**NASA DEVELOP National Program**



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Middle East Water Resources

Utilizing NASA Earth Observations to Create a Precipitation Climatology of Jordan, Israel, and the West Bank to Identify Optimal Rainwater Harvesting Locations for Underserved Schools

 **Technical Report**

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# 1. Abstract

Water resources are declining in the Middle East as a result of the combination of diminished supply from overexploitation and drought, increased demand due to growing populations, and inadequate infrastructure. Water shortages have led to sanitation issues in schools and, in severe cases, even school closures. Rainwater harvesting is an eco-friendly, low-tech, and cost-effective method of collecting and storing water for local use. The Water Resources Action Project, Inc. (WRAP) provides rain barrels and cisterns to underserved schools in the region to increase their water resources for sanitation purposes. This study used data from Tropical Rainfall Measurement Mission (TRMM), Global Precipitation Measurement (GPM), and other NASA Earth observations to quantify and visualize precipitation to identify locations most suitable for rainwater harvesting. Results indicate that precipitation is greatest in the north, nearest the Mediterranean Sea, and along the Jordan Rift Valley. The team created a climatology, which characterizes the precipitation regime of the region, as well as an interactive interface, PrIME, to help WRAP determine which schools would benefit most from their assistance. PrIME will be shared with the schools to which WRAP provides rainwater harvesting systems as an educational tool that can be used to improve students’ understanding of the region’s precipitation and climate as well as Geographic Information Systems and other monitoring and analysis technologies.

**Keywords**

QGIS, Google Earth Engine, Water Resources Action Project, Inc. (WRAP), data visualization tools, Python, JavaScript

# 2. Introduction

**2.1 Background Information**

The Middle East is home to 6.3% of the global population but contains only 1.4% of the world’s renewable fresh water, which has led to severe water scarcity in the region (Wessels, 2009). Historically, those living in the arid climate of the Middle East utilized tools such as cisterns to meet their household water needs and took every opportunity to collect and preserve water. However, in recent years, people have decreased their usage of alternative methods of water collection, and have increased their reliance on water supplied by the government, due to increased accessibility. As a result, the combination of population growth and urbanization has led to the overexploitation of aquifers and contamination of water resources, which has caused several countries within this region—Jordan, Israel, and the West Bank, in particular—to experience severe water shortages (Hadadin et al., 2009; Wessels, 2009).

Jordan, Israel, and the West Bank, located along the eastern coast of the Mediterranean Sea in a region historically known as the Levant, experience a rainy season from October through May. During this time, average monthly precipitation ranges from 0 mm to 280 mm. There is relatively high variation in precipitation year-to-year in both quantity and geographic distribution, which is characteristic of arid and semi-arid regions (Ghanem, 2009). In Jordan, the variation is considerably greater in the southern and eastern parts of the country than in and around Amman. The uneven distribution of resources is further exacerbated by rapidly growing populations (Sowers et al., 2009). Currently, the demand for water in Jordan far exceeds its availability, as evidenced by the employment of groundwater mining and wastewater reuse (Khaleq, 2009). Interestingly, the annual rainfall over Amman is enough to cover the needs of the population, but as much as 92% is lost to evaporation (Wahlin, 1995; Ghanem, 2009). The Levant is predicted to experience a decrease in precipitation as well as an increase of surface temperatures, which indicates further diminishment of water resources (Sowers et al., 2009). The combination of water scarcity and increased populations could result in hindered economic growth, and consequently, increased poverty, social instability, food insecurity, growing refugee populations, and subsequently, greater demands for water (Sowers et al., 2009; Brown & Crawford, 2009). Changes in climate may further decrease availability or accessibility of already-scarce water resources.

The minimal water resources in the Middle East, coupled with increased demand and climate variability due to climate change, necessitates more efficient management as well as alternative water collection and conservation strategies. Jordan aims to achieve “the highest possible efficiency in the conveyance, distribution, application and use” (Water Resource Strategy for Jordan, Hashemite Kingdom of Jordan, 1997), and has implemented several programs in an effort to reduce water usage and increase sustainability; including a tariff structure to incentivize conservation, media campaigns, a private sector participation in management, educational curriculums for schools, new consumption regulations, promotions of technology and water saving devices, and studies concerning the use of greywater (Khaleq, 2008). While these strategies focus on the demand and consumption of water resources, most strategies in the Middle East have focused on large scale supply-side projects, such as desalination plants, fossil groundwater use, and the reuse of treated wastewater. However, management of water demand and improvements in efficiency of water use will be essential in responding to the challenges generated by climate change (Sowers et al., 2009). Decreasing water resources coupled with increasing demand will force Middle Eastern countries to consider alternative adaptation strategies, such as rainwater harvesting, as the effects of climate change intensify.

Rainwater harvesting is a reliable alternative source of water, which has been implemented in the region for millennia. Rainwater harvesting systems must take into account the contributing rooftop area, local rainfall patterns, anticipated use, and cost (Traboulsi, 2014). Additionally, appropriate roof materials and design can minimize the contamination of harvested rainwater and maximize collection efficiency (Lange, 2014). The potential rainwater harvested volume can be estimated as a function of the average annual rainfall in the locality (R), the total roof area (A), and the runoff coefficient (K), as HW = R x A x K (Traboulsi, 2014). Rainfall harvesting and the use of cisterns could contribute considerably to the water supply.

**2.2 National Applications & Project Objectives**

This study addresses NASA’s water resources application area by exploring the potential of rainwater harvesting in the Middle East. Furthermore, it addresses the NASA application area of climate through the examination of the climatology of the region. The objectives of this study were to (1) identify and analyze patterns in rainfall in Israel, Jordan, and the West Bank from January 2005 to May 2016, and (2) develop an interactive interface to enhance the Water Resource Action Project, Inc. (WRAP) decision-making process and educational resources.

**2.3 Project Partner**

WRAP is a non-profit organization that provides rain barrels and cisterns to underserved schools in the Middle East to increase their water resources for sanitation purposes. WRAP currently uses data from the Food and Agricultural Organization (FAO) and the World Bank to understand rainfall and population patterns in order to select future rainwater collection programs for schools; this project supplemented that data by creating a precipitation climatology using Tropical Rainfall Measurement Mission (TRMM), Global Precipitation Measurement (GPM), and other NASA Earth observations data from the last decade to quantify and visualize monthly precipitation rates in order to identify locations most suitable for rainwater harvesting. Because WRAP works closely with schools’ faculty, students, and the surrounding communities to address water scarcity, the organization also requested an interactive interface to be shared with the schools as an educational tool that will be used to improve students’ understanding of the region’s precipitation and climate as well as geographic information systems and other monitoring and analysis technologies.

# 3. Methodology

***3.1 Data Acquisition***

**3.1.1 Precipitation Data**

The Middle East Water Resources team utilized precipitation data from both the Tropical Rainfall Measuring Mission (TRMM) and the Global Precipitation Measurement (GPM).

The team used the TRMM 3B43 data products for remotely sensed precipitation measurements of the region. TRMM’s Precipitation Radar (PR), which has a spatial resolution of 0.25° x 0.25° (approximately 25 km x 25 km), provided data in mm/hr from January 2005 to February 2014, in aggregated monthly intervals. TRMM travels in a non-sun-synchronous orbit at 403 km, at a 35° inclination angle to the equator, and the revisit time for the satellite is about 15 hours (Gomez, 2007). The team retrieved the TRMM data from the Goddard Earth Sciences Data and Information Services Center (Mirador) data portal.

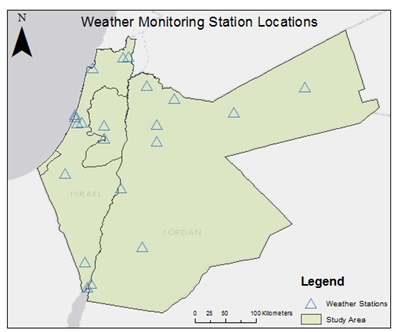
The Global Precipitation Measurement (GPM), which has a spatial resolution of 0.1° x 0.1° (approximately 10 km x 10 km), was used in conjunction with the TRMM data to observe precipitation patterns. GPM’s Dual-Frequency Precipitation Radar (DPR) provided precipitation measurements in mm/hr from March 2014 until January 2016, in aggregated monthly increments, and was retrieved via Open-source Project for a Network Data Access Portal (OPeNDAP).

**3.1.2 Elevation Data**

The team used SIR-C/X-SAR Shuttle Radar Topography Mission (SRTM) for the elevation data of the region, and retrieved the data from the USGS Earth Explorer website. SRTM is a radar-based, absolute elevation raster image with a 30 m horizontal resolution and 16 m vertical resolution.

**3.1.3 Groundwater Data**

The Gravity Recovery and Climate Experiment (GRACE), which has a spatial resolution of 300 km, provided land water storage (groundwater) data. The data from GRACE are available on 1-degree global grids and at a monthly increment. The team retrieved groundwater data from February 2005 to May 2016 from NASA’s Jet Propulsion Laboratory (JPL) website.

**3.1.4 Evapotranspiration Data**MOD16, from the Terra satellite’s Moderate Resolution Imaging Spectroradiometer (MODIS), provided evapotranspiration data, which the team included as contextual information for the educational component of the interface. The data has a resolution of .05 degrees and was retrieved for 2005 through 2014 at monthly increments.

**3.1.5 Validation Data**

The team used precipitation accumulation values from NOAA’s global surface summary of the day (GSOD) to validate the remotely sensed data. Within the study area, there were 15 weather stations that monitored precipitation during the study period (January 2005 - May 2016).

Figure 1. NOAA weather monitoring stations in Israel, the West Bank, and Jordan.

Table 1. Coordinates and countries of NOAA weather monitoring stations

|  |  |  |  |
| --- | --- | --- | --- |
| **Station** | **Country** | **Latitude (**°**N)** | **Longitude (**°**E)** |
| Beer Sheva City | Israel | 31.25 | 34.633 |
| Ben Gurion | Israel | 32.011 | 34.887 |
| Bet Dagon | Israel | 32 | 34.817 |
| Eilat | Israel | 29.561 | 34.96 |
| Har-Knaan (Zefat) | Israel | 32.967 | 35.5 |
| Irbid | Jordan | 32.55 | 35.85 |
| Ma'an | Jordan | 30.167 | 35.783 |
| Prince Hasan | Jordan | 32.161 | 37.144 |
| Queen Alia International | Jordan | 31.723 | 35.993 |
| Aqaba King Hussein International | Jordan | 29.612 | 35.018 |
| Ghor Safi | Jordan | 31.033 | 35.467 |
| H4 (Eastern Jordan) | Jordan | 32.534 | 38.195 |
| King Hussein | Jordan | 32.356 | 36.259 |
| Marka International | Jordan | 31.973 | 35.992 |
| Jerusalem | West Bank | 31.965 | 35.219 |

***3.2 Data Processing***  
In order to delineate the study area, the team merged shapefiles of Israel, Jordan, and the West Bank to form a single shapefile of the intended study area. Next, the team mosaicked thirty-nine SRTM tiles to create the DEM for the entire study area. TRMM and GPM data, which were in a NetCDF format, were then converted to a TIFF format, using a Python script, and clipped to the study area extent. The groundwater and evapotranspiration data were clipped to the same study area extent for consistency. The team geocoded the locations of the rain gauge data in QGIS and aggregated it from daily data to a monthly time step, which allowed for validation of the NASA TRMM and GPM data with the station rain gauge data. Because the NASA Earth observations precipitation data was recorded in units of millimeters per hour, the team converted the data from the raw rates into quantities, which required multiplying the daily data by the number of hours in that month, as seen in the table below. The team then extracted descriptive data, such as monthly precipitation averages, minima, maxima, and averages at rain gauge stations and at the locations of WRAP-affiliated schools.

Table 2. Number of hours per month.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Month** | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec |
| **Hours** | 744 | 672 | 744 | 720 | 744 | 720 | 744 | 744 | 720 | 744 | 720 | 744 |

\*February has 696 hours in Leap Years (2008, 2012, 2016, etc.)

***3.3 Interface Development***

After the team processed and validated the data, the team created an interface for data visualization and interaction in Google Earth Engine, called PrIME, the Precipitation Interface for the Middle East. The team created a Google Earth Engine account for the partner so that they would not have storage issues and so they could access the data easily. The team initially coded a functionality that automatically centers the interface at a longitude of 36.45264 and a latitude of 31.09057, and zooms to a level which is suitable for visualizing the data. Vector data was also uploaded via fusion tables, one for locations of WRAP schools, and another for the study area polygon. Fusion tables are an application created by Google which allow users to import their own data and visualize it on a map, and they work seamlessly with Google Earth Engine. Additionally, raster data often takes large amounts of space on computers, but Google Earth Engine allows users to upload as much as 250 gigabytes of data. After clipping our data to the study area, there was still plenty of storage available in the WRAP account. This process required uploading 328 rasters to Google Earth Engine, a combination of TRMM, GPM, GRACE, MODIS, and SRTM data. Each image was assigned a property of a date so that the interface understands the appropriate location of each image within the time series, and ensures that images are sorted into the appropriate image collection, which were determined by data type.

The creation of the time series charts required several steps, some of which were executed in ArcMap and then the resulting images were uploaded back into Google Earth Engine. To create time series charts, Google Earth Engine assigns each band associated with a TIFF a value, starting with b1. The band value is used by the pixel inspector to graph values over time. Initially, all TRMM and GPM images were assigned band values of 1, however, since the team wanted to have both data sources on the same precipitation time series chart, the team had to alter the band values. Each TRMM and GPM TIFF was loaded into ArcMap, and the TRMM data were resampled to have the same resolution as the GPM data so that the composites would have the higher resolution of the two datasets, rather than the default. A 0 raster was created and composited with the TRMM and GPM images to create two-band images. For the time period in which only TRMM data was available, TRMM was band 1 for the composites, and the 0 raster was assigned to be band 2. During the time period when TRMM and GPM were both active, the TRMM data was assigned to band 1 and the GPM data was assigned to band 2. For the time for which only GPM data is available, the 0 raster is assigned to be band 1 and the GPM data is assigned as band 2. After compositing the images, the composite’s minimum and maximum values for each band were manually changed to the values of the original rasters using the Minimum-Maximum Stretch’s Edit High/Low Values function in the Symbology tab of each layer’s properties. The composites were then uploaded to the Precipitation Image Collection in Google Earth Engine. This process allowed for the visualization of TRMM and GPM within the same precipitation time series chart in Google Earth Engine.

Next, the image collections were imported into the code editor and assigned unique names to perform functions on them individually. The code calls the image collections separately and specifies a unique date range and color palette to represent data, based on the minimum and maximum values of the data in the image collection. Once the data was visualized and center, the next step was to create the pixel inspector. A left panel was created, which displays instructions for how to use the pixel inspector and the coordinates of the selected points of interest, and the right panel serves as the backdrop for the pixel inspector output charts. In the script, the panel code is followed by three different blocks of code that are similar but perform functions on different image collections. They define the chart location, size, title, axis labels, and series name for each dataset, as well as how many layers will appear once the user clicks on the map. The three charts that are generated represent the data values at the pixel of interest over time for precipitation, groundwater, and evapotranspiration. The graphs can be exported as images, in PNG format, or as a table in CSV format.

***3.4 Data Analysis***

For statistical analyses, the team conducted linear regressions between the rain gauge monthly data and the precipitation data. A linear regression was chosen to compare these datasets because a previous study by Gomez (2007), which validated TRMM data with rain gauge data, and found linear correlations between the two. Some further statistics for each station included R² values, RMSE values, as well as monthly and annual averages, standard deviations, and minimum/maximums. Additionally, the team utilized scatterplots and other graphical methods to demonstrate the strength of the relationship between the two datasets.

# 4. Results & Discussion

***4.1 Validation Results***

Generally, the stations that received larger amounts of rain were more highly correlated with the NASA Earth observations data than those which received just trace amounts of precipitation. Results indicate that GPM has a stronger relationship to the rain gauge data than does TRMM, however, this increased accuracy could be due to the fact that GPM has a much smaller dataset than TRMM, and that any noisy data might not appear until more data becomes available. It also indicated that GPM is better at detecting precipitation in non-tropical regions than its predecessor, which is most likely due to its higher spatial resolution. Detailed results from the validation can be seen in Appendix A.

Table 3. R2 Values for TRMM and GPM Validation

|  |  |  |
| --- | --- | --- |
| **Station** | **TRMM** | **GPM** |
| Beer Sheva | 0.6637 | 0.9778 |
| Ben Gurion | 0.7902 | 0.989 |
| Bet Dagon | 0.8294 | 0.9601 |
| Eilat | 0.6556 | 0.1713 |
| Har-Knaan (Zefat) | 0.6939 | 0.8231 |
| Irbid | 0.7323 | 0.9776 |
| Ma'an | 0.0146 | 0.4454 |
| Prince Hasan | 0.186 | 0.2341 |
| Queen Alia International | 0.6627 | 0.8441 |
| Aqaba King Hussein | 0.1548 | 0.7463 |
| Ghor Safi | 0.0084 | 0.6178 |
| H4 | 0.2127 | 0.0137 |
| King Hussein | 0.2469 | 0.5377 |
| Marka International | 0.3458 | 0.3229 |
| Jerusalem | 0.8828 | 0.9478 |

***4.2 Climatology Results***

According to the data, at the locations of WRAP schools, the month with the highest average rainfall is January, and the month with the lowest average rainfall is August. An average of 101 mm of precipitation fall in January, whereas only 0.19 mm of precipitation fall, on average, at the same locations in August. One of the WRAP schools, Tuba Zangariya, which is located in northwest Israel, consistently received more rain than the rest of the schools. Because many of the schools are somewhat clustered in the northern and western parts of Israel, those near one another have fairly similar patterns of precipitation.

Figure 2. Time series of precipitation at WRAP schools

Figure 3. Average annual precipitation measurements for each rain gauge station.

Figure 4. Average monthly precipitation from all WRAP school locations.

***4.3 Interface Results***

PrIME integrates precipitation, evapotranspiration, groundwater, and elevation data into an interactive format which allows for the extraction of data at points of interest. Users can click anywhere where there is data and the interface will return the coordinates of the selected points, visualize that point with a red dot, extract the rasters and plot them in a time series chart. The interface generates three graphs: historical precipitation, groundwater, and evapotranspiration. The user can hover the cursor over any point on the graph to see that date’s data value, or can export the graph as an image or table to more thoroughly inspect the data. Through PrIME, the user will be able to determine the optimal locations of rainwater harvesting sites. Additionally, the user can incorporate new data as it becomes available to continue to monitor climatological trends. PrIME can be accessed through a shared link, which will allow WRAP to easily share it with their partner schools.

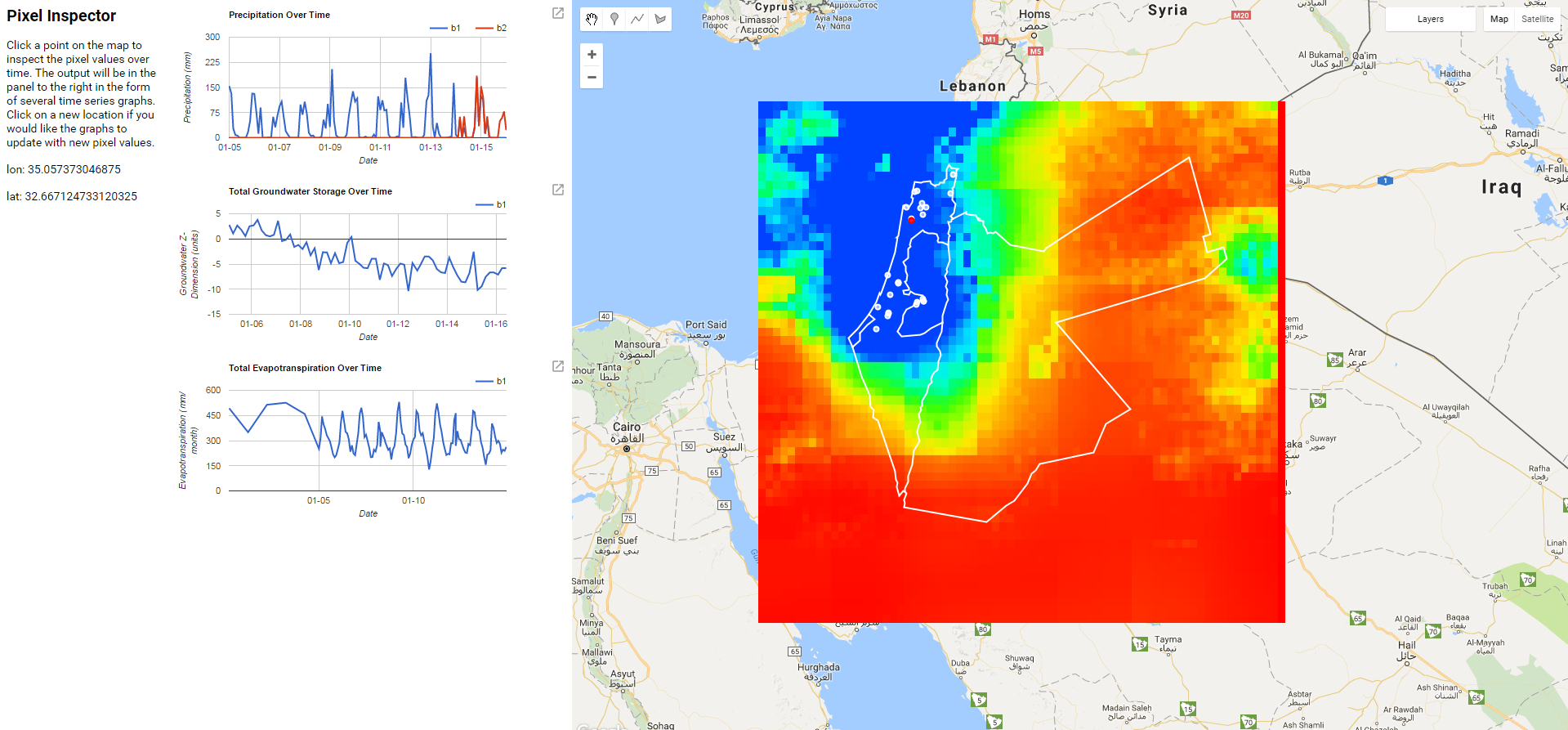


Figure 5. PrIME in Google Earth Engine with precipitation, groundwater, and evapotranspiration charts.

***4.4 Limitations***

The conversion of precipitation rates to amounts assumes that the precipitation falls at a constant rate (Kuligowki, 1997). These assumptions can be significant sources of error. Additionally, there can be changes in the precipitation field before the precipitation reaches the ground.

***4.5 Future Work***

The team aspires to develop a script which downloads new GPM data, coverts the data into a TIFF format, clips the TIFF to our study area, and converts the data values form rates to amounts. Additional future work could involve the development of an equally functional interface that could be used offline, such as QGIS. Additional datasets such as temperature or population could be added to the interface as contextual and educational information. Exploring population density around the study area may also aid in deciding which schools would benefit most from the rainwater collection efforts, as schools near larger, denser cities are likely have a larger student population. Teleconnections, such as the North Sea Caspian Pattern, could be given more attention and consideration concerning its effect on precipitation in the region.

# 5. Conclusions

PrIME, because of its ease of access and use, provides WRAP, and the schools with which it works, the ability to extract the historical precipitation at any point of interest within the region. PrIME’s accessibility and incorporation of several NASA Earth observations will allow WRAP to determine where in the region schools could benefit most from the implementation of rainwater harvesting systems and will, thus, enhance its decision-making process. The equation for the potential harvested rainwater is as follows (Boers & Ben-Asher, 1982):

Maximum runoff (Liters) = catchment area (m²) \* rainfall (mm²) \* runoff coefficient

This will allow WRAP to take the data from PrIME and estimate the amount of water that could be harvested given a certain location and school roof size. The interface will also serve as an interactive educational tool for students. Additionally, the functionality of the tool coupled with the tutorials provided to the partner will allow WRAP to upload new data for continuous monitoring of climatological trends in the region.

# 6. Acknowledgments

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# 8. Content Innovation

**Content Innovation #1**

**Inline Supplementary Material (figures, tables, etc.)**

* Figure 1. NOAA weather monitoring stations in Israel, the West Bank, and Jordan.
* Table 1. Coordinates and countries of NOAA weather monitoring stations
* Table 2. Number of hours per month.
* Table 3. R2 Values for TRMM and GPM Validation
* Figure 2. Average annual precipitation measurements for each rain gauge station.
* Figure 3. Average annual precipitation measurements for each rain gauge station.
* Figure 4. Average monthly precipitation from all WRAP school locations.
* Figure 5. PrIME in Google Earth Engine with precipitation, groundwater, and evapotranspiration charts.

**Content Innovation #2**

Interactive Map Viewer

* Waiting for software release before providing access

**Content Innovation #3**

* VPS: Make it Rain – The Water Cycle from Precipitation to Sanitation https://www.youtube.com/watch?v=T9E5QmYP1DY

# 9. Appendices

***Appendix A. Validation Results***

***Appendix B. Climatology Results***

**Sur Baher and Al Afuq School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 17.02 | 2009 | 163.18 | 2013 | 92.03476 |
| February | 32.83 | 2014 | 138.36 | 2009 | 87.78101 |
| March | 5.87 | 2008 | 75.2443 | 2014 | 43.31181 |
| April | 3.47 | 2009 | 85.9871 | 2006 | 20.91205 |
| May | 0.47 | 2009 | 45.28 | 2014 | 7.711283 |
| June | 0.03 | 2015 | 0.46 | 2010 | 0.160922 |
| July | 0.01 | 2006, 2007, 2015 | 0.15 | 2011 | 0.070173 |
| August | 0.00 | 2007, 2008, 2009, 2014 | 0.29 | 2011 | 0.051611 |
| September | 0.02 | 2007 | 3.16 | 2008 | 1.020426 |
| October | 0.08 | 2007 | 45.91 | 2015 | 14.42039 |
| November | 6.22 | 2008 | 125.64 | 2014 | 42.46214 |
| December | 32.68 | 2007 | 113.58 | 2013 | 60.3987 |

**Battir & Al Sedeeq Schools**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 17.02 | 2009 | 163.18 | 2013 | 92.78313 |
| February | 32.83 | 2014 | 138.36 | 2009 | 87.75345 |
| March | 5.87 | 2008 | 75.38 | 2014 | 43.28094 |
| April | 3.47 | 2009 | 85.99 | 2006 | 20.24903 |
| May | 0.47 | 2009 | 38.52 | 2014 | 7.104629 |
| June | 0.03 | 2015 | 0.46 | 2010 | 0.164316 |
| July | 0.01 | 2006, 2007, 2015 | 0.14 | 2012 | 0.070196 |
| August | 0.00 | 2007, 2008, 2009, 2014 | 0.29 | 2011 | 0.051114 |
| September | 0.02 | 2007 | 3.16 | 2008 | 1.029557 |
| October | 0.08 | 2007 | 45.62 | 2015 | 14.55026 |
| November | 6.22 | 2008 | 145.42 | 2014 | 44.63938 |
| December | 32.68 | 2007 | 113.58 | 2013 | 60.68598 |

**Eynot Yarden School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 12.22 | 2014 | 252.68 | 2013 | 111.9306 |
| February | 22.99 | 2014 | 193.64 | 2009 | 99.10465 |
| March | 0.70 | 2013 | 67.91 | 2009 | 34.92078 |
| April | 0.16 | 2010 | 94.58 | 2006 | 28.31442 |
| May | 0.65 | 2010 | 43.78 | 2014 | 11.70686 |
| June | 0.00 | 2015 | 1.40 | 2011 | 0.302042 |
| July | 0.06 | 2006 | 1.45 | 2011 | 0.318651 |
| August | 0.05 | 2012, 2013 | 3.42 | 2006 | 0.418509 |
| September | 0.09 | 2012 | 24.42 | 2009 | 3.920501 |
| October | 0.00 | 2011 | 76.68 | 2006 | 27.8266 |
| November | 0.01 | 2010 | 135.23 | 2014 | 55.68004 |
| December | 28.71 | 2014 | 157.54 | 2012 | 84.76485 |

**Tuba Zangariya**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 34.94 | 2014 | 284.09 | 2013 | 136.3498 |
| February | 67.47 | 2014 | 222.44 | 2009 | 131.3633 |
| March | 16.18 | 2015 | 189.86 | 2012 | 78.85869 |
| April | 0.02 | 2014 | 141.04 | 2011 | 44.81132 |
| May | 3.82 | 2006 | 50.41 | 2014 | 17.31548 |
| June | 0.00 | 2015 | 86.03 | 2010 | 14.87629 |
| July | 0.15 | 2015 | 46.82 | 2011 | 5.84513 |
| August | 0.02 | 2014 | 4.87 | 2007 | 1.3705 |
| September | 0.05 | 2015 | 40.80 | 2009 | 10.29687 |
| October | 3.47 | 2007 | 72.39 | 2006 | 39.14507 |
| November | 13.22 | 2010 | 161.73 | 2012 | 97.99494 |
| December | 26.98 | 2014 | 232.16 | 2012 | 131.0859 |

**Ofek and HaShalom High Schools**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Months | Min | Year | Max | Year | Average |
| January | 7.36 | 2014 | 246.28 | 2013 | 119.2322 |
| February | 4.79 | 2014 | 196.28 | 2009 | 100.4603 |
| March | 0.16 | 2013 | 86.18 | 2014 | 39.22821 |
| April | 0.01 | 2010 | 90.66 | 2006 | 29.22607 |
| May | 0.28 | 2010 | 52.38 | 2014 | 10.53251 |
| June | 0.00 | 2015 | 16.23 | 2010 | 1.872749 |
| July | 0.07 | 2012 | 0.83 | 2011 | 0.311898 |
| August | 0.02 | 2012, 2013, 2014 | 1.61 | 2006 | 0.360895 |
| September | 0.06 | 2015 | 13.55 | 2009 | 2.907927 |
| October | 0.70 | 2007 | 76.63 | 2006 | 29.99175 |
| November | 0.05 | 2010 | 163.64 | 2014 | 67.45522 |
| December | 32.92 | 2011 | 147.82 | 2013 | 97.17146 |

**Shfar'am High School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 7.36 | 2014 | 246.28 | 2013 | 119.9341 |
| February | 4.79 | 2014 | 196.28 | 2009 | 101.8919 |
| March | 0.16 | 2013 | 97.45 | 2014 | 40.09331 |
| April | 0.01 | 2010 | 90.66 | 2006 | 30.28993 |
| May | 0.28 | 2010 | 64.49 | 2014 | 11.63626 |
| June | 0.01 | 2015 | 16.23 | 2010 | 1.899748 |
| July | 0.07 | 2012 | 0.83 | 2011 | 0.308721 |
| August | 0.02 | 2012, 2013, 2014 | 1.61 | 2006 | 0.360572 |
| September | 0.08 | 2012 | 13.55 | 2009 | 2.920568 |
| October | 0.70 | 2007 | 67.09 | 2009 | 30.44367 |
| November | 0.05 | 2010 | 178.06 | 2014 | 69.34029 |
| December | 32.92 | 2011 | 147.82 | 2013 | 98.66608 |

**Tamra - Almuntanabi Junior High School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 7.36 | 2014 | 246.28 | 2013 | 117.6257 |
| February | 4.79 | 2014 | 196.28 | 2009 | 102.3085 |
| March | 0.16 | 2013 | 80.53 | 2014 | 38.59759 |
| April | 0.01 | 2010 | 90.66 | 2006 | 30.21129 |
| May | 0.28 | 2010 | 63.63 | 2014 | 11.5925 |
| June | 0.02 | 2015 | 16.23 | 2010 | 1.915783 |
| July | 0.07 | 2012 | 0.83 | 2011 | 0.309386 |
| August | 0.02 | 2012, 2013, 2014 | 1.61 | 2006 | 0.361176 |
| September | 0.08 | 2012 | 13.55 | 2009 | 2.926024 |
| October | 0.70 | 2007 | 76.63 | 2006 | 29.98334 |
| November | 0.05 | 2010 | 163.37 | 2014 | 67.56987 |
| December | 30.97 | 2014 | 147.82 | 2013 | 96.53396 |

**Bosmat High School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 14.39 | 2014 | 272.52 | 2013 | 134.4108 |
| February | 4.24 | 2014 | 187.46 | 2009 | 95.3108 |
| March | 1.01 | 2013 | 91.92 | 2011 | 36.13383 |
| April | 0.01 | 2010 | 96.78 | 2006 | 27.01756 |
| May | 0.14 | 2009 | 56.31 | 2014 | 9.988382 |
| June | 0.09 | 2013 | 1.23 | 2011 | 0.534517 |
| July | 0.09 | 2012 | 1.27 | 2011 | 0.35809 |
| August | 0.04 | 2014 | 0.57 | 2011 | 0.163683 |
| September | 0.01 | 2007 | 14.77 | 2009 | 3.045416 |
| October | 0.07 | 2007 | 84.34 | 2006 | 33.99449 |
| November | 6.13 | 2010 | 202.841 | 2014 | 80.18245 |
| December | 35.85 | 2011 | 179.60 | 2013 | 113.652 |

**Science and Leadership High School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 8.88 | 2014 | 252.04 | 2013 | 118.4381 |
| February | 1.06 | 2014 | 204.75 | 2009 | 99.01729 |
| March | 0.27 | 2013 | 81.23 | 2011 | 35.98596 |
| April | 0.03 | 2010 | 90.17 | 2006 | 29.30545 |
| May | 0.27 | 2010 | 63.88 | 2014 | 10.56806 |
| June | 0.00 | 2013 | 3.53 | 2010 | 0.628722 |
| July | 0.06 | 2005, 2012, 2015 | 0.30 | 2007 | 0.11875 |
| August | 0.01 | 2005, 2007, 2009, 2010, 2012, 2013, 2014 | 1.07 | 2006 | 0.142767 |
| September | 0.02 | 2012 | 9.53 | 2009 | 1.917661 |
| October | 0.40 | 2007 | 64.34 | 2009 | 28.59939 |
| November | 0.00 | 2010 | 185.15 | 2014 | 70.61394 |
| December | 29.73 | 2011 | 164.09 | 2013 | 96.59887 |

**Zarzir School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 8.88 | 2014 | 252.04 | 2013 | 115.7931 |
| February | 1.06 | 2014 | 204.75 | 2009 | 100.2704 |
| March | 0.27 | 2013 | 81.23 | 2011 | 36.24992 |
| April | 0.02 | 2014 | 90.17 | 2006 | 29.27694 |
| May | 0.27 | 2010 | 63.59 | 2014 | 10.71259 |
| June | 0.00 | 2013, 2015 | 3.53 | 2010 | 0.624545 |
| July | 0.06 | 2005, 2012 | 0.30 | 2007 | 0.122783 |
| August | 0.01 | 2005, 2007, 2009, 2010, 2012, 2013, 2014 | 1.07 | 2006 | 0.144284 |
| September | 0.02 | 2012 | 4.13 | 2011 | 2.017253 |
| October | 0.40 | 2007 | 64.34 | 2009 | 27.33128 |
| November | 0.00 | 2010 | 170.86 | 2014 | 68.17525 |
| December | 29.73 | 2011 | 164.09 | 2013 | 95.36436 |

**Darcha Begin Regional High School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 0.81 | 2009 | 201.89 | 2013 | 108.9292 |
| February | 19.18 | 2014 | 162.18 | 2009 | 87.88879 |
| March | 1.96 | 2008 | 82.56 | 2007 | 39.30933 |
| April | 1.09 | 2008 | 79.29 | 2006 | 18.53862 |
| May | 0.08 | 2006 | 38.19 | 2014 | 6.373872 |
| June | 0.00 | 2005, 2006, 2008 | 0.79 | 2010 | 0.175562 |
| July | 0.02 | 2005, 2008, 2010, 2012, 2013, 2015 | 0.13 | 2011 | 0.040863 |
| August | 0.00 | 2005, 2007, 2009, 2010, 2012, 2013, 2014 | 0.37 | 2011 | 0.041633 |
| September | 0.00 | 2005 | 8.73 | 2009 | 1.809306 |
| October | 0.65 | 2007 | 64.30 | 2008 | 23.76021 |
| November | 8.01 | 2008 | 190.89 | 2014 | 63.90632 |
| December | 27.39 | 2011 | 160.04 | 2013 | 78.08153 |

**Kfar Silver School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 0.05 | 2009 | 175.36 | 2013 | 95.30768 |
| February | 24.02 | 2014.00 | 154.06 | 2009 | 80.77305 |
| March | 0.30 | 2008 | 79.93 | 2007 | 38.2071 |
| April | 0.58 | 2008 | 61.69 | 2006 | 14.88948 |
| May | 0.05 | 2006 | 35.59 | 2014 | 5.797882 |
| June | 0.00 | 2006, 2007, 2009 | 0.81 | 2010 | 0.268965 |
| July | 0.00 | 2009 | 0.30 | 2011 | 0.061923 |
| August | 0.00 | 2005, 2007, 2008, 2010, 2012, 2014, 2013, 2009, 2015 | 0.33 | 2011 | 0.046843 |
| September | 0.00 | 2007 | 9.03 | 2009 | 1.906098 |
| October | 0.01 | 2007 | 83.33 | 2008 | 22.77166 |
| November | 4.48 | 2008 | 160.67 | 2014 | 56.35079 |
| December | 28.91 | 2011 | 171.89 | 2013 | 69.98404 |

**Meir & Rabin School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 0.05 | 2009 | 181.49 | 2013 | 97.05045 |
| February | 26.00 | 2014 | 149.55 | 2009 | 83.85772 |
| March | 0.57 | 2008 | 80.83 | 2007 | 39.40043 |
| April | 1.07 | 2008 | 70.02 | 2006 | 16.17567 |
| May | 0.09 | 2006 | 36.16 | 2014 | 6.007483 |
| June | 0.00 | 2005, 2006, 2007, 2008, 2009 | 0.66 | 2010 | 0.174345 |
| July | 0.00 | 2009 | 0.28 | 2011 | 0.059654 |
| August | 0.00 | 2005, 2007, 2008, 2009, 2014, 2015 | 0.38 | 2011 | 0.059574 |
| September | 0.00 | 2006 | 7.23 | 2009 | 1.61703 |
| October | 0.28 | 2007 | 71.60 | 2008 | 21.75145 |
| November | 5.03 | 2008 | 149.80 | 2014 | 52.32757 |
| December | 23.96 | 2011 | 147.38 | 2013 | 66.52527 |

**Netivot Yeshiva High School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 4.73 | 2009 | 130.97 | 2015 | 81.65099 |
| February | 24.94 | 2015 | 128.96 | 2009 | 71.63977 |
| March | 0.23 | 2008 | 88.69 | 2014 | 36.547 |
| April | 0.57 | 2008 | 51.85 | 2006 | 13.14466 |
| May | 0.04 | 2006 | 38.29 | 2014 | 5.769928 |
| June | 0.00 | 2005, 2006, 2007, 2008, 2009 | 0.69 | 2013 | 0.180969 |
| July | 0 | 2007, 2009, 2010, 2013 | 0.08 | 2011 | 0.018135 |
| August | 0 | 2005, 2007, 2008, 2010, 2012, 2014, 2015 | 0.25 | 2011 | 0.029473 |
| September | 0 | 2005, 2007 | 7.51 | 2009 | 1.529738 |
| October | 0.04 | 2007 | 74.89 | 2008 | 18.82652 |
| November | 2.16 | 2008 | 130.80 | 2014 | 46.86041 |
| December | 25.83 | 2011 | 129.98 | 2013 | 55.45255 |

**Kafr Manda - Almuntanabi Junior High School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 6.86 | 2014 | 240.59 | 2013 | 121.66 |
| February | 3.10 | 2014 | 213.678 | 2009 | 109.0366 |
| March | 0.49 | 2013 | 87.76 | 2007 | 48.11899 |
| April | 0.02 | 2014 | 102.03 | 2006 | 33.05791 |
| May | 0.20 | 2010 | 63.63 | 2014 | 13.04953 |
| June | 0.00 | 2013 | 3.03 | 2007 | 0.968542 |
| July | 0.07 | 2010, 2012, 2013 | 1.44 | 2007 | 0.370369 |
| August | 0.02 | 2010, 2013, 2014 | 2.12 | 2006 | 0.382035 |
| September | 0.08 | 2012 | 15.85 | 2009 | 3.957583 |
| October | 1.71 | 2011 | 78.41 | 2006 | 30.66587 |
| November | 0.08 | 2010 | 163.37 | 2014 | 77.61767 |
| December | 30.97 | 2014 | 166.36 | 2005 | 101.2449 |

**Ahmed Samach School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 23.05 | 2009 | 179.96 | 2013 | 104.4104 |
| February | 27.85 | 2014 | 163.13 | 2009 | 93.57685 |
| March | 10.16 | 2006 | 98.28 | 2011 | 45.93399 |
| April | 4.21 | 2009 | 94.53 | 2006 | 22.8615 |
| May | 0.38 | 2006 | 45.28 | 2014 | 7.798607 |
| June | 0.01 | 2007 | 0.50 | 2010 | 0.139681 |
| July | 0.01 | 2015 | 0.13 | 2011 | 0.053148 |
| August | 0.00 | 2005, 2007, 2009, 2010, 2012, 2013, 2014 | 0.29 | 2011 | 0.04062 |
| September | 0.08 | 2007 | 3.50 | 2009 | 1.10145 |
| October | 0.90 | 2007 | 45.91 | 2015 | 17.16937 |
| November | 9.26 | 2010 | 125.64 | 2014 | 48.68321 |
| December | 31.26 | 2011 | 121.37 | 2013 | 70.51094 |

**Ironi Yud Beit School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 18.10 | 2009 | 219.44 | 2013 | 119.9579 |
| February | 4.01 | 2014 | 165.22 | 2009 | 83.43533 |
| March | 0.11 | 2013 | 81.24 | 2014 | 34.42199 |
| April | 0.00 | 2010 | 87.03 | 2006 | 21.02841 |
| May | 0.05 | 2006 | 43.61 | 2014 | 6.809248 |
| June | 0.05 | 2015 | 1.25 | 2010 | 0.363077 |
| July | 0.04 | 2007 | 0.83 | 2011 | 0.209704 |
| August | 0.01 | 2014 | 0.60 | 2011 | 0.097623 |
| September | 0.00 | 2007 | 10.13 | 2009 | 2.285017 |
| October | 0.38 | 2007 | 87.38 | 2015 | 33.05058 |
| November | 11.78 | 2010 | 202.56 | 2014 | 75.746 |
| December | 29.02 | 2011 | 181.59 | 2013 | 101.5236 |

**Eitan School**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 0.05 | 2009 | 175.36 | 2013 | 94.20696 |
| February | 24.02 | 2014 | 154.06 | 2009 | 79.77395 |
| March | 0.30 | 2008 | 84.93 | 2014 | 38.94322 |
| April | 0.58 | 2008 | 61.69 | 2006 | 14.60643 |
| May | 0.05 | 2006 | 31.91 | 2014 | 5.401786 |
| June | 0.00 | 2006, 2007, 2009 | 0.81 | 2010 | 0.260528 |
| July | 0.00 | 2009 | 0.30 | 2011 | 0.060774 |
| August | 0.00 | 2005, 2007-2010, 2012, 2014, 2015 | 0.33 | 2011 | 0.046799 |
| September | 0.00 | 2007 | 9.03 | 2009 | 1.882295 |
| October | 0.01 | 2007 | 83.33 | 2008 | 22.21922 |
| November | 4.48 | 2008 | 132.64 | 2014 | 52.86899 |
| December | 28.91 | 2011 | 171.89 | 2013 | 69.05934 |

**Agro Farm & Hamapilim & Ganei Aviv Schools**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Month | Min | Year | Max | Year | Average |
| January | 0.81 | 2009 | 201.89 | 2013 | 110.1008 |
| February | 19.18 | 2014 | 162.18 | 2009 | 88.90394 |
| March | 1.96 | 2008 | 89.77 | 2014 | 40.20415 |
| April | 1.09 | 20008 | 79.29 | 2006 | 18.89548 |
| May | 0.08 | 2006 | 42.14 | 2014 | 6.869961 |
| June | 0.00 | 2005, 2006, 2008 | 0.79 | 2010 | 0.179643 |
| July | 0.02 | 2005, 2008, 2010, 2012, 2013, 2015 | 0.13 | 2011 | 0.041824 |
| August | 0.00 | 2005, 2007, 2009-2010, 2012-2014 | 0.37 | 2011 | 0.043783 |
| September | 0.00 | 2005 | 8.73 | 2009 | 1.808434 |
| October | 0.65 | 2007 | 66.84 | 2015 | 24.4184 |
| November | 8.01 | 2008 | 178.35 | 2014 | 62.36197 |
| December | 27.39 | 2011 | 160.04 | 2013 | 78.11661 |