Low-Cost UAV applications in urban change and damage assessment: Study on "Richards" Coastal Community in post-Hurricane Irma-Maria Loíza, P.R.

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Abstract — *The study aims to shed light into the quality and ease use of low cost UAVS in urban planning, damage assessment, environmental monitoring and urban change. Using DJI Mavic Air drone 47 images were acquired and orthorectified before digitizing building footprints to catalog and assess change, damage and overall community status. The findings indicate that while the methodology could use some adjustments, the final product can be used to monitor change in urban environments whereas no survey grade measurements can be made due to photograph distortions a general landscape of the communities can be analyzed.*

Key terms — *Hurricane Maria, Photogrammetry, Puerto Rico, UAV.*

INTRODUCTION

Remotely sensed data has been used successfully to predict the weather and to track hurricanes; observe coastal dynamics and detect pollutants; and map coastal land cover, including tidal wetlands, forests, agriculture, and urban areas. [1]

During the days after hurricane Maria passed through the island of Puerto Rico, there was a headline in Wired magazine that said, "Where are the drones that could save Puerto Rico?". If we had asked the same question before disaster stroke perhaps attending the diverse range of problems that inaccessible communities faced could have been easier. *The challenges and importance of structural damage assessment, in particular its critical role in efficient post-disaster response, have placed this discipline in the spotlight of the remote sensing community*. [2]

When considering the range of geographical problems, the people of Puerto Rico face on a yearly basis it is surprising how little literature there is about the topic in Puerto Rico. As a tropical island with a rich and varied topography, Puerto Rico is constantly exposed to natural phenomena such as landslides, floods, draughts, storms and other human derived problems such as traffic, road assessments, urban change, building rehabilitation, transportation logistics, biological vector mapping and agriculture among others. We can estimate that there would be multiple benefits of using UAVs in both urban planning and disaster assessment: It would save time in performing field work, it would increase accuracy and efficiency, it would go a long way to help calm public perception of accidents and disasters and it would also help to restore basic services more promptly. *If one uses small, unmanned aerial platforms, the cost drops dramatically. GPS-guided unmanned aerial vehicles (UAVs) have the capacity to obtain very high spatial resolution (,10 cm) imagery of specific landscape features with revisit times determined by the operator as opposed to fixed satellite revisit times* [3]. *As a result, UAVs, such as drones, quadcopters, balloons, and blimps are now being used effectively in many environmental studies* [4].

There are a couple of simple explanations that could point to the reason of why drones are not being used by the Puertorrican government to solve these problems, the first one being that the price point of UAV's in an economically challenged society immediately seems like an obstacle. While the first commercial drone released by DJI the "Phantom 1" was around $700 when released, drones marketed for professional use and governments quickly rocketed in price up to $15,000+ and with it the technical expertise required to operate them, and no single obvious choice has been available.

In addition, our research returned that there is no single source detailing the quality of the product and the usability of cheaper alternatives that are often labeled for "hobbyists". If we add to it the fear of losing the investment because of the lack of capacitated personnel to handle the equipment, it is no wonder why drones are not being used today.

Though public policy and perception also play a significant role into the adoption of this relatively new technology. The object of this research project is to shed light into the ease of use and range of applications that low-cost UAVs can offer to both the public and private sector should the technology be fully embraced.

STUDY AREA

The study area we chose was the "Richards" community in Loiza, Puerto Rico. As part of the plan for community rehabilitation, "Richards" was estimated to have suffered significant damages during the passing of Hurricane Maria. It presented us with an opportunity to both carry out the investigation and also come up with a product that would have use in the community. By estimating the damages present in the community, we help solidify the recovery efforts being carried out by the **"Community Based Climate Change Adaptation Plan for the Municipality of Loiza".**

Figure 1
Location Map 1

Figure 2
Richards Community

The community is located east of "Urb. Vistas del Oceano", at Richards street on the municipality of Loiza. It's community's absolute location is bound by a frame with northwest coordinates of **18° 26' 4.7843'' N and 65° 51' 40.7336'' W,** northeast coordinates of **18° 26' 4.6439'' N and 65° 51' 36.648'' W,** southeast coordinates of **18° 25' 37.0492'' N and 65° 51' 38.5744'' W** and southwest coordinates of **18° 25' 37.4545'' N and 65° 51' 42.1686'' W.**

PROBLEM

Puerto Rico, an island in the Caribbean with an land area of 8,879.583 square kilometers and a road density to match, is home to 3,337,177 inhabitants according to the 2017 population estimates in the American Fact Finder of the Census website. Though the recent passing of hurricane Maria has triggered an exodus that will definitely impact the population, with some outlets citing up to 250,000 people already having left the island, the fact remains that in terms of square kilometers P.R. still has a population density of 375.82 per square kilometer (977.1473 per square miles). These statistics along with a persons' living experience on the island are enough to appreciate the importance that urban planning, transportation logistics, risk assessment and damage control contribute to the quality of life of its residents.

As it is, Puerto Rico relies on satellite imagery with subpar spatial resolution at predetermined timeframes. Though they offer a larger area coverage and multispectral analysis for environmental research they are constantly affected by atmospheric phenomena likes clouds that directly obstruct view of an area and make them less reliable for localized analysis. *Traditionally, satellites have offered large-area coverage, multispectral imaging, and a reliable revisit time for environmental change studies, yet they lacked the spatial resolution required by many applications* [4].

Alternatively, Puerto Rico uses aerial photographs that are costly and hard to acquire, e.g. the current aerial photography of the island is dated for the year 2010 and if not for the passing of Hurricane Maria (and the 2017 NOAA Emergency Aerial Images), and the island of Puerto Rico would still not have new aerial images on 2018. These dates are far off in between and nearly a decade which can mean a lot in terms of urban change. Satellite Imagery and Planned Flights Aerial Photography serve a lot of purpose but fall behind in terms of the on demand needs many organizations have.

Now that environmental awareness is gaining more ground and the increasing need of sustainable development it is more important than ever to maintain a closer and more detailed scrutiny over the geospatial reality (e.g. shoreline changes, urban communities, street networks, transportation networks, geological risks, etc.) of the island. The environment can pose serious risks if left unchecked at the time of urban planning, one such example is a tree that fell over a house over at “Richards Community” as shown in Figure 3.

Figure 3
Fallen Tree over House

Having said this, it is implied that new data acquisition methodologies and technologies have to be incorporated into our workflows to compliment the already existing ones and provide a wider range of options to analyze data. This also creates the need for adequately trained personnel to handle such needs.

So, the following questions arise:

- What kind of quality can we expect from these new intelligent and economically accessible drones?
- What learning curve or level of expertise do they have?
- What advantages or limitations they present?

METHODOLOGY

Though there are a variety of UAV types and models available like fixed wing, octocopters and quadcopters. We chose to use a quadcopter due to their relatively low cost compared to octacopters, their ease of use, intelligent flight modes and the fact that *helicopters have one major advantage over fixed-wing aircraft in that they can hover over a target site, descend for a closer inspection, and change altitude to provide imagery for mapping at preferred spatial resolutions* [4].

Hardware

A series of drones (UAVs) where considered for use in this project among them:

- DJI Phantom 4 (Pro)
- DJI Mavic Pro
- DJI Inspire 2
- Parrot Bluegrass
- Parrot Bebop Pro
- 3DR Solo
- GoPro Karma

Ultimately, by the time the research was starting DJI announced and released the **DJI Mavic Air**. Which presented the unique opportunity to evaluate the pros and cons of using a new technology for urban analysis. The DJI Mavic Air Advanced Pilot Assistance System (APAS) technology helps with pilot confidence when taking first flights and goes a long way in shortening the learning curve that comes with this kind of equipment. APAS is an obstacle sensing system that feeds out of 7 sensors located on the device facing forward, downward and backward. The intelligent flight modes that the drone provided in combination with the affordable price point ($799) made this drone the obvious choice for the project.

Figure 4
Mavic Air Unfolded

The DJI Mavic AIR is a 430g drone that has a 12mp camera and a 3-axis gimbal. Its 1/ 2.3” sensor has a 4.7 mm focal length, it has a maximum flight time of 21 minutes under no wind resistance and 20 minutes hover time. It can fly at up to 42 mph under sport mode or at 17 mph on intelligent flight modes.

Figure 5
Holdpeak 866B-APP Anemometer

An anemometer from Holdpeak was chosen to measure windspeeds at flight location. Due to the maximum wind speed resistance of 22 mph, it was necessary to have specific wind measurements of the study area in order to minimize errors in photography and avoid problems when flying the drone. Holdpeak 866B-APP was chosen due to its ability to transfer readings to a digital phone application. The recorded readings for the flight dates were the following:

Max Wind Speed	Date
18 mph	4-Feb
19 mph	19-Feb
16-mph	22-Feb
16-mph	26-Feb
16 mph	28-Feb

Figure 6
Wind Speeds

Software

A variety of automatic mapping software were considered for use in the project, among them:

- Drone Deploy
- Pix4D
- PrecisionMapper
- Litchi

This software specializes in generating automatic orthomosaics with corresponding flight paths and coordinates to make the image acquisition process more fluid. However, the dangers of acquiring modern technologies is that they are not always compatible with existing ones. After having marketed the drone’s compatibility with Waypoint Flight, DJI removed the listing on the last second. Something which came to our attention after the first flight and forced some adjusting to the planned methodology.

In addition to considering the automatic mapping software, GIS software was used for post processing, digitizing and to perform further corrections on the aerial imagery to be obtained.

ArcGIS Pro was used because of its Orthomosaic Workspaces functionality which is compatible with a variety of drones and cameras. ArcGIS Pro Ortho Workspace automatically determines focal length and pixel size on sensor based on camera model.

Since the Mavic Air keeps the same camera sensor as the previous Mavic Pro, ArcGIS Pro was compatible with the drone and facilitated the image

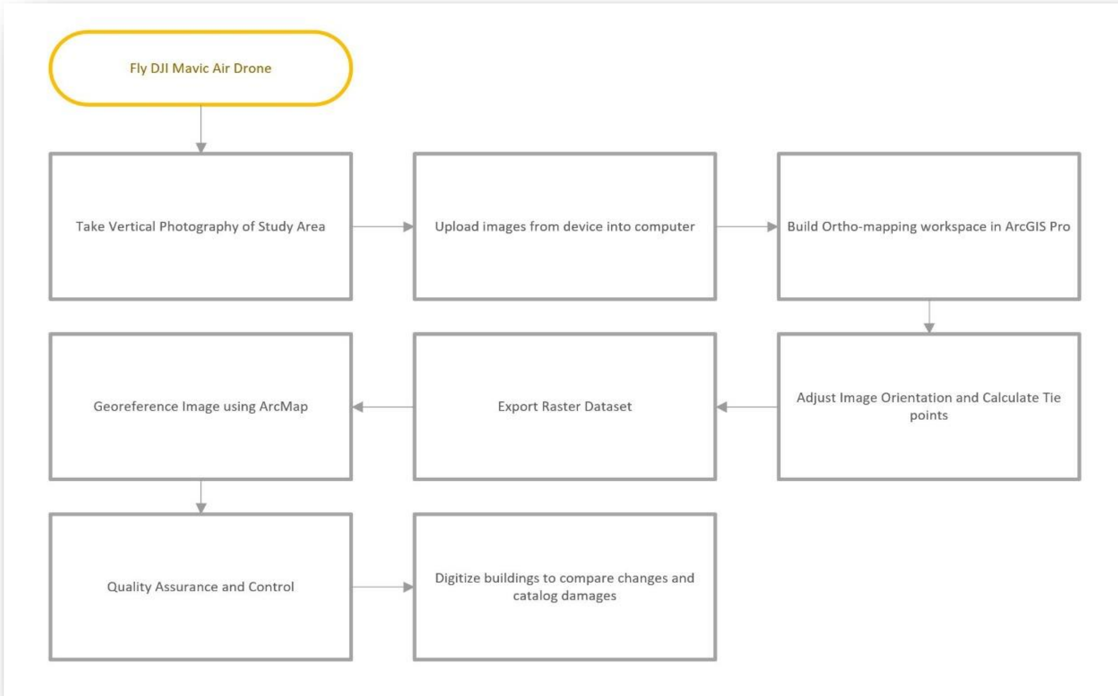


Figure 7
Workflow Diagram

processing. This was used to generate Flight Path and Photo Extents from the Aerial Photos EXIF data, which then were used to compute tie points and generate an orthomosaic. The orthomosaic was then exported and processed in ArcMAP 10.6 Prerelease due to familiarity with the software in order to Georeference the resulting mosaic, 8 ground control points where acquired and used to tie the mosaic to the 2010 aerial photos of Puerto Rico, the points used will be discussed further on when speaking regarding relative and absolute accuracy.

Data Acquisition and Processing

The data used for the project came from multiple sources:

- Firsthand acquisition from the Mavic AIR drone flight.
- Puerto Rico planning board (administrative limit shapefiles, roads, Aerial Imagery of 2010).
- NOAA (Emergency Imagery for Sep 2017).
- PR CRIM Organization (land parcel analysis).

Data – NOAA Emergency Imagery

To acquire NOAA Emergency Imagery, we had to contact the service department of National Geodetic Survey at NOAA. We were provided with an index shapefile (qsi_4band_index) to download original orthorectified 4 band aerial photographs. After having identified the corresponding images with a location analysis in ArcGIS Pro, six images where found to correspond to the area, out of which only one (**OPuerto_Rico_01909-Col.jp2**) had complete coverage of the study area. The new aerial photographs were obtained from:

- https://s3.amazonaws.com/fema-cap-imagery/ Others/Maria

Aerial Photographs List for Richards Community Loiza P.R.	
Batch 7 4 Band	OPuerto_Rico_01909-Col.jp2
Batch 7 4 Band	OPuerto_Rico_01293-Col.jp2
Batch 7 4 Band	OPuerto_Rico_01907-Col.jp2
Batch 7 4 Band	OPuerto_Rico_01908-Col.jp2
Batch 7 4 Band	OPuerto_Rico_01292-Col.jp2
Batch 7 4 Band	OPuerto_Rico_01294-Col.jp2

Figure 8
NOAA Emergency Imagery

The NOAA Emergency Imagery was used to compare spatial resolution and quality of the final orthomosaic in general, as well as to revise buildings that had suffered damage on roofs before installing a blue roof tarp.

Data – DJI Mavic AIR Photographs

The DJI Mavic AIR photographs were taken in the straightest line possible under manual flight. Multiple flights were done on different dates to understand the functionality of the drone and test weather situations. The flight path followed a parallel line to the Richards Street were the community is located at. 47 vertical photographs at 300 feet (91.5m) altitude and 4 oblique images were acquired during the 13-minute flight window that we used.

A list of aerial photos was compiled along with camera location coordinates, altitude, camera model, date and time taken, the complete list is included in the appendix. Just one Mavic AIR battery was used for the acquisition of the imagery, though if the area to be studied would've been any larger more batteries would've been needed to speed up the process.

In addition to the 13-minute flight time a 5-minute preparation window was required to take flight, making the whole process of data acquisition 18-minutes for an 129430.2 square meter area.

Post Processing

As mentioned previously, the ArcGIS Pro software was used to process the imagery. We obtained flight path information and the orthomosaic from the ortho-mapping workspace included in the software package. ArcMap was used to correct georeference errors through ground control points.

The digitizing of features was done inside ArcGIS Pro, where 71 buildings where digitized, indexed and classified according to the damage suffered. We evaluated whether the building had walls, roofs, blue roofs or if they were present on the 2010 aerial photos for Puerto Rico.

PROBLEMS ENCOUNTERED

- A variety of problems surfaced as the project started taking shape. Initially, the study area was going to be an urbanization called "Las Ramblas" in the municipality of Guaynabo P.R. The area however had to be discarded due to a combination of factors, among them:
    - Inadequate weather for drone flight in given timeframe
    - Waypoint flight removed from Mavic AIR required manual flight for photograph acquisition, extension of area was too large.
- In addition, to changing study area, weather problems kept being an issue throughout the whole project. Puerto Rico's tropical climate and varied orography means more rainfall even outside of rainfall season, in combination with inexperience flying drones it meant that a lot of trial and error was involved in flight planning, it is estimated that future studies would go a lot smoother taking into consideration wind speeds and weather patterns on the island.
- The removal of DJI Waypoint intelligent flight mode became an obstacle in the original methodology, though initially advertised as included the removal of the function meant that third or first party automatic flight software could not be used and forced the adjusting of the methodology.
- Time of day also became a problem. Being limited by daylight in addition to weather and flight time was problematic due to available hours for the research.
- Another problem that was encountered was the difficult to acquire ground control points for georeferencing the orthomosaic. Since the community runs parallel to a straight street, acquiring evenly distributed ground control points became a challenge. This is something that could be corrected by acquiring images over a larger area with predetermined ground control points.

ACCURACY

The accuracy of photogrammetry is dependent on the precision of the camera used and the quality of the photos taken, and the functionality of the photo processing software applied [5]. In order to judge the usability of our product we must measure the positional accuracy of the georeferenced orthomosaic. *Positional accuracy can be illustrated in Relative accuracy and Absolute accuracy.*

RELATIVE ACCURACY

Relative accuracy is defined as the measure of how objects are positioned relative to each other. The ortho-mapping workspace from ArcGIS Pro returns residuals for tie and solution points considered.

The mean projection error return was 0.72 (pixel) this pixel error represents the average reprojection error when recomputing orientation and tie points of photographs in relation to one another.

The report also produced GPS positioning deviations of each individual image which indicated that an average of .2 meters of deviation were found in respect to X, 3.76 meters of deviation in respect to Y and 0.42 meters in respect to elevation.
In addition, the GPS on board the DJI Mavic Air has an accuracy of ±3 meters.

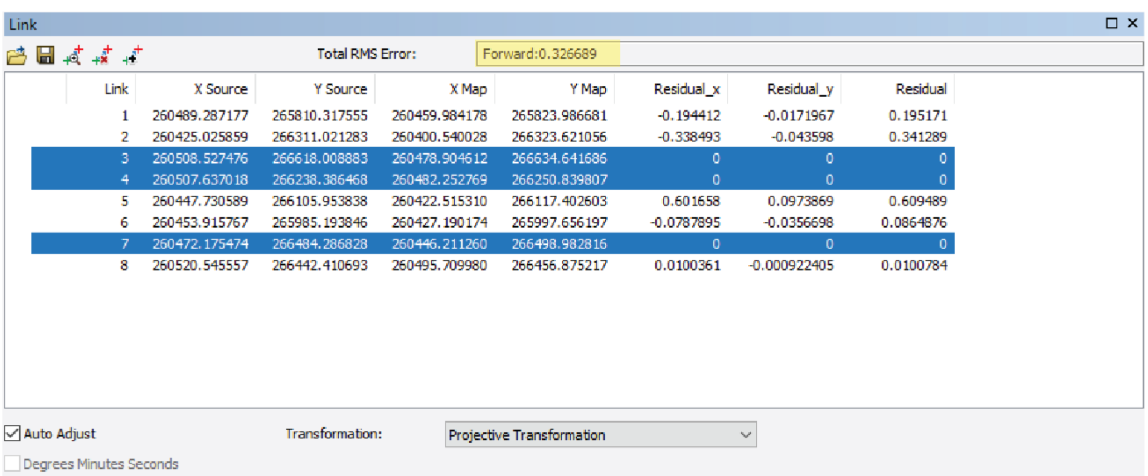
GPS Positioning Deviations			
	X (m)	Y (m)	Z (m)
Min	-14.251	-12.922	-1.761
Max	17.525	19.179	0.742
Median	-1.153	3.827	0.192
Average	0.242	3.76	0.042

Figure 9
GPS Positioning Deviations

ABSOLUTE ACCURACY

Positional absolute accuracy is the measure of how spatial objects are accurately positioned on the map with respect to the true position on the ground.

These positions are captured through ground control points and tie points positioned on the accurate source and the map respectively. The range of values gathered from these solution points generate differences in relation to one another, these differences are called residual. In a normal distribution this difference could be assessed using the arithmetic mean, however this is not true when the values are dispersed as is the case with residuals. In this case, the most useful measure is the standard deviation. *The standard deviation is a way of describing the dispersion of values around the mean of a normal distribution* [6].


Link

Total RMS Error: Forward:0.326689

Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
1	260489.287177	265810.317555	260459.984178	265823.986681	-0.194412	-0.0171967	0.195171
2	260425.025859	266311.021283	260400.540028	266323.621056	-0.338493	-0.043598	0.341289
3	260508.527476	266618.008883	260478.904612	266634.641686	0	0	0
4	260507.637018	266238.386468	260482.252769	266250.839807	0	0	0
5	260447.730589	266105.953838	260422.515310	266117.402603	0.601658	0.0973869	0.609489
6	260453.915767	265985.193846	260427.190174	265997.656197	-0.0787895	-0.0356698	0.0864876
7	260472.175474	266484.286828	260446.211260	266498.982816	0	0	0
8	260520.545557	266442.410693	260495.709980	266456.875217	0.0100361	-0.000922405	0.0100784

Auto Adjust
Transformation: Projective Transformation
Degrees Minutes Seconds

Figure 10
Ground Control Points and RMSE

Another name for the standard deviation is the Root Mean Square, this measure gives us an idea of how good our model performs with respect to the real values. ArcMap's georeferencing tool conveniently returns the RMSE (Root Mean Square Error) which is calculated using the residuals obtained from the differences between the ground control points and the tie points in the georeferencing procedure.

In the case of our project ArcMap returned an RMSE of .32 (m) which means our Georeference has an absolute accuracy of less than a meter.

RESULTS/FINDINGS

The research projects yielded multiple findings in the areas of urban change, building damage and surprisingly factors of social geography like income inequality.

Figure 11
Comparison of 2010 Image and 2018

Urban Change – Results

After having digitized buildings, they were indexed, and the resulting footprints were compared to the footprints of the 2010 aerial photographs, the research results indicate that 10% (7 buildings) of the buildings had been modified (enlargements), 34% (24 buildings) were not present on 2010 and 56% (40 buildings) of the buildings remained the same, as can be seen in figure 12.

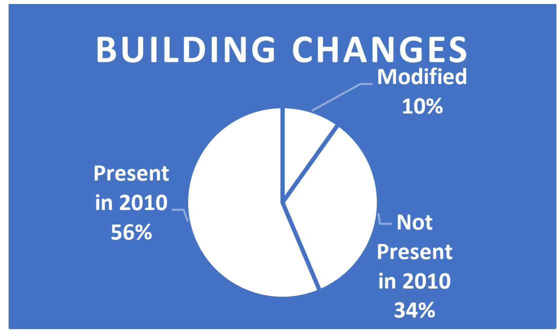


Figure 12
Building Changes Chart

Damage Assessment – Results

As mentioned before, the damage assessment consisted in quantifying the buildings that had suffered damage on walls, roofs and/or had blue roof tarps over them indicating that the roof was lost, and they had either received help from FEMA or installed a tarp themselves. The results were as follow:

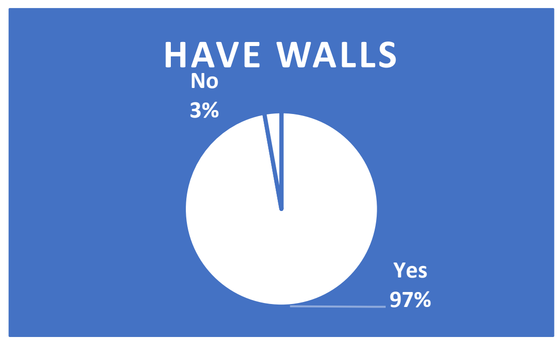


Figure 13
Wall Changes

Out of the 71 buildings digitized, 97% (69 buildings) still had their walls while 3% (2 buildings) had lost all but the building base, this can be seen in the figure 13 chart.

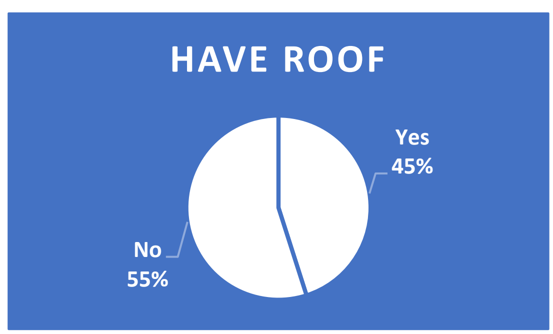


Figure 14
Damage on Roofs

As for the roofs, 45% (32 buildings) had roofs and 55% (39 buildings) had lost their roofs. (Figure 14) Out of those 39 buildings only 27 buildings (38% of the total) had blue roof tarps while 44 buildings either didn't have or didn't need the blue roof (Figure 15).

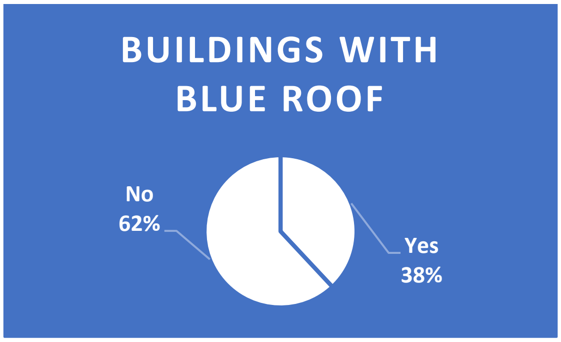


Figure 15
Buildings with Blue Roof

Economic Inequality and Quality of Life

The surprising finding throughout the research was the presence of a modern, more expensive urban project to the side of the community. The buildings in "Urb. Vistas del Oceano" are all built on concrete and suffered no damage in their entirety. An oblique photograph of the communities (Figure 16) side by side show how much low-income communities get affected by disasters such as Hurricane Maria.

Figure 16
Richards Community North to South Oblique Aerial Photography

Conclusion

After having analyzed the results of the study, taking into consideration the series of complications and technical expertise of the project. It can be concluded that the use of a low-cost UAV is adequate to carry out general urban and damage assessments on communities. Though it is important to point out the range of tools and methodologies involved in the production of the orthomosaic.

The series of tools and methodologies to carry out this type of study can be learned within a month of dedicated training though it is highly recommended to have a background in geographic or surveying science, so the error margin of the product is reduced. Nonetheless, the results indicate that a <20-minute flight with the UAV is sufficient to produce results. Longer more planned out flight paths with automated software would make the process less technical and easier to implement to economically challenged municipalities that don't have the resources to hire the experienced personnel required for the alternative. It is important to mention that as time passes technology becomes smaller, more efficient and more affordable. As it is, it is not hard to implement the methodology used in this research but it we can also expect it to become easier and more accurate with time. Thus, it would be wise to start incorporating these new techniques into our workflows.

Looking back into the initial inquiries. We can conclude that the quality of the imagery is enough to perform semantic spatial analysis and could be improved in further studies to perform area calculations depending on the results of new orthomosaics. The camera of the drone can provide sub centimeter pixel resolution depending on the flight altitude of the UAV.

The learning curve of the process is not steep and allowed for full appreciation of controls and technique within a month of use.

References

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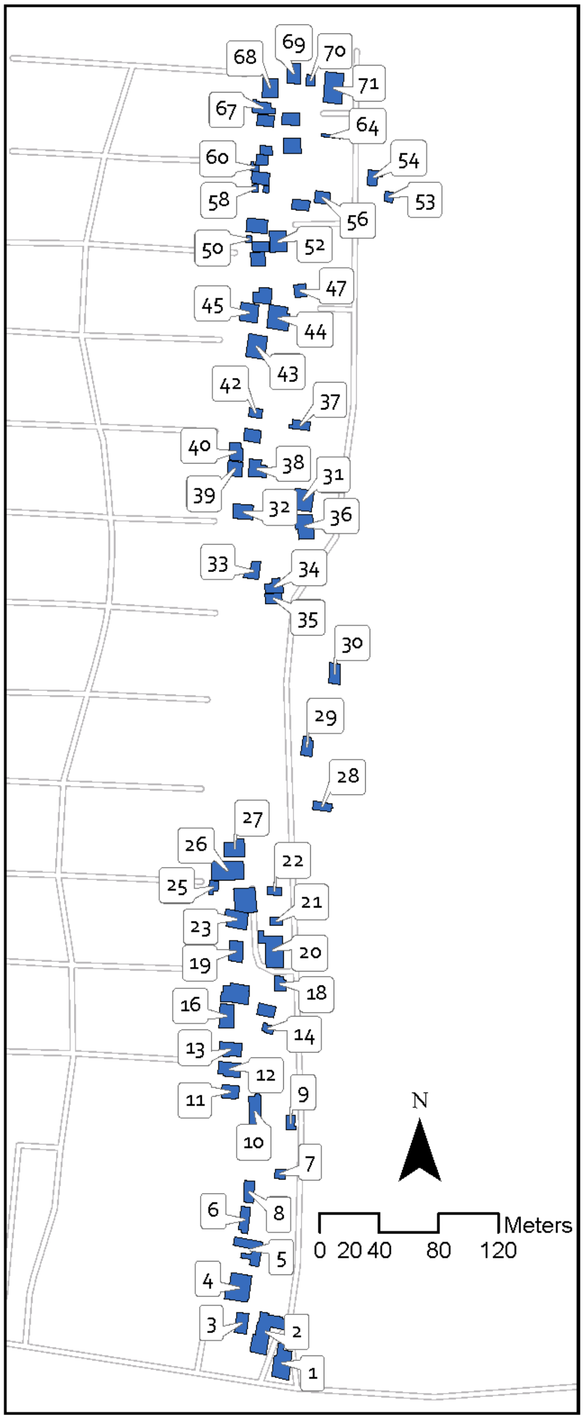
Appendix

BUILDINGS DIGITIZED FROM ORTHOMOSAIC



Num	Status	Area	Walls	Roof	BlueRoof	YEAR
1	Present in 2010	230.69	No	No	No	2018
2	Present in 2010	344.26	Yes	Yes	No	2018
3	Present in 2010	109.95	Yes	Yes	No	2018
4	Present in 2010	264.05	Yes	Yes	No	2018
5	Present in 2010	200.37	Yes	Yes	No	2018
6	Present in 2010	108.70	Yes	No	No	2018
7	Not Present in 2010	45.81	No	No	No	2018
8	Present in 2010	99.17	Yes	No	No	2018
9	Present in 2010	61.47	Yes	Yes	No	2018
10	Present in 2010	177.97	Yes	No	Yes	2018
11	Not Present in 2010	102.51	Yes	Yes	No	2018
12	Present in 2010	139.29	Yes	Yes	No	2018
13	Present in 2010	136.96	Yes	No	Yes	2018
14	Present in 2010	42.62	Yes	No	Yes	2018
15	Present in 2010	88.43	Yes	No	Yes	2018
16	Present in 2010	152.99	Yes	Yes	No	2018
17	Present in 2010	220.78	Yes	Yes	No	2018
18	Present in 2010	74.88	Yes	No	Yes	2018
19	Present in 2010	127.29	Yes	Yes	No	2018
20	Present in 2010	284.00	Yes	Yes	No	2018
21	Present in 2010	43.33	Yes	Yes	No	2018
22	Present in 2010	53.01	Yes	No	Yes	2018
23	Present in 2010	164.40	Yes	Yes	No	2018
24	Not Present in 2010	237.44	Yes	Yes	No	2018
25	Not Present in 2010	52.11	Yes	Yes	No	2018
26	Not Present in 2010	265.15	Yes	Yes	No	2018
27	Not Present in 2010	149.54	Yes	Yes	No	2018
28	Present in 2010	70.91	Yes	No	Yes	2018
29	Present in 2010	90.56	Yes	No	Yes	2018
30	Present in 2010	102.91	Yes	No	Yes	2018
31	Present in 2010	184.10	Yes	No	No	2018
32	Not Present in 2010	137.60	Yes	Yes	No	2018
33	Present in 2010	94.46	Yes	No	Yes	2018
34	Present in 2010	97.55	Yes	No	Yes	2018
35	Present in 2010	78.60	Yes	No	Yes	2018
36	Present in 2010	186.18	Yes	Yes	No	2018
37	Modified	76.30	Yes	Yes	No	2018
38	Not Present in 2010	125.94	Yes	No	No	2018
39	Not Present in 2010	96.35	Yes	Yes	No	2018
40	Present in 2010	104.11	Yes	No	No	2018
41	Modified	93.21	Yes	No	No	2018
42	Present in 2010	54.28	Yes	No	No	2018
43	Modified	196.77	Yes	Yes	No	2018
44	Modified	217.41	Yes	Yes	No	2018
45	Modified	148.72	Yes	No	Yes	2018
46	Modified	115.78	Yes	No	Yes	2018
47	Not Present in 2010	70.01	Yes	No	No	2018
48	Present in 2010	87.77	Yes	Yes	No	2018
49	Present in 2010	79.20	Yes	No	Yes	2018
50	Not Present in 2010	18.39	Yes	No	Yes	2018
51	Not Present in 2010	129.73	Yes	Yes	No	2018
52	Present in 2010	161.45	Yes	Yes	No	2018
53	Not Present in 2010	38.48	Yes	No	Yes	2018
54	Not Present in 2010	81.37	Yes	No	Yes	2018
55	Present in 2010	80.83	Yes	No	No	2018
56	Present in 2010	81.42	Yes	No	Yes	2018
57	Not Present in 2010	16.82	Yes	No	Yes	2018
58	Not Present in 2010	20.50	Yes	No	Yes	2018
59	Not Present in 2010	96.90	Yes	No	Yes	2018
60	Not Present in 2010	29.19	Yes	No	Yes	2018
61	Not Present in 2010	56.24	Yes	Yes	No	2018
62	Not Present in 2010	50.76	Yes	No	Yes	2018
63	Not Present in 2010	117.52	Yes	Yes	No	2018
64	Not Present in 2010	23.50	Yes	Yes	No	2018
65	Present in 2010	95.82	Yes	No	Yes	2018
66	Present in 2010	85.85	Yes	No	Yes	2018
67	Modified	112.59	Yes	No	Yes	2018
68	Present in 2010	134.28	Yes	Yes	No	2018
69	Not Present in 2010	121.04	Yes	Yes	No	2018
70	Present in 2010	44.27	Yes	No	No	2018
71	Not Present in 2010	257.48	Yes	Yes	No	2018


2010
2017
2018

List of Aerial Photographs along with information derived from EXIF file.

ID	Image	Latitude	Longitude	Altitude	DateTaken	Camera
1	DJI_0061.JPG	18° 25' 37.00" N	65° 51' 39.00" W	91.70	2/28/2018 12:24:00 PM	DJI
2	DJI_0062.JPG	18° 25' 38.00" N	65° 51' 40.00" W	91.40	2/28/2018 12:24:21 PM	DJI
3	DJI_0063.JPG	18° 25' 39.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:24:34 PM	DJI
4	DJI_0064.JPG	18° 25' 40.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:24:41 PM	DJI
5	DJI_0065.JPG	18° 25' 40.00" N	65° 51' 40.00" W	91.70	2/28/2018 12:24:49 PM	DJI
6	DJI_0066.JPG	18° 25' 41.00" N	65° 51' 40.00" W	91.40	2/28/2018 12:24:57 PM	DJI
7	DJI_0067.JPG	18° 25' 42.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:25:04 PM	DJI
8	DJI_0068.JPG	18° 25' 42.00" N	65° 51' 40.00" W	91.40	2/28/2018 12:25:14 PM	DJI
9	DJI_0069.JPG	18° 25' 43.00" N	65° 51' 40.00" W	91.60	2/28/2018 12:25:20 PM	DJI
10	DJI_0070.JPG	18° 25' 43.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:25:28 PM	DJI
11	DJI_0071.JPG	18° 25' 44.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:25:34 PM	DJI
12	DJI_0072.JPG	18° 25' 44.00" N	65° 51' 40.00" W	91.40	2/28/2018 12:25:41 PM	DJI
13	DJI_0073.JPG	18° 25' 45.00" N	65° 51' 40.00" W	91.60	2/28/2018 12:25:46 PM	DJI
14	DJI_0074.JPG	18° 25' 45.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:25:53 PM	DJI
15	DJI_0075.JPG	18° 25' 46.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:25:59 PM	DJI
16	DJI_0076.JPG	18° 25' 47.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:26:05 PM	DJI
17	DJI_0077.JPG	18° 25' 47.00" N	65° 51' 40.00" W	91.60	2/28/2018 12:26:11 PM	DJI
18	DJI_0078.JPG	18° 25' 48.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:26:18 PM	DJI
19	DJI_0079.JPG	18° 25' 48.00" N	65° 51' 40.00" W	91.40	2/28/2018 12:26:24 PM	DJI
20	DJI_0080.JPG	18° 25' 49.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:26:31 PM	DJI
21	DJI_0081.JPG	18° 25' 50.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:26:37 PM	DJI
22	DJI_0082.JPG	18° 25' 50.00" N	65° 51' 40.00" W	91.60	2/28/2018 12:26:44 PM	DJI
23	DJI_0083.JPG	18° 25' 51.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:26:51 PM	DJI
24	DJI_0084.JPG	18° 25' 51.00" N	65° 51' 40.00" W	91.40	2/28/2018 12:26:57 PM	DJI
25	DJI_0085.JPG	18° 25' 52.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:27:04 PM	DJI
26	DJI_0086.JPG	18° 25' 52.00" N	65° 51' 40.00" W	91.40	2/28/2018 12:27:11 PM	DJI
27	DJI_0087.JPG	18° 25' 53.00" N	65° 51' 40.00" W	91.60	2/28/2018 12:27:17 PM	DJI
28	DJI_0088.JPG	18° 25' 54.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:27:24 PM	DJI
29	DJI_0089.JPG	18° 25' 54.00" N	65° 51' 40.00" W	91.60	2/28/2018 12:27:31 PM	DJI
30	DJI_0090.JPG	18° 25' 55.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:27:37 PM	DJI
31	DJI_0091.JPG	18° 25' 56.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:27:46 PM	DJI
32	DJI_0092.JPG	18° 25' 56.00" N	65° 51' 40.00" W	91.50	2/28/2018 12:27:53 PM	DJI
33	DJI_0093.JPG	18° 25' 57.00" N	65° 51' 40.00" W	91.40	2/28/2018 12:27:58 PM	DJI
34	DJI_0094.JPG	18° 25' 57.00" N	65° 51' 39.00" W	91.60	2/28/2018 12:28:04 PM	DJI
35	DJI_0095.JPG	18° 25' 58.00" N	65° 51' 40.00" W	91.40	2/28/2018 12:28:11 PM	DJI
36	DJI_0096.JPG	18° 25' 59.00" N	65° 51' 40.00" W	91.60	2/28/2018 12:28:17 PM	DJI
37	DJI_0097.JPG	18° 25' 59.00" N	65° 51' 40.00" W	91.60	2/28/2018 12:28:25 PM	DJI
38	DJI_0098.JPG	18° 25' 60.00" N	65° 51' 39.00" W	91.50	2/28/2018 12:28:32 PM	DJI
39	DJI_0099.JPG	18° 26' 1.00" N	65° 51' 39.00" W	91.40	2/28/2018 12:28:39 PM	DJI
40	DJI_0100.JPG	18° 26' 1.00" N	65° 51' 39.00" W	91.60	2/28/2018 12:28:45 PM	DJI
41	DJI_0101.JPG	18° 26' 2.00" N	65° 51' 39.00" W	91.60	2/28/2018 12:28:52 PM	DJI
42	DJI_0102.JPG	18° 26' 2.00" N	65° 51' 39.00" W	91.60	2/28/2018 12:28:59 PM	DJI
43	DJI_0103.JPG	18° 26' 3.00" N	65° 51' 39.00" W	91.70	2/28/2018 12:29:07 PM	DJI
44	DJI_0104.JPG	18° 26' 3.00" N	65° 51' 39.00" W	91.60	2/28/2018 12:29:13 PM	DJI
45	DJI_0105.JPG	18° 26' 4.00" N	65° 51' 39.00" W	91.50	2/28/2018 12:29:20 PM	DJI
46	DJI_0106.JPG	18° 26' 4.00" N	65° 51' 39.00" W	91.60	2/28/2018 12:29:25 PM	DJI
47	DJI_0107.JPG	18° 26' 5.00" N	65° 51' 39.00" W	91.40	2/28/2018 12:29:32 PM	DJI