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Monitoring the Syrian Humanitarian Crisis with the JRC's Global Human Settlement Layer and Night-Time Satellite Data

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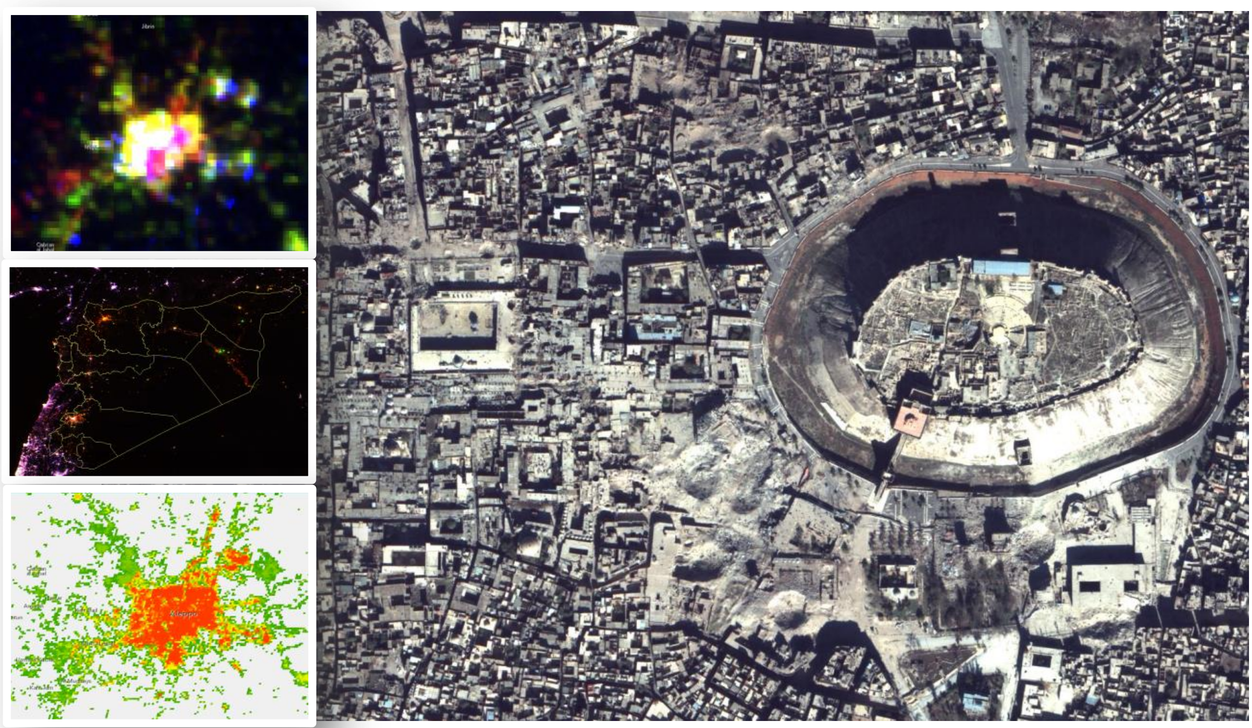

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Abstract

The JRC's Global Human Settlement Layer (GHSL) and the derived population data were integrated with night-time satellite imagery to assess the humanitarian impact of the Syrian conflict.

The results demonstrate that the methodology allows estimating in a timely and consistent manner the number of affected people during crisis using satellite-derived indicators.

Estimates of affected people that match with the official figures including registered refugees and IDPs were obtained with this method.

The approach has a potential in estimating in an objective and timely way the impacts of humanitarian crisis.

Prospective studies can make use of the temporal and spatial advantages of open-access geospatial data (night-time satellite imagery and GHSL derived products) in the field of disaster risk management to investigate the role of social dynamics over space and time in the occurrences of disasters and provide evidence-based knowledge to support disaster risk reduction plans and actions.

1. Insights to the humanitarian aspects of the Syrian Crisis

The on-going Syrian conflict, which broke out in April 2011, is the worst humanitarian crisis since World War II. As of May 2016, it is estimated that over 250,000 people have been killed and over one million injured. 4.1 million Syrians have been forced to leave the country, and 6.5 million are internally displaced (IDPs), making Syria the largest displacement crisis globally.

Accurately estimating affected and displaced people is important for assessing the real magnitude of the crisis and informing planning and provision of live saving humanitarian assistance.

Under-estimation can result in additional suffering and delayed response, while over-estimation may lead to needless additional costs and discredit of institutions.

Currently witness reports are the main sources for the Syrian crisis evaluation which makes it difficult to appraise in terms of neutrality, and comprehensiveness. Besides, while the number of registered refugees is regularly updated by UNHCR[1], estimates of IDPs are more difficult to obtain. Attempts to enumerate or estimate IDPs may be clouded by political interests, fundraising, and intra-organizational relationships and often lack continuity and consistency [1].

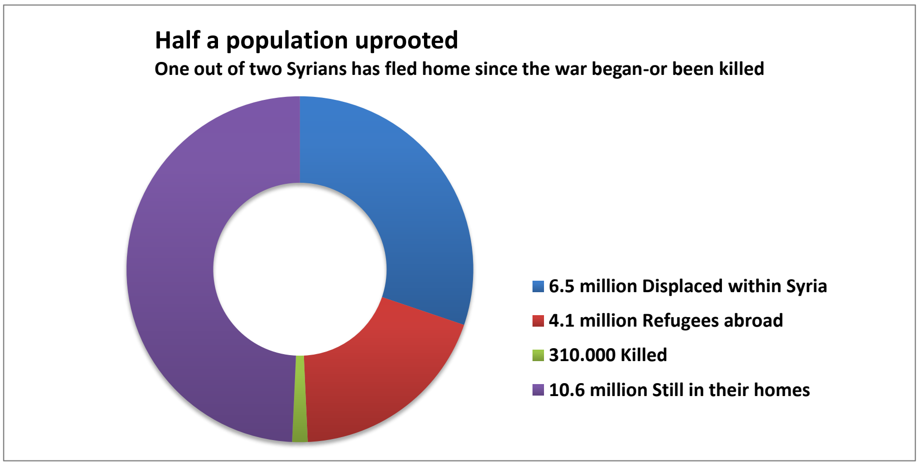

Figure 1. Estimated affected population in Syria (Source: the Syrian Observatory for Human Rights)

Earth Observation satellites can monitor large areas of land and sea (including in hard to reach areas such as war zones), have ability to collect data in a timely and objective manner and to disseminate up-to date observations to decision makers. Satellite images can provide invaluable information for humanitarian response when data is difficult to access due to political, security or geographical reasons. The rising role of Earth Observation technologies in monitoring conflicts and supporting humanitarian response is evidenced in several international initiatives: e.g. the mapping of expanding camps of refugees in Jordan and Syria by Copernicus Emergency Management Service[2], UNOSAT, Amnesty International's remote sensing based assessment of the damage and casualties due to assaults of Boko Haram attack on Baga in Nigeria, etc.

[1] **Source: http://data.unhcr.org/syrianrefugees/regional.php**
[2] **http://emergency.copernicus.eu/mapping/list-of-components/EMSR025**

Recently, a study [2] provided a preliminary evaluation of the value of satellite data and more precisely of night-light data to the Syrian crisis. A linear correlation between the IDPs and night-light loss was observed showing the potential of exploiting satellite data for evaluating humanitarian situations. Based on this first experiment, a follow-up study made use of night-light satellite data to detect an ISIS offensive against Iraq in 2014 [3] by assessing the response of city lightening levels to the insurgency.

Building on those two earlier studies, the current work attempts to go a step further and assess the humanitarian impact of the Syrian conflicts using night-light satellite imagery. Taking stock of open and free Earth Observation data, we develop an approach for assessing and monitoring the number of affected people in Syria. The two building blocks of the method are the residential population density grid data derived from the JRC's Global Human Settlement Layer (GHSL) and night-light satellite imagery.

2. Integrating GHSL derived population data with night-light satellite imagery

Knowing that some humanitarian disasters, like conflicts, typically produce a decline in nigh-time lighting, the approach is based on the assumption that time-persistent decline in night-light imagery is a consequence of damage to buildings and infrastructure and hence can be used as proxy for evaluating the affected resident population. To test this hypothesis, gridded resident population data, produced in the framework of the GHSL project was combined with monthly composite images derived from night-light data of the Visible Infrared Imaging Radiometer Suite sensor (VIIRS).

In the following, the different datasets used in this study are presented followed by a description of the methodology.

2.1 Study data

2.1.1 Night-light satellite images

Night-light images are a class of satellite observations and derived products based on the detection of light emissions from the earth's surface. Primarily developed for meteorological applications (lightening statistics in clouds), the sensors also detect (wild) fires and anthropogenic lights such as street illumination. Most prior studies have exploited night-light data of the Defense Meteorological Satellite Program Operational Line Scanner (DMSP/OLS) released in 1992, because the sensor has a large geographic coverage and a long-term archive. However, the DMSP data and products have a set of well-known shortcomings [4]: coarse spatial resolution, six bit quantization, saturation on bright lights, lack of in-flight calibration, lack of spectral channels suitable for discrimination of thermal sources of lighting and lack of low light imaging spectral bands suitable for discriminating lighting types. Launched in 2011, the Visible Infrared Imaging Radiometer Suite sensor (VIIRS) provides imagery in a higher spatial resolution of about 750 m and better radiometric attributes compared to DMSP/OLS. Monthly average radiance composite images derived from VIIRS are freely available for download from the NOAA National Geophysical Data Center website[3].

The VIIRS datasets were used in this study. The selected monthly composites span over the time period January 2013– December 2015. Earlier monthly composites are not

[3] http://ngdc.noaa.gov/eog/viirs/download_monthly.html

available and the data in 2012 are not of the same quality as the composite products released in 2013.

2.1.2 Population data (GHS-POP)

The JRC has developed an innovative concept for the mapping of human settlements at local, regional and global scales from Earth Observation data. The GHSL concept allowed producing the most spatially detailed data globally available today dedicated to human settlements. The GHSL built-up grids were derived from the analysis of Landsat imagery collections (epochs: 1975, 1990, 2000 and 2013-2014) [5]. GHSL technology relies on automatic analysis of satellite imagery to produce unprecedented fine scale maps quantifying built-up structures in terms of their location and density [6].

Data derived from the GHSL, such as built-up density, was used to produce a dataset with improved depictions of population distribution and densities in space and time at the global level (GHS-POP). Using a dasymetric mapping approach, population is disaggregated from finest census or administrative units to built-up areas. The GHS-POP is a 250-m resolution grid representing resident-based population distribution in 1975, 1990, 2000 and 2015 and has better accuracy and a higher spatial resolution than other previously available products [7], [8]. For the purpose of this study, the 250-m grid of 2015 was aggregated at 750 m to match with the spatial resolution of the VIIRS data.

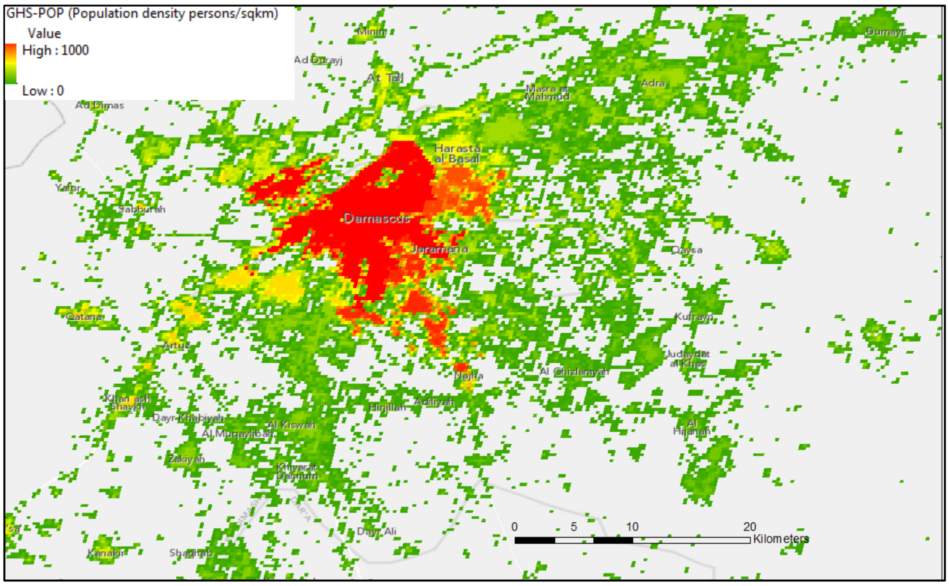

Figure 2. Population distribution in Damascus in 2015 as represented in the GHS-POP layer.

2.2 Analysis of night-lights

Syria has many oil and gas wells which flare gas and hence represent a possible source of night-light that needs to be separated from city lights. Therefore the first step consisted in using the GHSL built-up layer for masking the night-light data to focus the analysis on the built-up areas.

The second step consisted in calculating differences in light intensities between each two consecutive months for the period January 2013- December 2015[4]. The magnitude of night-time decrease (light loss) in one month time was considered as a proxy to the presence of damage in the area, then spatially joined with the presence of affected residential population. The threshold for statistically relevant night-light loss was set by assuming Israel as a reference for stable lights. The assessment is done at the minimal surface unit (pixel) level. Whenever a significant amount of light loss is detected, the number of affected people for that pixel is calculated from GHS-POP.

The last step consisted in aggregating the number of affected people per month by administrative region. The final results are computed in terms of absolute number of affected people per month and per governorate (*muhafazat*). Since some areas might suffer several light loss events, the population may be counted several times, resulting in a possible overestimation of the number of affected people.

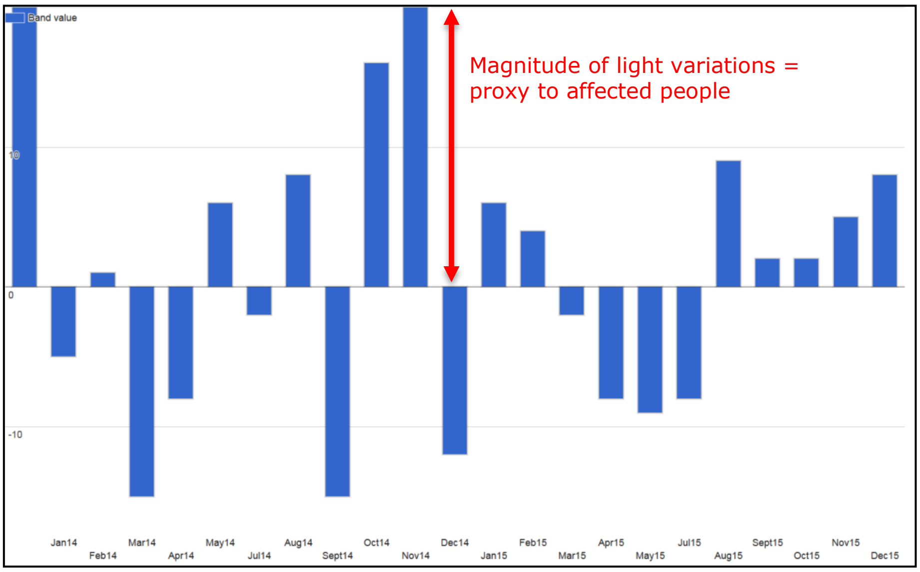

Figure 3. Analysis of monthly variations in night-light intensity

3. Results

The results of the assessment are shown in Figure 4Figure 5 in terms of estimated affected people per governorate (Figure 4) and for the whole Syrian territory (Figure 5). In Figure 5, the number of affected people obtained from remote sensing data is compared to monthly reports of registered refugees (source: UN OCHA[5]) and to key events of the conflict[6]. A total of 11.9 million affected people was obtained using geospatial data integration and analysis. These estimates converge with the estimated displaced persons reported by the Syrian Observatory for Human Rights, UN OCHA and Worldvision[7] : "4.6 million Syrians are refugees, and 6.6 million are displaced within

[4] For the first period, the difference between April 2012 and January 2013 was calculated. These 2 products are early release composites with discontinuous acquisitions. The starting date for version 1 composites is January 2013. Some composites (e.g. June 2014 and 2015) were corrupted.

[5] **Source: http://data.unhcr.org/syrianrefugees/regional.php**

[6] **Source: https://news.vice.com/article/syria-after-four-years-timeline-of-a-conflict**

[7] **Source: http://www.worldvision.org/news-stories-videos/syria-war-refugee-crisis**

Syria” thus totalling 11 million. As previously mentioned, given that some areas might suffer several light loss events, the affected population may be counted several times, thus explaining the overestimation of the number of affected people.

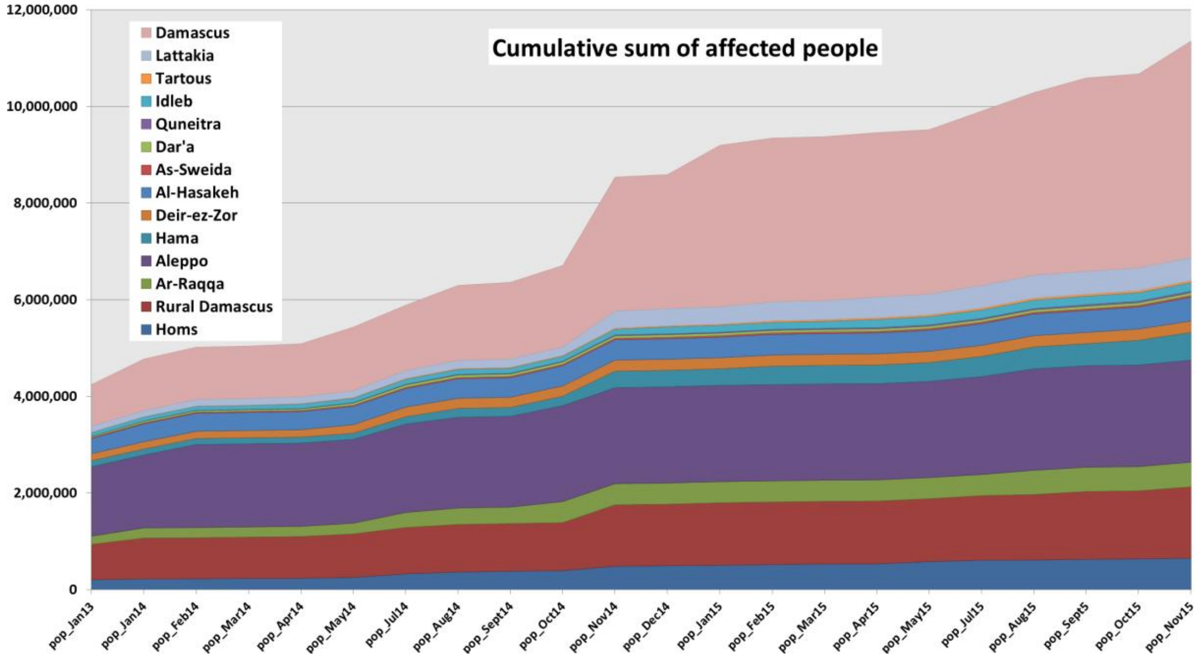

Figure 4. Estimated number of affected people per governorate

Figure 6 shows an overview of night-time lights in Syria and neighbouring countries in November 2014. By overlaying the nightlights on built-up areas obtained from the GHSL, it is possible to assess the impacted areas where no or low intensity light is observed in association with built-up areas. A close-up view over Damascus shows the variations of light for three periods (January 2014, November 2014 and December 2015). Those variations can be correlated with the estimated affected people in Damascus represented in Figure 4.

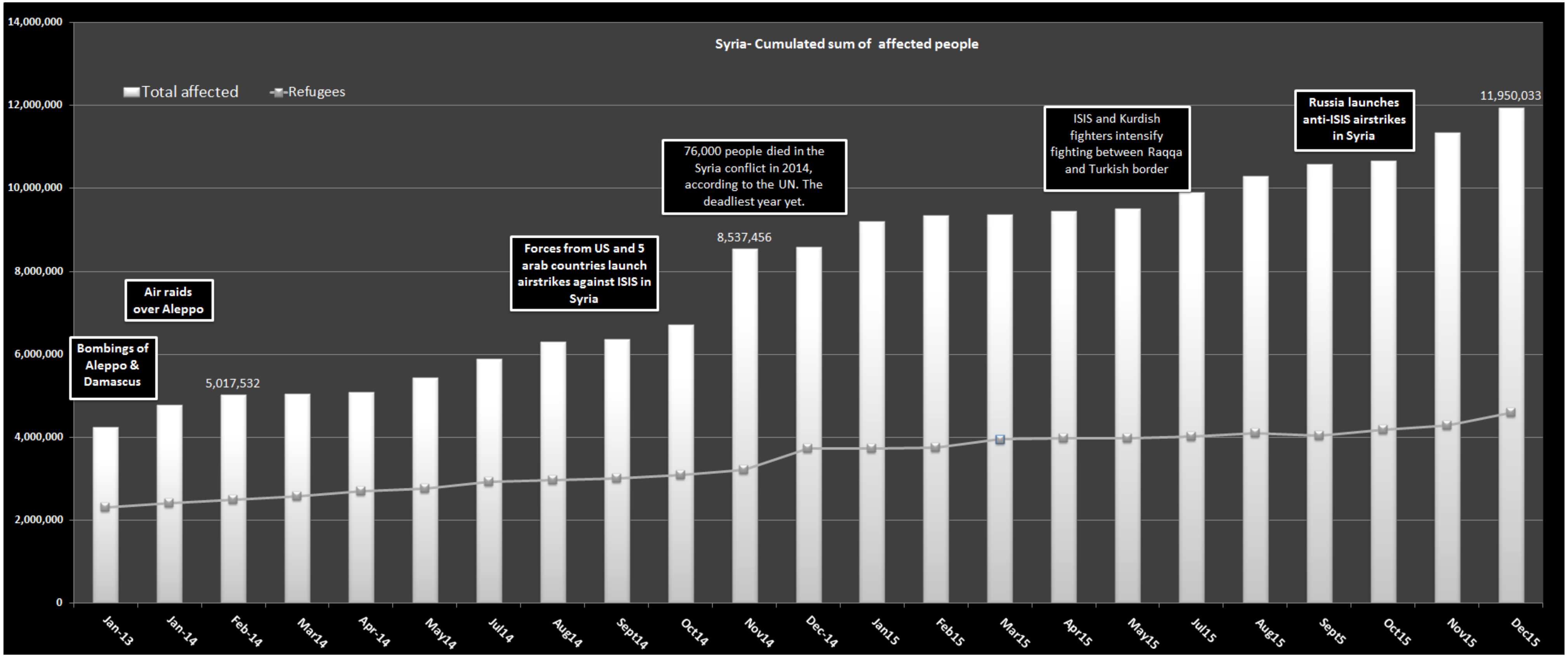

Figure 5.Comparison of the number of affected population derived from geospatial analysis with the number of registered refugees (source: UN OCHA) and key events in the conflict.

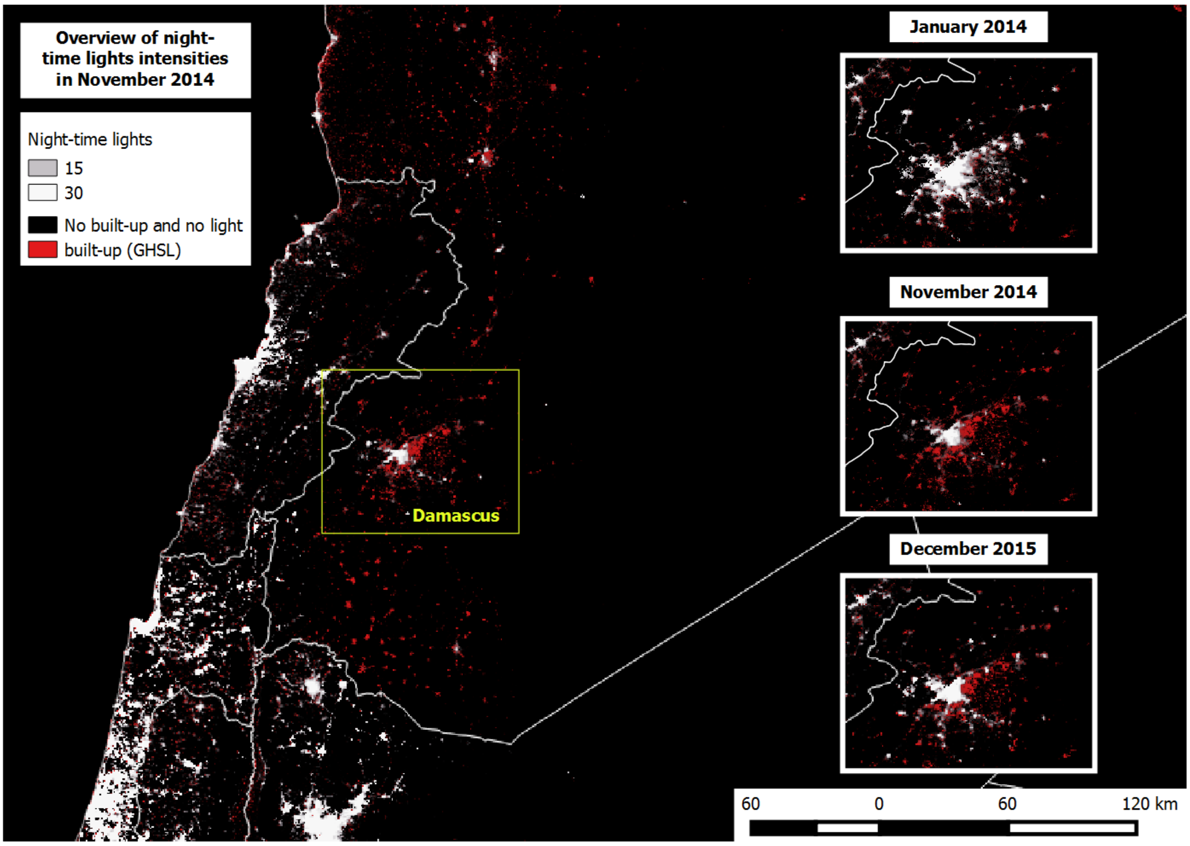

Figure 6. Overview of night-time lights in November 2014 overlaid on the built up areas from GHSL, with close-up view of light intensity variations in Damascus in three periods (January 2014, November 2014 and December 2015)

Figure 7 shows a three-band colour composite of the three masked layers for affected people in Damascus for the following dates: January 2014 (in Red), November 2014 (in green) and December 2015 (in blue). It shows the spatial extent of the affected population with January 2014 being the month with the greatest impact area. According to the Guardian Liberty Voice [9] in January 2014, several barrel bombs were dropped from helicopter over Damascus suburbs including Duma and Darayya. Another source [10] reports on Syria's air force striking rebel-held areas with barrel bombs near Damascus and Aleppo.

In Figure 8, the affected population in Aleppo area is shown also in the form of a three-band colour composite for the following dates: January 2013 (in Red), January 2014 (in green) and December 2015 (in blue). We can observe the extent of the affected area which expands beyond the city of Aleppo. In particular, the city of As-Safira which sits 25km southeast of Aleppo, seems to have suffered important damages as indicated by widespread light loss between January 2013 and January 2014. This can be verified by sources[8] indicating that the regime forces have been trying to capture the town through intense bombing due to its strategic importance which stems from the nearby location of a regime weapons-manufacturing factory where, according to rebels, chemical weapons have been stored.

[8] **Source:** http://syriadirect.org/news/syrian-air-force-drops-more-than-15-barrel-bombs-in-al-safira-square/

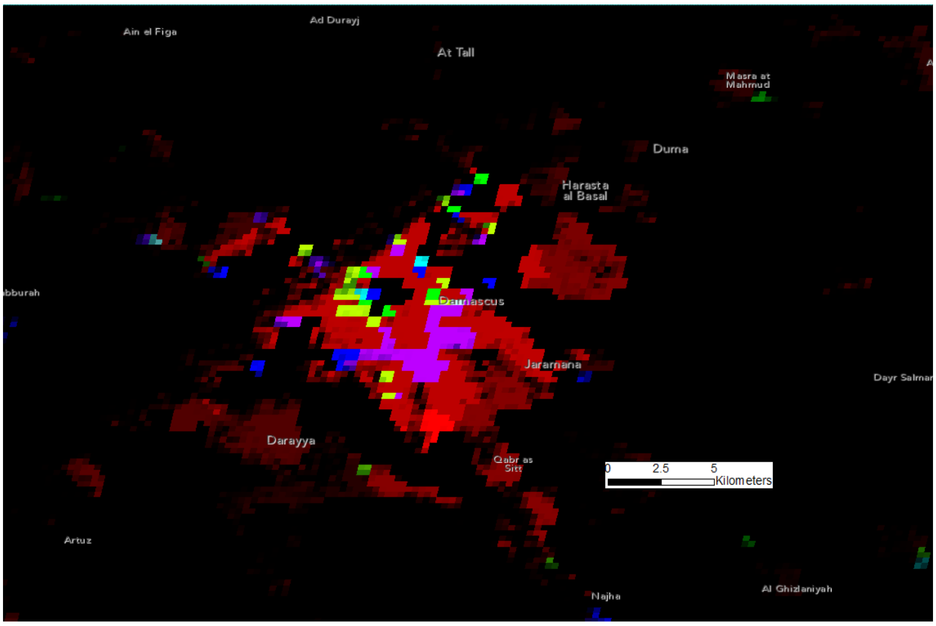

Figure 7. Three-band colour composite of three layers of affected people in Damascus for the following dates: January 2014 (in Red), November 2014 (in green) and December 2015 (in blue)

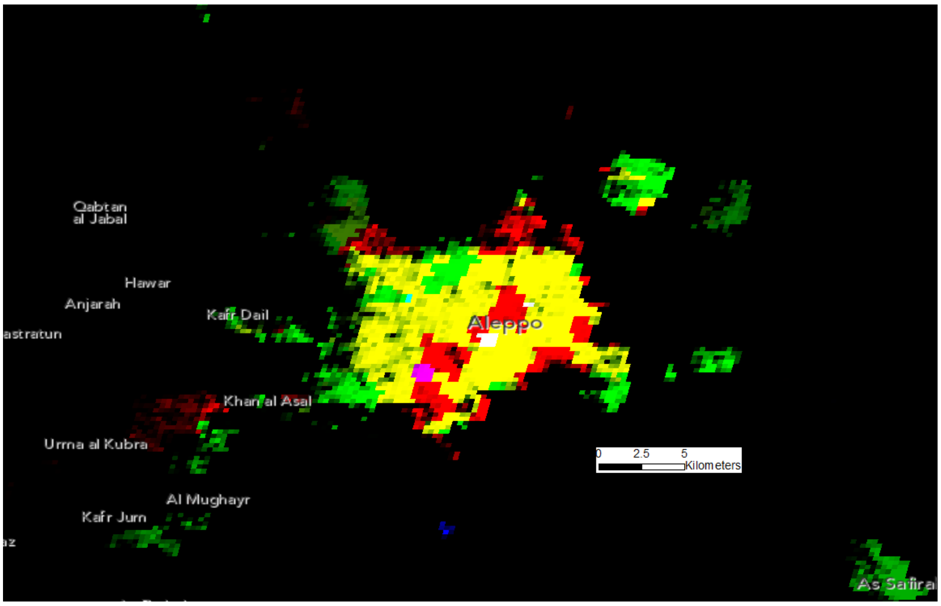

Figure 8. Three-band colour composite of three layers of affected people in Aleppo for the following dates: January 2013 (in Red), January 2014 (in green) and December 2015 (in blue)

The comparison of the nightlight intensities and visual damage assessment based on very high spatial resolution satellite imagery is illustrated for Aleppo in Figure 9. The government controlled central and western part of the city are still illuminated, while the rest of the city is mostly dark. There is obviously a difference between damaged and affected area.

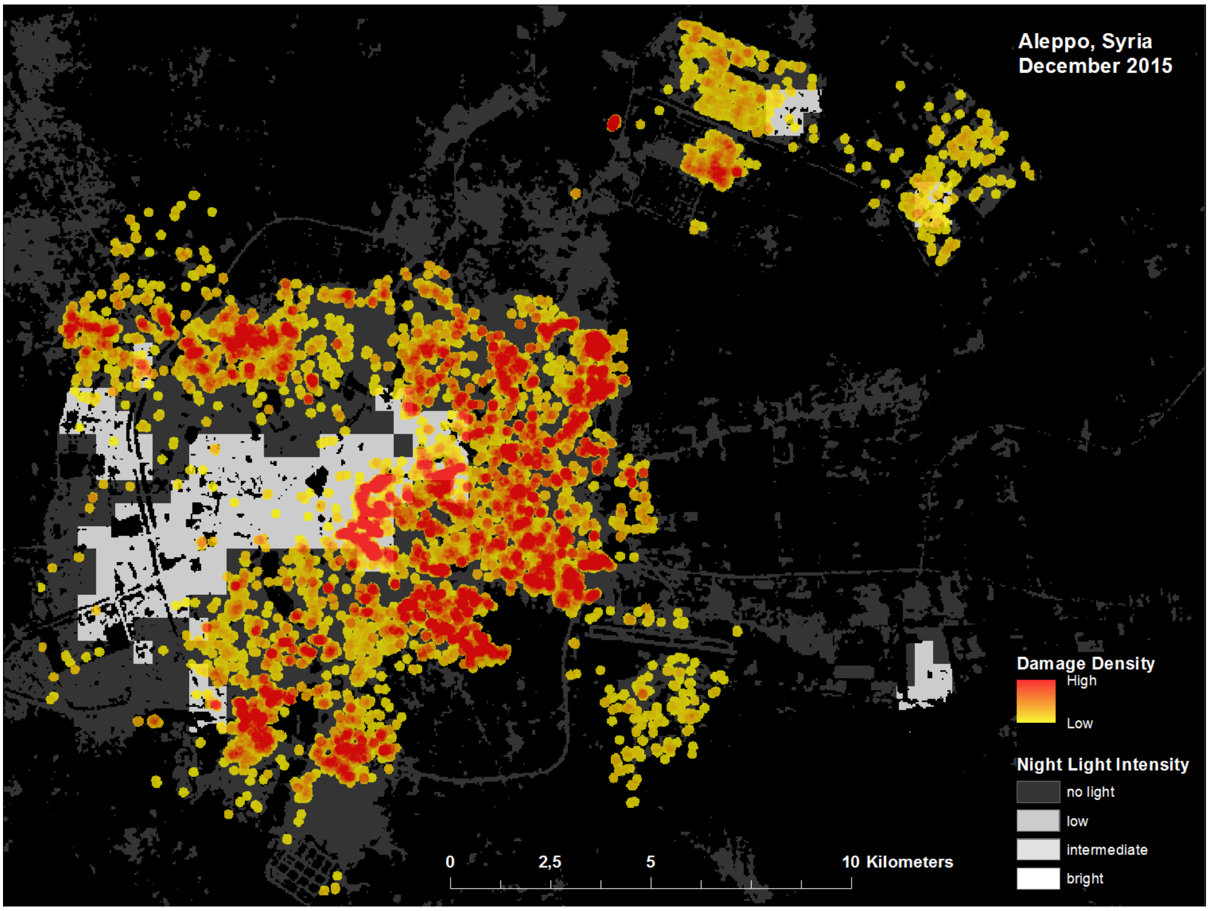

Figure 9. Aleppo (Syria). The map shows the night-light intensity in the built-up areas combined with the damage intensity as observed by the visual interpretation of very high spatial resolution satellite imagery. Most of the damages cluster around the government controlled central and western part of the city.

4. Towards a humanitarian crisis now-casting system

This study provides a preliminary analysis of the contribution of night-light data to generate policy relevant information on the Syrian crisis. It illustrates the potential of assessing and characterizing the affected area and estimating the impacted population through the integration of free and open satellite imagery with detailed estimates of population distribution derived from the GHSL. The availability of independent and open sources is very relevant for conflict situations, where information is often biased by the information provider or not at all available in besieged or hard-to-reach areas as it is the case in Syria.

The foresight methodology developed in this experiment has many potential applications for the assessment of affected people in crisis situations. It suggests that the humanitarian impact of conflicts can be monitored in near-real time using open and free earth observation data. The approach has been also developed in an open-source platform (Google Earth Engine) to ensure reproducibility. The use of the globally available VIIRS imagery offers a neutral and independent tool to monitor the impacts of disasters with open and timely data. The assessments obtained with this technology can feed into migration forecasting models, whose inherent uncertainty is compounded by the intrinsic errors in scarce data.

Prospective studies can make use of the temporal and spatial advantages of open-access geospatial data (VIIRS imagery and GHSL derived products) in the field of disaster risk management to investigate the role of social dynamics over space and time in the occurrences of disasters and provide evidence-based knowledge to support disaster risk reduction plans and actions.

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