sustainability

Article

Sustainability by Using IoT-PWS Data and Remote Sensing and Geographic Information Systems Technology in Erasmus+ Supported Project: The Case of Antalya/Aksu

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Abstract: Due to climate change, situations that threaten humanity, such as temperature increases, drought, forest fires, sea level rise, erosion, floods, and migrations, are gradually increasing. Understanding climate change has gained more importance day by day due to the negative effects of disasters. Quantitative spatial analyses were carried out with the help of Remote Sensing (RS) and Earth Observation (EO) technology using Geographic Information Systems (GIS) by establishing an Internet of Things (IoT) Meteorological Station (IoT-PWS) with Erasmus+ support. The dataset consists of Road, Meteorological Station, Climate (Temperature, Wind Speed), Land Use—Land Cover (Copernicus LULC), and Population data. As a result of the findings of the research, it was determined that IoT-PWS has a positive contribution to many areas such as agriculture, traffic, scientific studies, local administration, and local public information in the region, and the positive contribution will continue as the station data flow continues. The study is designed as a guide to the use of GIS, RS, and EO technology for educators working on curriculum renewal and project implementation in the field of Environment and Combating Climate Change, one of the four key priorities of Erasmus+. The study contributes indirectly to all indicators in the Sustainable Development Goals as well as directly contributes to Goal 11, Goal 13, and Goal 15.

Keywords: Erasmus+; climate change; GIS; remote sensing; earth observation; meteorological station; IoT-PWS-PWS; sustainability; earth observation; SDGs

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1. Introduction

Climate change threatens humanity by causing negative changes in the air, land and sea due to global warming and increases in greenhouse gases. This situation negatively affects terrestrial life and life in the seas. [1].

One of the most important tools in combating climate change is education and raising social awareness. For this purpose, various projects have been carried out for some time in order to include climate change, and GIS topics in the education system. The common aim of the projects is to increase the use of spatial analysis methods, to specialise in GIS-RS-EO, and to extend the use of professional tools. Many countries and organisations have worked on GIS, EO, and climate change in the past. Examples of past activities are listed below to give information.

The Geographical Society of the United Kingdom encourages studies on climate change to be carried out using EO methodology and makes the necessary materials available on its website [2]. The iGUESS2 project was carried out to inform geography teachers in the European Union (EU) countries about GIS topics. Within the scope of the project, studies on disaster and global warming, which are sub-headings of climate change, as well as examples of the use of GIS, RS and EO technology were carried out in the practice [3]. Reseau Canop of the French Ministry of Education has developed a course curriculum and course materials to increase the use of GIS technologies by geography teachers in the classroom [4]. Apart from European countries, developed countries have also used GIS, RS and EO technology in education and project studies. In 2010, in the USA, studies were first started to be carried out in order to gain professional competence at the high school level and have been used intensively until today [5]. In Greece, it was aimed to establish an EO methodology in providing climate change training. Monitoring of cases such as natural disasters, floods, sea rise and forest fires were carried out. Monitoring of natural disasters, floods, sea rise and forest fires was carried out [6]. The European Space Agency (ESA) and The European Space Education Resource Office (ESERO) provide the necessary materials for EO in the member states of the European Union. These materials are available at various levels from basic to advanced. The fact that the training materials are in the form of free software and documents makes their use widespread.

Science-Technology-Engineering-Mathematics (STEM) and European Action Plan for the Mobility of University Students (ERASMUS) activities have an important place in the efforts to combat climate change today. The Ecomet project 'Erasmus KA 220 VET Ecology and Meteorology' was carried out in cooperation with Turkey, Serbia and Portugal. Within the scope of the project, installation of IoT-PWS, acquisition of data, obtaining reports and map findings from the data using RS and GIS technology, and interpretation of these outputs were carried out. Road, Meteorological station coordinates, Climate (Temperature, Wind Speed), Land Use—Land Cover (Copernicus LULC), and Population data were used. Some of the data used in the research were obtained from the open data platforms of the organisations, and some of them were obtained by us by using RS and GIS techniques.

In this study, the Ecomet project 'Erasmus KA 220 VET Ecology and Meteorology' used RS and GIS methodology. The findings of the region's Road Network Information, Spatial Distribution Information of Meteorological Stations, Climate Characteristics, Land Use-Land Cover Information, and Population Distribution Information were obtained as table and map outputs. In line with the findings obtained, the following findings were also collected for the characteristics of the project implementation phase:

- High Density Road Network
- Dense Population
- Dense Building (construction area)
- Densely cultivated area (Crop)
- Low density Grass
- Low density Water
- Defined as prone to flooding Flooded Vegetation

According to the results obtained, it was determined that the IOT-PWS established within the scope of the project will make a positive contribution to decision-making authorities and local people in the fields of traffic, agriculture, and public health in the region. It was identified that RS and GIS technology made significant contributions to the acquisition and interpretation of the findings in the study. Meteorological data are of great importance for decision-makers in climate change studies. The data used are Ground Meteorology data, UAV-based data, Aircraft-based data, and Satellite-based data. The data were spatially analysed using open-source software QGIS 3.38, Python2.7.12, and R4.4.1. The model proposed in this study is determined to be a guide for researchers and project coordinators who will work on this topic. The use of IoT-PWS stations will increase the accuracy of interposlayon maps produced with climate parameters.

With the increase in the severity of climate change, the negativities experienced in many topics such as water scarcity, hunger, poverty, and migration are increasing as well. In environmental sustainability and climate change studies, IoT-PWS technology provides the information source required for technical struggle and raising awareness of societies [7].

With this study, the IoT-PWS model provides the necessary information source in the field of renewable energy such as solar and wind. The data obtained with this model can be used in productivity analyses. In agricultural studies, model data are used as data layer in studies such as drought, harvest time determination, and irrigation. It is of great importance for farmers to make the right decision and strategy in their precision agriculture activities. In Disaster Management studies, model data contributes to the monitoring of drought, migration, and environmental pollution, which are medium- and long-term disasters, in planning and immediate and post-disaster rehabilitation studies. In emission-reduction studies, the air pollution sensors in the model are also associated with meteorological data, and spatial data are provided to decision-makers, which enhances the planning of experts [8].

In terms of sustainability, the study presents a model that will contribute to the achievement of the United Nations' Sustainable Development Goals (SDGs) by utilising the concepts of RS, GIS, EO, and Erasmus. Explanations of Goal 11, Goal 13, and Goal 15, to which it directly contributes, are provided below.

Goal 11: Make cities inclusive, safe, resilient, and sustainable: IoT-PWSs fulfil the task of determining the living comfort areas required in the city planning study and providing data for the city to be resistant to climate change.

Goal 13: Take urgent action to combat climate change and its impacts: IoT-PWSs provide an important contribution in terms of increasing the spatial resolution in obtaining climate data required for monitoring climate change. In light of these data, climate planning and policy determination can be provided.

Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss: IoT-PWSs contribute to the monitoring and management of forest and wildlife natural resources. It contributes to the prevention and intervention of environmental threats and destructive events such as forest fires and biodiversity studies, and indirectly provides information to other sustainability studies [8]. Apart from these indicators, it contributes to the planning, management, and process evaluation sections of the indicators by providing data for other indicators to which it contributes indirectly.

2. Study Area

The centre of our study area is the campus area of Aksu Aircraft Maintenance Technology Vocational and Technical High School in the Aksu district of the Antalya province. In the IoT-PWS maps in Figure 1 below, Antalya province meteorological stations are shown in blue and IoT-PWS is shown in red.

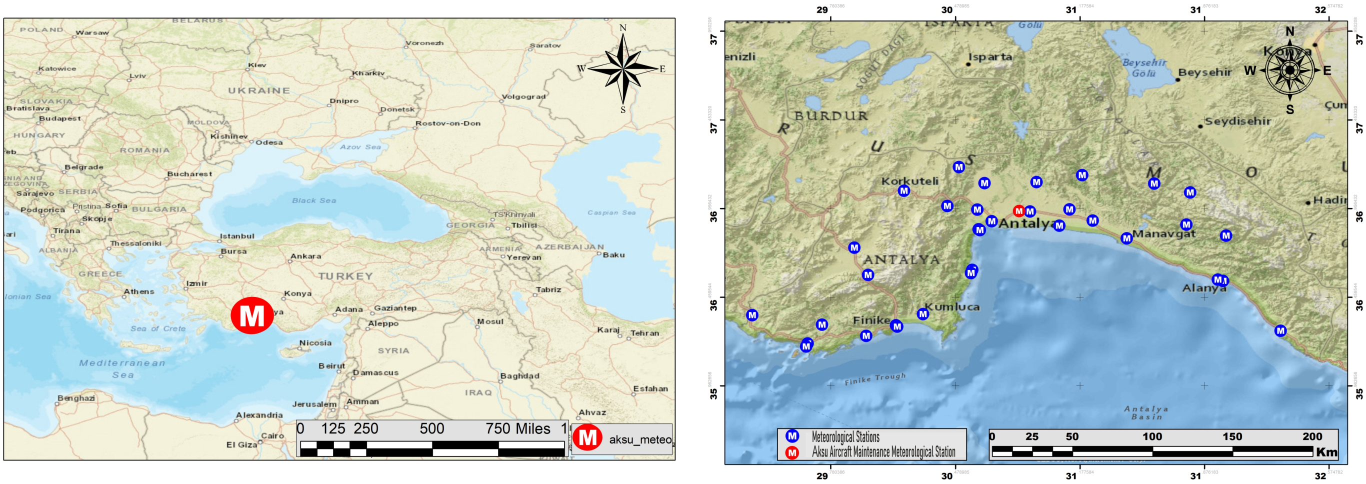

Figure 1. IOT-PWS Location.

3. Datasets, Methods and Analysis

3.1. Datasets and Preparation

Roads (OpenStreetMap, OSM), Meteorological stations (General Directorate of Meteorology, MGM, Land Use and Land Cover (Copernicus, Land Use and Land Cover, LULC), Population (WorldPop_GP_100m_pop, WorldPOP), Climate (IDA-HO_EPSCOR_TERRACLIMATE, Temperature, Velocity), and IoT-PWS information are shown in Datasets in Table 1.

Table 1. Datasets.

Datasets		
OSM	https://www.openstreetmap.org/ (accessed on 14 August 2024)	
Layer Description	OpenStreetMap Road data	OSM open sources
Layer Name	Road	
Layer Type/Unit	Vector data/Unitless	
MGM	https://www.mgm.gov.tr/kurumsal/istasyonlarimiz.aspx?il=Antalya(accessed on 14 August 2024)	
Layer Description	Meteorological station coordinates	MGM station data
Layer Name	mgm_ist	
Layer Type/Unit	Vector data/Unitless	
LULC	https://land.copernicus.eu/en/products/corine-land-cover (accessed on 9 August 2024)	
Layer Description	Land Use and Land Cover	LULC open sources
Layer Name	lulc	
Layer Type/Unit	Raster/m^2	
World Pop	https://developers.google.com/earth-engine/datasets/catalog/WorldPop_GP_100m_pop (accessed on 14 August 2024)	WorldPop_GP data
Layer Description	Population data	
Layer Name	worldpop	
Layer Type/Unit	Raster data/Number of people per unit	

Table 1. *Cont.*

Datasets		
Climate Data	**https://developers.google.com/earth-engine/datasets/catalog/IDAHO_EPSCOR_TERRACLIMATE** (accessed on 14 August 2024)	Terraclimate data
Layer Description	Monthly data on climate and climatic water balance	
Layer Name	terraclimate	Temperature, Velocity
Layer Type/Unit	Raster/meter	
IOT Meteorology Station Data	https://weathercloud.net/ (accessed on 20 August 2024)	weathercloud.net data
Layer Description	IOT-PWS measurement data	
Layer Name	tiotws	
Layer Type/Unit	Text/°C, hPa	

The data source, data name, and data characteristics of the above data are shown. Additional explanations for these data are given below where relevant.

3.2. OpenStreetMap (OSM)

OpenStreetMap (OSM) is a volunteer-driven data source. Updates are provided by data input by volunteers. Data can be downloaded in GIS data format. In this study, road data and neighbourhood data were obtained using the code.

In the study, road data were obtained from OSM data source, an open-source data platform. The data are divided into multiple subgroups such as Grade 1 and Grade 2. In our study, roads in the first-degree important group were included in the study. This group includes state, provincial, and international road types. The data-collection years are 2015 and 2000 [9].

3.3. General Directorate of Meteorology (MGM)

The organisation carries out the collection and operation of atmospheric meteorological information in order to provide citizens with meteorological information of the country. The General Directorate of Meteorology is a governmental organisation that provides weather forecasts and warnings of weather events. It is under the Ministry of Environment, Urbanisation and Climate Change [10,11].

Meteorological events such as temperature and precipitation are one of the important factors that cause accidents on the roads. It has been determined that drivers' behaviours are badly affected in adverse weather conditions such as rainy, snowy, icy, and foggy conditions. Behaviours such as speed reduction and sudden braking are seen as negative behaviours of drivers. It has also been determined that the increase in temperature causes intense stress in drivers [12,13].

It has been shown that accidents occurring in foggy weather, which impedes visibility, are more severe than other accidents. Rain has been found to increase the accident rate during the day and at night [14,15].

The relationship between traffic volume and meteorological events was also determined. It was found that the decrease in traffic volume in cold weather events such as snow decreases the number of accidents, while precipitation indirectly negatively affects the traffic volume and speed-occupancy relationship [16].

The study area is within the provincial border of Antalya. The locations, International Civil Aviation Organisation (ICAO) codes, and district names of the meteorological stations affiliated to MGM within the provincial borders are given in the IoT-PWSM Meteorological Station table in Table 2 below.

Table 2. IOT Weather Station.

Station_No	Latitude	Longitude	Name	ICAO	Province
A1	36.9425	30.837778	Aksu Aircraft Maintenance		Aksu
17302	36.8851	30.6828	Antalya Region	ANTA	Muratpaşa
17304	36.84	30.61	Konyaaltı		Konyaaltı
17310	36.5507	31.9803	Alanya	ALAN	Alanya
17375	36.3024	30.1458	Finike		Finike
17380	36.2002	29.6502	Kaş	KASD	Kaş
17473	36.1839	29.6422	Kaş Bayındır Main Breakwater		Kaş
17474	36.2953	30.1533	Finike Balıkçı Fisherman Shelter		Finike
17475	36.6131	30.5744	Kemer Sığlık Lighthouse		Kemer
17476	36.835	30.6167	Konyaaltı/Antalya New Harbour Breakwater		Konyaaltı
17477	36.5581	31.9514	Alanya New Harbour Breakwater		Alanya
17895	36.9393	30.898	Aksu/Boztepe Tigem	AKTG	Aksu
17915	36.8604	31.0627	Serik/Belek		Belek
17917	36.8886	31.2494	Manavgat/Taşağıl Forest Area		Manavgat
17926	37.0565	30.191	Korkuteli	KORE	Korkuteli
17927	37.0968	31.5952	İbradı	IBRD	İbradı
17951	36.3646	30.2978	Kumluca	KUML	Kumluca
17952	36.7372	29.9121	Elmalı	ELML	Elmalı
17953	36.5942	30.5672	Antalya/Kemer	KEMR	Kemer
17954	36.7895	31.441	Manavgat	MNGV	Manavgat
17970	36.2421	29.979	Demre	KALE	Demre
17974	36.2715	32.3045	Gazipaşa	GPAS	Gazipaşa
18008	37.189	30.4995	Dağbeli		Döşemealtı
18009	36.3592	29.3403	Kaş/Çavdır Forest Area		Kaş
18010	36.305	29.7306	Kaş/Kasaba Forest Area		Kaş
18011	37.1441	31.1909	Manavgat/Beşkonak Forest Area		Manavgat
18012	36.8043	31.9979	Gündoğmuş Forest Depot		Gündoğmuş
18013	36.8659	31.775	Akseki/Murtiçi Forest Area		Akseki
18014	37.1046	30.9345	Serik/Gebiz Orman Sahası		Serik
18015	36.9703	30.4339	Korkuteli/Bük Forest Area		Korkuteli
18016	36.9501	30.6025	Döşemealtı/Nebiler Forest Area		Döşemealtı
18047	37.047	31.797	Akseki		Akseki
18305	36.5842	29.9892	Elmalı Forest Area		Elmalı
18306	36.9517	31.1189	Serik		Serik
18307	37.0987	30.6425	Döşemealtı/Karain Aircraft		Döşemealtı
17300	36.9063	30.799	Antalya Airport	LTAI	Muratpaşa

Source: https://www.mgm.gov.tr/kurumsal/istasyonlarimiz.aspx?il=Antalya (accessed on 14 August 2024).

3.4. The Land Use and Land Cover (LULC)

In the study, Land Use and Land Cover (LULC) data were used to determine the characteristics of the area served by IOT-PWS. Thanks to these data, land use and land cover information of the study area was obtained [17].

LULC is a product of the Coordination of Environmentally Relevant Information, one of the land management projects under the European Union GMES (Global Monitoring for Environment and Safety) Programme.

The database created for our country is the result of the combination of the 'Classification According to Land Statistics Used' data carried out by EUROSTAT RS Programme and the 'CORINE Land Cover' data produced by the European Union.

The database consists of land use (land cover information) maps covering location-based land information. The land cover information database of our country has been methodologised according to the land cover characteristics of our country.

With the realisation of the CORINE project, data production has been ensured within the framework of the standards set by the countries. A database has been established at three main levels determined by the European Environment Agency. Agriculture, Wetland, Urban, Water body and Forest land are classified as Level 1 [18]. These main groups are divided into 15 subclasses at the second level and 44 subclasses at the third level. This product was used in the study. It covers 39 countries, including Turkey, and covers an area of 5.8 million km^2. Real-time (NRT) land use land cover (LULC) classification was produced by applying deep learning method to Sentinel-2 images with 10 m resolution. Table 3 below shows the LULC Type produced [19].

Table 3. LULC Type.

Class Type	LULC Type
0	Water
1	Trees
2	Grass
3	Flooded vegetation
4	Crops
5	Shrub and scrub
6	Construction area
7	Bare ground
8	Snow and ice

3.5. World Pop

WorldPop data, a project funded by The Bill and Melinda Gates Foundation, has a resolution of 92.77 pixels. The population data image generated is the estimated number of inhabitants in each grid cell. Values are between minimum 0 and maximum 21,171. The data is raster data. The project aims to measure the population growth in our world in the most accurate way and to make preventive planning by utilising the changes that occur.

By applying machine learning to the data, population changes and geographical criteria were applied and a grid structure consisting of cells of approximately 100 × 100 m was created. In 2020, gender data was added. The WorldPop data was created with contributions from scientists at the University of Libre de Bruxelles, the University of Southampton, and the University of Louisville. The data is freely available [20–23]. The characteristics of the data are shown in Table 4 below in the Population Data table. The dataset was created by selecting open-source data related to meteorology in order to reveal the spatial characteristic of the data.

Table 4. Population Max/Min Table.

Name	Min	Max	Resolution	Explanation
Population	0 *	21,171 *	92.77 m	Estimated number of persons residing in the grid cell

* Estimated minimum or maximum value.

3.6. Climate Data

(TerraClimate: Monthly Climate and Climatic Water Balance for Global Terrestrial Surfaces, University of Idaho, Temperature, Wind Veloncity) (* Temperature data maximum value is used.)

It is a dataset containing monthly climate and climatic water balance. It is produced as a digital map by applying interpolation process to the existing data. WorldClim uses data sources from the Centre for Environmental Data Analysis (CEDA) and Japan's 55-year-old Reanalysis [24]. The accuracy resolution of the dataset is low. The data obtained from the data source are given in Table 5 below, which shows the data and their contents. The data obtained from the data source are given in Table 5 below, showing the data and their contents.

Table 5. Climate Data.

Name	Units	Min	Max	Explanations
aet	Mm	0 *	3140 *	Actual evapotranspiration obtained using a one-dimensional soil water balance model
def	Mm	0 *	4548 *	Climate water deficit was obtained using a one-dimensional soil water balance model
pdsi		−4317 *	3418 *	Palmer Drought Severity Index
pet	Mm	0 *	4548 *	Reference evapotranspiration (ASCE Penman–Montieth)
pr	Mm	0 *	7245 *	Precipitation accumulation (Used)
ro	Mm	0 *	12,560 *	Runoff obtained using a one-dimensional soil water balance model
soil	Mm	0 *	8882 *	Soil moisture obtained using one-dimensional soil water balance model
srad	W/m^2	0 *	5477 *	Downward surface shortwave radiation
swe	Mm	0 *	32,767 *	Snow water equivalent obtained using one-dimensional soil water balance model
tmmn	°C	−770 *	387 *	Minimum temperature
tmmx	°C	−670 *	576 *	** Maximum temperature
vap	kPa (English)	0 *	14,749 *	Vapour pressure
vpd	kPa (English)	0 *	1113 *	Vapour pressure deficit
vs	m/s	0 *	2923 *	** Wind speed at 10 metres

* Estimated minimum or maximum value, ** Data used.

3.7. IOT-PWW Weather Station

The manufacturer of the IOT-PWWW Weather Station is a company founded in 2012 by entrepreneurs from Barcelona, Spain. The station has a virtual platform that collects, stores, and presents weather data through its own platform with a real-time network. The product users are amateur weather data collectors, agriculturalists, scientific researchers, and students. The platform features are given in Table 6 below.

In Table 6, 'Temperature' and 'Veloncity' data, which are common data of Climate data and IoT-PWS data, were used in the study. The characteristics of the data used in IoT-PWS are given in Table 7 below.

Table 6. IoT-PWS Features.

Feature No	Feature Name	Feature Name	Feature Content
1	Local and Cloud	Local and Cloud	Data control competence over the company server
2	Real Time	Real Time	Real-time compatibility of sensor data
3	Flexibility	Flexibility	Additional sensor integration
4	Scalability	Scalability	Accessibility to data from mobile devices
5	User Role	User Role	User customisability
6	Easy to Use	Easy to Use	Ownership of standards of ease of use
7	Company Supportability	Company Supportability	Company technical support right
8	API usage	API usage	API providing ease of data access

Table 7. IOT-PWW Weather Station Data.

Name	Units	Layer Name	Explanation
Temperature	°C	iot_temp	temperature
Wind Velocity	m/s	iot_vs	Wind speed at 10 m (Used)

3.8. Methodology

The process of the study, which includes literature review and previous studies, determination of the study area and criteria within the area, obtaining the data catalog from open sources, obtaining maps and numerical value findings with GIS and RS tools, creating maps and making inferences, is given in the flow diagram from Start to End in Figure 2 below.

After the installation of IoT-PWS, firstly, a literature review of the study was carried out by analysing the previous studies on the subject. As a second step, the boundaries of the study area were determined. In the third step, a dataset was created by combining Road, Meteorological station location information, Population, LULC, and Climate (Temperature, Wind Speed) data. In the fourth step, the findings were obtained by using open-source GIS3.38 (Qgis) and RS2.7.12 (Python) software. In light of the findings, the conclusions in the Section 5 were reached.

In the study, data on roads, district boundaries, meteorological stations, land use and land cover, population, climate, and IoT-PWSws were collected. Road, mgm_ist, lulc, worldpop, terraclimate and IoT-PWSws names were created in QGIS software.

Two types of datasets were used in the study. These are vector and raster data types. Vector data are Road, Stations. Road is in-line data type while Stations is in-point data type. Raster data types are LULC, Temperature, Velocity, and POP data.

Vector and Raster data were created as shp file type in the layer structure in QGIS software. Shp file type is the standard file type in GIS studies. Since it is compatible with other GIS software, it was preferred for the sustainability of data usage.

Roads and road data were downloaded from the data source ‘https://www.openstreetmap.org/web’ (accessed on 14 August 2024), and ‘shp’ data was generated from the platform. The generated data was derived by giving the ‘road’ layer name in GIS software. The study area vector data was downloaded using Java language in the editor section of the OSM platform. In QGIS software, the downloaded data was created with the layer name ‘road’.

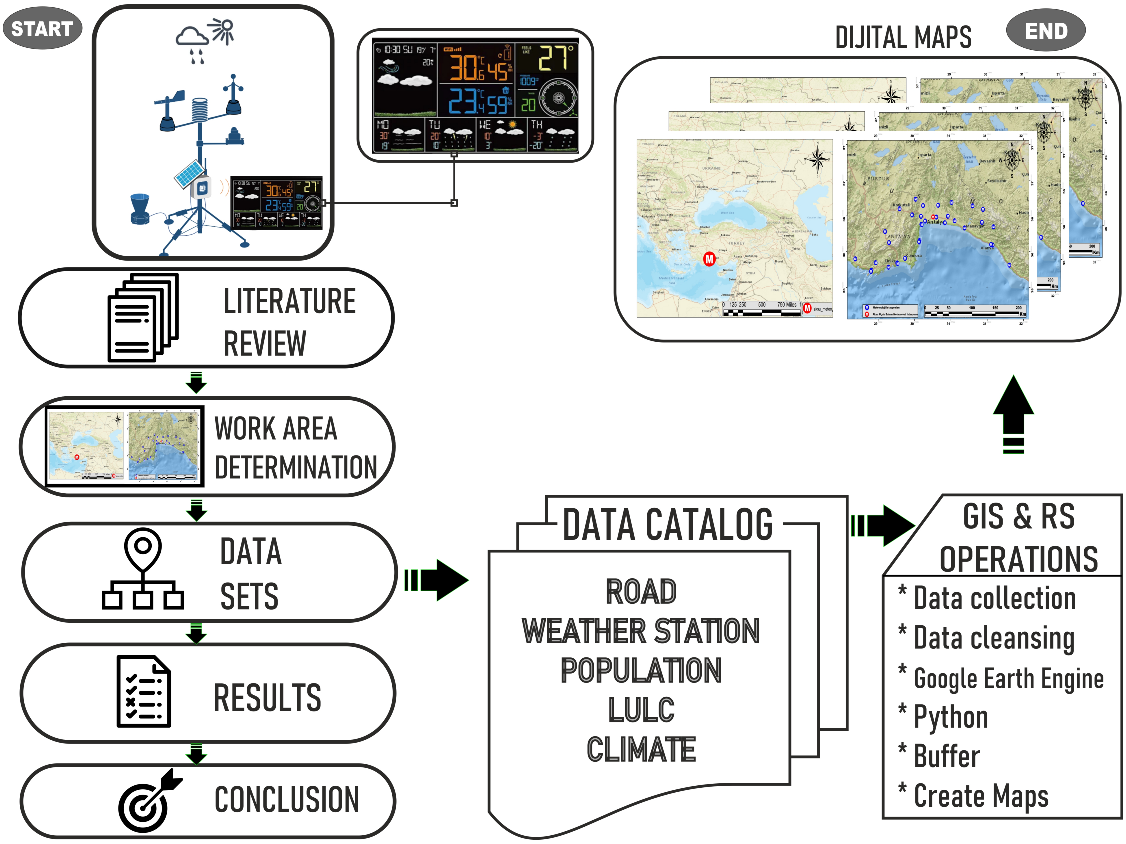

Figure 2. Flow Chart.

Meteorological Stations, meteorological station data were downloaded from the data source 'https://www.mgm.gov.tr/kurumsal/istasyonlarimiz.aspx?il=Antalya' (accessed on 14 August 2024). The generated data was produced by giving the layer name 'mgm_ist' in the GIS software. The station data, which is open data of the institution, also includes the characteristics of the station. The process was created using the downloaded data in QGIS software with the layer name 'mgm_ist'.

Population, population data downloaded from data source "https://developers.google.com/earthengine/datasets/catalog/WorldPop_GP_100m_pop" (accessed on 14 August 2024). The reproduced data was obtained by calling the 'worldpop' layer in the GIS software. The process was done by downloading data from the source, which is an open-source data platform, and the layer name 'worldpop' was created using the downloaded data in QGIS software.

Land Use and Land Cover, "Land Use and Land Cover" data were downloaded from the data source "https://land.copernicus.eu/en/products/corine-land-cover" (accessed on 9 August 2024). The generated data was derived in GIS software with the layer name 'lulc'. The data were downloaded from the source, which is an open-source data platform, and the downloaded data were generated in QGIS software under the layer name 'lulc'. Categories were created as Agriculture, Forest, Water body, and Wetland names.

Climate, Climate data downloaded from 'https://developers.google.com/earth-engine/datasets/catalog/IDAHO_EPSCOR_TERRACLIMATE' (accessed on 14 August 2024) data source. The produced data was created in GIS software by giving the name of 'terraclimate' layer. The data were downloaded from the source, which is an open-source data platform, and the 'terraclimate' layer was created by opening the downloaded data in QGIS software. Temperature and wind data were generated.

IOT Weather Station, "IoT-PWS 'data "https://weathercloud.net/" (accessed on 20 August 2024) data source. The generated data was created by giving the layer name 'IoT-PWS' in GIS software. Temperature and wind data were generated.

Data downloading with GIS and RS techniques, Buffer application to determine the station impact zone, calculation of LULC layers in the buffer area with Zonal Statistic and obtaining land class sizes, station areal distribution with mapping, and revealing the uncertainties of intermediate values were performed. While the open-source programming language was used for downloading, operations such as Buffer and Zonal Statistic were performed using QGIS.

4. Result and Discussion

In the study, Road Network Map was created using the data type shp file obtained from the OSM data source and QGIS software. The resulting map is shown in Figure 3 below.

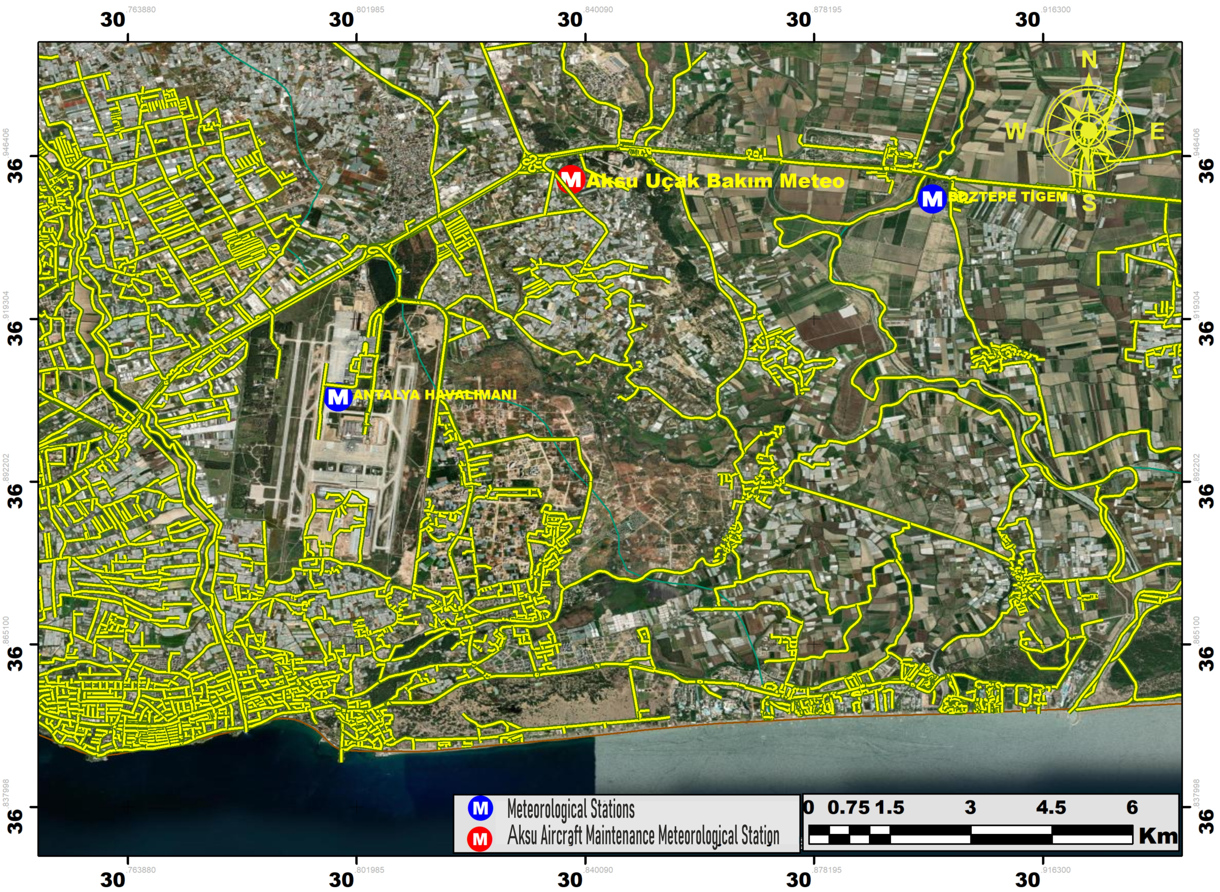

Figure 3. Road Network Map.

IoT-PWS has heavy traffic due to the region being a tourist attraction. The station is located very close to the D400 (Antalya–Mersin) road, which has the busiest traffic in Antalya province, approximately 185 metres away. In the OSM subheading in the dataset section, it was identified and emphasised that the relationship between traffic and meteorology is highly correlated. As seen in Figure 4, the map showing the relationship between IoT-PWS and Road is located approximately 1200 m from the junction, which is the most important point of traffic. It has been determined that it has positive effects such as being closer to its location compared to other stations and providing support with meteorological information.

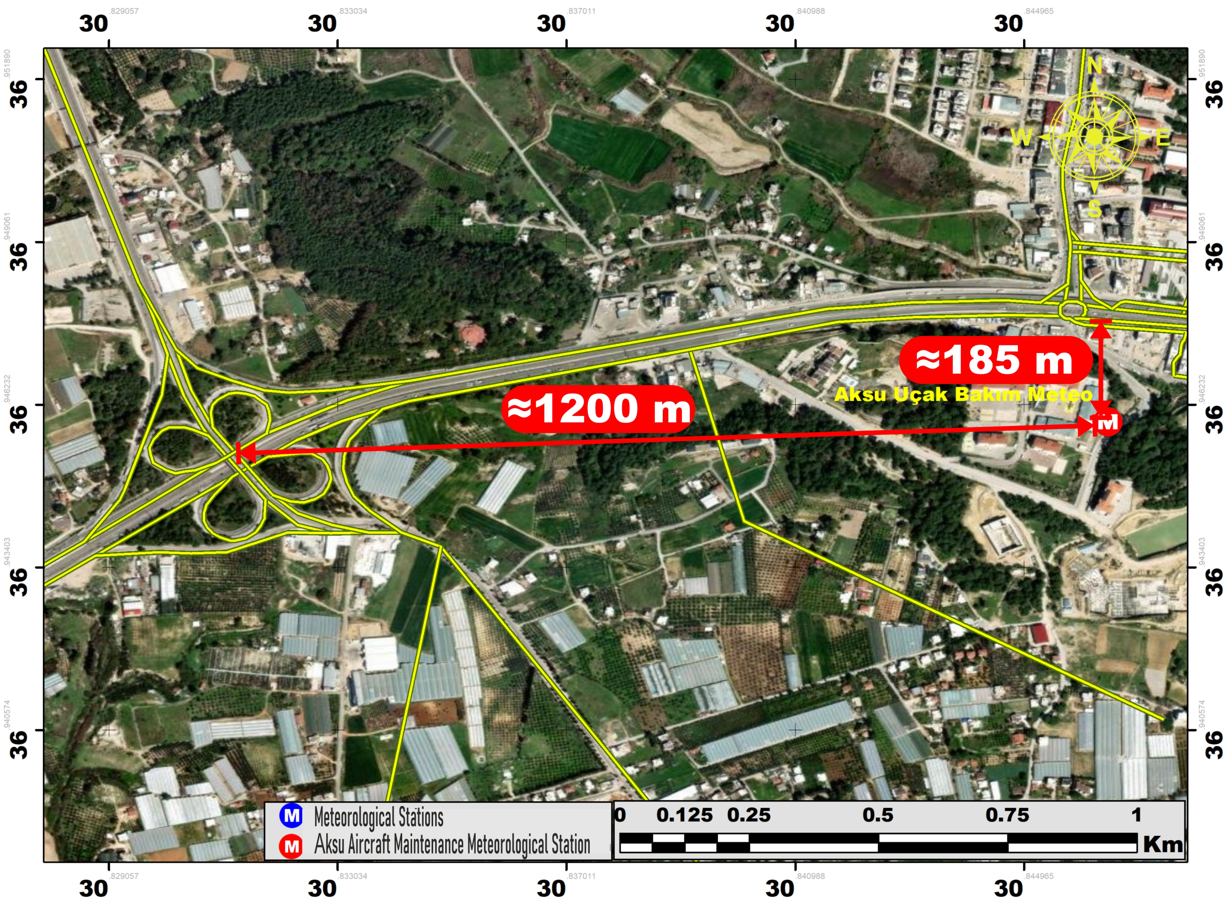

Figure 4. IoT-PWS and Road.

The IoT-PWS was supplied and installed under the supervision of a meteorologist. The product was funded from the project budget. Data sharing is provided through the website https://weathercloud.net/ (accessed on 20 August 2024). The station is shown in Figure 5 below.

Figure 5. Aksu Aircraft Maintenance Technology Vocational and Technical Anatolian High School. Source: https://aksuucakbakim.meb.k12.tr/icerikler/aksu-ucak-meteorology-istasyonu-faaliyete-gecmistir_15089362.html (accessed on 20 August 2024).

To show the spatial distribution of Io T-PWS and other MGM stations, the station Spatial Distribution Map shown in Figure 6 below was created. The process was created using the coordinates of the meteorological station in GIS3.38 software. The digital map is in 'shp' file format.

In order to understand the spatial status of IoT-PWSs and other stations installed within the scope of the project, the following IoT-PWSs and Meteorological Station relationship maps were created using GIS software. In Figure 7a, the corporate weather stations surrounding the IoT-PWS are shown on the corporate weather station map surrounding the IoT-PWS map. In Figure 7b, the nearest station, which is approximately 4.5 km away, is shown on the MGM station Information Map near the station map.

The climate data in the study area, temperature (tmmn), and wind (pr) data in "TerraClimate" were converted into a raster map. Due to the increasing negative effects of global warming, climate data has become an important data in solving the problems of global warming sources. As can be seen in the Climate Temperature Map in Figure 8 below, the study area is generally under the influence of high temperatures. The fact that the station area data supports the important economic activities of the region, such as temperature, health, traffic density and agricultural activities with warnings and information transfer, makes the activities of the station valuable.

The study area is under the influence of moderate wind. The region is occasionally threatened by high intensity and destructive winds. Greenhouse activities are carried out intensively in the station area. Strong winds cause material damage to greenhouses in the region. Station data provides important information support for those carrying out greenhouse activities. As can be seen in the Climate Speed Map in Figure 9 below, the study area is generally under the influence of moderate wind.

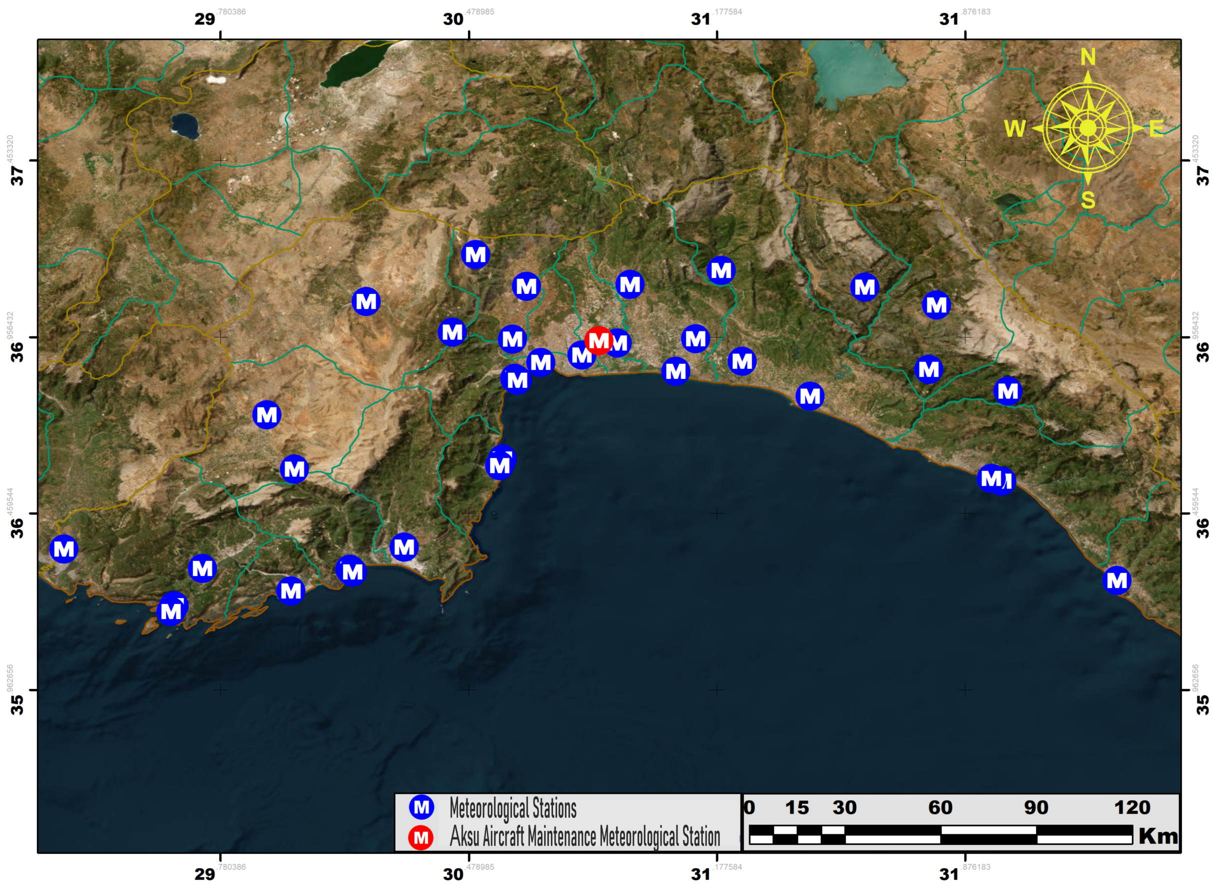

Figure 6. Station Spatial Distribution Map.

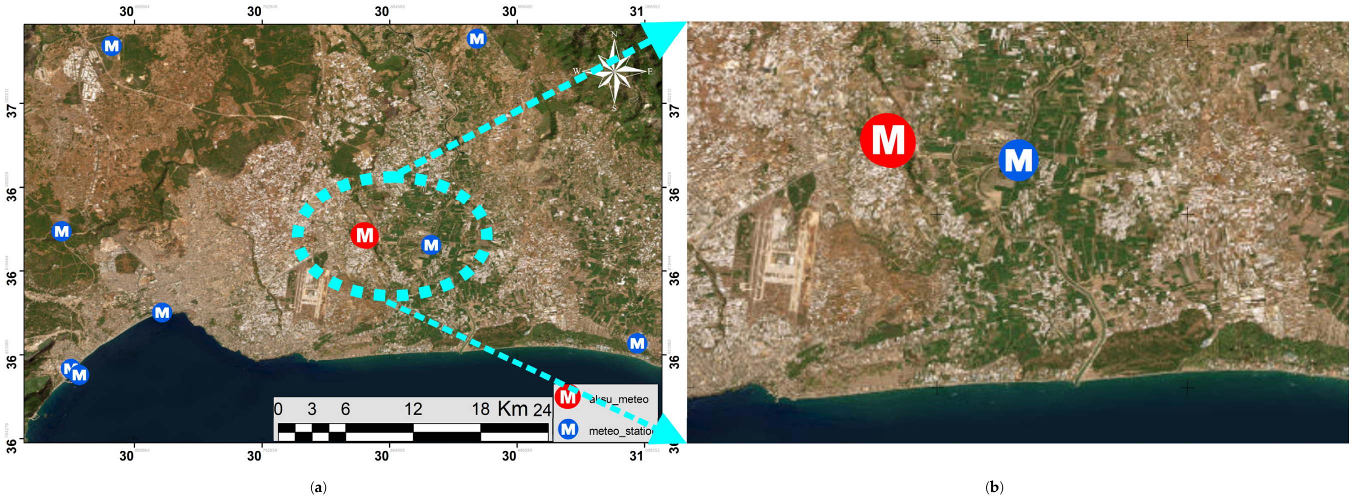

Figure 7. IoT-PWS and Weather station relationship Maps, (**a**) IoT-PWS surrounding corporate meteorological station, (**b**) MGM station Information Map Near the Station.

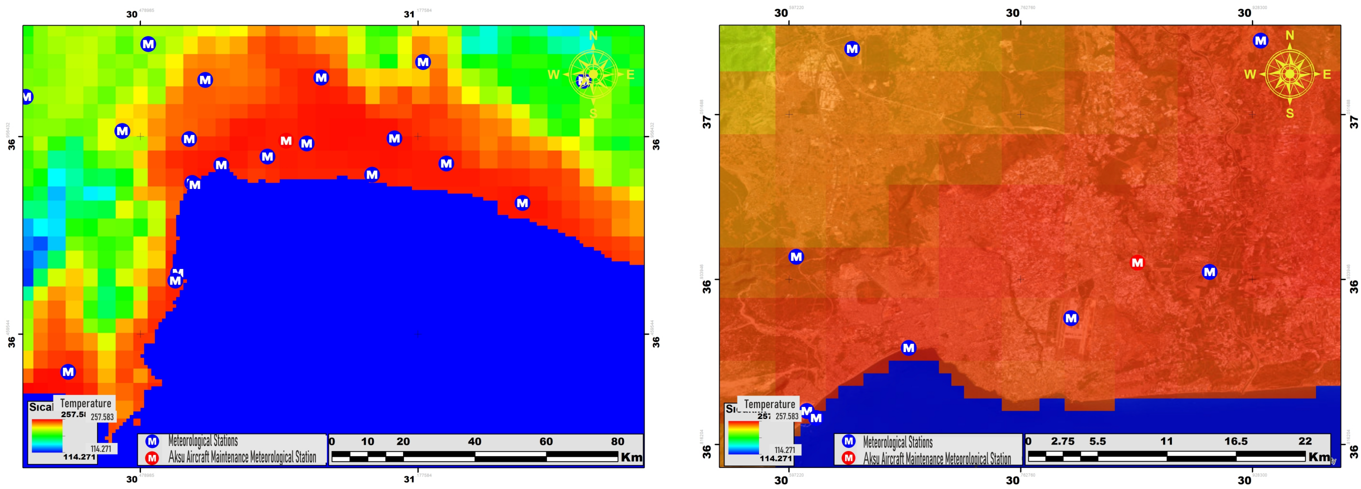

Figure 8. Climate Temperature Map.

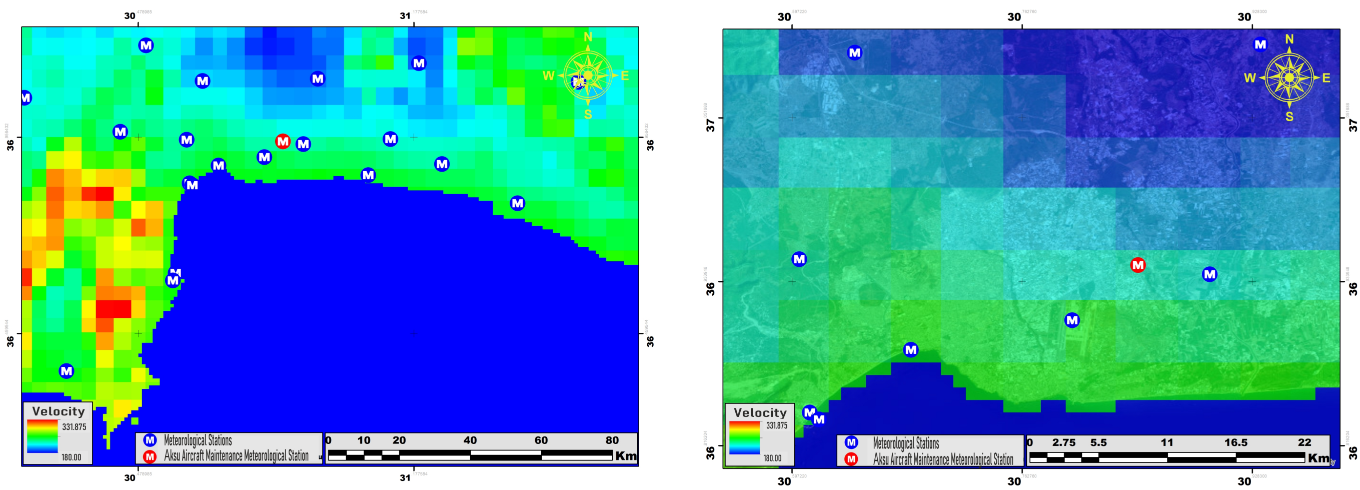

Figure 9. Climate Velocity Map.

WorldPop data was converted into a raster map using QGIS3.38 software. The resulting map gives importance to the study area. As can be seen in the WorldPop Map in Figure 10 below, the Figure 10 study area is defined as the region with high population density. Since the study area covers the district center, the population density is increasing day by day. For these reasons, IoT-PWS data contains regional value.

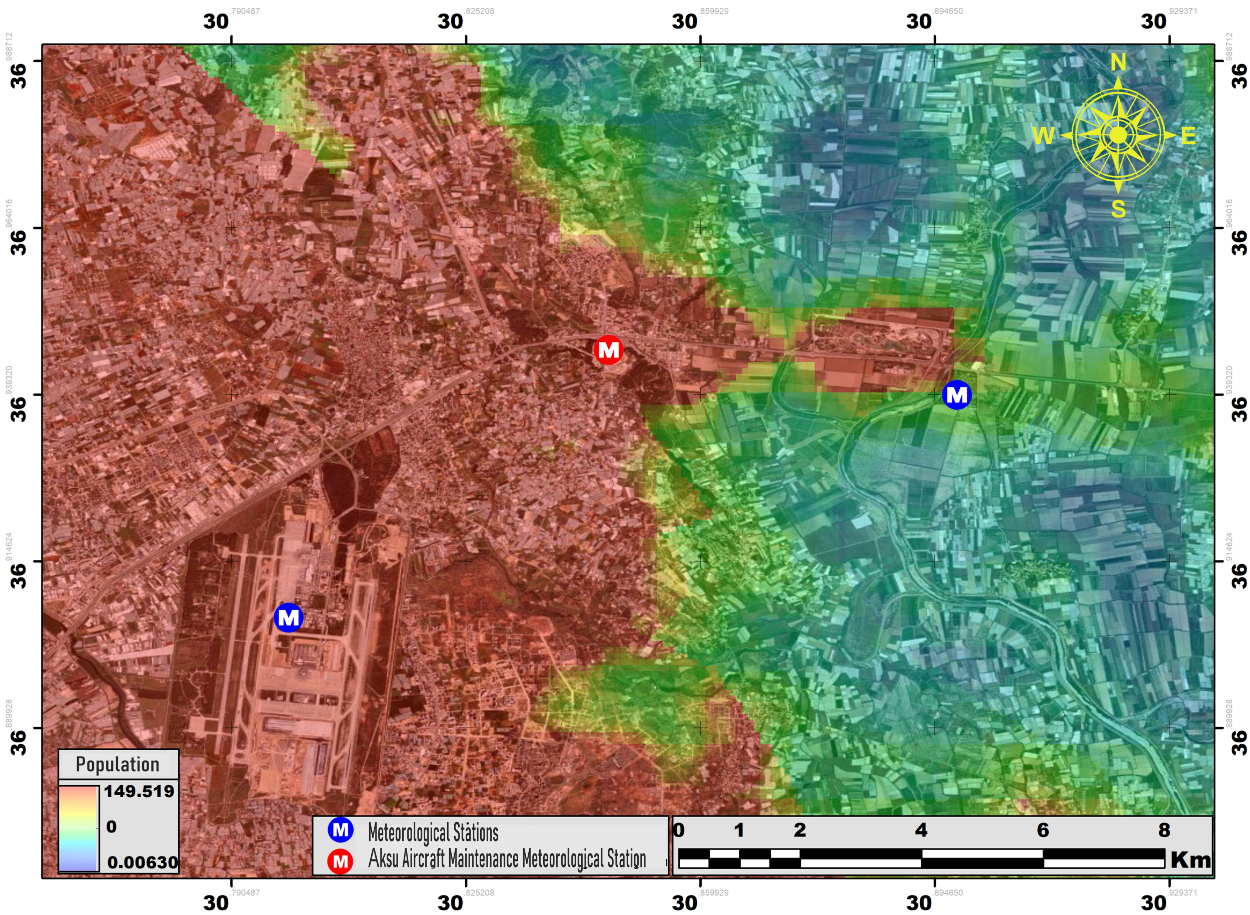

Figure 10. WorldPop Map.

The spatial calculation of the LULC dataset with land use data was done using QGIS software. It is shown as in the Land Use and Land Cover Map in Figure 11 below.

"One of the GIS techniques, "Buffer", was applied to create a "Circle" with a radius of 3 km, centered on the IoT-PWS point. This "Circle Buffer" area was created as a separate layer with the "Clip" application. The resulting "Circle Buffer Map" Figure 12 from the process is shown in Figure 12 below.

Numerical values of the field were obtained by applying the "Raster Calculator" to the remaining LULC classes in this new layer. The resulting values are shown in the LULC Field Spreadsheet in Table 8 below.

The highest values were found to be in the "Built-in" and "Clipping" fields. The lowest values were found to be in the "Grass", "Water" and "Flooded Vegetation" areas. Quantitative area information was extracted using LULC class information, GIS, RS and EO technology, which is an important data source to extract the characteristics of the region served by the station.

The importance of meteorological data in projects related to climate change and global warming is accepted by all authorities. Aksu district of Antalya province, where IoT-PWS is located, is the region where tourism and agricultural activities of the country are intense. The study area, ring road traffic density, agricultural land density, population density, air traffic density, and river source are important spatial criteria of the region that should be taken into consideration.

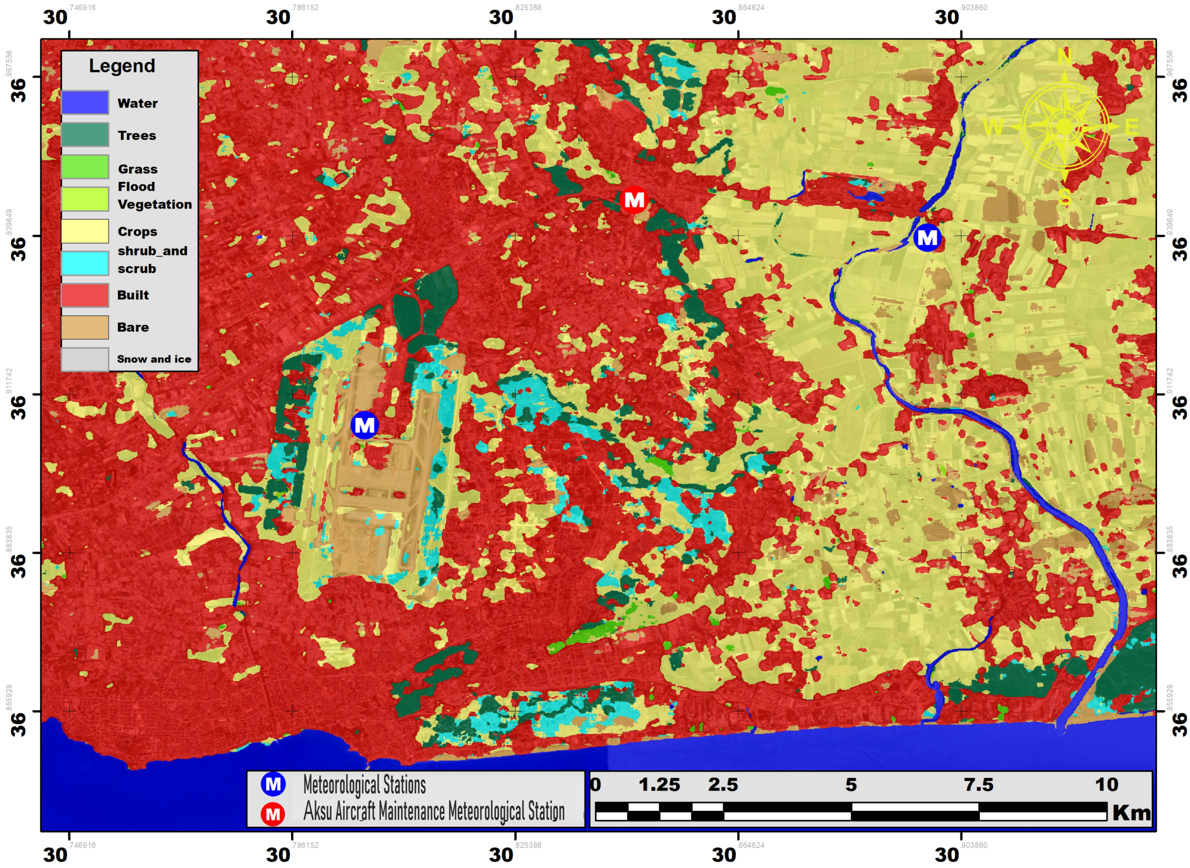

Figure 11. The Land Use and Land Cover Map.

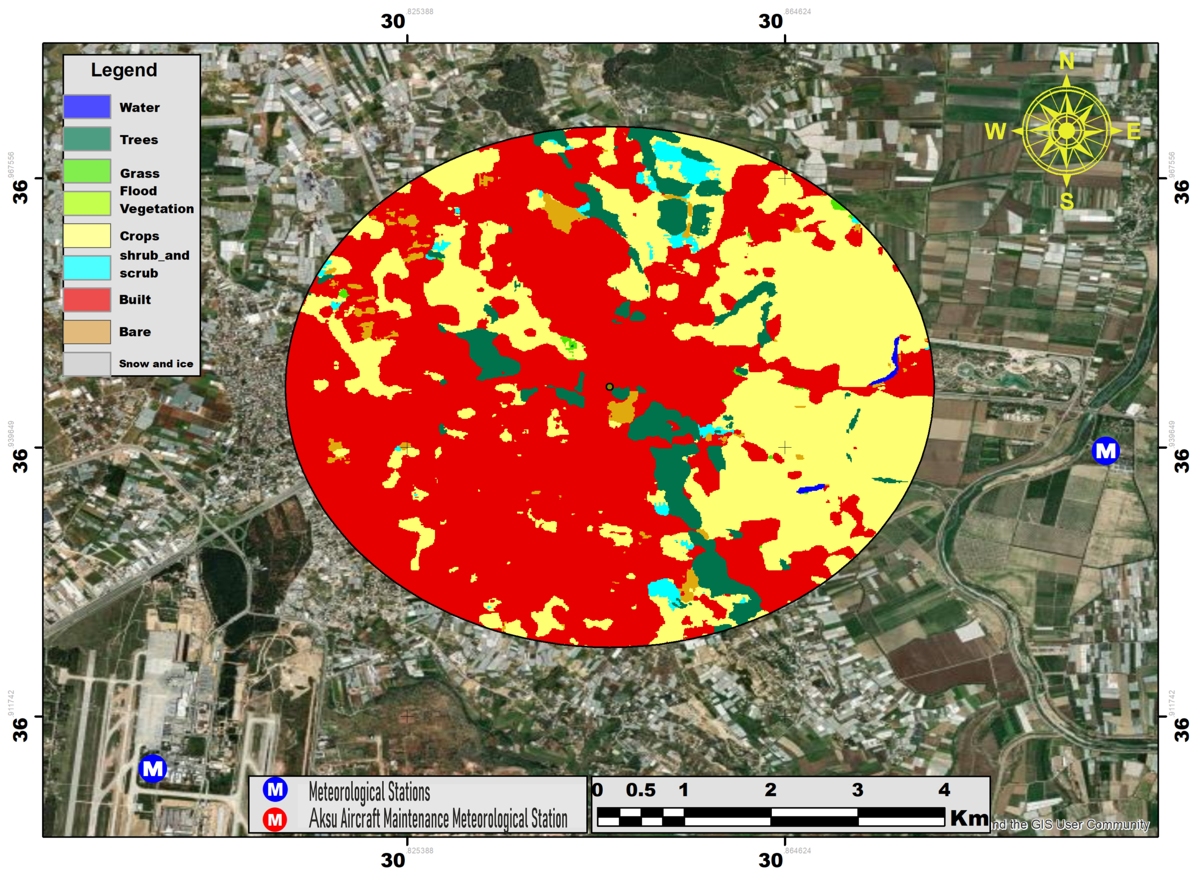

Figure 12. Circle–Buffer Map.

Table 8. LULC Area Spreadsheet.

Nu	Name	Count	Area_ha	Percentage
7	Construction Area	203,013	1644.4053	57.30%
5	Crops	117,690	953.289	33.22%
2	Trees	22,662	183.5622	6.40%
8	Bare	5373	43.5213	1.52%
6	Shrub_and_Scrub	4419	35.7939	1.25%
3	Grass	579	4.6899	0.16%
1	Water	534	4.3254	0.15%
4	Flooded vegetation	3	0.0243	0.00%

Station is providing instant data for traffic safety, information support to farmers about destructive meteorological events in agricultural activities, and weather information for the local people to benefit from in their daily life activities, as well as offering meteorological data services for scientists working with the region to provide data for use in their studies and for authorities to use in regional planning. These contributions are highly valuable.

LULC data used to infer the spatial characteristics of the region served by IOT-PWS has quantitatively revealed that the region is an area of high structuring and intensive agricultural production. The fact that the data used is open-source data increases the usability of the proposed working model and provides an advantage for its continuity.

When considered in terms of sustainability, the study presents a model that will enable the United Nations to contribute to the achievement of the Sustainable Development Goals (SDGs) by making use of RS, GIS, EO, and Erasmus concepts. IoT-WSs make significant contributions to Sustainable success indicators. IoT-WSs contribute to the Climate Action (Goal 13) indicator by collecting and serving climate data and real-time weather modelling activities [25]. It contributes to the Zero hunger (Goal 2) indicator with activities such as preventing agricultural disasters and providing atmospheric data required in production activities [26]. It contributes to the Sustainable cities and communities (Goal 11) indicator with the provision of climate data in activities under the heading of climate change-resilient cities and Smart cities [27]. Having solar-powered equipment during the works contributes to the Affordable and clean energy (Goal 7) indicator with the use of renewable energy and environmentally friendly energy [28]. It contributes to the Industry, Innovation, Technology, and Infrastructure (Goal 9) indicator in terms of contributing to the collection of the necessary data for the preliminary work required in project and entrepreneurial activity projects [29]. These explanations summarise the contributions of IoT-WS to the SDGs.

IoT-WS has important contributions in combating climate change as well as some limitations. The high initial establishment cost emerges as the first investment barrier for the start of these studies. The fact that the data is private information reveals the situation of data security vulnerability [30]. The need for regular checks and calibration for data accuracy and the lack of traditional station data reliability in the use of data [31]. The need for regular energy will negatively affect carbon-reduction activities in the world [32].

Due to the low spatial resolution of traditional stations, the importance of IoT-WSs is increasing day by day [29]. IoT-WSs collect and serve real-time climate and atmospheric data. It makes an important contribution in terms of increasing the accuracy in planning and prediction modelling to combat disasters such as floods and extreme precipitation. With the development of artificial intelligence and machine learning technology, major damages are prevented with early warning systems applications in many areas such as security, transport, and agricultural activities. The project contributes to increasing the accuracy of climate models by providing data for infrastructure planners and academicians.

With this feature, its sustainability is strengthened. IoT-WS is of great importance as it provides important contributions in many topics such as reducing the impact of disasters and food security [26]. Increasing civic participation and social awareness in climate change is an important achievement in the fight against climate change [27].

5. Conclusions

In studies on these indicators and other indicators, climate-related data are used from national meteorological stations. It does not use the meteorological data of the IoT-PWS stations that are the subject of the study. These data are not included because the data standards are at national standards. In fact, IoT-PWSs use calibrated and certified products. As seen in this study, the national meteorological stations are at far distances and the interpolation method between the two stations uses hypothetical values as intermediate values. The value of the region between two stations is calculated by the inverse distance interpolation method between the two stations and is included in the system. In fact, ignoring the IoT-PWS station values between the two hypothetical stations in this study area not only misses the opportunity to improve the quality of the data, but also misses the opportunity to fully utilize these facilities, for which existing economic investments have been made. The recommendation put forward by this study suggests that these IoT-PWS station values should be included in SDGs studies as well as national meteorological stations.

The use of RS, GIS, and EO technology in Erasmus projects related to climate change not only increases the amount of work, but also contributes to the creation of the necessary materials to train qualified personnel for the sector.

This study is valuable as it guides people who aim to produce projects related to the use of RS, GIS, and EO technology in their work. Theoretical and practical modelling of these technologies also contributes greatly to strengthening the bond between educational institutions and industry.

The model proposed by the study is to carry out studies to include national meteorological stations as well as IoT-PWS station data in SDGs studies, project studies, and scientific studies by setting certain criteria. In this respect, this study reveals the studies to be done in the future and provides the basis for the future studies.

The fact that these studies were carried out in a global project such as Erasmus, and that the model proposed in the study can be disseminated, makes the study valuable in this aspect.

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