Unpredictable profitability of investments in digital systems caused by the impact of climate change on the condition of crops	Lack of trust in systems based on artificial intelligence	Lack of institutional support (through consulting and training)	Difficult access to agricultural plots	There are no barriers	Negative attitude of the local community towards this type of solution
Precision farming systems	**Total**	**56.30**	**46.53**	**25.19**	**24.94**	**18.77**	**18.77**	**17.74**	**11.83**	**11.05**	**9.25**	**8.74**	**6.43**	**5.66**	**0.77**	**0.51**
	≤ 2.7 ha	27.36	88.68	10.38	18.87	5.66	8.49	10.38	2.83	4.72	6.60	8.49	0.00	2.83	0.00	0.00
	>2.7ha≤4ha	59.14	54.84	23.66	34.41	25.81	20.43	13.98	10.75	13.98	5.38	15.05	1.08	5.38	0.00	0.00
	>4ha≤7.8ha	59.57	34.04	37.23	20.21	21.28	19.15	21.28	20.21	9.57	10.64	7.45	13.83	7.45	2.13	1.06
	>7.8ha	82.29	4.17	31.25	27.08	23.96	28.13	26.04	14.58	16.67	14.58	4.17	11.46	7.29	1.04	1.04
Plant production automation systems based on AI	**Total**	**56.30**	**45.50**	**24.94**	**24.42**	**20.05**	**17.99**	**15.17**	**13.88**	**10.80**	**9.77**	**8.74**	**6.17**	**5.14**	**0.77**	**0.51**
	≤ 2.7 ha	26.42	84.91	11.32	17.92	8.49	6.60	8.49	4.72	11.32	4.72	5.66	2.83	0.00	0.00	0.00
	>2.7ha≤4ha	56.99	53.76	26.88	33.33	19.35	25.81	10.75	10.75	16.13	12.90	3.23	5.38	1.08	0.00	0.00
	>4ha≤7.8ha	62.77	32.98	34.04	22.34	21.28	20.21	20.21	23.40	8.51	7.45	11.70	8.51	11.70	2.13	1.06
	>7.8ha	82.29	6.25	29.17	25.00	32.29	20.83	21.88	17.71	7.29	14.58	14.58	8.33	8.33	1.04	1.04

Source: own study.