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Assessment of groundwater quality and rainfall analysis: A review

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ABSTRACT

Groundwater is a critical resource in the hydrological cycle, serving as the source of life and a major component of the earth's water cycle. Groundwater quality is influenced by rainfall patterns and hydrogeological systems, including complex uncertainty factors. Rainfall, measured by intensity and duration, can influence variations in water flow and flood potential, especially in areas with different catchment characteristics. This study analyzed the relationship between rainfall and groundwater quality using an elasticity approach, which is the ratio of the relative change in river flow to the relative change in rainfall. Data were analyzed using elasticities y_1 and y_2 to identify the sensitivity of streamflow to rainfall in wet and dry catchments. Results show that dry areas exhibit higher elasticity to changes in rainfall than wet areas. These findings highlight the importance of rainfall patterns on groundwater quality and the need for stakeholder involvement in water resources management.

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1. INTRODUCTION

The quality of groundwater is affected by the probability of rainfall and flood discharge, both in practical and theoretical contexts. The occurrence of excessive rainfall is affected by the climatological circumstances specific to an area. This study indicates that daily data exhibit a stronger association than hourly data, as hourly data are more affected by convection processes, whereas daily data are further influenced by mechanisms like as large-scale dynamics and orographic effects, which are more prominent on an annual scale.

A approach to assess groundwater quality in relation to rainfall is to employ the idea of elasticity. Elasticity is defined as the ratio of the relative variation in streamflow to the relative variation in rainfall. Years characterised by extreme rainfall events, such as those induced by tropical storms, typically elevate the coefficient of variation (CV) of the rainfall distribution, thus enhancing the steepness of the rainfall frequency curve. The correlation between yearly precipitation and streamflow indicates that streamflow exhibits heightened sensitivity to variations in rainfall throughout arid catchments, attributable to nonlinearities in the runoff-rainfall dynamics.

In wet catchments, the water storage capacity is generally reduced, and the runoff coefficient is typically elevated, hence augmenting the flood discharge likelihood relative to dry catchments. Conversely, in arid catchments characterised by predominant excess infiltration processes, the incident runoff coefficient exhibits greater randomness compared to humid catchments, where the runoff coefficient is more stable and less variable [5]. In instances of severe precipitation and inundation, this susceptibility seems to be elevated in arid catchments. Water resources continue to rely on technocratic and instrumental techniques that do not leverage recent significant scientific advancements in science and policy.

2. THEORITICAL REVIEW

2.1. Groundwater Theory

Groundwater is described as water contained within the soil strata, encompassing both unsaturated and saturated levels. Numerous specialists have articulated the definition of groundwater according to their individual perspectives and areas of expertise. Groundwater refers to a water supply that is finite in both quantity and availability. Damage to groundwater can have extensive repercussions, and recovery is often challenging and costly. Prior to using groundwater supplies, it is essential to comprehend its type and features. Groundwater plays a crucial function in the hydrological cycle, serving both as a component of the cycle and as a vital resource for the sustenance of terrestrial life.

2.2. Precipitation

Precipitation is categorised into two segments: heavy rain and very heavy rain. This classification is predicated on the intensity of rainfall sufficient to potentially induce numerous dangers. The Meteorology, Climatology, and Geophysics Agency (BMKG) establishes a criterion to assess rainfall intensity. Rainfall denotes the accumulation of rainwater on a level surface, excluding evaporation, absorption, or runoff. Rainfall intensity signifies the quantity of precipitation that occurs within a specified duration.

2.3. Territorial Area

Austria's area is 84,000 square kilometres. In the north, east, and southeast, altitudes are below 200 meters above sea level, whilst the highest summits of the Alps exceed 3,500 meters.

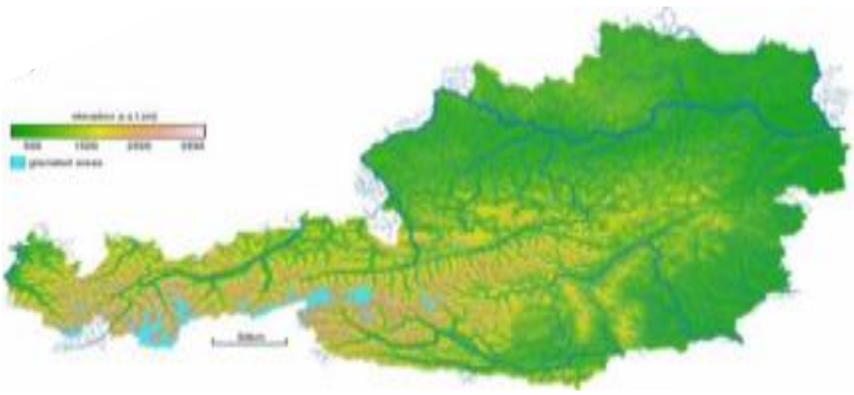

Figure 1. Austrian topography depicting the river network and glaciated regions.

3. RESEARCH METHODS

The management of groundwater quality through various techniques aims to assess the influence of precipitation on groundwater and the extent of uncertainty within the groundwater system. Stakeholder engagement is a critical element for assessing groundwater consequences for several reasons:

- Hydrogeologic processes are intricate and frequently challenging for non-experts to comprehend;
- Uncertainty regarding groundwater consequences is often significant due to variations in groundwater quality.

In instances of significant ambiguity concerning the operation of the hydrogeologic system. Controls may encompass assessments of water levels and groundwater quality. Rainfall can influence groundwater quality. A way to assess groundwater quality in relation to rainfall is elasticity.

4. RESULTS AND DISCUSSIONS

4.1. Elasticity

The elasticity of y_1 in response to variations in rainfall, with d held constant, is illustrated in Figure 2 and represented as a map in Figure 3. In Figure 3, the point size represents the y_1 value for each measured catchment, with the point located at the centre of each catchment. The backdrop pattern is produced by interpolating these values. During the period T = 2 years, the correlation between rainfall and probability exhibits significant elasticity (i.e., y_1) in the lowlands, whereas the Alpine region demonstrates a greater elasticity. Elasticities approaching one, specifically y_1, are illustrated in Figure 2 on the left and in Figure 3 In the glacial area at Austria's highest peak (shown in red in Figure 3), the connection is inelastic ($\ddot{y}_1 < 1$). For the return period T = 100 years (shown on the right side of Figures 2 and 3), the geographical pattern stays consistent, although the elasticity tends to converge towards a value of one.

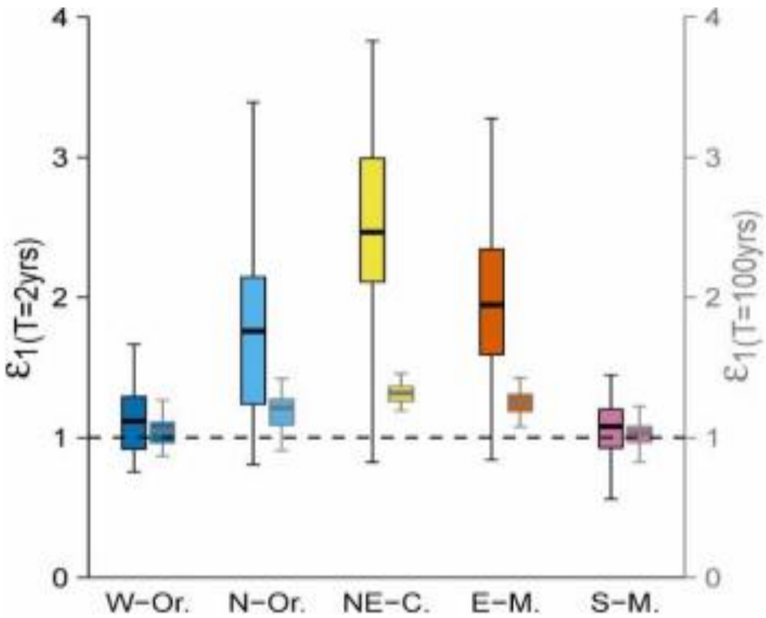

Figure 2. Elasticity of $\ddot{y}_1$ extreme river flow in response to variations in extreme rainfall.

The elasticity y_1 for T = 2 years has a positive association with the coefficient of variation of the runoff coefficient rc_{CV} (rs= 0.59) and the slope of the runoff coefficient rc_{CS} (rs = 0.49). This suggests that y_1 is generally elevated in regions characterised by increased runoff variability and a more asymmetrical runoff distribution allocation of runoff. The elasticity of y_1 signifies the percentage variation in flood discharge resulting from a 1% alteration in extreme precipitation, provided the duration d remains unchanged. The highest y_1 values are located in the arid lowlands of the Northeast and Southeast areas (Figures 2 and 3). For T = 2 years, this elasticity is up to four times the average in the Alpine catchment. Alpine watershed. The elasticity of y_1 approaches unit elasticity as the return period increases, as illustrated in Figures 2 and 3.

The y_2 elasticity of river flow in relation to rainfall varies under the assumption of constant T. The y_2 value for each catchment is assessed at the centre of each catchment, whereas the background pattern is produced via interpolation of the catchment values. A y_2 value approaching one indicates a greater similarity between the duration of flood-triggering rainfall and the period of concentration within the catchment. Conversely, the elasticity of y_2 in Alpine regions, particularly in the torographic areas of the North, is generally lower. y_2 denotes the percentage variation in flood discharge resulting from a 1% alteration in extreme precipitation, presuming a constant return period T. In these areas, the duration of pertinent storms is typically brief due to the prevalence of convective rainfall, which, along with the swift catchment response, accounts for the elevated y_2 elasticity. Conversely, locations exhibiting low y_2 elasticity demonstrate a delayed catchment response.

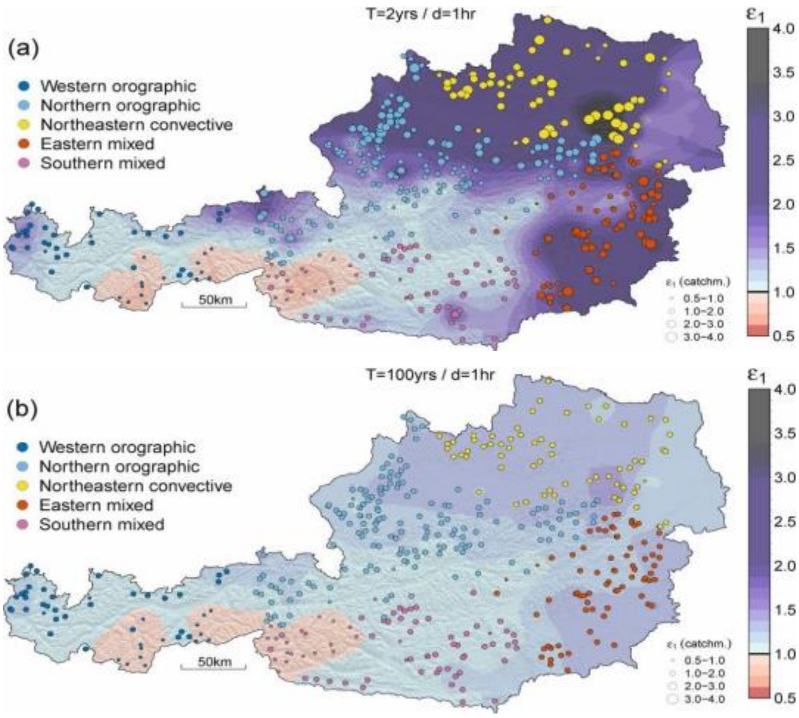

Figure 3. illustrates the elasticity of extreme river flow I_q in response to variations in extreme rainfall, assuming a constant period of d = 1 hour in Austria for (a) T = 2 years and (b) T = 100 years.

5. CONCLUSION

Regions with minimal yearly precipitation, marked by brief and convective rainfall, demonstrate greater flexibility than locations with elevated annual rainfall, where precipitation typically endures for extended periods. The quality of groundwater is profoundly influenced by precipitation patterns and uncertainty in the hydrogeologic system. Due to the intricacy of these processes and their unpredictable effects, proactive stakeholder involvement is essential for efficient management and decision-making.

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