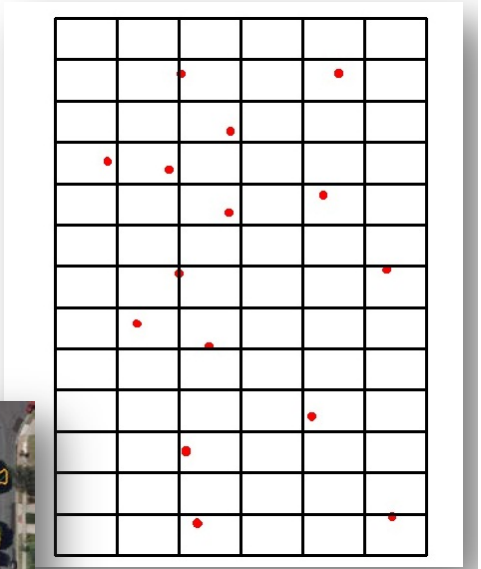
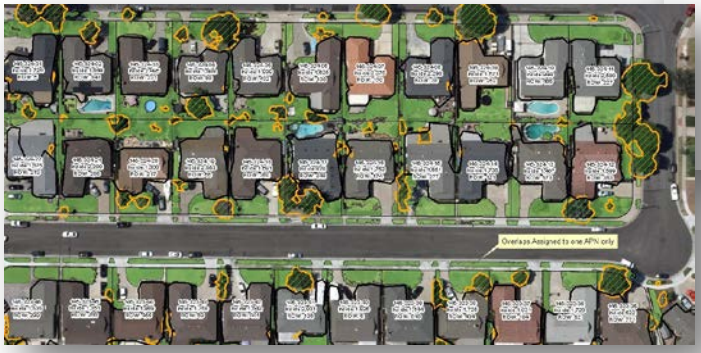
Santa Ana River Watershed

LiDAR/Infrared Imagery

Landscape Mapping

Demonstration Project





Dean Unger
Information Technology Manager - **Santa Ana Watershed Project Authority**
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SAWPA

Final Project Description

The purpose of the proposed project is to demonstrate the use of color orthophotography and LiDAR for identification of areas of irrigated plant types and locations. The identification occurs by matching color cells from the color orthophotography and the height from the LiDAR data. LiDAR creates a contour map including the buildings and plants. There will be three areas of study to determine the feasibility of identifying irrigated landscapes. Each of the areas will be located in the Santa Ana Watershed and will represent urban, mixed use, and predominately agriculture land use. This will improve water use efficiency by providing an accurate ground picture of irrigated land when applying tiered water rates. Irrigation of landscaping within the Santa Ana Watershed accounts for approximately 70% of the water delivered to the average customer.

SAWPA acquired the orthophotography and LiDAR data through Resource Strategies Inc. who provided the expertise and knowledge to SAWPA. Resource Strategies Inc. has coordinated with SAWPA for the flight planning, imagery acquisition, imagery modeling, orthorectification and digital compression and packaging. Resource Strategies Inc. worked with SAWPA to ensure proper review of data prior to completion and approval of the data set.

The orthophotography and LiDAR data sets were delivered to SAWPA and then a step by step process through the data was evaluated in order to clearly identify the required attributes from which a determination was made for the area of irrigated landscape. Steps included analysis of infrared imagery, assessing the color spectrum of vegetation within each study area, selecting several parcels within each study area for ground truthing, and then using the site visits to tune each of the areas color definitions and LiDAR data to maximize the accuracy of the measurement of irrigated landscape area.

Completed Tasks

Task	Planned Completion Date	Actual Completion Date
Locate and Create three study areas within the Santa Ana Watershed	October 15th 2014	October 15th, 2014
Fly the three Study Areas to acquire up-to-date infrared photogrammetry and LiDAR	November 31st , 2014	January 10th, 2014
Process and evaluate the data sets	December 31st , 2014	February 1st, 2014
Fine Tune the processing of the data sets	January 31st , 2015	February 15th, 2014
Document the process	February 1st, 2015	March 15th 2014
Finalize the results and detail benefits	March 1st, 2015	June 1st 2014

Milestones and Timeline Expectations

The overall project timeline was shifted based upon recommendations from our project consultant that October (the fall) was not an ideal time of the year to fly the proposed study areas to acquire infrared photogrammetry, based upon the data we were looking to gather. It was suggested that the flights be rescheduled for January (early spring). This modification of the project schedule has resulted in the entire project schedule being shifted by four months. However, this has not impacted our ability to complete the remaining tasks in a timely order, and the project has completed in a timely manner.

Milestones

The task "Finalize the results and detail benefits" is under current revision. In each of the study areas there are approximately 20,000 parcels and 25 sample areas in which we used to identify vegetation types. Managing this many data points has taken longer than expected and has affected the summations for this task, and we completed our tasks on June 1st.

Schedule

The final task of "Finalize the results and detail benefits" was completed on June 1st, 2015. This new completion date reflects a delay as outlined above due to the overall accumulation of large amounts data and the need to summarize its outcomes.

Original Cost Estimate

The project costs are generally matching the original cost estimate

Invoicing

SAWPA has invoiced for the balance of the grant funding.

Related issues

We have no related issues with the project status

Water Savings

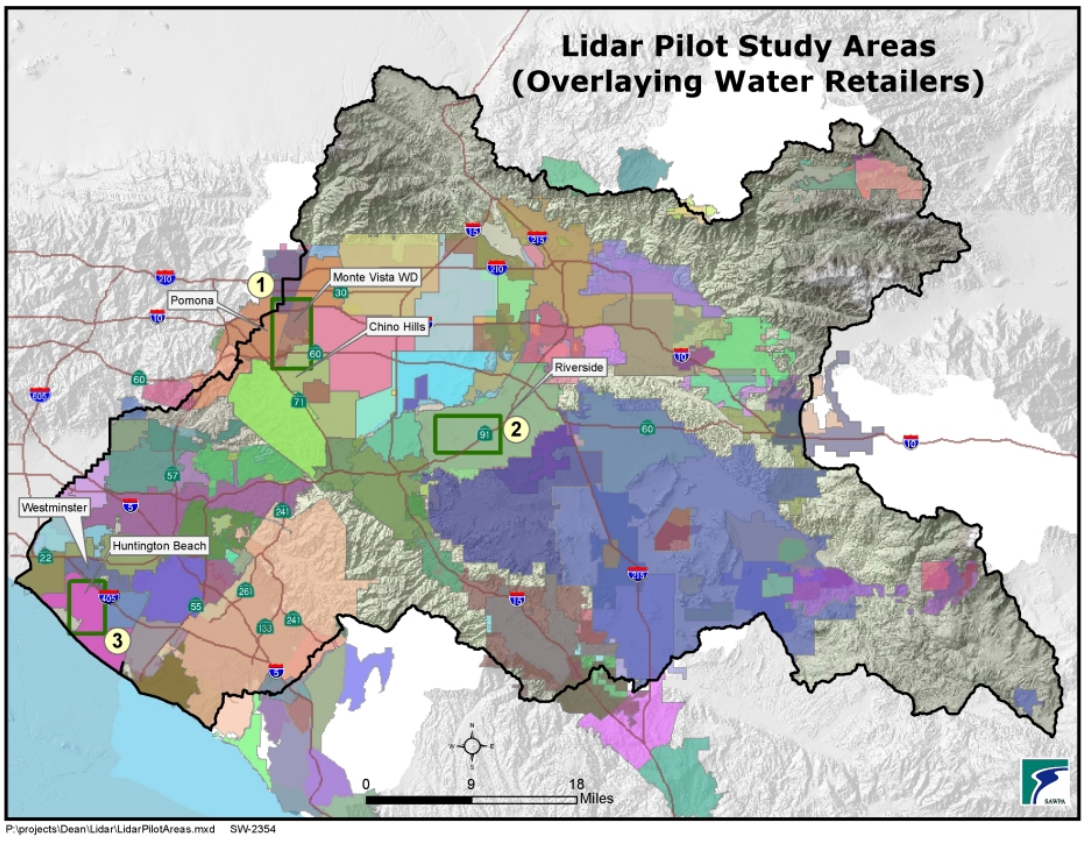
SAWPA did not see any difference in water savings from our original projections. Water savings benefits projected from the implementation of the project were estimated as future savings from water conservation, based upon the ability of LiDAR to accurately measure the areas irrigated in the watershed. We estimate that the amount of water wasted in the watershed on landscape is approximately 85,340 acre feet per year.

With the use of this technology, the watershed agencies will identify the outdoor water needs of individual customers and can notify the customer of over watering. If 20% of the customers adjusted their outdoor water use then the watershed could save 17,680 acre feet per year. It has been estimated over 50% of the water used by households within the Santa Ana River Watershed is used for outdoor landscape watering. It has also been estimated that these same households overwater their landscaping by 85% (California Home Foundation, 2010). Converting estimate at 50% overwatering would yield 85,340 acre feet per year savings if 100% of the households

Findings

Locations

SAWPA chose three locations within the Santa Ana Watershed by using several determining factors. The first factor was citing the study areas to locations in both the upper and lower watershed, as well as within in one of the five wholesaler's territories in the district. The reason for using the wholesalers' territories is due to SAWPA having easier access to their wholesale water agency staff that can simplify getting data and acquiring information. We also wanted to have the locations fall mostly in one retailer's territory which again made getting information about the area easier. The three locations chosen were (1) Monte Vista Water District in San Bernardino (Montclair and Chino), (2) the City of Riverside in Riverside County, and (3) Hunting Beach in Orange County (lower watershed) as seen below.



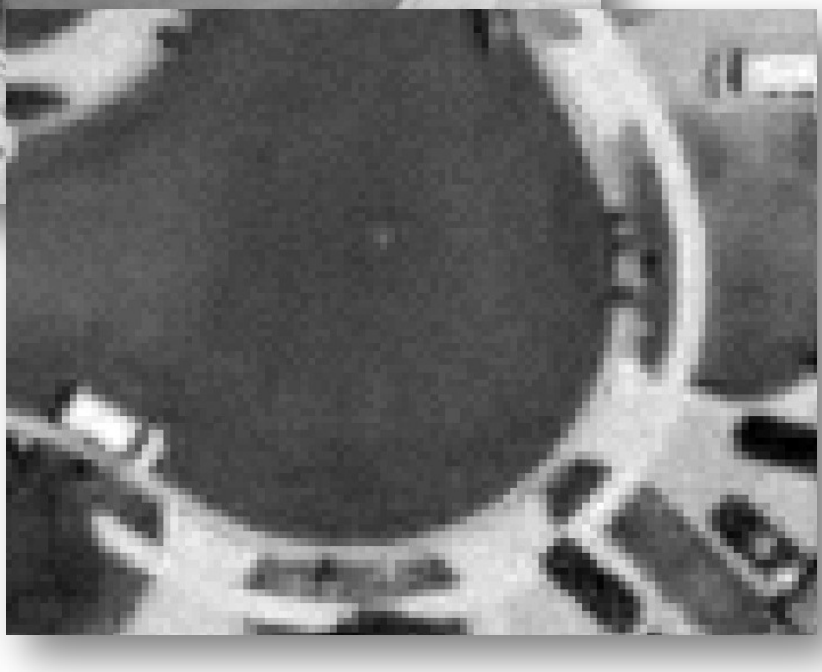
Aerial photography

SAWPA had asked for the aerial photography vendor to supply imagery for three locations and in three resolutions. SAWPA wanted to understand the impact of image resolution to the accuracy of measurement of the vegetation. Below are images with different capture resolutions. The first image is one pixel equals three inches on the ground. The second image is one pixel equals six inches on the ground and the third image is one pixel equals twelve inches on the ground. The three images represent the same location but the manhole in the street is only clearly visible in the three inch per pixel image and the car is much clearer. This difference should impact the measuring of vegetation by allowing the computer to more accurately delineate the vegetation.

3 inch

6 inch

12inch

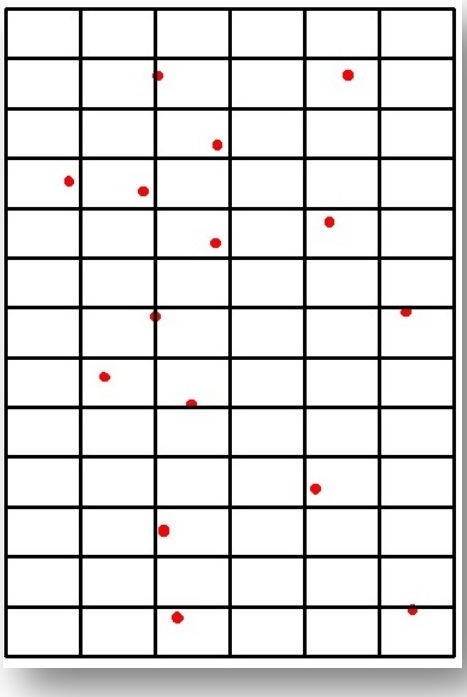


Building Footprints

SAWPA used the LiDAR data to generate building foot prints. The building footprints would help eliminate non vegetated areas. Since LiDAR creates both height values and color values, roof areas can be generated.

Training the Image Analysis Software

SAWPA staff went into the field and chose points on the ground and identified them as turf, trees or shrubs. SAWPA sampled them in a wide area across the three sample locations. The grid below represents the aerial photographs in given area and the red dots represent sample location collection points. These points trained the computer to identify the infrared color that represented vegetation types on the ground.



Vegetation Identification

SAWPA assembled the multiple layers and began to determine the areas for turf and trees. Several nuances were discovered in this process. The front part of the lawn on the other side of the sidewalk, sometimes referred to as the parkway is not in a parcel. SAWPA developed a methodology to include the parkway since owners are responsible for watering this area.

Accuracy of Measurements by resolution

After careful analysis SAWPA staff saw accuracy measurements of 80% from the 3 inch aerial photography and the field measurements versus 73% with 6 inch aerial photography.

OBJECTID	Name	APN	SQFTVEGMAN	SQFTVEG3IN	PCT3INMAN	SQFTVEG6INV2	PCT6INV2MAN	SQFTVEG6IN	PCT6INMAN	SQFTVEG1FT	PCT1FTMAN
1	House1	145-173-07	3,282	2,050	0.62	2,769	0.84	1,789	0.55	625	0.19
2	House2	153-063-34	3,402	2,732	0.80	3,381	0.99	2,411	0.71	1,465	0.43
3	House3	163-164-59	1,830	1,446	0.79	1,727	0.94	1,257	0.69	699	0.38
4	House5	110-512-37	3,568	2,760	0.77	4,084	1.14	2,280	0.64	1,012	0.28
5	House4	167-331-18	6,927	4,567	0.66	7,633	1.10	5,388	0.78	3,524	0.51
6	House6	142-052-53	4,536	3,981	0.88	4,375	0.96	3,819	0.84	1,434	0.32
7	House7	146-292-34	3,328	3,184	0.96	3,350	1.01	2,821	0.85	672	0.20
8	House8	146-103-14	1,734	1,911	1.10	2,438	1.41	1,655	0.95	205	0.12
9	House9	159-061-39	2,569	2,228	0.87	3,050	1.19	2,589	1.01	1,867	0.73
10	House10	142-284-10	2,275	2,110	0.93	2,563	1.13	1,280	0.56	918	0.40
11	House11	146-502-26	3,438	2,787	0.81	3,544	1.03	2,321	0.68	1,480	0.43
12	House12	145-264-30	2,154	1,940	0.90	2,040	0.95	1,744	0.81	310	0.14
13	House13	165-111-06	2,970	1,336	0.45	2,850	0.96	1,655	0.56	1,082	0.36
14	House14	165-344-12	2,531	2,124	0.84	2,902	1.15	2,117	0.84	1,229	0.49
15	House15	110-471-18	4,149	3,719	0.90	4,575	1.10	2,236	0.54	1,053	0.25
16	**Totals**		**48,693**	**38,872**	**0.80**	**51,281**	**1.05**	**35,361**	**0.73**	**17,575**	**0.36**

Detailed Three Area Results

Huntington Beach

Percentage	VegMan	Veg3	Veg6	Veg6s	Veg12
% of Manual	100%	108.04%	88.75%	105.32%	83.39%
% diff from Manual	0%	8.04%	-11.25%	5.32%	-16.61%

Notes

VegMan = Manual Measurements using 3" imagery flown 6/2014 and google maps street view

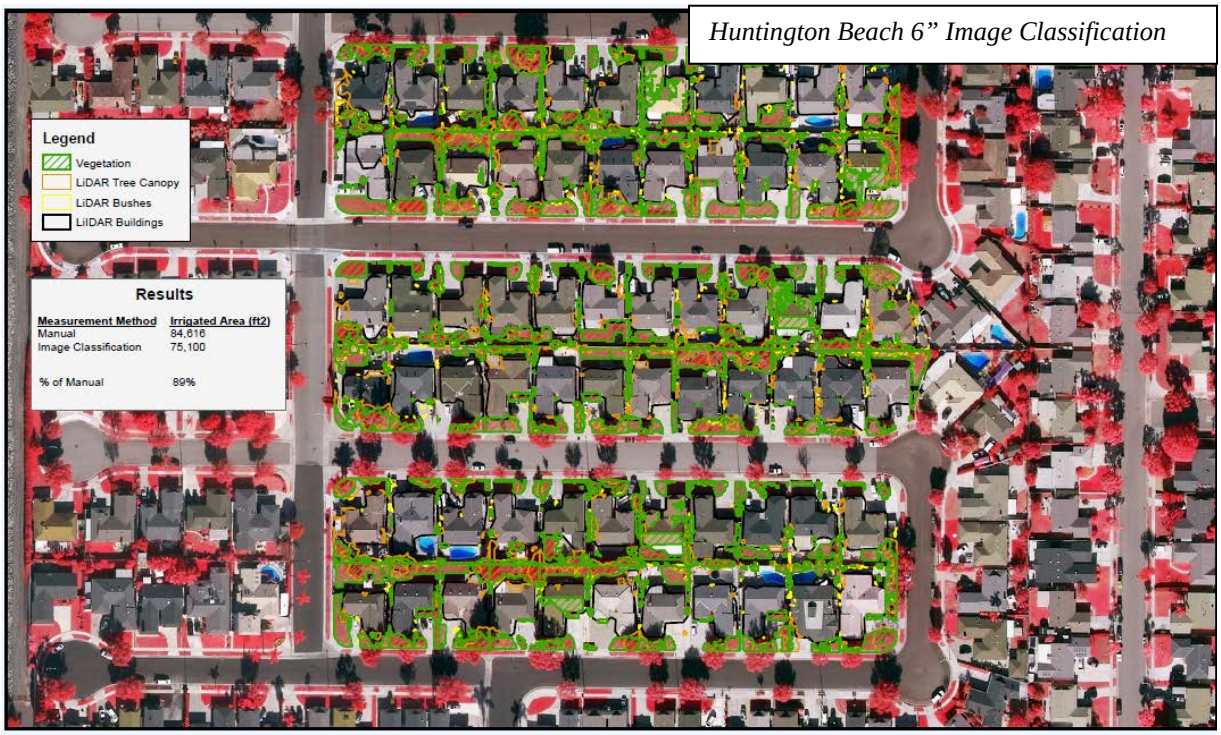
veg3 = 3" image class flown 6/2014

veg6 = 6" image class flown 12/2014

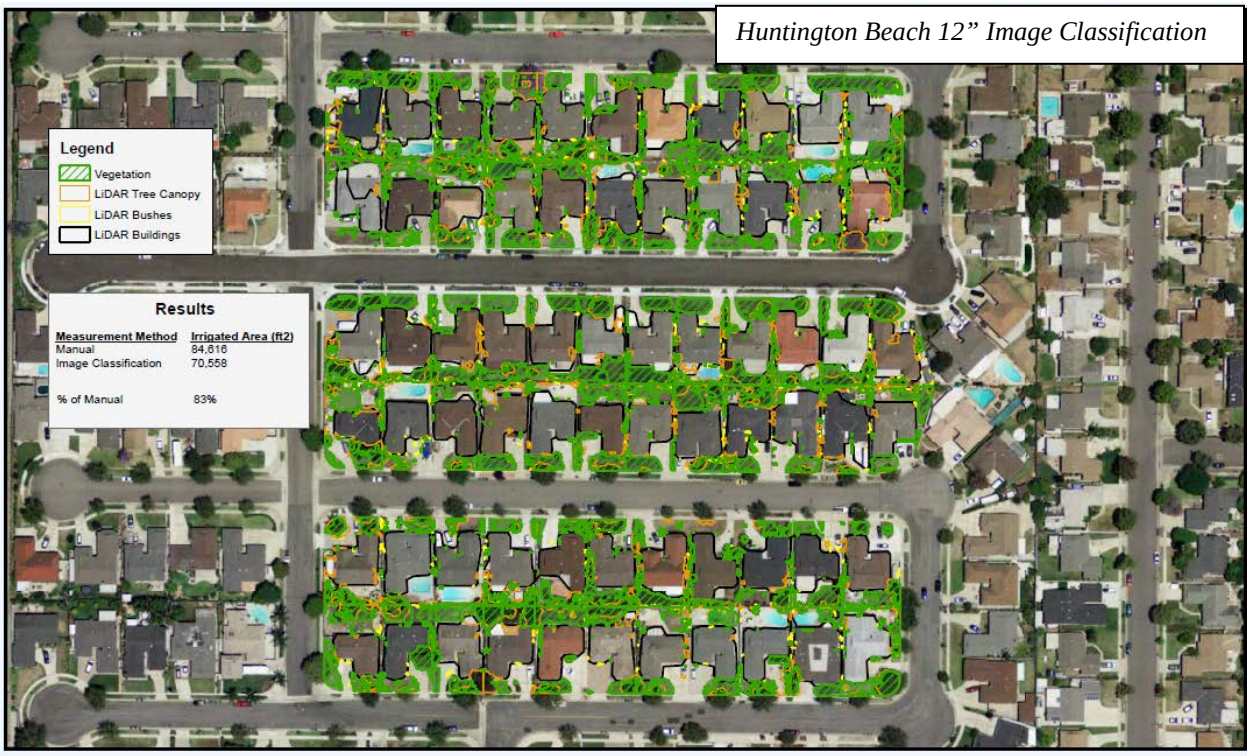
veg6s = 6 " image class flown 12/2014 with detected veg areas from 12" inserted into shadow areas

veg12 = 12" image class flown spring 2012

Huntington Beach 3" Image Classification



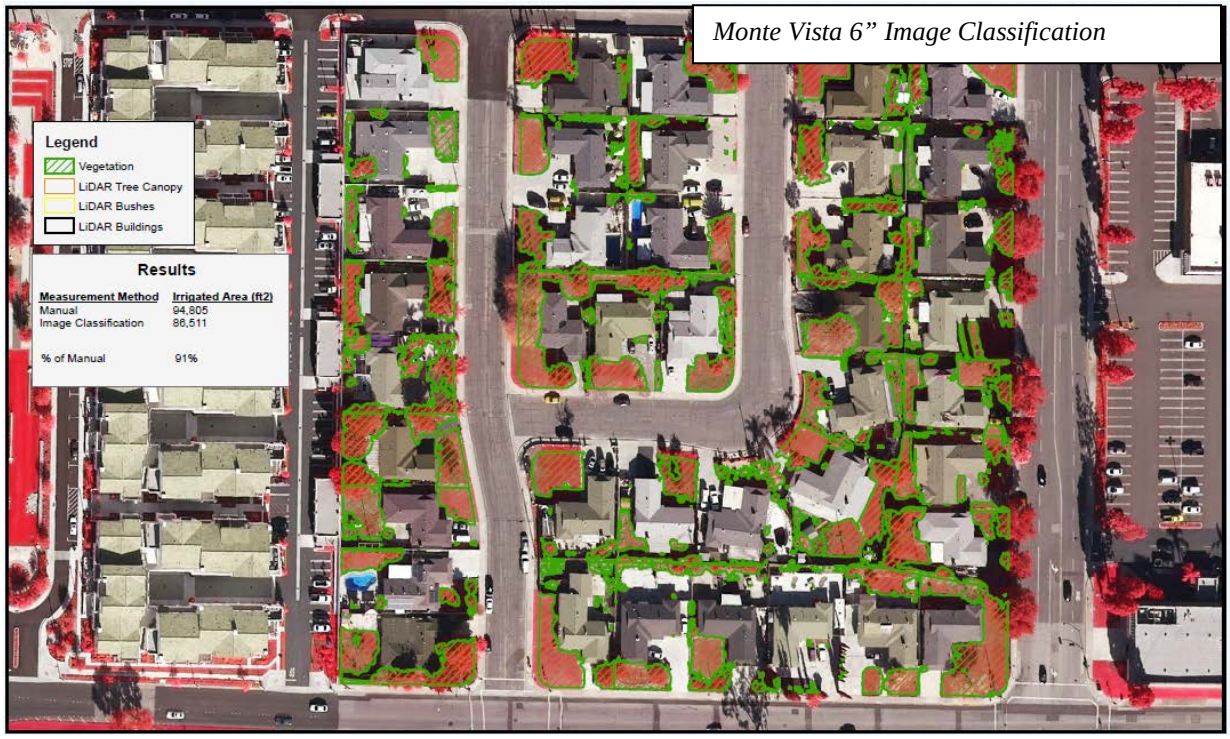
Huntington Beach 6" Image Classification



Huntington Beach 12" Image Classification

Monte Vista Water District

Percentage	VegMan	Veg 6”	Veg 12”
% of Manual	100%	91.25%	63.01%
% diff from Manual	0%	-8.75%	-36.99%

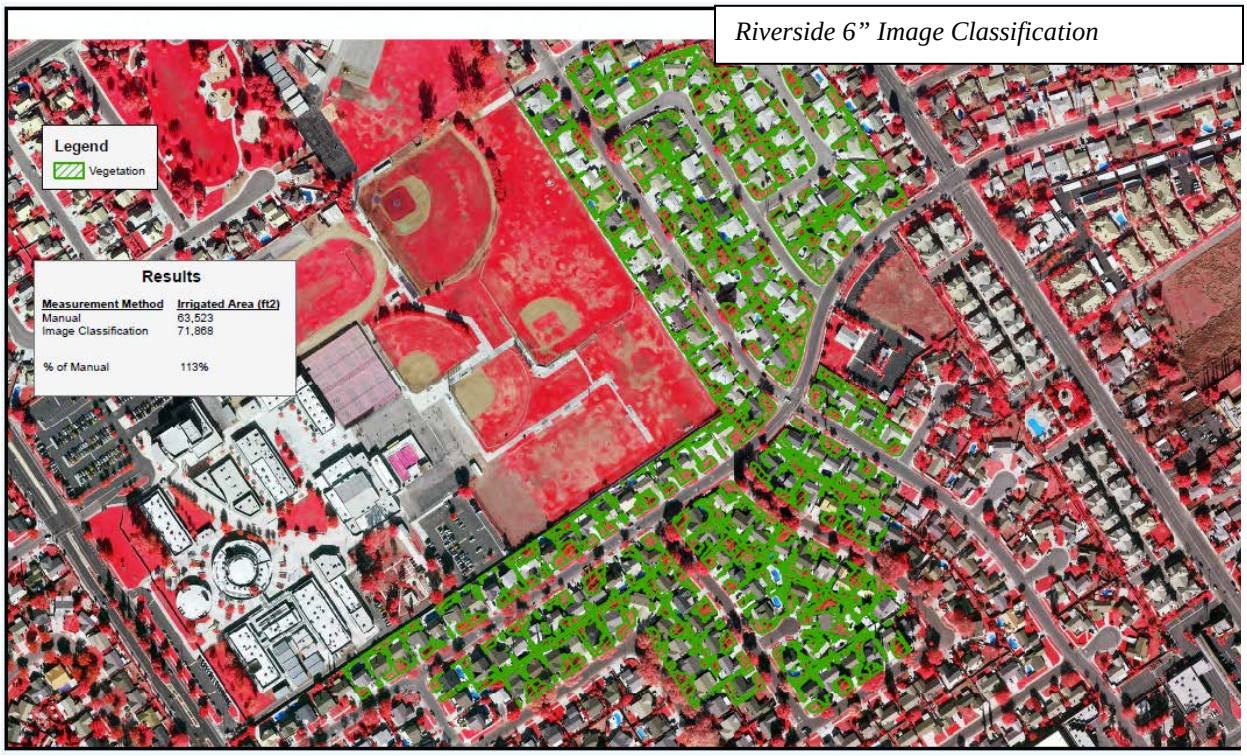


Monte Vista 6” Image Classification

Monte Vista 12” Image Classification

Riverside

Percentage	VegMan	Veg6
% of Manual	100%	113.14%
% Diff from Manual	0%	13.14%



Riverside 6" Image Classification

Results

- Irrigated vegetation can be delineated quite well using automated image classification methods. Automated methods generally differed by about 10 – 15% from manual measurements.
- Higher resolution imagery resulted in more accurate classification. However areas of shadow were also an important factor in determining the accuracy of results.
- The automated method we used could not classify in shadowed are as so limiting the number of shadows by collecting data during spring or early summer and during the middle of the day greatly improves accuracy.
- LiDAR could detect the presence of grass beneath tree s but could not delineate it.
- LiDAR delineated building footprints within about 10% of manual measurements.
- The tree canopy calculated using LiDAR differed widely from manual measurements. The differences could have been due to density limitations of LiDAR as well as difficulties and the subjectivity of delineating tree canopy manually.

LiDAR advantages and disadvantages (in the context of vegetation area measurements)

Advantages

- LiDAR can determine tree and vegetation heights.
- LiDAR can see through most canopies and determine what's underneath.
- LiDAR can be used to generate 3D models
- Can generate contours and building footprints
- Can generate 3d models or views.

Disadvantages

- Resolution (needed to measure an area): Currently high resolution LiDAR is 16 points per meter which means there are 16 points that tell you objects color and the X, Y and Z values. The 3 inch orthophotography has 144 points or 3" ground points / 1 pixel that tell you an objects color and X and Y.
- LiDAR can see what's under canopies but only if it can penetrate the canopy. It still cannot measure what's under the trees in any accurate comparison to visible areas by image analysis.
- Data size: LiDAR data is large, which makes any process against it take a long time.
- Cost: Although costs have come down tremendously in recent years due to many more vendors have the special equipment used in LiDAR generation, it still is expensive.

Aerial Imagery Resolution comparison

- 12 inch per pixel
  - Free or near freely available every year
  - Very small data footprint
  - May cause poor accuracy of measurement
- 6 inch per pixel
  - Low cost and may be available from other local projects
  - Medium size data footprint
  - Reasonable accuracy except for shadows
- 3 inch per pixel
  - High cost but may use economies of scale to reduce costs
  - Large data footprint making data hard to use unless managed
  - Good accuracy even in shadowed arears

<u>Final conclusions</u>

SAWPA continued the process of sifting data to determine accuracy of the measurements for a multitude of methods using both LiDAR and infrared photogrammetry. The primary goal of this study was to measure the vegetated area of a parcel. We used vary resolutions of imagery and 8 points per meter resolution LiDAR. We then compared image resolution to imager resolution in area measurements as well as LiDAR. In a comparison of using similar costing LiDAR against high resolution imagery, LiDAR has a much lower resolution and thus less accurate in measuring area. Another weakness of LiDAR in respect to area measurement was that it can see thru canopies and determine the underlying vegetation but cannot determine the area of that vegetation. The one advantage that maybe important in the future is that it can determine vegetation height. Unfortunately the vegetation height is not yet part of determining a water budget for individual water meters. The other capabilities of LiDAR only become a factor if there are multi users and needs for using the data outside of landscape measurements.

The most important imagery conclusion was that there were significant gains in using the highest resolution of imagery that the project can afford. This cost is still well below the cost of similar resolution LiDAR data.

SF 425 Form Invoice
Attached

FEDERAL FINANCIAL REPORT

(Follow form instructions)

1. Federal Agency and Organizational Element to Which Report is Submitted	2. Federal Grant or Other Identifying Number Assigned by Federal Agency (To report multiple grants, use FFR Attachment)	Page	of
Bureau of Reclamation Lower Colorado Region PO Box 61470, Boulder City NV 89006-1470	Agreement Number: R14AP00060	1	pages

3. Recipient Organization (Name and complete address including Zip code)
Santa Ana Watershed Project Authority, 11615 Sterling Avenue, Riverside CA 9253

4a. DUNS Number	4b. EIN	5. Recipient Account Number or Identifying Number (To report multiple grants, use FFR Attachment)	6. Report Type	7. Basis of Accounting
86591575	95-2899964		☐ Quarterly ☒ Semi-Annual ☐ Annual ☐ Final	☒ Cash ☐ Accrual

8. Project/Grant Period From: (Month, Day, Year)	To: (Month, Day, Year)	9. Reporting Period End Date (Month, Day, Year)
October 1, 2014	March 31, 2015	03/31/15

10. **Transactions**	Cumulative
(Use lines a-c for single or multiple grant reporting)	
Federal Cash (To report multiple grants, also use FFR Attachment):	
a. Cash Receipts	0
b. Cash Disbursements	0
c. Cash on Hand (line a minus b)	0
(Use lines d-o for single grant reporting)	
Federal Expenditures and Unobligated Balance:	
d. Total Federal funds authorized	38,448.33
e. Federal share of expenditures	0
f. Federal share of unliquidated obligations	0
g. Total Federal share (sum of lines e and f)	0
h. Unobligated balance of Federal funds (line d minus g)	38,448.33
Recipient Share:	
i. Total recipient share required	38,448.33
j. Recipient share of expenditures	42,964.50
k. Remaining recipient share to be provided (line i minus j)	
Program Income:	
l. Total Federal program income earned	
m. Program income expended in accordance with the deduction alternative	
n. Program income expended in accordance with the addition alternative	
o. Unexpended program income (line l minus line m or line n)	

11. Indirect Expense	a. Type	b. Rate	c. Period From	Period To	d. Base	e. Amount Charged	f. Federal Share
	Provisional	156.9%	07/01/14	06/30/15	13,322.42	20,902.88	10,451.44
				g. Totals:	13,322.42	20,902.88	10,451.44

12. *Remarks: Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation:*

13. Certification: By signing this report, I certify to the best of my knowledge and belief that the report is true, complete, and accurate, and the expenditures, disbursements and cash receipts are for the purposes and intent set forth in the award documents. I am aware that any false, fictitious, or fraudulent information may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 18, Section 1001)

a. Typed or Printed Name and Title of Authorized Certifying Official	c. Telephone (Area code, number and extension)
Karen Williams, Chief Financial Officer	951-354-4231
	d. Email address
	kwilliams@sawpa.org
b. Signature of Authorized Certifying Official	e. Date Report Submitted (Month, Day, Year)
Karen Williams	April 30, 2015
	14. Agency use only:

Standard Form 425 - Revised 6/28/2010
OMB Approval Number: 0348-0061
Expiration Date: 10/31/2011