SATIM Monitoring Satelitarny Sp. z o.o.
ul. Urzędnicza 36/1, 30-048, Kraków

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SURFACE MONITORING OF LANDSLIDE
73253 KRO
Zbyszyce - Gródek nad Dunajcem rural commune
BY RADAR INTERFEROMETRY

REPORT

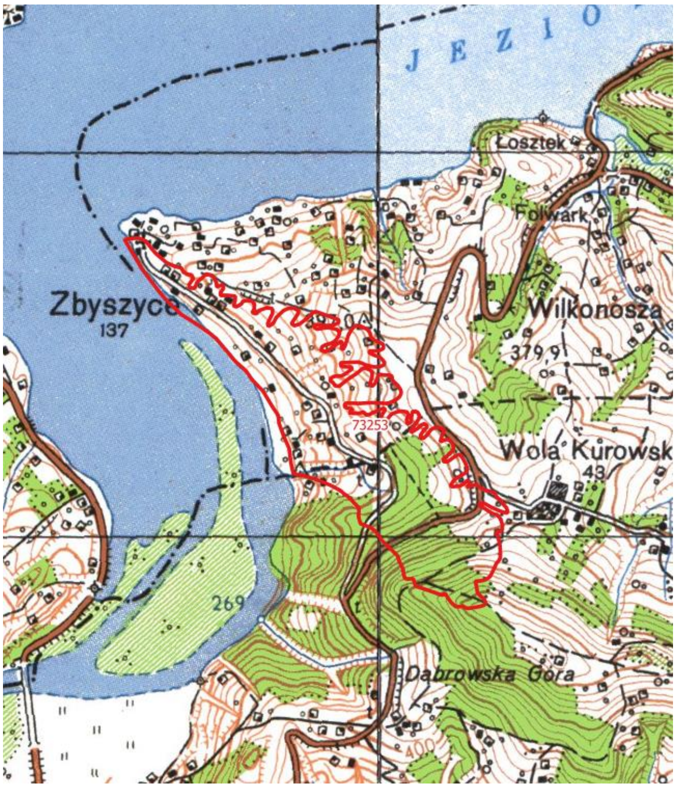
Kraków, 07.05.2020

Employer:
County Office
in Nowy Sącz
ul. Jagiellońska 33
33-300 Nowy Sącz

phone +12 315 73 51
e-mail: kontakt@satim.pl

1 RESEARCH AREA

Area 73253 is located in the Lesser Poland Voivodeship in the Nowosądecki Poviat in the commune of Gródek nad Dunajcem in the village of Zbyszyce. The ordinates of the area covered by mass movements at its lowest point are 266 m a.s.l. (shore of Lake Rożnów), while the highest point of the studied area rises to a height of about 565 m a.s.l. The geographical coordinates of the central point of the analysed landslide are: 49°42'9.69"N and 20°40'39.64"E. The landslide surface area is 1.091 km².



This area has been identified as part of the SOPO project and divided into a periodically active area in its north-west part, an inactive area (southern part of area 73253) and a continuously active central part of the analysed landslide area. The extent of the landslide and the division into activity zones presented on the maps in this report comes from the database of the Landslide Protection System of the Polish State Geological Institute.

This area was subjected to satellite surface monitoring from February 26, 2017 to February 23, 2020. The analysis was made on the basis of analysis of 82 satellite images from the Sentinel-1 satellite by radar interferometry, IPTA technique.

2 RESEARCH METHODOLOGY

InSAR (Interferometric Synthetic Aperture Radar) interferometry is a remote sensing method, the purpose of which is to calculate the phase shift of radar echoes recorded on two independent SAR images, for the same area and in a given time interval. SAR imaging is an active system, i.e. it has its own source of electromagnetic radiation. This makes it possible to record SAR images both during the day and at night, regardless of the weather conditions. The source data in this technique are SAR radar images with high spatial and temporal resolution, covering an area of up to hundreds of square kilometres. An orbiting satellite has a transceiver antenna that records the amplitude and phase of the returning radar waves. The phase is a specific part of the sine wave cycle that gives information about the variable distance of the recorded point from the antenna.

Knowing the wave phase values for two images, it is possible to calculate their difference

and, based on it, calculate the phase shift of a given object between these images (Δr). The phase shift can then be converted to the value of the land movements.

Fig. 1 Visualization of the wave phase shift

One of the most common applications of InSAR techniques is DInSAR (Differential InSAR). It uses two SAR images to calculate the interferogram, i.e. the phase shift image. Then, using a digital terrain model, the topographic component is subtracted and a differential interferogram is calculated that shows movements of the surface of the land covered by SAR images. The disadvantage of DInSAR measurements is the lack of information about local deformations of individual infrastructure objects.

The second method used in the commissioned study is the IPTA technique (Interferometric Point Target Analysis), which uses a set of SAR images between which the phase shift value for each pixel is calculated. In this way, differential interferograms are created. The IPTA analysis is performed only for stable coherent points, i.e. those that are characterised by the invariability of the way the waves are reflected in time. First of all, these are points in built-up areas (mainly on building elements), and their density reaches several thousand points per each km2. This method allows calculations of movements for individual objects, also when it is only local deformation. IPTA analyses are carried out for long periods of time, e.g. the whole year. Several or even several dozen SAR images can be used that are recorded periodically every few days (depending on the type of satellite). In this way it is possible to determine the value of movements for a selected period of time and the velocity of these

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deformations. The result of IPTA analyses is a spatial set of measuring points for which the values of object movement velocities (usually in the unit of mm/year) along the LOS radar signal incidence line (Line Of Sight) were calculated.

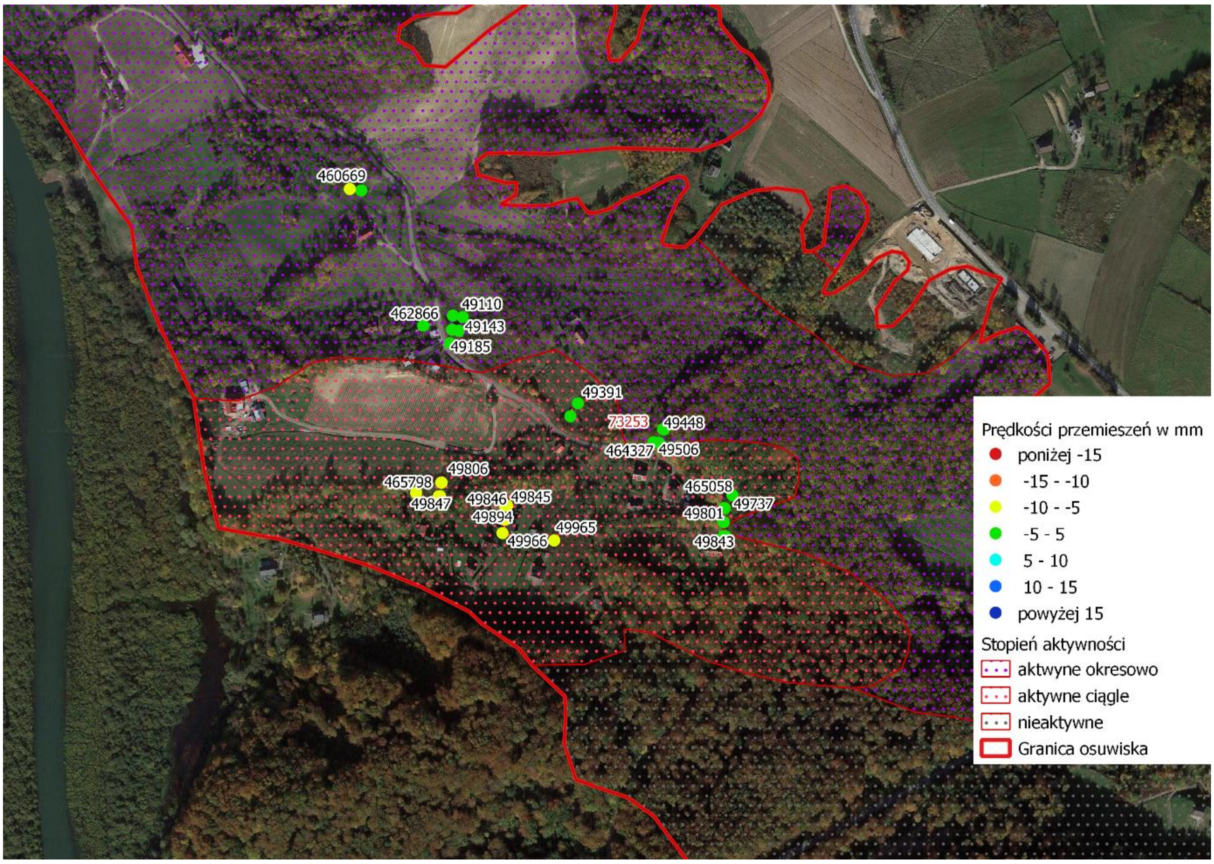
The main parameter describing the possibility, accuracy and, above all, the density of stable PS measuring points for the IPTA analysis is the coherence value for a given area. Coherence is a measure of the consistency of two SAR images. Its value is primarily influenced by two factors: time de-correlation (mainly related to changes in land use or humidity between two images) and the impact of land cover (analysis in forest, swampy and water areas is practically impossible, while in built-up areas - the most effective).

InSAR techniques have been used since the early 1990s (Pratti C., et al., 1994; Hanssen R., 1999; Ferretti A., et al., 2007). The calculation algorithms have been and are being perfected by eminent scientists from around the world. At the beginning of the 21st century, the first PS analyses were created (Ferretti A., et al., 2000, 2001). Many scientific articles have also been published that focus on comparing the PS technique

with ground-based geodetic methods (Wei-Chia Hung, et al., 2011; Crosetto M. et al., 2009). They confirmed millimetre accuracy per year for techniques using PS points. In this study, the accuracy of determining the value of vertical movements by the IPTA method was assumed to be +/- 2 mm per year.

All SAR image analyses were carried out by experienced SATIM employees with a university degree in geology, geodesy, remote sensing and computer science.

3 MAP OF MEASURING POINTS



Movement velocity in mm
below -15
-15 - -10
-10 - -5
-5 - 5
5 - 10
10 - 15
above 15

Activity level
periodically active
continuously active
inactive
landslide border

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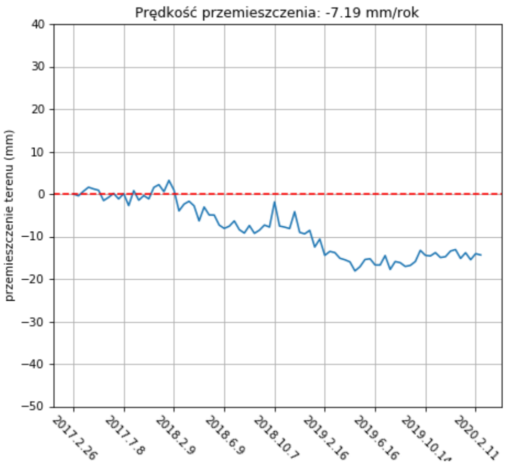
4 SELECTED MEASURING POINTS

Measuring point ID	Land movements [mm]											
	2017			2018				2019			2020	TOTAL
	Quarter 2	Quarter 3	Quarter 4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 1	
49965	-2.36	-4.5	4.35	-1.91	1.84	-6.39	1.05	0.94	-1.31	-1.14	-5.12	-5.51	-20.06
49846	-1.11	-2.77	-1.11	-2.02	0.53	-2.62	-2.2	-0.8	-1.14	0.37	-3.6	-2.44	-18.91
465796	-2.74	-1.42	-1.01	-2.52	-0.24	-2.19	-2.12	-0.47	-0.6	-0.04	-3.49	-1.43	-18.27
49845	-1.88	-1.14	-1.63	-2.4	0.2	-2.05	-2.61	-0.79	-0.66	0.48	-3.88	-1.76	-18.12
49847	-3.66	-0.24	-0.75	0.27	-4.41	-2.41	1.85	-3.33	-1.12	-0.18	0.21	-4.27	-18.04
465798	-6.64	0.3	1.47	-0.91	-4.4	0.08	-0.61	-1.68	-3.26	0	-0.6	-1.68	-17.93
49893	-2.72	-0.65	-1.7	-2.13	0.32	-3.15	-1.59	-0.48	-0.74	0.22	-3.54	-1.41	-17.57
49894	-3.24	-0.38	-1.21	-2.4	0.44	-3.29	-2.42	0.25	-1.51	0.89	-3	-1.59	-17.46
49805	-1.6	-2.01	0.76	-0.29	-3.16	-2.67	-0.4	0.06	-4.13	1.53	0.1	-4.51	-16.32
49848	-6.5	1.52	1.5	-1.36	-5.26	0.71	-0.13	-1.75	-2.88	0.16	-0.4	-1.74	-16.13
49806	-4.31	-4.51	5.66	-1.23	-4.36	-0.05	-0.4	-1.09	-3.48	0.71	-0.28	-2.52	-15.86
49966	-7.74	4.45	1.64	-3.65	-2.29	-1.99	-2	0.73	-2.2	2.81	-4.35	0.22	-14.37
460669	-1.19	-1.56	4.27	-4.34	-4.79	-0.2	-1.6	-5.74	-1.59	0.82	2.83	-1.27	-14.36
49844	-2.49	0.48	0.55	-2.28	1.54	0.61	-1.27	-3.99	-2.43	2.66	-0.07	-2.42	-9.11
49843	-2.36	0.67	-0.06	-0.53	-0.78	1.21	-0.61	-4.57	-2.04	2.86	-0.22	-2.42	-8.85
465791	-1.64	0.22	-0.17	-0.8	0.17	0.6	-1.49	-3.71	-1.5	2.16	-0.08	-1.85	-8.09
49801	-1.36	0.09	-0.04	-0.7	0.51	-0.06	-1.33	-3.32	-1.99	2.18	-0.09	-1.69	-7.8
49737	-0.25	0.07	-0.64	-0.81	1.19	-0.31	-1.97	-2.42	-2.33	2.17	-0.44	-1.91	-7.65
49738	-0.89	0.53	-0.77	-0.58	0.2	0.89	-2	-2.57	-2.13	1.59	-0.14	-1.61	-7.48
49802	-1.68	0.59	-0.22	-0.74	0.16	0.8	-1.57	-3.27	-1.87	1.88	-0.21	-1.29	-7.42

5 GRAPHS FOR SELECTED MEASURING POINTS



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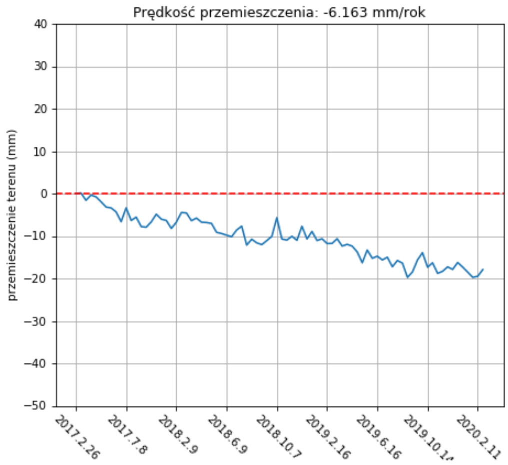

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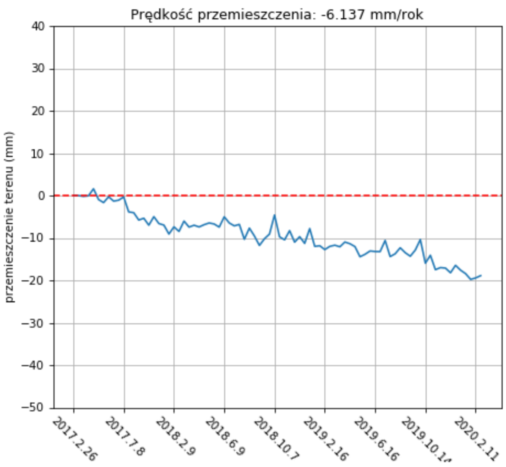

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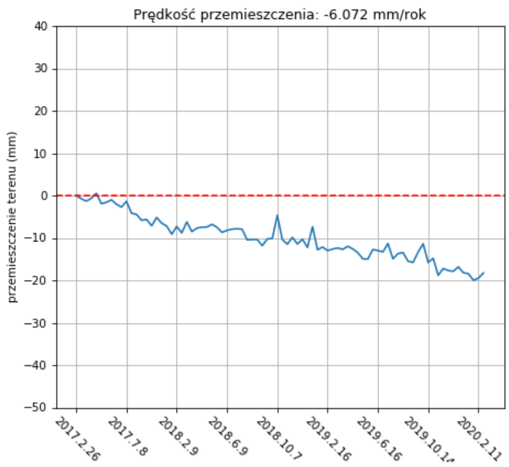

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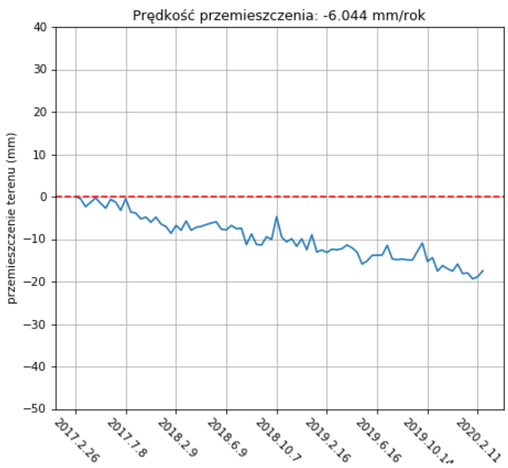

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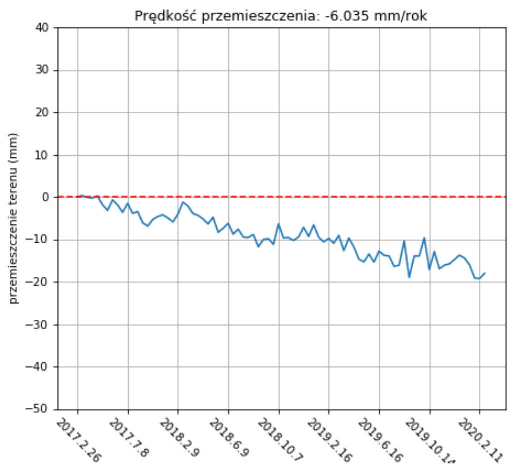

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6 SUMMARY AND EVALUATION OF RESULTS

During this monitoring for area 73253 Zbyszyce - Gródek nad Dunajcem, 34 stable measuring points were generated. The landslide in the period from February 26, 2017 to February 23, 2020 was characterised by land movements of -7.1690 mm/year - lowering (measuring point ID = 460669) and a slight raising of 2.404 - (measuring point ID = 48697)

Measuring points were generated in urbanised areas that are located in the central part of the landslide area.

Detailed movement velocities for each measuring point analysed on each satellite imaging can be seen in the attached XLSX file and the SHP file.