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Determination of rainwater harvesting potential in GIS using UAV imagery with machine learning classification

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Abstract

The importance of water is increasing with the growing world population. Therefore, preserving and collecting water is essential for the continuation of life. Rainwater harvesting is one of the long-standing methods of water collection. With advances in Geographic Information Systems (GIS), Unmanned Aerial Vehicle (UAV) based remote sensing and Machine Learning (ML) image classification technologies, it has become easier to calculate rainwater harvesting potential. However, methods need to be customized for different man-made objects. In this study, the rainwater harvesting potential of a building complex with its surrounding marble ground surface located in the Harran University Osmanbey Campus was determined in GIS by using UAV imagery with ML classification techniques. The results showed that a 4153 m^2 grass area can be irrigated every day for a year from this potentially harvested rainwater.

1. Introduction

Turkey is a water-stressed country in terms of the average amount of available water per person per year. It is below the world average with approximately 1500 m^3 (Alparslan et al., 2008; Şahin & Manioğlu, 2011; Yiğit et al., 2020). Therefore, preserving and collecting water is essential for the country.

Rainwater harvesting is a long-standing method used by people all over the world to collect water (Boers & Ben-Asher, 1982). In parallel with Geographic Information Systems (GIS) and Remote Sensing (RS) technologies, methods for calculating rainwater harvesting potential have also developed. In addition, image acquisition techniques such as Unmanned Aerial Vehicles (UAV) and Machine Learning (ML) image classification techniques have facilitated this process.

In literature, there are many studies using GIS and RS techniques to determine rainwater harvesting potential (Campisano et al., 2017; Hari et al., 2018; Mbilinyi et al., 2007; Mwenge Kahinda et al., 2009; Shokati et al., 2021). The majority of the rainwater harvesting potential calculations are based on urban building roofs only. However, different building complexes may need different methods.

In this study, the rainwater harvesting potential for a building complex located in the Harran University Osmanbey Campus was determined in GIS by using UAV imagery with ML classification techniques. The marble surface area on the ground between the building blocks was also taken into account for the rainwater harvesting potential calculation.

2. Method

Calculating rainwater harvesting potential in terms of different impervious surfaces is achieved mainly in five phases: i. obtaining images of the study area from UAV, ii. generating orthophoto of the study area, iii. performing ML classification with the defined parameters, iv. calculating area based on classes and v. calculating rainwater harvesting potential (Fig 1).

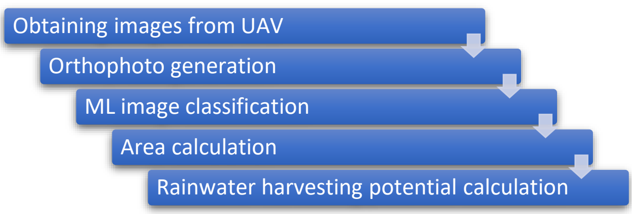

Figure 1. The overall methodology of the study

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The images of the study area were obtained from a UAV (DJI Mavic 2 Pro) with 80 m altitude flight and 70 % overlap for both sides. Orthophoto generation from these images was performed using the Agisoft software package.

To classify image based on surface types, an image classification was needed. Although there are many different algorithms for image classification such as support vector machines, k-nearest neighbor and maximum likelihood, in our case, according to preliminary studies, the random forest algorithm performed the best in terms of time efficiency and visual comparison of accuracy. Therefore, the pixel-based random forest algorithm which is an ML classification method was applied to the orthophoto to identify four surface types of the study area. These classes are soil, green, metal roof, concrete and marble. While these surfaces have different behaviors in terms of rainwater flow, they need to be distinguished in order to calculate rainwater harvesting potential more accurately. However, green and soil areas which are not impervious surfaces were not considered for the rainwater harvesting potential. Thus, metal roof, concrete and marble areas have been calculated from the classified image. Concrete and marble classes were merged due to the similar spectral reflectance and same flow coefficient (see Table 1).

The rainwater harvesting potential for both metal roof and concrete&marble areas were calculated according to Equation 1.

$$rainwater\ harvesting\ p.\,(m^3) = \frac{area \times precip \times coeff \times filter}{1000} \quad (1)$$

To calculate *rainwater harvesting potential* in the equation, the *area* is the surface type area to be calculated, *precip* denotes the average precipitation amount in mm per year which is 460.1 for the Şanlıurfa region (TSMS, 2022), *coeff* is the coefficient for rainwater flow on surface types and the *filter* denotes the filter efficiency coefficient which is 0.9 according to the DIN (1989).

The rainwater flow coefficient for the surface types used in the study area were given in Table 1.

Table 1. The flow coefficients for surface types (DIN, 1989)

Class	Flow Coefficients
Metal Roof	0.9
Concrete	0.7
Marble	0.7

3. Results

The study area is a building complex consisting of the Faculty of Engineering and GAP YENEV (GAP Renewable Energy Research Center) on the Harran University Osmanbey campus (Fig 2).

A total of 172 images were obtained by a UAV flight with the given parameters in the methods section. These images were then used to generate an orthophoto of the study area (Fig 3).

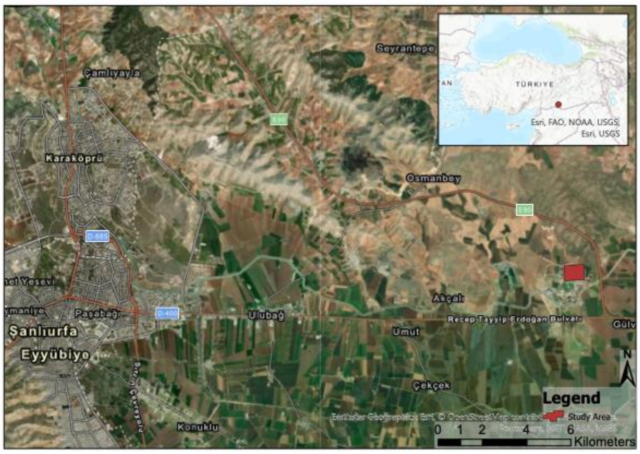

Figure 2. Location of the study area

Figure 3. Orthophoto of the study area

As can be seen in Fig 3, the faculty of engineering consists of several blocks (right) and a circular building of GAP YENEV (left). The joints and gaps between blocks on the ground also are made of marble. This makes it possible to collect rainwater not only from the roofs of the building but also from the marble floor. In order to accurately calculate rainwater potential, surfaces need to be classified. Therefore, the random forest algorithm, one of the ML classification methods for geospatial images, was used. The method parameters were set: 80 for maximum number of trees, 40 maximum tree depth and 1500 maximum number of samples per class. The sample statistics for the training model are given in Table 2.

Table 2. The train samples statistics

Class	Num. of Samples	Pixels (%)
Green	12	13.23
Soil	11	4.79
Metal Roof	5	16.63
Concrete&Marble	42	65.34

The classification was performed with a training accuracy of 0.987. The image of the study area classified into the four surface types is given in Fig 4.

In order to find potential areas for rainwater harvesting, it is necessary to calculate the areas according to the surface types. For this reason, the areas of the surface types subject to the study were calculated from the classified image and given in Table 3.

Figure 4. The classified image of the study area

Table 3. The area and the ratio of the surface types

Class	Area (m²)	the ratio of total area (%)
Green	14613.62	22.2
Soil	11190.61	17.0
Metal Roof	1777.33	2.7
Concrete&Marble	38245.55	58.1
TOTAL	**65827.11**	**100**

According to Equation 1, the rainwater harvesting potential was calculated for concrete&marble and metal roof surface types. The result can be seen in Table 4.

Table 4. The rainwater potential

Class	Rainwater harvesting Potential (m³)
Metal Roof	662
Concrete & Marble	11086
TOTAL	**11748**

A total of 11748 m3 of rainwater can potentially be collected from the study area. According to Erdoğan (2002) and Yiğit et al. (2020), 7.75 m^3/day of water is needed for the irrigation of 1000 m² of grass area. Therefore, with the amount potentially collected, 4153 m² of grass can be irrigated every day for a year.

4. Discussion

The images used for classification were acquired in the afternoon. Therefore, the shadows of the objects affect the classification results. Thus, it should be noted that the time of flight is an important factor and should be closer to noon to obtain images with fewer shadows.

The random forest algorithm can be used for the ML classification of geospatial images. However, it is a parametric method where these parameters can affect the result. These three parameters namely, maximum number of trees, maximum tree depth and maximum number of samples per class can be used by default (respectively: 50,30,1000) or empirically. In this study, these parameters were tested several times with different combinations and decided by a visual accuracy comparison. Although the area of the study is relatively small, the samples used for training are sufficient to cover the surface types and are suitable for application to larger areas.

Accuracy was not assessed in the study, as a visual accuracy comparison seems sufficient for the calculation of rainwater harvesting potential.

Collecting and storing rainwater on marble floors may not be as easy as on building roofs. Therefore, UAV imagery with a high-resolution digital elevation model makes it possible to determine runoff directions and accumulation for accurate storage planning.

5. Conclusion

In this study, a UAV flight was conducted to acquire high-resolution image data of a building complex. These images were then used to generate an orthophoto of the study area. This orthophoto was classified by the random forest algorithm to obtain different surface types of the study area. Based on the classified image, the impervious surface areas were calculated not only for the building roofs but also for the ground marble area between the building blocks. As a result, the rainwater harvesting potential of the building complex was calculated according to different surface types.

Classification of UAV imagery with ML algorithms provides fast solutions in applications such as determining rainwater harvesting potential. In addition, many applications such as solar panel installation on roofs, landscape monitoring and land use/land cover detection can also benefit from this method.

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References

Alparslan, N., Tanık, A., & Dölgen, D. (2008). *Türkiye'de Su Yönetimi Sorunlar ve Öneriler*.

Boers, T. M., & Ben-Asher, J. (1982). A review of rainwater harvesting. *Agricultural Water Management*, *5*(2), 145–158. https://doi.org/10.1016/0378-3774(82)90003-8

Campisano, A., Butler, D., Ward, S., Burns, M. J., Friedler, E., DeBusk, K., Fisher-Jeffes, L. N., Ghisi, E., Rahman, A., Furumai, H., & Han, M. (2017). Urban rainwater harvesting systems: Research, implementation and future perspectives. *Water Research*, *115*, 195–209. https://doi.org/10.1016/j.watres.2017.02.056

DIN-1989–1. (1989). *Rainwater Harvesting Systems—Part 1: Planning, Installation, Operation and Maintenance*.

Erdoğan, O. (2002). *Kocaeli İli Sahil Düzenlemesinin Sulama Sistemi Projelendirilmesi, Masters Thesis*. İstanbul Üniversitesi Fen Bilimleri Enstitüsü.

Hari, D., Ramamohan Reddy, K., Vikas, K., Srinivas, N., & Vikas, G. (2018). Assessment of rainwater harvesting potential using GIS. *IOP Conference Series: Materials Science and Engineering*, *330*(1). https://doi.org/10.1088/1757-899X/330/1/012119

Mbilinyi, B. P., Tumbo, S. D., Mahoo, H. F., & Mkiramwinyi, F. O. (2007). GIS-based decision support system for identifying potential sites for rainwater harvesting.

Physics and Chemistry of the Earth, *32*(15–18), 1074–1081. https://doi.org/10.1016/j.pce.2007.07.014

Mwenge Kahinda, J., Taigbenu, A. E., Sejamoholo, B. B. P., Lillie, E. S. B., & Boroto, R. J. (2009). A GIS-based decision support system for rainwater harvesting (RHADESS). *Physics and Chemistry of the Earth*, *34*(13–16), 767–775. https://doi.org/10.1016/j.pce.2009.06.011

Şahin, N. I., & Manioğlu, G. (2011). Binalarda Yağmur Suyunun Kullanılması. *Tesisat Mühendisliği*, *125*, 21–32.

Shokati, H., Kouchakzadeh, M., & Noroozi, A. (2021). *Designing of Rainwater Harvesting Systems Using Drone*. *14*(48), 73–85. https://doi.org/10.30495/wej.2021.4590

TSMS. (2022). *Turkish State Meteorological Service*. https://www.mgm.gov.tr/?il=Sanliurfa

Yiğit, A. Y., Orhan, O., & Ulvi, A. (2020). Investigation of The Rainwater Harvesting Potential at the Mersin University, Turkey. *Mersin Photogrammetry Journal*, *2*(2), 64–75. https://dergipark.org.tr/en/pub/mephoj/issue/58058/836719