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EVALUATION OF THE QUANTITY AND QUALITY OF RUNOFF WATER FROM A STRAWBERRY RANCH SLOPING GROUND DURING WINTER STORM EVENTS IN THE CALIFORNIA CENTRAL COAST

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ABSTRACT

Surface runoff from strawberry fields with plastic bed mulching during winter storms is a problem in strawberry production in the California Central Coast due to the high volumes and low quality of the water discharged, and poses important environmental concerns. In this project, we measured the quantity runoff from a 3.7 ac block in a strawberry ranch in Prunedale, CA during four storms in winter 2015-2016. The total solids and nitrate dissolved in the runoff water was also measured taking three samples per storm. The results indicate that a fraction ranging from 70% to 80% of water runs off from strawberry fields with slopes up to 10%, and the fraction of runoff was relatively constant across a range of rain intensities and duration of storm events. The results suggest an average of 20365 gallons (2723 ft^3) of runoff generated by each acre per inch of rain.

Keywords: strawberry, runoff, winter storm, plastic mulch, California Central Coast

INTRODUCTION

Surface runoff from strawberry fields during winter storms is a concern in Santa Cruz and Monterey counties due to the high volumes and low quality of the water discharged, and poses important challenges to growers and ranch managers. In strawberry production, the impervious surface given by the plastic bed lining limits water infiltration and increases runoff. The issue is particularly important in sloping ranches and in marginal agricultural communities. Growers typically manage the situation by building a retention basin at the lower end of the ranch and lining ditches with plastic to prevent erosion. However, when it comes to sedimentation basin design, little is known about the quantity of water infiltrated and runoff generated by a ranch for a given expected depth of rain. Also, the quantity of sediment and of nitrate that leaves the ranch with the runoff water is difficult to predict.

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In this project, we measured the quantity runoff from a strawberry ranch in Prunedale, CA during four storms in winter 2015-2016 exploring the following questions: what is the percentage of infiltrated water and runoff during a winter storm in a sloping ground? Is the runoff percentage dependent on rain intensity? What are the quantities of sediment and nitrate expected to run off from a typical storm event?

METHODS

Four storms were monitored, on 12/9/2015, 12/18/2015, 12/21/2015 and 1/4/2016 in a commercial strawberry field near Prunedale, CA. The runoff measured came from two blocks with a total area of 3.7 acres (Figure 1). The monitored field presented a slope ranging from 1 to 10% (average 6%), and the soil was Elkorn fine sandy loam. The soil presented saturated hydraulic conductivity of 10 cm/hr (4 inches/hour) in the first 66 cm (26 inches) and of 1 cm/hour (0.4 inch/hour) in the deeper layers. (NRCS survey, SSURGO dataset).

The field was cover cropped the season before the experiment and the cover crop was incorporated in June 2015. The beds were listed on October 2015 and no pre-plant fertilizer was applied.

The runoff from the field was measured with a 90 V-notch weir built in a plywood box with the following dimensions: 48 inch wide, 48 inch long and 24 inch high. The V-notch was cut in the wide side and was 36 inches at the widest point (Figure 2). The weir was equipped with a standing well made by a 2” PVC pipe perforated to allow the entry of water and screened from the entry of sediment. The standing well was installed vertically and secured to a metal bar driven 3 feet into the ground. Inside the standing well, hydrostatic pressure was measured with a pressure transducer, HOBO Water Level Logger, model U20L-04 (ONSET, Cape Cod, MA). The pressure measured by the instrument was corrected for barometric pressure obtained from the Prunedale weather Underground station (data available on www.wunderground.com). The obtained pressure was converted to inches of water head above the V-notch and from this the flowrate in gpm was calculated with the formula (7-3), page (7-9) from the Water Measurement Manual of the U.S. Bureau of Reclamation (Revised 2001 edition).

Three runoff water samples were taken from three of the storm events monitored with self-sealing Nalgene Storm Water Sampler bottles (Thermo Fisher Scientific) installed at different heights in the weir box. The samples were taken at 2, 4 and 6 inches above the V-notch (corresponding to a flowrate of 13, 73 and 199 gpm) for the storm of 12/9/2015, and at 1, 3 and 5 inches above the V-notch (2, 36 and 127 gpm) for the storms of 12/18/2015 and 1/4/2016. Therefore the samples represented the concentration in the water at the time when the water level in the box first reached the bottle height. The samples were analyzed for total dissolved solids and for nitrate. From these concentrations and the flowrate measured during sampling, the total

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Volume:03, Issue:06 "November-December 2017"

volume of nitrogen and sediment leaving the ranch during sampling was calculated. An attempt was made to estimate the total nitrogen and sediment discharged in the storm event based on the average concentrations measured and total runoff.

Local precipitation measured every 5 minutes was obtained from the Prunedale Weather Underground station.

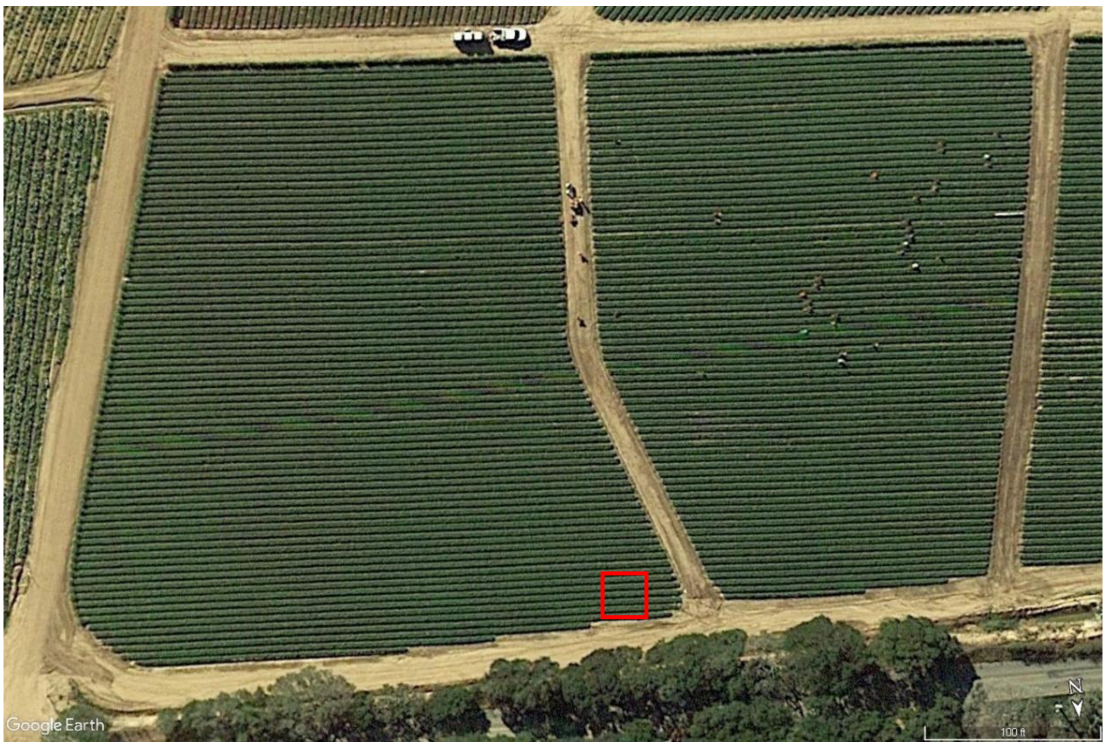


Figure 1: Map of the monitored 3.7 acre field. The location of the water measurement device is indicated by the red square.

ISSN: 2455-6939

Volume:03, Issue:06 "November-December 2017"

Figure 2: The V-notch weir used to measure flowrate.

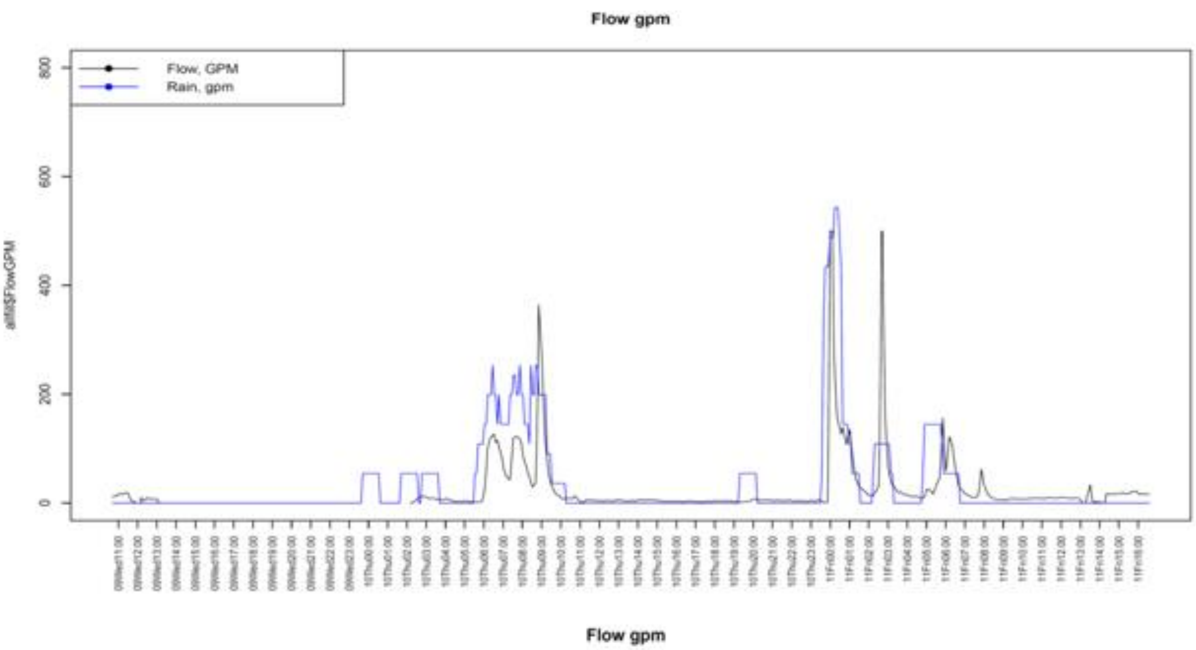
RESULTS

The four storms monitored produced range of rain depth, from about half inch (12/18/2015) to one inch (12/9/2015) to about two inches (12/21/2015 and 1/4/2016) (Table 1). The maximum rain intensity observed during the storms ranged from 0.001 inch/min to 0.005 inch/min (0.06 and 0.3 inch/hour). The maximum runoff measured occurred during the storm of Jan 4, 2016 and reached 785 gpm.

The runoff data obtained from the weir showed good agreement with the precipitation data from the weather station (Figure 3). Rain events generating less than 100 gpm and lasting about one hour did not result in measurable runoff, but when the flowrate from the rains approached 200 gpm or lasted more than 2 hours, runoff was always observed. The data also showed a "funneling effect" where a relatively long pulse of low intensity rains resulted in a concentrated shorter peak of high flow of runoff. For instance consider the rain events of December 11th at 3:00 or January 5th at 16:00 (Figure 3). This effect is also shown in the maximum runoff flow measured during each storm that in some instances was higher than the maximum flow generated by rains, for example on 12/18/2015, 181 gpm of rains resulted in 225 gpm of runoff (Table 1).

Table 1: Summary of characteristics of the storms monitored

Date	Total storm time	Max rain intensity	Total rain	Max runoff flow
	min	inch/min	inch	gpm
12/9/2015	838	0.0051	0.98	500
12/18/2015	750	0.0018	0.47	225
12/21/2015	1784	0.0028	1.98	112
1/4/2016	1420	0.0055	1.94	785



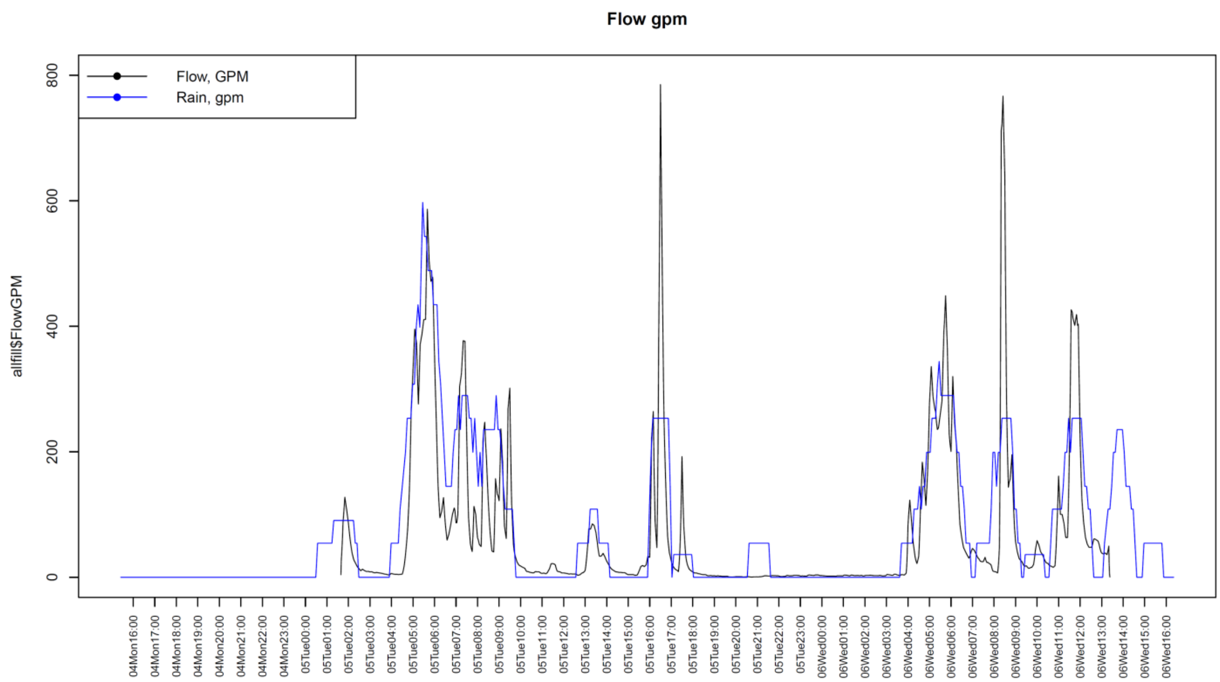


Figure 3: Example of runoff measured by the weir (black line) and rains for the storms of December 9th, 2015 and Jan 4th, 2016.

Table 2: Summary of rains and runoff measured in the experiment

Date	Area	Rain		Runoff		% of rain ran off
	Acres	Inch	Gallons	Inch	Gallons	
12/9/2015	3.7	0.98	98259	0.69	69100	70%
12/18/2015	3.7	0.47	47656	0.38	37858	79%
12/21/2015	3.7	1.98	199265	1.42	142209	71%
1/4/2016	3.7	1.94	195062	1.58	158627	81%

The total volumes and depths of rain and runoff water are reported in Table 2 and Figure 4. Regardless of the intensity, duration and total depth of water produced by the storm, the percentage of rains resulting in runoff water was relatively reproducible and ranged from 70% to 81% (Table 2).

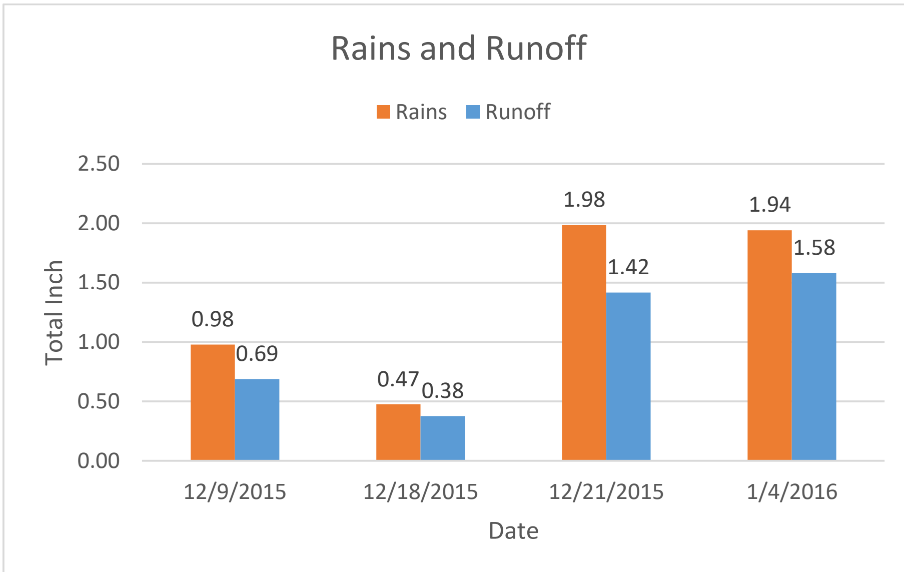


Figure 4: Rains (orange) and runoff (blue) measured in the experiment expressed in inch of depth of water

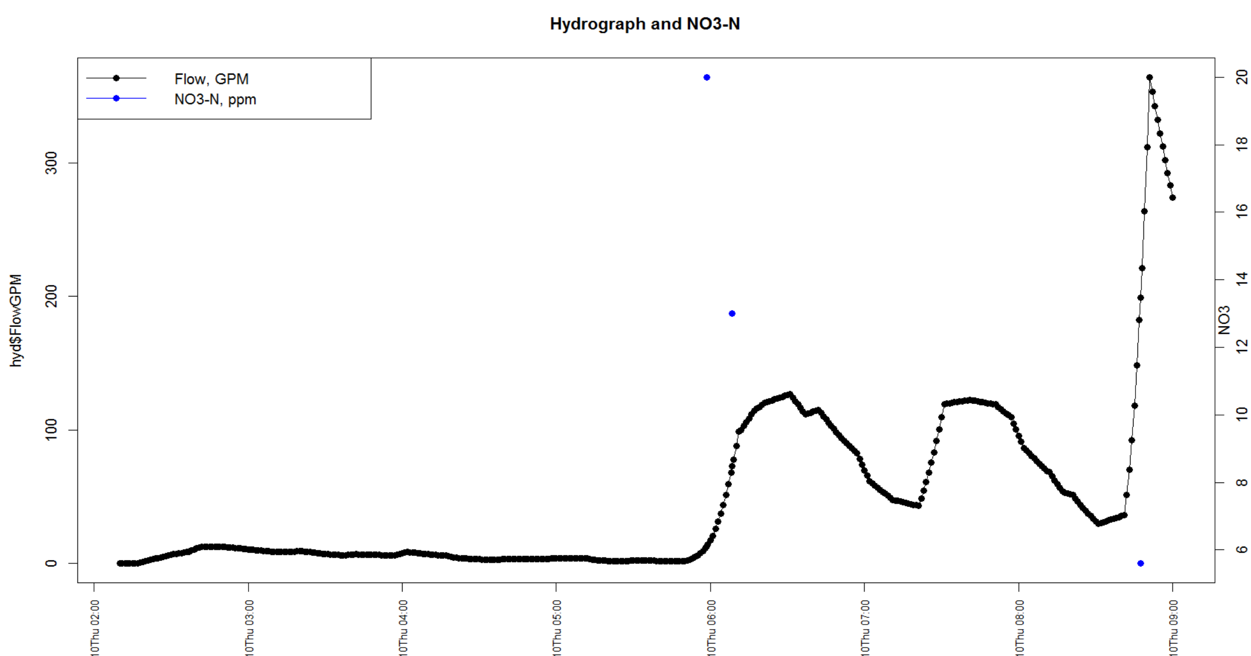


Figure 5: Example of flowrate hydrograph during sampling. The blue dots represent concentration of NO_3-N for three samples when the water in the weir box reached 2,4 and 6 inches (13, 72 and 199 gpm).

Table 3 shows the results from the lab analysis of the of the water samples. The concentration of nitrogen ranged from 1 to 23 ppm and derived mostly from mineralization of organic matter. During the storms of 12/9/2015 and 1/4/2016, nitrogen concentration decreased in time, suggesting a depletion effect, but on 12/18/2015 the concentration increased in time. Large quantities of sediment were collected in the sampling bottles with values ranging from 400 to 7900 ppm of total dissolved solids. The time pattern of sediment was also not reproducible.

Table 3: Summary of the lab results of the water samples

Date	Sample height	NO_3-N	Total Suspended Solids
	inch	ppm	ppm
12/9/2015	2	20	380
	4	13	400
	6	5.6	2300
12/18/2015	1	11	4500
	3	6.8	1400
	5	23	5900
1/4/2016	1	3.6	3700
	3	1	5600
	5	1.5	7900

Table 4: Measured Nitrogen and sediment discharged in the runoff water during sampling and estimate for the whole storm

Date	Sampling Duration	Runoff Volume during sampling	N in runoff water during sampling	Sediment in runoff water during sampling	Estimated N in runoff for the whole storm	Estimated Sediment in runoff for the whole storm
	min	gallons	lb/ac	lb/ac	lb/ac	lb/ac
12/9/2015	414	19572	1.892	62	6.679	219
12/18/2015	13	1298	0.016	16	0.473	473
1/4/2015	15	1055	0.003	17	0.406	2519
Total	**442**	**21925**	**1.9**	**95**	**7.6**	**3211**

The total time and volume of runoff water measured during the sample bottles were filling are reported in table 4. The measured total quantity of nitrogen and sediment that left the field with runoff during the sampling period are also in table 4. An estimate of the total quantity of nitrogen and sediment lost in the whole storm is also reported, based on the average concentrations of the samples. On the average, these quantities corresponded to 2.7 lb/ac of nitrogen and 839 lb of sediment lost per inch of rain. This figures are remarkable considering that the monitored ranch was not fertilized.

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Volume:03, Issue:06 "November-December 2017"

CONCLUSION

To sum up, our study indicated that an average of 75% of runoff can be expected from plastic lined strawberry fields with slopes ranging from 5% to 10%, for a wide range of the intensities and durations of the storm. Thus, a retention basin capable of capturing the runoff from a 5 acres strawberry field in a 2-inch storm event should have a volume of 27230 ft^3. The results further suggest that due to a concentration effect, the instantaneous runoff flowrate can be higher than the flowrate generated at any moment by the rains. Finally, the study results show that on average, 2.7 pounds of nitrogen and 839 pounds of sediment can be lost during storm events from one acre of strawberry with one inch of rains.