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Original Research Article

DO CHANGES OF RAINFALL TRENDS AFFECT CHOICE OF DRAINAGE SYSTEMS?

Katarzyna KUBISZYN[1], Dorota ŁOCHAŃSKA[2]
[1]Faculty of Civil Engineering, Architecture and Environmental Engineering, Institute of Environmental Engineering, University of Zielona Góra, Zielona Góra, Poland
[2]Faculty of Civil Engineering and Resource Management, AGH University of Science and Technology, Kraków, Poland

A b s t r a c t

Precipitation is one of the main factors causing surface, linear and landslide erosion. Their influence on erosion processes is determined by such parameters as: precipitation frequency, amount, duration and intensity. These features affect the rate of infiltration and the intensity of surface runoff, and thus the occurrence, course and effectiveness of erosion processes [2, 3, 4].
The aim of research was to analyse the 40-years of rainfall measurements data from the Lubuskie Voivodeship and inspect whether occurring of heavy rains are random events or maybe indicate some long period trends. To analysis was used non-parametrical Mann-Kendall test and correlation test.
What is more the authors' prepared a path of selecting the optimal dewatering system, where would be taken into consideration ground stability and changes in the rainfall trends. For this purpose, the paper contain short overview existing dewatering systems which are used to reducing risk of landslides.

Keywords: local precipitation trends, Mann-Kendall test, slope stability, dewatering systems, decision-making process map

[1] Corresponding author: Faculty of Civil Engineering, Architecture and Environmental Engineering, Institute of Environmental Engineering, University of Zielona Góra, ul. prof. Z. Szafrana 15 65-516 Zielona Góra, Poland, e-mail: kkubiszyn@iis.uz.zgora.pl

1. INTRODUCTION

What is the difference between climate and weather? According to definition, which were found on the web site of National Centres for Environmental Information, climate is that what we expect and the weather what we get. In other words, weather is mix of the events occurring every day in the atmosphere. Whereas climate describes what the weather is like over a long period in specific area. When climatologists talk about climate, they think about averages of temperatures, precipitations, sunshine, humidity, winds, and other measures of weather occurring at least over 30 years. The 30th years average refer to Climate Norms. Climate Norms help to answer on a question, what kind of weather can be expected in particular seasons, or when and where is the warmest and the coldest day of the year. They also tell us, what the standard amount of precipitation is in given month [1].

The weather news' from last couple of years seems to indicate the changes in intensity of natural phenomena, especially in the precipitation. The negative effects of heavy rainfalls are flooded streets, roads and railroads, landslides, etc. Sample high-profile disaster cases of local floods occurred in Poland: in 2022 – Małopolska and Gorzów Wielkopolski, 2021 - Zielona Góra, 2020 – Podkarpacie, 2017 – Warszawa, 2013 – Kraków, 2011 – Bełchatów or 2010 – Turów. What is more, precipitation is one of the main factors causing surface, linear and landslide erosion. Their influence on erosion processes is determined by such parameters as: precipitation frequency, precipitation amount, duration and intensity. These features affect the rate of infiltration and the intensity of surface runoff, and thus the occurrence, course and effectiveness of erosion processes [2, 3, 4].

By the years it was created, many criteria of rainfall classification refer to 'heavy precipitation' for example Chomicza's Classification, which refer to heavy and torrential rains [5]. The amount of water falling to the ground in 60 minutes exceed the 40 mm. torrential rains. Those classifications were based generally on two factors – amount of rainfall and duration. However gaining such data is very difficult, that is why authors of this paper to analysis of changes trends in local precipitation took the classification presented in the "Klęski żywiołowe a bezpieczeństwo wewnętrzne kraju' published by Institute of Meteorology and Water Management (IMGW). The classification is based on the analysis of empirical data of intensity of daily rainfalls and its effects. Due to the hazards for the environment, society and economy precipitation were divided into 4 groups, causing [6]:

1. minor flooding – amount of precipitation above 30 mm/day – cause local flooding of low located areas and basements/spaces, on streets arise stagnate layer of water formations, and in places where terrain is diverse occur the quick surface runoff, ground erosions , also can be noticed problems with pedestrian and road traffic,

2. flood-dangerous – amount of precipitation above 50 mm/day – water from rainfall creates “rivers/streams”, both in undeveloped and urban areas, occur to bigger infrastructure destructions, eroding of tree roots and possible of occurring mudslides,
3. flood – amount of precipitation above 70 mm/day – absorption of water by the ground is limited, storm drains and sewage pipes cannot get back such amount of water, what causes that the streets become water channels. In areas with slopes, are created rushing streams destroying everything on their way. The roads and railway are washed out, and the level of water in rivers suddenly increase. What is more landslides and mudslides are formed. Help of rescue organisations is needed.
4. catastrophic flood – amount of precipitation above 100 mm/day – in addition od the events listed in point 3, it occurs uncontrolled runoff of water into rivers as a consequence of high intensity of precipitation. Such rainfall occurring in shorter periods may be classified as torrential rain. The water in rivers exceed the level of riverbanks which in consequence case the catastrophic destructions of all infrastructure including bridges. It is natural disaster causing of humans death. The help of local as well as national and even international rescue organisations is required. Physical, medical, psychological, and financial assistance is essential for affected population.

The authors of this paper try to find the answer for the question about the scale of changes in the structure of local precipitation, and whether they can affected the selection of drainage systems to reduce the risk of landslides and slopes. Analysis of local, regional and global changes of precipitation trends provide many researchers around the world. Results of studies shows that in the XX century average level of yearly precipitation increased. However, there are also research indicate that increasing trend is not typical for each place. For example in Poland on the base of precipitation data from 1951-2009, it was found increasing precipitation trend in Podkarpacie Voivodeship and in the same time decreasing trend was noticed in west part of Poland [3, 5, 7, 8, 6, 9, 10]

The paper contains results of analysis a daily precipitation data, from 17 stations located in Lubuskie Voivodeship, which were collected over the past 40 years. In climatologic time series, tests for finding the trends can be categorized as parametric and non-parametric methods. Parametric trend tests need data to be independent and normally distributed, while non-parametric trend tests require only that the data be independent [11]. In this paper, for examination the trends directions, were used such statistic techniques as Mann-Kendall test and Sen’s slope estimator. What is more the authors’ prepared a path of selecting the most optimal dewatering system, where would be taken into consideration ground stability and changes in the rainfall trends. For this purpose, the paper contain short overview existing dewatering systems which are used to reducing risk of landslide and on this base, it was prepared decision-making map of selection the optimal dewatering system.

2. RESOURCES AND STUDIE METHODS

The analysis of changes in the precipitation structure was limited to the area of the Lubuskie Voivodeship and last 40 years. Lubuskie Voivodeship is located in central-western part of Poland and covers an area of approx. 14 000 km^2. Characteristic for this region is lots of wooded areas and little industrialization. The climate is one of the warmest in Poland. In the north part, it is slightly cooler and quite humid, compared to the central and southern parts, where it is warmer and drier. The average air temperature in the region is 8.5 ° C, and the typical annual precipitation totals are between 500-600 mm. Although in the last decades in Zielona Góra (located in the centre of Lubuskie Voivodeship,) amount of worm seasons increased compere to cold, level of yearly participation did not change a lot. The lack of variability in the average annual rainfall results from the fact that the intensity of rainfall changed [12].

The studies data comes from website of IMGW, where can be find the measurements of daily precipitation from all meteorological station located in Poland. From such amount of data, it was selected 17 stations, which have been carrying out measurements continuously for 40 years in and near Lubuskie Voivodeship. The location of the meteorological stations shows Fig. 1.

The Mann-Kendall test statistic S is used to determine whether a time series has a monotonic upward or downward trend. Data for this test do not have to be linear or normally distribute. The null hypothesis for Mann-Kendall test assumes no trend, on the other hand, the alternative hypothesis indicates on a trend in the two-sided test or that there is an upward trend (or downward trend) in the one-sided test [13]. A very high positive value of S is an indicator of an increasing trend and a very low negative value indicates a negative trend. The S is calculated as [11, 8]:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sign}(x_j - x_i) \tag{2.1}$$

where:
n – number of data points,
x_j, x_i – data values in time series i and j (j > i),
$\mathrm{sign}(x_j - x_i)$ – sign function in accordance with formula (2.2):

$$\mathrm{sign}(x_j - x_k) = \begin{cases} 1 \text{ for } x_j - x_i > 0 \\ 0 \text{ for } x_j - x_i = 0 \\ -1 \text{ for } x_j - x_i < 0 \end{cases} \tag{2.2}$$

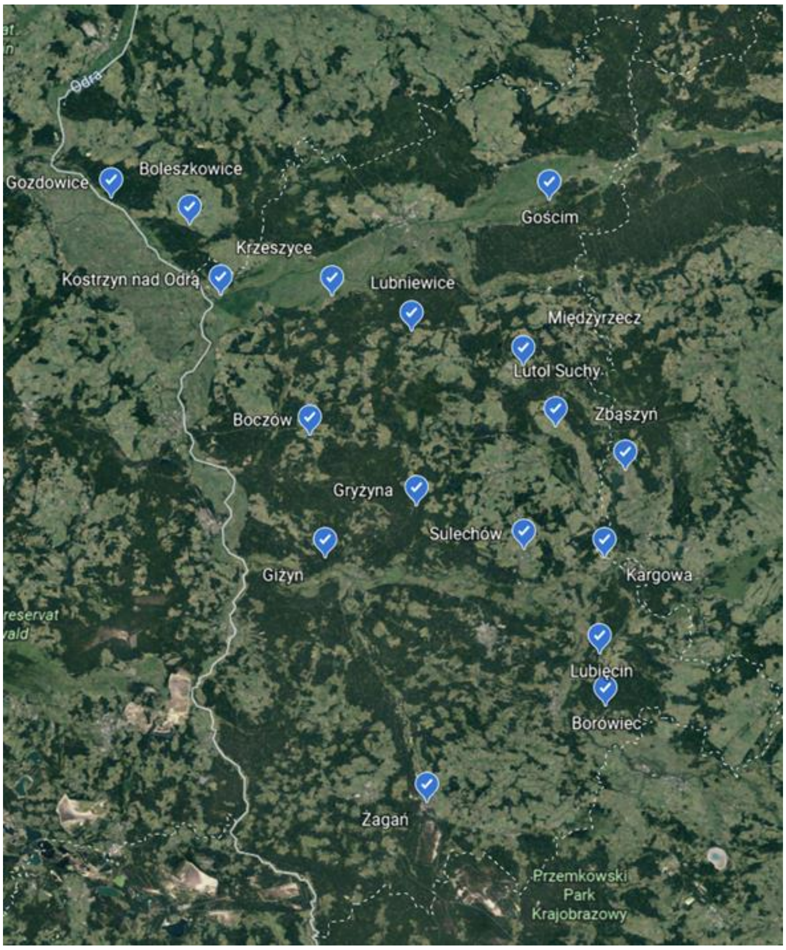

Fig. 1. Localisation of meteorological stations in Lubuskie Voivodeship

As in studies n above 10 means that distribution of S is similar to normal distribution, with mean zero and variance. The variance of S can be calculated as in (2.3) [14, 13, 11]:

$$\mathrm{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i\,(t_i - 1)(2t_i + 5)}{18} \tag{2.3}$$

where:

m – number of tied groups
t_i – the number of ties of extent i.
The tied group is a set sample data with the same value.

The standard normal test statistic (Z_S) count by using formula (2.4) can be used to determine whether the time series data exhibits a significant trend [14, 11]:

$$Z_S = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, \text{if } S > 0 \\ 0, \quad \text{if } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, \text{if } S < 0 \end{cases} \quad (2.4)$$

Positive value of Z_S point at increasing trends, while negative show decreasing trends. What is more, when $|Z_S| > Z_{1-\alpha/2}$, the null hypothesis is rejected and a significant trend exist in the time series. Testing trends is done at the specific α significance level, which in this paper is 0.05 [14, 11].
Non-parametric correlation coefficient is a statistic (τ) defined by a relationship (2.5) which takes values in the range [-1;1] [11]:

$$\tau = \frac{2S}{n(n-1)} \quad (2.5)$$

Positive values of τ indicates upward tendency, negative - downward tendency, and values near zero indicates lack of tendency [11].
Changes of analysis tendency can be describe by correlation coefficient (β) expressed by the Sen's slope defined as [11]:

$$\beta = \text{median}\left(\frac{x_j - x_i}{j - i}\right) \quad (2.6)$$

where: $i < j$ and ($i = 1,2,\ldots,n-1$, and $j = 2,3,\ldots,n$).

Analysis was done for four seasonals (winter, spring, summer and autumn) and yearly data and for two groups (no precipitation, precipitation ≥ 30mm/day). In this paper value of significance level is interpret according to following scale [8]:

- p > 95% (<0.05) - significant change
- p = 90 - 95% (0.05-0.10) - near significant change
- p = 75-90% (0.10-0.25) - tendency to change

Results of statistic test are presented in the Tables 1 to 5.

What is more, there were analyzed the correlation between amount of measurements indicating "no precipitation" and precipitation equal or above 30 mm in annual time period and seasonal periods. Results were interpreted according to following assumption:

- 0.0 – 0.3 – weak relationship,
- 0.3 – 0.5 – moderate relationship,
- 0.5 – 1.0 – strong relationship.

Analysis were done by using the Data Analyzing Tool from MS Excel.

3. ANALYSIS

Data were tested in 5 different time periods: Annual, Winter, Spring, Summer and Autumn. Analyzing results from table 2, it can be noticed that trends in annual period for Lubuskie Voivodeship do not occur in both analyzed groups. However it can be see some significant trends at individual stations, in ‘no precipitation’ group. The decreasing tendance is in two stations, while increasing in seven other points. For second group tests do not show any trends in that time period.
In this time period were also studied correlation between two tasted groups. Results of analysis are presented in Tab. 1 and Fig 2. We can see that correlation between ‘No precipitation’ and ‘Precipitaion ≥ 30 mm’ has moderate relationship. What is more correlation between time series (Years) and data from ‘No precipitation’ is higher than correlation with second group.

In the Fig. 2 it can be noticed that linear trends increase for both group (slope factor is positive), but for orange graph R^2 is 10 times higher. Nevertheless value of both R^2 confirm lack of relationship between trends and time series.

Taking account results for seasonal periods, we see that most amount of trends occur in first group of data. For whole area of Lubuskie Voivideship trend in ‘no precipitation’ group increase in Winter, while in Summer and Spring the trend decrease. Increasing significant trend in winter time occur also in 10 form 17 stations. In Summer and Spring the trends decrease for Lubuskie but data from particular station are not so compatible with general trend for voivodeship, as like trends from Winter period. There can be see both increasing and decreasing trends. For the second group of date there is no trends.

Correlation test results for seasonal periods indicate on weak correlation between dry spells and precipitation above 30 mm/day. The positive correlation occur in Autumn and Spring, in Summer it is negative. On graphs can be noticed that amount of dry spells has decrease in Summer and Spring, and increase in Winter and Autumn. In the opposite in second group of data, precipitation occure more often in Summer and Spring than in Winter and Autumn. Results of test are presented in the Tab.7. and on the Fig. 3-6.

Table 1. Results of correlation analysis for annual time period

Annual time period	No precipitation	Precipitaion ≥ 30 mm/day	Years
No precipitation	1		
Precipitaion ≥ 30 mm/day	0,315	1	
Years	0,377	0,125	1

Table 2. The trend of changes in the number of measurements indicating no precipitation and precipitation ≥ 30 mm / day in years 1981-2021

Annual	No precipitation				Precipitation ≥30 mm/day			
	S	τ	β	p	S	τ	β	p
BOCZÓW	51	0,065	0,08	0,559	12	0,015	0	0,892
BOLESZKOWICE	-130	-0,167	-0,1	0,130	65	0,083	0	0,418
BOROWIEC	278	0,356	0,7	0,001	95	0,122	0	0,249
GIŻYN	-180	-0,231	-0,25	0,037	61	0,078	0	0,459
GOŚCIM	101	0,129	0,235	0,243	30	0,038	0	0,719
GOZDOWICE	236	0,303	0,44	0,006	124	0,159	0	0,117
GRYŻYNA	287	0,368	0,18	0,001	15	0,019	0	0,862
KARGOWA	37	0,047	0,08	0,673	94	0,121	0	0,256
KOSTRZYN NAD ODRĄ	-40	-0,051	0	0,649	56	0,072	0	0,494
KRZESZYCE	-138	-0,177	-0,14	0,110	46	0,059	0	0,570
LUBIĘCIN	223	0,286	0,31	0,010	-40	-0,051	0	0,630
LUBNIEWICE	-109	-0,140	-0,08	0,206	-71	-0,091	0	0,372
LUTOL SUCHY	297	0,381	0,48	0,001	-3	-0,004	0	0,980
MIĘDZYRZECZ	-140	-0,179	-0,2	0,105	-21	-0,027	0	0,801
SULECHÓW	276	0,354	0,46	0,001	1	0,001	0	1,000
ZBĄSZYŃ	369	0,473	0,33	0,000	-68	-0,087	0	0,399
ŻAGAŃ	-350	-0,449	-0,75	0,000	172	0,221	0	0,035
LUBUSKIE VOIVODESHIP	48	0,062	1,215	0,584	51	0,065	0,14	0,560

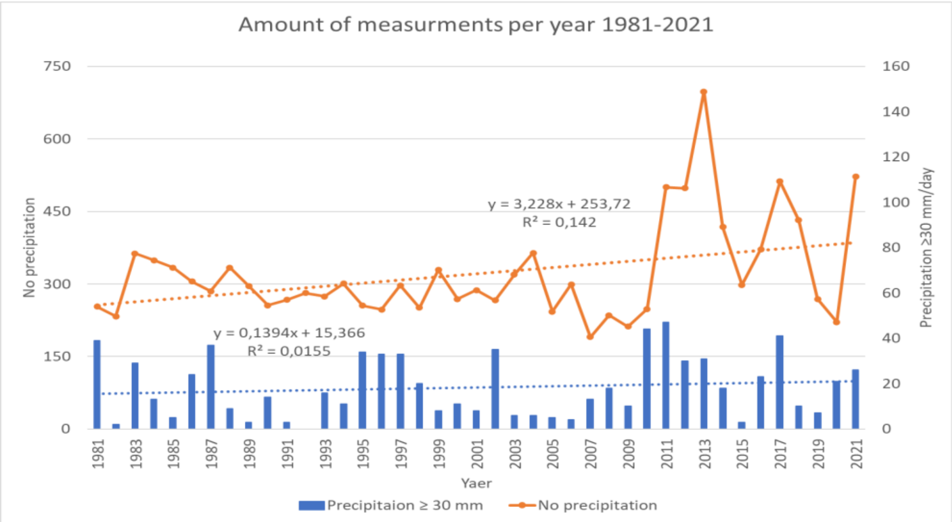

Fig. 2. Amount of measurements per year - 1981-2021. Source: author's compilation based on [24]

Table 3. The trend of changes in the number of measurements indicating no precipitation and precipitation ≥ 30 mm /day in the years 1981-2021 in Winter

Winter	No precipitation				Precipitation ≥30 mm/day			
	S	τ	β	p	S	τ	β	p
BOCZÓW	177	0,216	0,15	0,046	-40	-0,049	0	0,238
BOLESZKOWICE	-26	-0,032	0	0,773	-39	-0,048	0	0,108
BOROWIEC	398	0,485	0,38	0,000	-6	-0,007	0	0,880
GIŻYN	54	0,066	0,05	0,548	-39	-0,048	0	0,108
GOŚCIM	278	0,339	0,25	0,002	-39	-0,048	0	0,108
GOZDOWICE	204	0,249	0,22	0,022	0	0,000	0	1,000
GRYŻYNA	350	0,427	0,09	0,000	-24	-0,029	0	0,486
KARGOWA	218	0,266	0,14	0,014	-39	-0,048	0	0,108
KOSTRZYN NAD ODRĄ	-68	-0,083	0	0,449	-3	-0,004	0	0,960
KRZESZYCE	128	0,156	0,1	0,151	-24	-0,029	0	0,486
LUBIĘCIN	244	0,30	0,24	0,006	0,00	0,00	0,00	1
LUBNIEWICE	-15	-0,018	0	0,873	-24	-0,029	0	0,486
LUTOL SUCHY	262	0,320	0,17	0,003	-39	-0,048	0	0,108
MIĘDZYRZECZ	89	0,109	0,08	0,320	-39	-0,048	0	0,108
SULECHÓW	346	0,422	0,33	0,000	-39	-0,048	0	0,108
ZBĄSZYŃ	312	0,380	0,145	0,000	-39	-0,048	0	0,108
ŻAGAŃ	31	0,038	0	0,735	0	0,000	0	1,000
LUBUSKIE VOIVODESHIP	211	0,257	1,77	0,018	24	0,029	0	0,648

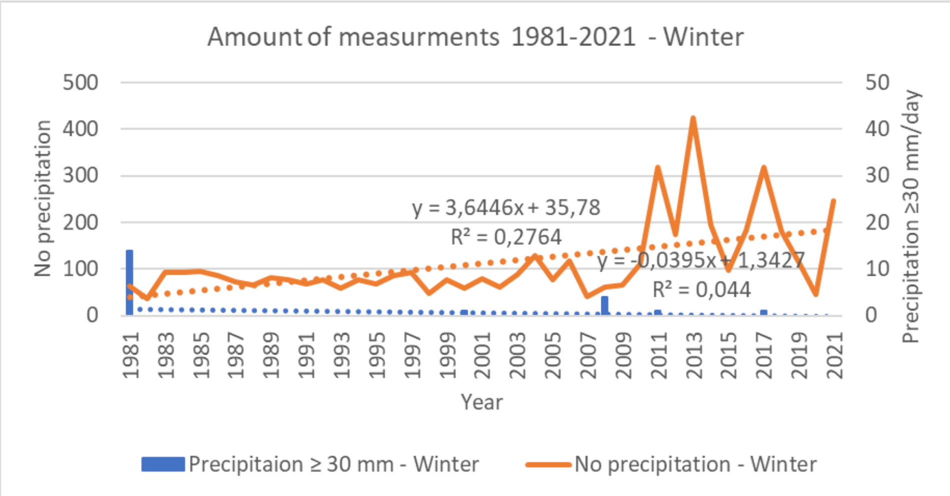

Fig. 3. Amount of measurements per year - Winter - 1981-2021. Source: author's compilation based on [24]

Table 4. The trend of changes in the number of measurements indicating no precipitation and precipitation ≥ 30 mm / day in the years 1981-2021 in Spring

Spring	No precipitation				Precipitation ≥30 mm/day			
	S	τ	β	p	S	τ	β	p
BOCZÓW	-143	-0,174	-0,05	0,106	-23	-0,028	0	0,762
BOLESZKOWICE	-239	-0,291	0	0,003	33	0,040	0	0,580
BOROWIEC	168	0,205	0,095	0,059	65	0,079	0	0,359
GIŻYN	-427	-0,521	-0,145	0,000	35	0,043	0	0,646
GOŚCIM	-84	-0,102	-0,04	0,347	-43	-0,052	0	0,562
GOZDOWICE	58	0,071	0	0,520	59	0,072	0	0,412
GRYŻYNA	12	0,015	0	0,893	-89	-0,109	0	0,220
KARGOWA	-185	-0,226	-0,04	0,035	-21	-0,026	0	0,788
KOSTRZYN NAD ODRĄ	-12	-0,015	0	0,901	-2	-0,002	0	0,988
KRZESZYCE	-246	-0,300	-0,09	0,005	27	0,033	0	0,695
LUBIĘCIN	94,00	0,11	0,03	0,291	-67	-0,08	0	0,335
LUBNIEWICE	-193	-0,235	0	0,015	-73	-0,089	0	0,276
LUTOL SUCHY	237	0,289	0,07	0,005	-17	-0,021	0	0,768
MIĘDZYRZECZ	-224	-0,273	-0,1	0,011	-36	-0,044	0	0,609
SULECHÓW	182	0,222	0,06	0,040	-76	-0,093	0	0,298
ZBĄSZYŃ	310	0,378	0,08	0,000	-51	-0,062	0	0,434
ŻAGAŃ	-295	-0,360	-0,27	0,001	98	0,120	0	0,094
LUBUSKIE VOIVODESHIP	-177	-0,216	-0,505	0,048	-8	-0,010	0	0,937

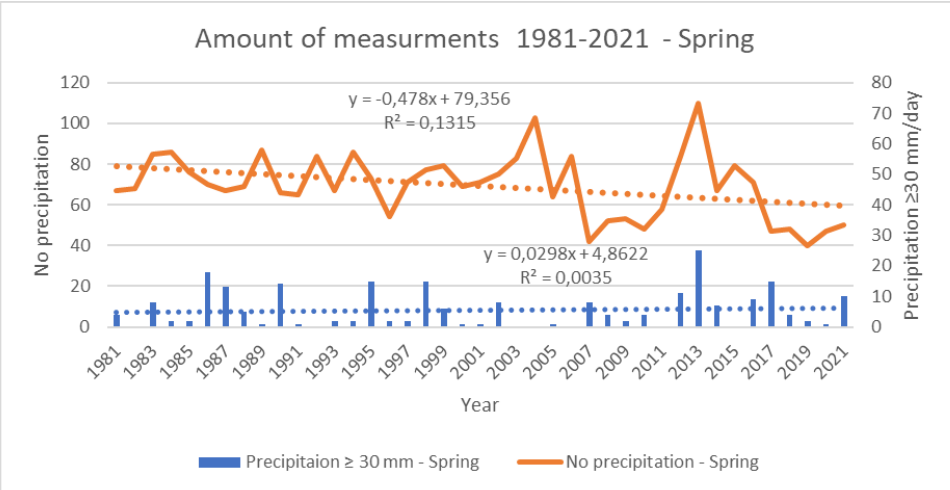

Fig. 4. Amount of measurements per year - Spring - 1981-2021. Source: author's compilation based on [24]

Table 5. The trend of changes in the number of measurements indicating no precipitation and precipitation ≥ 30 mm / day in the years 1981-2021 in Summer

Summer	No precipitation				Precipitation ≥30 mm/day			
	S	τ	β	p	S	τ	β	p
BOCZÓW	-264	-0,322	-0,105	0,003	57	0,070	0	0,477
BOLESZKOWICE	-335	-0,409	-0,03	0,000	58	0,071	0	0,465
BOROWIEC	165	0,201	0,075	0,063	51	0,062	0	0,541
GIŻYN	-247	-0,301	-0,09	0,005	35	0,043	0	0,659
GOŚCIM	-95	-0,116	-0,03	0,286	101	0,123	0	0,208
GOZDOWICE	71	0,087	0	0,428	72	0,088	0	0,340
GRYŻYNA	89	0,109	0	0,256	59	0,072	0	0,468
KARGOWA	-144	-0,176	0	0,094	80	0,098	0	0,332
KOSTRZYN NAD ODRĄ	-71	-0,087	0	0,427	52	0,063	0	0,508
KRZESZYCE	-238	-0,290	-0,1	0,007	11	0,013	0	0,893
LUBIĘCIN	-21	-0,03	0	0,821	-31	-0,04	0	0,711
LUBNIEWICE	-158	-0,193	0	0,046	1	0,001	0	1,000
LUTOL SUCHY	269	0,328	0,05	0,001	45	0,055	0	0,572
MIĘDZYRZECZ	-319	-0,389	-0,1	0,000	24	0,029	0	0,764
SULECHÓW	-21	-0,026	0	0,820	5	0,006	0	0,960
ZBĄSZYŃ	186	0,227	0	0,029	12	0,015	0	0,888
ŻAGAŃ	-366	-0,446	-0,29	0,000	79	0,096	0	0,341
LUBUSKIE VOIVODESHIP	-281	-0,343	-0,79	0,002	80	0,098	0,09	0,374

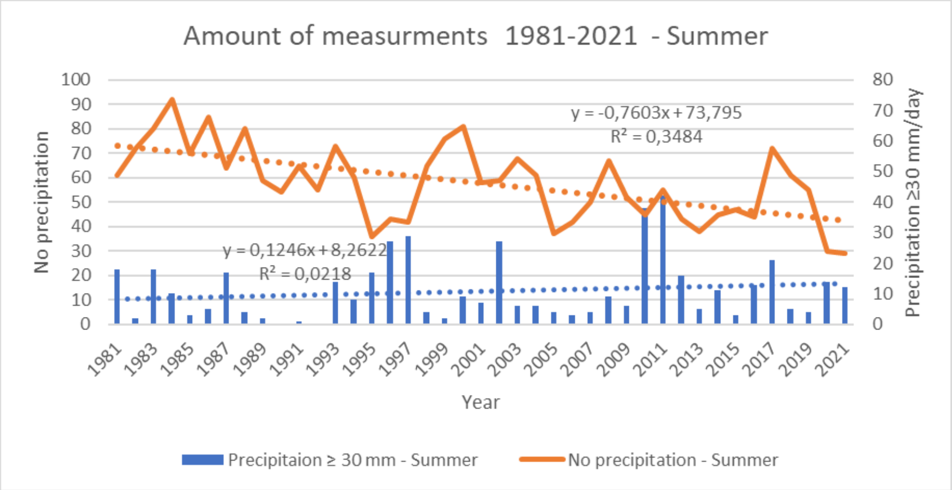

Fig. 5. Amount of measurements per year - Summer - 1981-2021. Source: author's compilation based on [24]

Table 6. The trend of changes in the number of measurements indicating no precipitation and precipitation ≥ 30 mm / day in the years 1981-2021 in Autumn

Autumn	No precipitation				Precipitation ≥30 mm/day			
	S	τ	β	p	S	τ	β	p
BOCZÓW	142	0,173	0,05	0,109	-27	-0,033	0	0,271
BOLESZKOWICE	-146	-0,178	0	0,074	0	0,000	0	1,000
BOROWIEC	221	0,270	0,14	0,013	39	0,048	0	0,108
GIŻYN	-240	-0,293	-0,09	0,007	33	0,040	0	0,333
GOŚCIM	38	0,046	0	0,675	0	0,000	0	1,000
GOZDOWICE	-19	-0,023	0	0,838	0	0,000	0	1,000
GRYŻYNA	14	0,017	0	0,877	0	0,000	0	1,000
KARGOWA	-174	-0,212	-0,05	0,049	39	0,048	0	0,108
KOSTRZYN NAD ODRĄ	-19	-0,023	0	0,838	-27	-0,033	0	0,431
KRZESZYCE	-155	-0,189	-0,04	0,080	0	0,000	0	1,000
LUBIĘCIN	122	0,15	0,07	0,171	12	0,01	0	0,739
LUBNIEWICE	-146	-0,178	0	0,090	-27	-0,033	0	0,271
LUTOL SUCHY	120	0,146	0,04	0,173	0	0,000	0	1,000
MIĘDZYRZECZ	-304	-0,371	-0,115	0,001	23	0,028	0	0,352
SULECHÓW	103	0,126	0,06	0,248	64	0,078	0	0,057
ZBĄSZYŃ	94	0,115	0	0,282	0	0,000	0	1,000
ŻAGAŃ	-332	-0,405	-0,18	0,000	39	0,048	0	0,108
LUBUSKIE VOIVODESHIP	-46	-0,056	0	0,613	93	0,113	0	0,091

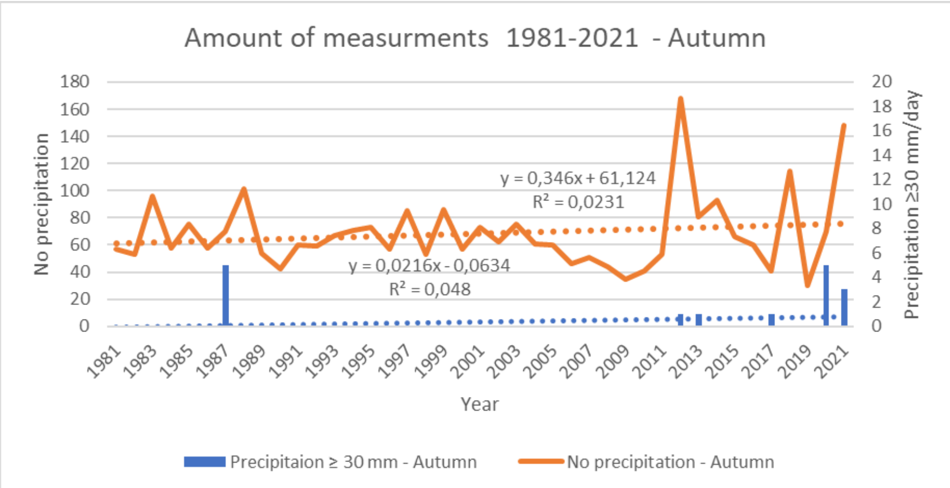

Fig. 6. Amount of measurements per year - Autumn - 1981-2021. Source: author's compilation based on [24]

Table 7. Results of correlation analysis for seasonal time periods

Seasonal	*Years*	*No precipitation - Winter*	*Precipitaion ≥ 30 mm/day - Winter*	*No precipitation - Spring*	*Precipitaion ≥ 30 mm/day - Spring*	*No precipitation - Summer*	*Precipitaion ≥ 30 mm/day - Summer*	*No precipitation - Autumn*	*Precipitaion ≥ 30 mm/day - Autumn*
Years	1,000								
No precipitation - Winter	0,526	1,000							
Precipitaion ≥ 30 mm - Winter	-0,210	-0,071	1,000						
No precipitation - Spring	-0,363	0,104	-0,095	1,000					
Precipitaion ≥ 30 mm - Spring	0,059	0,431	-0,050	0,120	1,000				
No precipitation - Summer	-0,590	-0,272	0,083	0,166	-0,071	1,000			
Precipitaion ≥ 30 mm - Summer	0,148	0,266	0,144	-0,264	0,021	-0,202	1,000		
No precipitation - Autumn	0,152	0,257	-0,126	0,185	0,190	-0,177	0,021	1,000	
Precipitaion ≥ 30 mm - Autumn	0,219	0,116	-0,067	-0,199	0,221	-0,295	0,124	0,264	1,000

4. INFLUENCE OF DRY SPELLS ON GROUND CONDITION

Analysing the intensity of precipitation in the Lubuskie Voivodeship it can't be said that correlation between dry spells and occurrence of more intensity precipitation was found. However scientist around the world observes such correlations. What is more researchers form Czech Republic found correlation between dry spell periods, rains, and increasing number of landslides episodes in Carpathian region. Problem of landslides cause by the correlation of dry periods with intensity rains are discussed in many geoengineering handbooks, and conclusions coming from there, point at that dry spell periods results in lowering ground stability by an increasing number of cracks in the ground, and this same it causes increasing the ground water permeability. When torrential rain suddenly occurs under such condition, it may lead to formation of landslides [9, 15, 16]. A landslide is a geological form that results from gravitational displacement along a slip, runoff, or detachment of rock material [17]. The formation of a landslide is the result of the impact of new forces or a reduction in the shear resistance of the soil and thus the loss of stability by the slope. Stability is defined as maintaining stabilizing and destabilizing interactions in constant equilibrium [18]. This means that a slight change in the balance of power is enough to occur mass movements. Among the many factors affecting stability, slope failure may be the consequence of combination a transient pore pressure in response of a large amount of infiltrating water [19]. The question is may such changes as growing trends of days without precipitation influence on the well-established methods of choosing the dewatering systems? The answer is: 'it depends'. Taking account above results of research and literature review, which shows that even in close area condition of precipitation may be different, following assumption can be taken: apart from hydrogeological conditions, also local trends of precipitation should be analysed before deciding about choosing the drainage systems. Changing in the amount of precipitation can result in changes of pore water pressure, increasing the water permeability, and at this same time lowering the stability of ground. Level of changes and degradation will depend from a kind of hydrogeological conditions. By analyzing the local precipitation conditions, instead of taking account indicators form books for large areas, engineer will have better control under the selecting optimal system of protection against landslides.

5. DEWATERING SYSTEM AS A METHOD PROTECTED AGAINST LANDSLIDES

One of the methods of counteracting mass movements is regulation the water conditions. Infiltration of precipitation water causes changes in the hydrostatic pressure in the soil pores, which next can lead to the formation of runoff pressure, which overcomes the frictional resistance between the medium particles and increases the sliding forces, and consequently lead to formation of a landslide

Controlled lowering of the water table leads to increasing the shear strength, which in turn has a positive effect on the stability of ground. The regulation of water conditions is carried out through the implementation of an appropriate drainage system, i.e. a system of correctly selected technical solutions aimed at limiting the water inflow (passive drainage) or intake of surface and deep waters (active drainage), and discharge to destination point of collection [20, 21].

Depending on the type of discharging water, there are following drainage systems [22]:

- surface systems,
- deep systems,
- combined systems.

In surface systems, there are distinguish sumps and drainage ditches. Sump is a reservoir of water located at the lowest point of the drainage area, from which the pumps and a pipeline systems drain collected water. Whereas drainage ditches are artificial channels for self-draining of water. The advantages of these systems are ease of implementation and relatively low costs of preparation and use. They are useful in rocky soils and hard clay or loam. The disadvantages of these systems are little control over the water level and pore pressure, limited applicability as stand-alone drainage systems and a high probability of water pollution [20].

Among the deep systems, there are horizontal and vertical drainage wells and drains, suction wells, stream wells, supporting wells, wellpoints, siphon drains, a closed-circuit systems [20].

Vertical drains are used to facilitate the vertical flow of water in the ground. They help with acceleration of soil consolidation, lowering the water table, when the flow of water from the drainage layer to the lower layers is limited by the presence of layers with low permeability, or when the water is trapped in the slope, and leaving this water in such place may result in a landslide. Drains are made by drilling a hole with an appropriate length and diameter, and then filling it with easily permeable material such as sand and / or gravel. Vertical drains are made of a water-permeable core surrounded by a geosynthetic filter. These types of drains have a relatively low vertical flow capacity. That is why, there are usually installed linearly at short distances from 0.5 to 3 m [20].

Apart from vertical drains, as well horizontal drains can be used for soil drainage. Horizontal drains are holes made at a small angle and used to drain the stratified formations [22, 20].

Next example of deep drainage system is a drainage well. That are drill holes made from the ground surface with permanently or periodically installed pumps. The purpose of the drainage wells is to depress the water table and thus drain the rock mass [18]. The advantages of running the drainage system with a system of vertical wells include a wide range of operation and the possibility of achieving large lowering of the water table. The disadvantages, on the other hand, are high operating costs and low efficiency in stratified soils [22]. In contrast to vertical wells, horizontal wells as well as horizontal drains are suitable for drainage of stratified soils. Their quantity needed to drain a particular area is less then vertical wells. A significant disadvantage is the high cost of preparation [22, 20].

The other system is wellpoints, in simple terms, it is construction of pipelines with a short perforation (filter), which are placed in the ground in such a way that the filter part is below the target groundwater level. Usually, wellpoints are placed around the trench, keeping a meter distance between them and connecting them to the suction collectors. Then, the collectors are attached to the pump unit that creates a vacuum, which allows water to be sucked in and drained from the system [23]. Wellpoints work well in all types of soil their unquestionable advantages are relatively quick installation and quick impact. The disadvantage, however, is the limited possibility of lifting the water, amounting to max. 6 m [22, 20].

The system used to drain poorly permeable soils such as silty sands or clay is the system of ejector wells. The jet pump forces the fluid into the well. Fluid flowing through the small diameter nozzle and Venturi tube, according to the Bernoulli equation, increases velocity while reducing pressure. This creates a negative pressure, and in consequence, the groundwater drawn into the well and is pumped out together with the pumped medium. The advantages of this system are the lack of restrictions to the head of water, as well as lower construction costs compared to drainage wells. Moreover, it is ideal for pore pressure control. The disadvantages are inefficient and extensive system of water supply and drainage, as well as high operating costs [22].

There are also systems such as electropneumatic and siphon drains. Electropneumatic pumps are installed at the required depth in each well. The compressed air passes from the air compressor through the inlet pipe to the pump, causing the rise of water level in the well. Water fills the pump chamber through the ball check valve at its base. The compressed air pass through the air inlet tube to the top of the pump chamber, filling it with air and forcing the water from the pump through the outlet tube to the ground surface to discharge into the manhole. The ball check valve prevents the pumped water flowing back into the pumping chamber. Electropneumatic drains let for drainage to the depth of 40 m in moderately permeable soils, and can work automatic in a continuous system. One of the advantage of this system is lack of mechanical moving parts in the pump, which significantly reduce repair costs. Necessity of build the additional drainage infrastructure is disadvantage of the electropneumatic systems [15].

The siphon drains system consist of vertical drilled wells, installed within the landslide body in spaced between 3 to 6 m. Wells are drilled so deep as to reach the layers, which need to be drain. Drainage is result of a passively working pumping system, built with small diameter siphon tubes. One end of tube is placed into the bottom of the well. The second end of the siphon tube is placed in a manhole located under the slope, at the same level as the bottom of the tube in the up well. The downstream ends of the tubes are connected with flushing system, which maintain the siphon filled of water. The diameter of the tubes (mostly from 10 to 30 mm) control the volume of water flow from each well. When the water level increase in the well above the bottom of siphon end, water is started to flow downstream of slope through the tube. The flow will continue until the water level in the well falls back to the level of the bottom of the tube. Advantages of such system are possibility to draining soils with poor water permeability and law operating costs. The biggest disadvantage is limited high of water lifting [15].

The drainage system most often used for slopes stabilisation has been collected and compered in terms of the most important factors affecting on their applicability in Table 8. As easy to see, decision about selecting the optimal dewatering system depends on many factors. The map of decision-making process allows to organize the approach of choice the most optimal drainage method by excluding step by step the least suitable systems in particular hydrogeological-atmospherical-economic conditions. The decision-making map is presented in Fig. 7

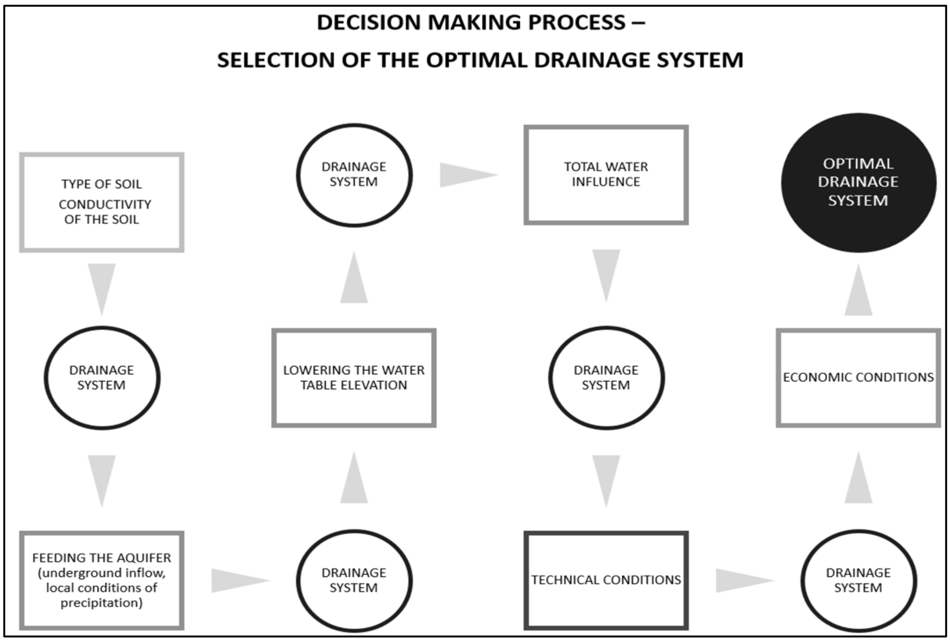

Fig. 7. Decision-making map of choosing the optimal drainage system

Table 8. Comparison of drainage systems and conditions of their use developed on the base of following sources: [16, 25, 21, 23]

System	Conditions												
	Ground				Hydrology								
	Silty and clayey sands	Clean sands and gravels	Stratified soils	Clay or rock at subgrade	High hydraulic conductivity	Low hydraulic conductivity	Proximate recharge	Remote recharge	Control of pore water pressure	Dewatering below the ground level [m]	Wells pattern [m]	Range of capacity per unit[l/min]	Electricity demand [Y/N]
Surface drinage (drainage ditch, sump)	3	4	3	1	3	1	3	1	N	<5	-	INV	Y/N
Vertical dreins	3-2	1	3-2	3	1	3-2	3	1	N	INV	>15	INV	N
Horizontal drains	1(INV)	1	1	1(INV)	1	1	1	1	N	INV	-	INV	N
Siphon drains	1	-	-	1	-	1	1	1	Y	<10	3-6	15	N
Wellpoint systems	1	1	1	2-1	1	1	1	1	Y	<6	1-5	0.4-95	Y
Deep wells	3-2	1	3-2	3	1	3-2	3	1	Y	No limit	>15	0.4-11360	Y
Horizontal wells (HDD)	1(INV)	1	1	1(INV)	1	1	1	1	N	INV	-	-	Y
Ejector system	1	3	1	2-1	3	1	3-1	1	Y	<50	3-6	0.4-150	Y
Suction wells	3	1	3	3	1	3	3	1	Y	<7	6-12	190-2270	Y
Electropneumatic drains	1	-	-	1	-	1	1	1	Y	<40	3-6	35	Y
Vacuum wells	1	-	-	1	-	1	-	-	Y	INV	1-2,5	INV	Y
Electroosmosis	1	-	-	1	-	1	-	-	Y	INV	3-5	INV	Y

Note: 1 – good, 2 – fair, 3 – poor, 4 – unsatisfactionary, INV - need to be investigated, Y – yes, N – no

6. CONCLUSION

Summarizing the above considerations, the following can be concluded:

1. It the article were analysed occurrence of trends in the number of days without precipitation and precipitation above 30 mm/day in 1981-2021 in the Lubuskie Voivodeship in annual and seasonal time period.
2. Data to analysis was taken from 17 meteorological stations located in or nearby Lubuskie Voivodeship.
3. To trends analysis was used Mann-Kendall test and linear correlation test was use to find the correlation between two groups of data.

4. Correlation between dry spells and occurrence of more intensity precipitation was no found for this region. However there is increasing trend for days without precipitation.
5. Scientific publications indicate dependency between dry spell periods, rains, and increasing number of landslides episodes.
6. Changes in the amount of precipitation can result in conversion of pore water pressure, increasing the water permeability, and at this same time lowering the stability of ground.
7. Dewatering systems are one of methods protected against landslides. As condition of precipitation may be different in near area, local trends of precipitation should be analysed.
8. Analyzing the local precipitation conditions, instead of taking account indicators form books for large areas, helps with selecting optimal system of protection against landslides.
9. In order to choose the optimal drainage system, many factors must be taken undern consideration, especially local hydrogeological and atmospheric conditions, as well as technical and economic factors.

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