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Historical Moisture Content Analysis for Ash Dam Facility in South Africa

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Abstract - This article articulates a three-year moisture content analysis carried out at the Duvha Ash Dam Facility to identify locations with increasing moisture content values using satellite technology. An increase in moisture content values can be an indicator of failed drainage. For this reason, a historical analysis helps identify locations that have suffered from high moisture content, and this can be validated against historical data held regarding the condition of the ash dam facility. In terms of methodology, the researchers using Soil Moisture Active Passive (SMAP) measured soil moisture. The SMAP mission is an orbiting observatory that measures the amount of water in the surface soil everywhere on Earth. Soil moisture is an important measurement for weather forecasting, failed drainage, drought and flood predictions. The researchers used SMAP radiometers to measure radiation data to calculate water content. The findings were that soil moisture on the ash dam facility stands at 0.09 cm3/cm3. In addition, soil moisture is highest during the summer months at the ash dam facility. During the winter months the soil moisture is low. This makes monitoring of soil moisture generally during the summer months critical. In conclusion SMAP has the advantage of effectively covering large spatial areas at low cost, a regular acquisition of measures over time, and the availability of large historical data archives to perform retrospective studies. However, this technology is yet to be adopted by the South African industry.

Key words: Moisture Content, SMAP, Ash Dam Facility, South Africa

1. Introduction

South Africa is still faced with the challenge of electricity supply, and the future strategy is based on energy mix; with no doubt, coal will still play a major role [1]. Therefore, a successful pilot can lead to optimised productivity by ensuring the smooth running of the power plant and elimination of partial/total shutdown through environmental requirements compliance and maintaining the structural stability of the ash dam facilities (ADF)s [2]. Ensuring ash from power generation has minimal impact on the surrounding environment, vegetation, and ecosystem will contribute to the case for coal as a source of clean energy, thereby improving the Nation's delivery according to global sustainability best practices [3].

2. Literature Review

Soil Moisture Active Passive (SMAP) is a metric used to quantify soil moisture [4]. Everywhere in the world, the SMAP project is an orbiting observatory that measures the amount of water in the surface soil [5]. In agriculture, drought and flood forecasting, weather forecasting, and other fields, soil moisture is a crucial metric [6]. Everywhere on Earth that is not frozen or covered in water, SMAP calculates the amount of water in the top 5 cm of soil [7]. Additionally, it makes a distinction between frozen and thawed ground. SMAP examines the water content between the minerals, rocky material, and organic particles present in soil worldwide, in areas where the ground is not frozen [8]. Ice cannot be measured by SMAP, but it can measure liquid water at the topmost layer of the earth [9]. The amount of water in the soil affects the amount of microwave radiation that is released, yet this energy is present in all types of soil [10]. Microwave energy increases with dry soil and decreases with wetter soil. This radiation is measured by radiometers, and scientists use the results to determine the water content [11]. SMAP monitors radiation in the L-band microwave wavelength (30–15 cm & 1-2 Ghz frequency), because this radiation wavelength can pass through clouds, SMAP can monitor soil moisture in overcast conditions [12].

3. Methodology

The researchers conducted a three-year moisture content analysis along the ADF to identify locations with increasing moisture content values [13]. Increase in moisture content can be an indicator of failed drainage [14]. Historical analysis helps identify locations that have suffered from high moisture content, and this can be validated against historical data held regarding the condition of the ADF [15].

Soil moisture is measured as Soil Moisture Active Passive (SMAP) [4]. The SMAP mission is an orbiting observatory that measures the amount of water in the surface soil everywhere on Earth [5]. Soil moisture is an important measurement for weather forecasting, drought and flood predictions, agriculture, and more [6]. SMAP measures how much water is in the top layer (5 cm) of soil everywhere on Earth not covered with water or not frozen [7]. It also distinguishes between ground that is frozen or thawed. Where the ground is not frozen, SMAP measures the amount of water found between the minerals, rocky material, and organic particles found in soil everywhere in the world [8] (Feng et al., 2024). SMAP measures liquid water in the top layer of ground but cannot measure ice [9]. All types of soil emit microwave radiation, but the amount of water changes how much of this energy is emitted [10]. The drier the soil, the more microwave energy; the wetter the soil, the less energy [11] (Abdulraheem et al., 2024). Radiometers measure this radiation, and scientists use the data to calculate water content [12]. SMAP measures radiation in the L-band microwave wavelength (30–15 cm & 1–2 Ghz frequency) (see fig.1) [4]. This wavelength of energy penetrates clouds, so SMAP can measure soil moisture regardless of cloudy [8].

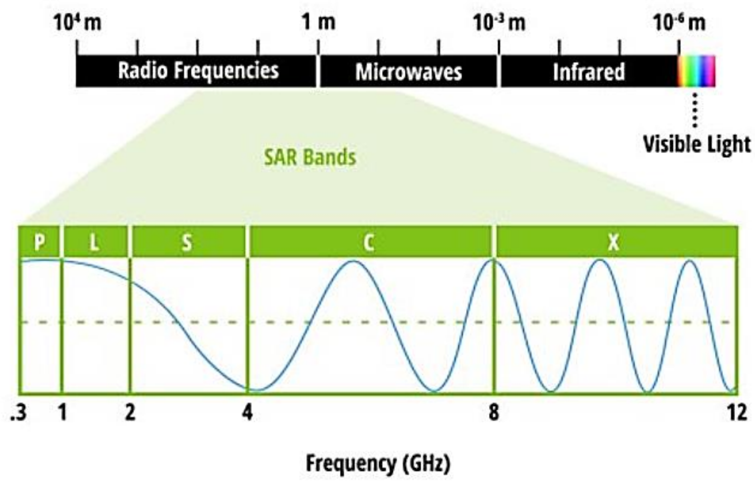

Fig.1: The L-band microwave wavelength that is measured by SMAP. (Source: Researchers).

SMAP was launched in January 2015 and started operation in April 2015 with two instruments onboard to measure soil moisture: an active radar and a passive radiometer (see table 1) [16]. The radar instrument ceased operation in early 2015 due to failure of radar power supply but collected close to 3 months of science data that are available from the Alaska Satellite Facility [17]. The passive L-band radiometer collects daily data at 6 a.m. (descending) and 6 p.m. (ascending) local solar time for complete global coverage every 2–3 days [18]. This permits changes, around the world, to be observed over time scales ranging from major storms to repeated measurements of changes over the seasons [19].

Table 1: The Radiometer of SMAP.

Frequency	Polarization	Resolution	Relative accuracy
1.41 Ghz	H, V	36-km original, 9-km enhanced	1.3 K

SMAP's radiometer collects naturally emitted energy from the surface with a 20-foot-wide mesh antenna that rotates 14 times per minute – the largest such spinning antenna in space [20].

4. Results/Findings

The soil moisture analysis was conducted for the period 2020 to 2024. A measure of the amount of water in the surface soil was carried out. SMAP measured how much water is in the top layer (5 cm) of soil. On average it was found to stand at 0.09 cm3/cm3 due to the ashing and the damming necessary because of the ashing. The researchers selected the dam facility as their area of interest on SMAP visualization App as shown in fig.2.

Fig.2: Selected area of interest on SMAP visualization App. (Source: Researchers).

The researchers then drew a line polygon of study area of the fly ash dam facility and selected a four-year period as shown in fig.3.

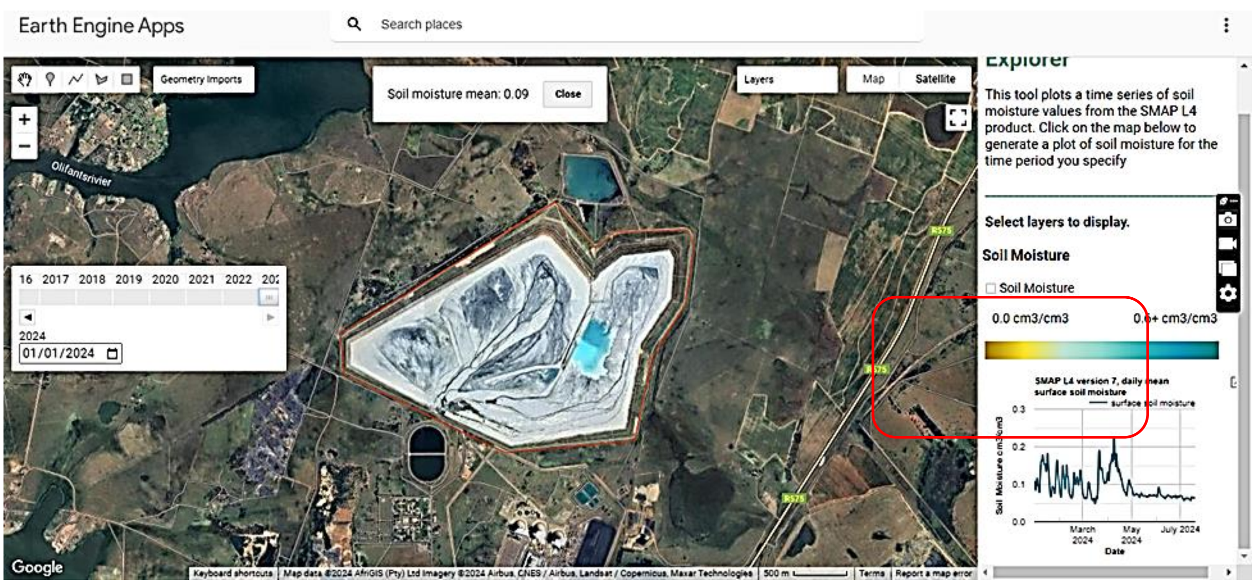

Fig.3: Line polygon of study area. (Source: Researchers).

For visualization we selected the soil moisture tab and compared the resulting values by zooming in and out of our study area. When the researchers selected the stop drawing tab and clicked on the map to reveal soil moisture value, researchers were given a value of (0.09 cm3/cm3) in our case (see fig.4). As is shown in fig.3 (encircled in red) anything above 0.6 cm3/cm3 is considered problematic.

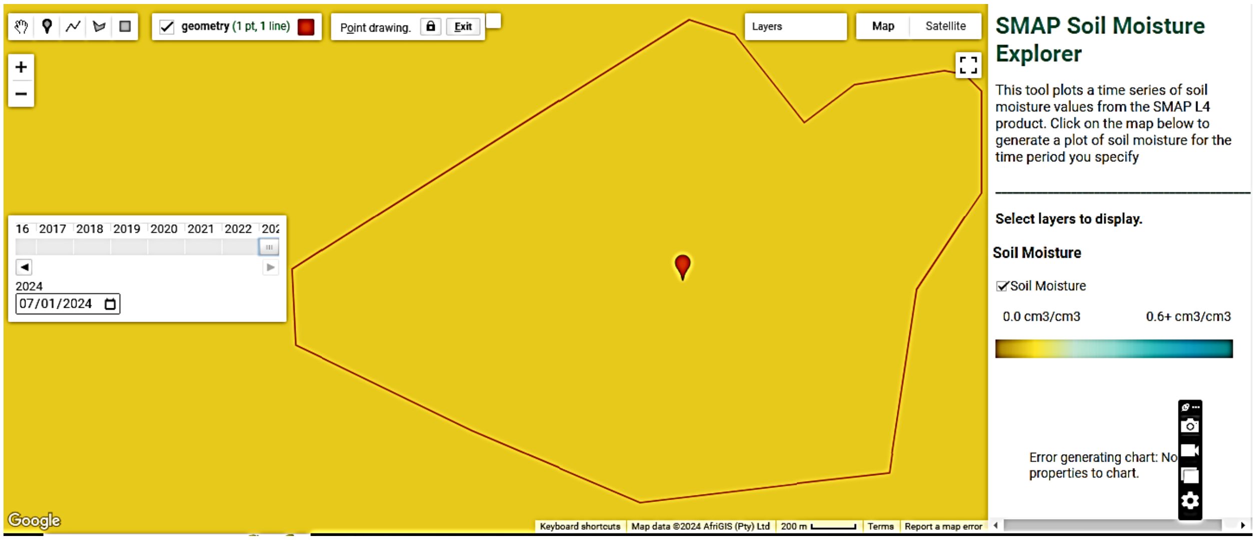

Fig.4: Visualization of selected study area for the soil moisture value. (Source: Researchers).

From fig.5 to fig.9, it's evident that soil moisture is highest during the summer months at the ash dam facility. During the winter months the soil moisture is low. It rains regularly during the summer months. It is perhaps drier in the winter months. Ashing at the fly ash facilities is carried out throughout the year. The water dams are also operational throughout the year. This makes ashing during the summer months critical. It also makes monitoring of soil moisture generally during the summer months critical as well.

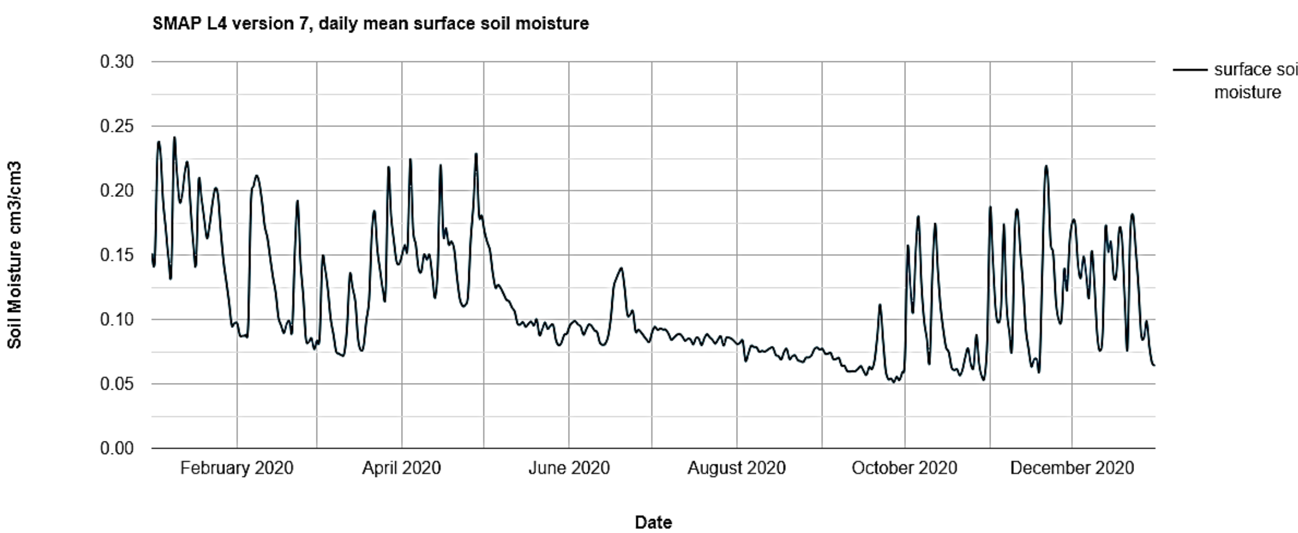

Fig.5: ADF SMAP 2020. (Source: Researchers).

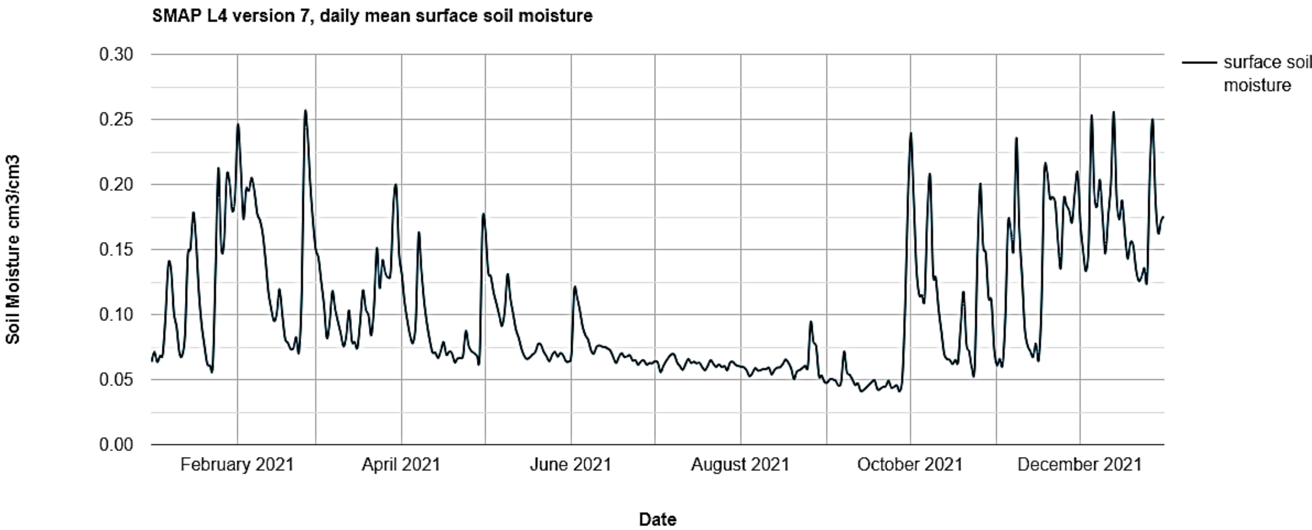

Fig.6: ADF SMAP 2021. (Source: Researchers).

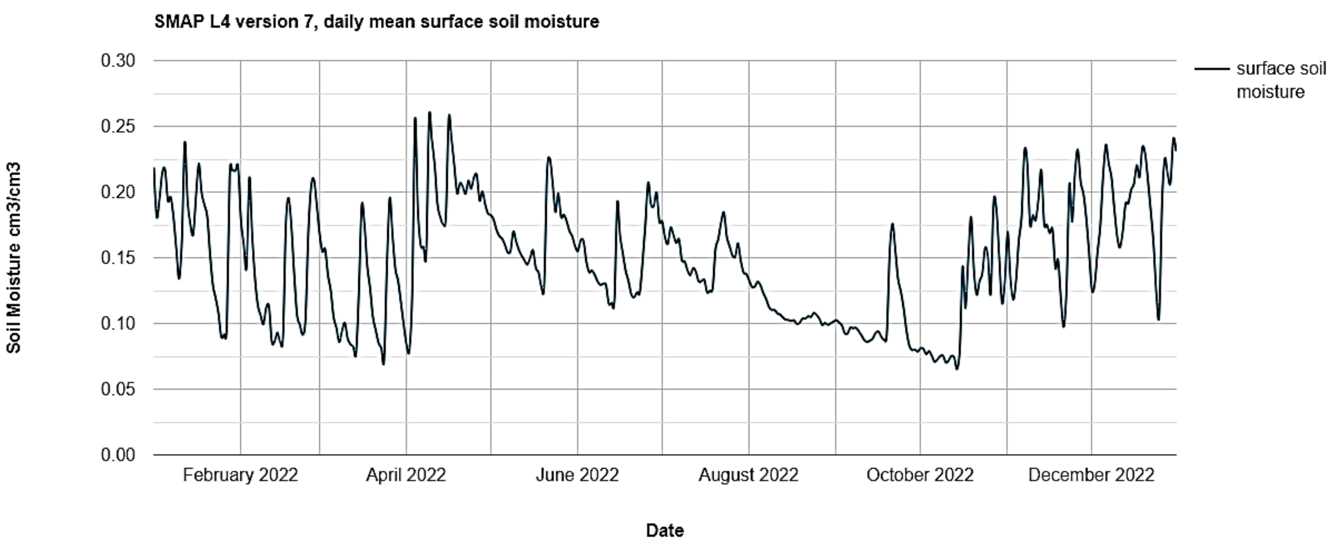

Fig.7: ADF SMAP 2022. (Source: Researchers).

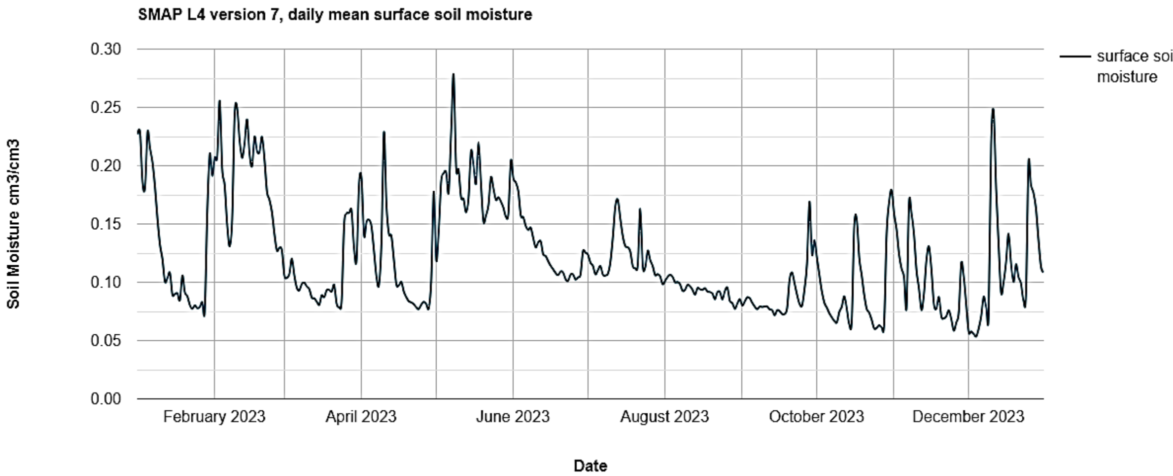

Fig.8: ADF SMAP 2023. (Source: Researchers).

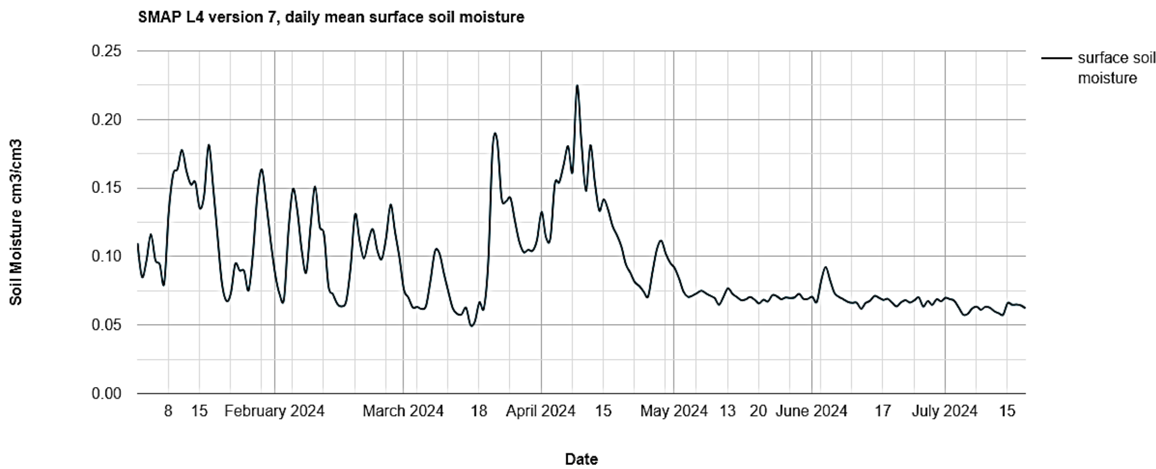

Fig.9: ADF SMAP 2024. (Source: Researchers).

5. Conclusions and recommendations

During the winter months the soil moisture is low. It rains regularly during the summer months. It is perhaps drier in the winter months. Ashing at the ADF is carried out throughout the year. The water dams at the ADF are also operational throughout the year. This makes ashing during the summer months critical. It also makes monitoring of soil moisture generally during the summer months critical as well. The phreatic levels should be closely observed in the summer months. In summary, there is need to investigate whether the triggering parameters have changed with time, to correlate the change in trend of soil moisture with rainfall.

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