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Evaluation of the quality of climate time series maps extracted from GEE: A case study of Arasbaran Region - Iran

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Abstract

As one of the 13 biosphere reserves of Iran, the precious forests of Arasbaran are exposed to damage caused by climate change. For its protection, management and continuous monitoring, it is necessary to obtain accurate, correct and timely environmental data and information, including climate data. Due to the insufficient number and inappropriate distribution of meteorological stations in the region, the use of (RS&GIS) data in the GEE platform to extract climatic parameters was put on the agenda. These data were prepared either in the form of existing products or by applying valid formulas on satellite images. Daily minimum, daily maximum and daily average temperatures, along with the temperature of the earth's surface every 16 days (resulting from Landsat 8) as well as daily precipitation, monthly cumulative precipitation and daily maximum wind speed, related to the first six months of the year 1400, are from both sources of information mentioned (GEE and the aforementioned meteorological station) were extracted and compared. Examining the relationship between these climate maps (produced in GEE) with the meteorological data recorded at the Jolfa meteorological station (for example), except for the maximum daily wind speed parameter, other parameters of daily cumulative precipitation, minimum, maximum and daily average temperature, showed a good correlation and the data can be trusted.

1. Introduction

Arasbaran forest is a complex and dynamic ecosystem, in which its constituent parts are always in balance. These valuable forests, which were registered in 1977 as one of the 13 biosphere reserves of Iran in the UNESCO Man and Planet Earth program, when they are affected by natural or artificial destructive factors, depending on the type and intensity of the destructive factors, the state of equilibrium or its self-regulation get weak and gradually disappears may be reached. Therefore, it is necessary to protect and support these valuable forests against various environmental and human factors.

For this, we need to obtain accurate, correct and timely environmental data and information for continuous monitoring and optimal management of this unique ecosystem. Collecting the required ecological and climatic data with field methods has been very expensive and time-consuming, and among them, climatic information is of special importance due to its variable and dynamic nature. The use of meteorological climate stations faces serious limitations due to the insufficient number and inappropriate distribution at the regional level (Rahimi and Esmaili, 2009; Kerr and Stroskai, 2003). In this connection, remote sensing and geographic information system (RS&GIS), especially with today's satellites with spatial, temporal, production and radiometric resolution, are suitable for selecting climatic stations with acceptable accuracy and reliability and independent of Geology data is presented.

The important challenge in using satellite images is the huge volume, especially in studies that require downloading multiple and voluminous time series data and heavy processing due to the multitude of parameters required for studies related to forest fires. This problem is well solved by Google Earth Engine (GEE). This system enables users to perform calculations on a large amount of data (from a spatial resolution of 10 meters to several kilometers) without the need for high-powered systems. This system hosts a huge database of satellite image data, which includes images from more than forty years ago.

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These images, which are captured daily, include a searchable data catalog including the entire Landsat satellite catalog (USGS/NASA), multiple MODIS sensor data sets, Sentinel-1 satellite data, NAIP (National Agriculture Imagery Program) data, Rainfall data, sea surface temperature data, weather data ,CHIRPS (Climate Hazards Group InfraRed Precipitation with Station) and altitude data (Gurlik et al., 2017).

The purpose of the research is to use the remote sensing technology and the technical capabilities of the GEE system in order to compensate for the lack of climatic data resulting from meteorological stations in a cold semi-humid forest area in the middle latitude of the earth.

2. Method

In order to include the climatic parameters in this research, due to the limited number and long distance of the stations on the one hand and the extreme topography and diverse land covers of the region on the other hand, which has caused the creation of different microclimates in the region. Practically, the use of interpolation and zoning methods to apply climatic parameters to the entire region will not be logical and reality.

Therefore, in this research, the use of hourly, daily or monthly climate data resulting from telemetry data in the GEE was considered. These data were prepared in two ways; In the form of ready data available on reliable sites (Product) or by applying accepted scientific formulas and relationships (citing reliable articles and sources) on different bands of satellite images and achieving the desired climate parameter which is applied to each pixel according to the dimensions and reflection of each pixel (spatial and spectral resolution).

Therefore, regardless of the type of topography and land cover, the climate parameter is applied to each pixel independently of other pixels. The type of climatic data extracted from the telemetry data used in this research and the source of their preparation are shown in the following tables.

Table 1. The type of climate data extracted from telemetry data used in the research

Dataset Availability	period	Image level	Satellite OR product
2013-04-11 - 2021-12-11	7:37:48 AM	Level 2, Collection 2, Tier 1	Landsat 8
1979-01-02 - 2020-07-09	Daily	Climate Reanalysis Produced by ECMWF / Copernicus Climate Change Service	ERA5
1981-01-01- 2021-09-29	Hourly	Land Hourly - ECMWF Climate Reanalysis	ERA5
1958-01-01 - 2020-12-01	Month	Monthly Climate and Climatic Water Balance for Global Terrestrial Surfaces, University of Idaho	TerraClimate
1981-01-01 - 2021-11-30	Daily	Climate Hazards Group InfraRed Precipitation with Station Data (Version 2.0 Final)	CHIRPS
2009-01-01 - 2021-11-11	10 days	Actual Evapotranspiration and Interception	WAPOR

2.1. Study area

Arasbaran or Qara Dagh is a vast mountainous area in the north of East Azarbaijan province in the northwest of Iran. In 1976, UNESCO registered 72,460 hectares of the region's land as a biosphere reserve. UNESCO's general description is as follows; This biosphere reserve is located in the Caucasian mountains of Iran near the country's border with the Republic of Azerbaijan and Armenia. The region, being located between the Caspian, Caucasian and Mediterranean regions, includes high mountains, alpine meadows, semi-arid plains, pastures and forests, rivers and springs. An area equal to 634,719 hectares (about 4 times the pure area of Arasbaran forests) was selected according to Figure 1, including the uses of forest, pasture, agriculture, residential and water areas. Arasbaran and Dizmar National Park and Protected Area and parts of Kental National Park and Kiamaki Wildlife Sanctuary are included in the study area. The altitude range of the study area ranges from 187 meters in the northeast of the region in Larijan to 3254 meters in the Kantal peak in the west of the region. The most important river is Aras in the northern border of the region, where Selenchai, Kaleybarchai, Setenchai, Ilganehchai, Mardanqomchai and Hajilerchai rivers flow into Aras River from east to west respectively.

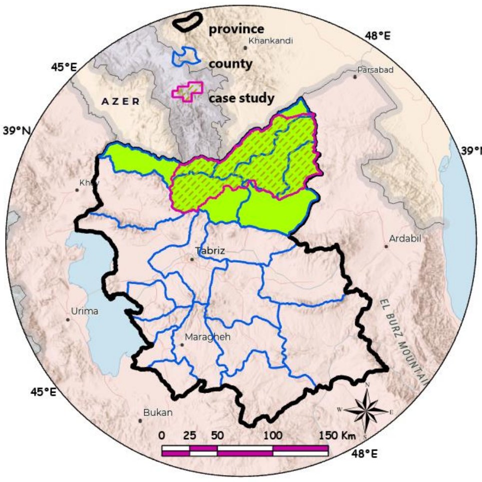

Figure 1. Case study

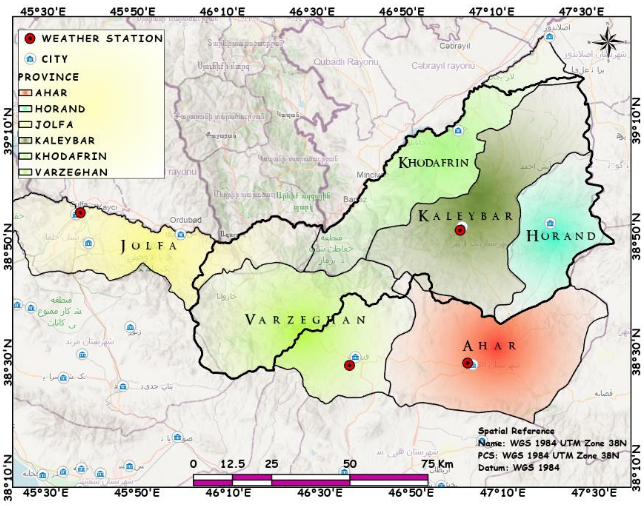

Figure 2. The location of the closest meteorological stations to the study area

3. Results

In this research, climate maps were produced from Landsat 8 and Sentinel 2 satellite images, which are available in the GEE database, by applying known and confirmed formulas and Indicators. As an example, some of the maps produced for the entire study area are given below (**Figure 3-7**).

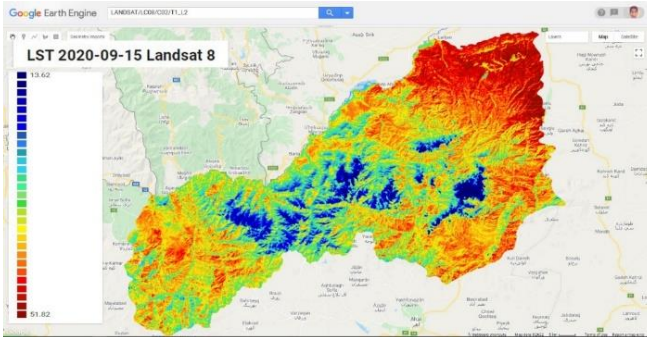

Figure 3. Land surface temperature (LST) .prepared in GEE based on Landsat 8

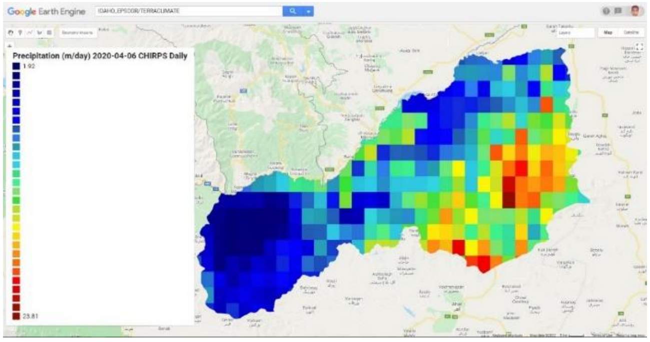

Figure 4. Daily rainfall, prepared in GEE.

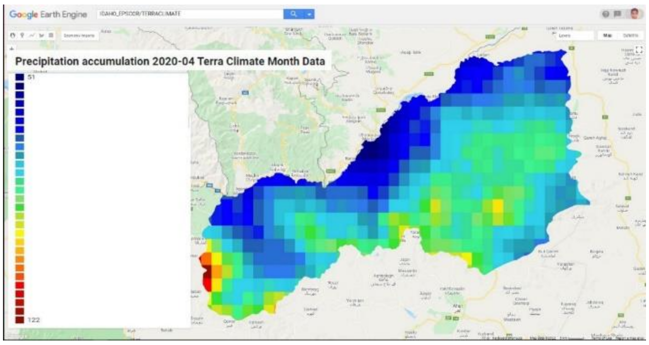

Figure 5. Cumulative monthly rainfall map, prepared in GEE.

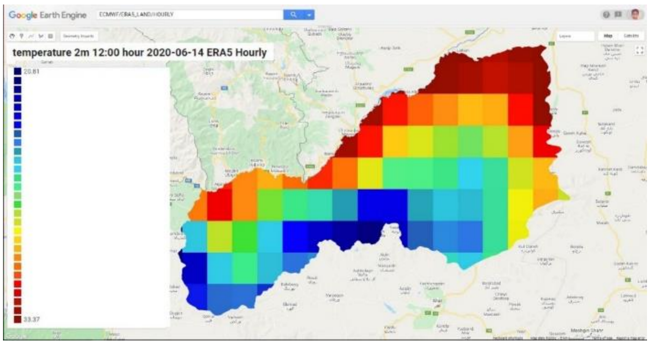

Figure 6. Hourly temperature map, prepared in GEE.

3.1. Evaluation of climatic data extracted from GEE in comparison with meteorological station data

In order to validate the mentioned data, one of the meteorological stations (Jolfa meteorological station) and the climate data downloaded or produced based on the formulas and relationships compiled with the hourly and daily data of the existing meteorological stations were compared and assessed for accuracy. For this purpose, the data: daily minimum, daily maximum and daily average temperatures, along with the temperature of the earth's surface every 16 days (extracted from Landsat 8) as well as daily rainfall, monthly cumulative rainfall and daily maximum wind speed, related to the first six months of 2021 was extracted and compared from both mentioned sources of information (GEE and the mentioned meteorological station). The comparison of these statistics actually showed how much the climate maps extracted from remote sensing in the GEE can be trusted.

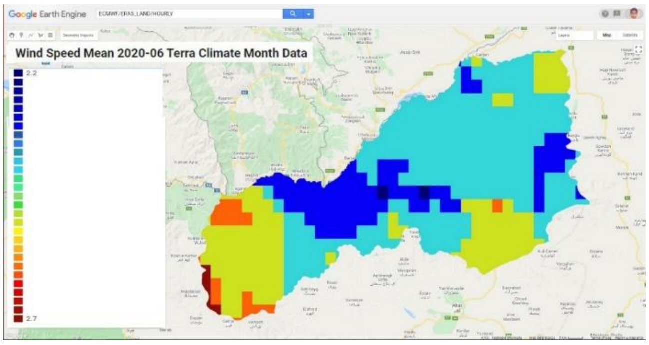

Figure 7. Average monthly wind speed map, prepared in GEE.

According to Figure 8 there is a very strong correlation between the temperature of 10 specific days in the first six months of 2021, obtained from the Landsat 8 satellite image, and the temperature of the meteorological station on the same days. With the explanation that the temperature obtained from the satellite image is higher than the temperature of the station during the days, which will be applied when entering the temperature map in the process of the necessary calibration. Figure 8 shows the relationship between the daily maximum wind speed between the original data from the ERA5 product site and the meteorological station, that the fluctuations of the meteorological station data are more intense and with more details, while the data from GEE has less fluctuations and a lower amount. Although the data of the meteorological station is more precise and accurate in point form, but if the goal is to produce a climate parameter map for the entire region and each pixel of the image, the accuracy and precision of the map obtained from the meteorological data is definitely lower due to the long distance and low density in the area will not be reliable and dependable.

According to Figure 8, the relationship between the daily cumulative precipitation of telemetry data and meteorological station is strong and it shows the appropriate accuracy of telemetry data. Figures 8, which respectively deal with the relationship between the minimum, maximum and daily average temperature of telemetry data with meteorological station, also shows a good correlation.

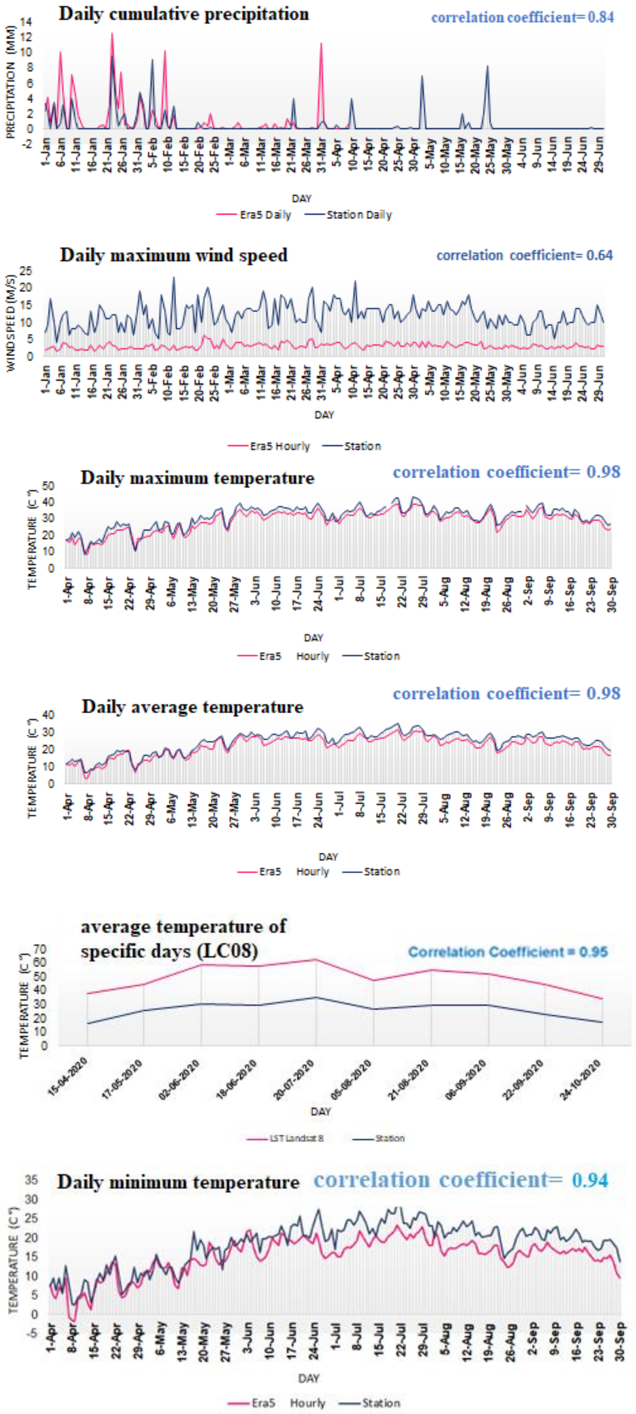

Figure 8. The relationship between the telemetry and the meteorological stations data.

4. Conclusion

The precious Arsbaran forest is a complex and dynamic ecosystem, in which its components are always in balance. When it is affected by natural or artificial destructive factors such as fire, according to the type and severity of the destructive factors, its balance or self-regulation may weaken and gradually disappear.

Preparing a map of burnt areas in the forest and pasture, as well as collecting the ecological and climatic data needed to study the fire, with field methods is very costly and time-consuming and the use of climate data from weather stations faces serious limitations in terms of using interpolation and zoning methods due to the insufficient number and inappropriate distribution in the region. In this connection; remote sensing and geographic information system (RS&GIS) are useful tools.

The purpose of the present research; The use of RS&GIS technology and the technical capabilities of the GEE system was aimed at compensating for the lack of climatic data extracted from meteorological stations in the forests of Arasbaran.

Therefore, in this research, the use of hourly, daily or monthly climate data resulting from telemetry data in the GEE was considered. Examining the relationship between these climate maps (produced in GEE) with the meteorological data recorded at the Jolfa meteorological station, except for the maximum daily wind speed parameter, other parameters of daily cumulative precipitation, minimum, maximum and daily average temperature of the telemetry data showed a good correlation with the meteorological station and can trust these datas.

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