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Plant Establishment with Rainfall Simulators for Erosion Control

Presented at:

International Erosion Control Association, Conference 33, Orlando, Florida, February 25-March 1, 2002 (included in conference proceedings).

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Biographical Sketches

Brent G. Hallock

Brent G. Hallock, Ph.D., CPSS, and CPESC, is a professor at California Polytechnic State University, San Luis Obispo, since 1979. He teaches an undergraduate course in Soil and Water Conservation, an upper division course in Rangeland Resources, and a graduate course in Soil Erosion and Sediment Control. Brent earned Cal Poly's highest award of Distinguished Teacher in 2000. He has taught over 30 seminars and short courses in site analysis, erosion control, and selection of management measures. Dr. Hallock's research grants with Caltrans, RWQCB, and EPA on the use of vegetation in erosion control and water quality total over two million dollars in the past six years.

Steve Rein

Steven Rein, Ph.D. is an assistant professor in the Statistics Department at Cal Poly State University in San Luis Obispo, California. Between receiving his Ph.D. in 1993 from U.C. Berkeley and coming to Cal Poly in 1998, he was an assistant professor at Virginia Commonwealth University in Richmond, Virginia where he held appointments in both the Mathematical Sciences Department and at the Center for Environmental Studies. His primary area of research interest is in the application of statistical methodology to problems in ecology and the biological sciences. Past work includes an analysis of the relationship between environmental factors and California's Chinook salmon population and contributing to the development of Virginia's Environmental Quality Index (VEQI).

Misty Scharff

Ms. Misty Scharff has been involved with California State University Sacramento performing research on erosion and sediment control for Caltrans since 2000. Misty was educated in soil science from California Polytechnic State University, San Luis Obispo, were she assisted in numerous erosion control research studies. Misty has been a member of IECA since 1996.

Michael Curto

Michael Curto earned a BS in Ecology & Systematic Biology from California Polytechnic State University, San Luis Obispo. His interests and experience center on plant biogeography, ecology, and systematics, especially of Western North American grasses. As a consultant to the Utah Department of Transportation (UDOT), he designed and constructed ***RoadVeg***, their statewide database inventory of roadside vegetation (now a GIS) and performed field inventories of over 2500 miles of Utah roadways.

Abstract

Hydroseeding failures on disturbed sites are usually attributable to combinations of improper species selection, seeding at inappropriate times, and/or improper seed mixes, fiber, and tackifier. To investigate these factors, California Polytechnic State University, San Luis Obispo, in conjunction with the California Department of Transportation (Caltrans) and California State University, Sacramento, conducted a study of these factors' affect on vegetation establishment.

The goal was to identify initially fast growing vegetation that demonstrates long-term erosion control effectiveness. Native plant species common to District 5, along the California Central Coast, were used. Treatments were conducted in 0.6 by 2 m by 30 cm soil test boxes set at a 2:1 (H:V) slope. Boxes were filled with a medium sandy loam soil (USDA), typical of District 5 fill slopes, compacted to 90 percent. Erosion control treatments included combinations of imprinted straw and hydroseeding of fiber, fertilizer, and tackifier. All boxes were planted with the same native seed mix that included shrubs, forbs, and grasses. Norton Ladder rainfall simulators were used to simulate natural rainfall patterns found in the area. The rainfall regimes applied were natural precipitation, 53.3 cm (21 in/yr during the study period) and uniform rainfall at the mean annual rate, 56 cm (22 in/yr), half the mean annual rate, 28 cm(11in/yr) and double the mean annual rate, 111 cm (44in/yr). The rainfall simulators mimicked rainfall characteristics for the California coast, such as drop size distribution, terminal velocity and a range of storm intensities. In all, 24 boxes were established and treated under rainfall simulators, eight additional boxes were subjected to natural rainfall, and two more boxes were untreated (bare soil). Percent cover and runoff quality (measured as Suspended Sediment Concentration) were measured for each box.

The boxes treated with straw and fertilizer showed greater percent cover than those treated with tackifier and no fertilizer. The ANOVA results indicated that this effect statistically significant to a high degree (p=.001). The effect on runoff was marginally significant (p=.048). Runoff volume was greatest on the heavy rainfall treatments. Higher rainfall treatments showed an increase in the quantity of the native plants of yarrow (*Achillea millefolium*), lupine (*Lupinus succulentus*), and California brome (*Bromus carinatus*). Shrubs and deer lotus (*Lotus scoparius*) were the least common species under all rainfall regimes. This project demonstrates using hydroseeding that includes tack and fertilizer is not as effective in establishing native plant cover without the treatment of straw.

Key Words: Native Vegetation, Rainfall Simulators, Hydroseeding, Erosion Control, and Caltrans

Marketing Paragraph

This paper discusses the use of rainfall simulators in establishing native vegetation using typical hydroseeding techniques along the California Central Coast. Treatments included straw, tackifier, fertilizer, and fiber under three rainfall regimes. Native vegetation, runoff, and water quality were dependent on rainfall and treatments. The highest percentage of vegetation was the non-native species that already had a seed bank in the soil. The results will be presented on what treatment is most effective and how hydroseeding affects native plant establishment and water quality.

Project Overview

The purpose of this study was to develop guidance for effective establishment of erosion control vegetation for rapid short-term growth and for long-term establishment. The plants examined in this study included both native and non-native or adapted species.

The California Department of Transportation (Caltrans) will use the results of this study in an effort to increase vegetation establishment, decrease erosion and thereby improve water quality. There is a need to address proper seed selection, proper time of year for seeding, appropriate methods of hydroseeding and plant establishment criteria as it relates to erosion control and soil stabilization.

Goals

The main goal was to identify and select plant species for hydroseeding that demonstrate initially fast growth and potential long-term erosion control under a variety of rainfall regimes. The criteria was defined as what methods would produce the required 70 percent cover in the shortest time period? Rainfall simulators were used on test boxes to evaluate the main goal.

A secondary goal was to measure the effectiveness of a native hydroseeded erosion mix in controlling sediment transport under varying rainfall regimes and application methods. Water quality sampling was used to evaluate this goal

The third goal was to characterize how various rainfall regimes affect seed germination and plant establishment. Statistical analysis was used to determine any significant difference or identify trends in plant cover.

Box Design

Two criteria were used to determine the size of the erosion test boxes. The first criterion was that the boxes had to be of a size and weight that could be easily handled by two people using a simple one-ton chain hoist which was already located at the test site. The other criterion was to select a plot (box) size, which was present in the erosion literature. Pearce et al (1998) utilized field micro-plots of 0.6 meters (2 feet) by 2.0 meters (6.6 feet) alongside standard plots of 3.0 meters (9.9 feet) by 10 meters (32.9 feet). It was found that a box having the same dimensions as the micro-plots and with a soil depth of 20 cm (7.8 inches) would weigh less than a ton when saturated and could be easily moved by two people using the hoist.

A total of 36 erosion test boxes, each measuring 0.6 meters by 2.0 meters by 30. cm were eventually constructed and filled with soil. One end of each box was cut to a height of eight inches to coincide with the height of the added soil. Four of the boxes were left bare and tested at the end of the study

In addition to the erosion test boxes, Clint Iwanicha Designs created plans for a support stand. Ten of these supports were used in this study. The supports, also constructed with pressure treated lumber, use 2.5 cm diameter, schedule 40, galvanized steel pipe to support the boxes at a 2:1 slope. The supports were used for the two boxes during the simulation and the eight natural rainfall boxes.

Each box had a designated space under the box transport system. The erosion test boxes were situated next to each other, five boxes per row with a total of five rows. One space left empty for the duration of the experiment since there were a total of 24 boxes to be exposed to simulated rainfall.

A length of vinyl gutter was used to collect runoff from the base of the erosion test box and channel it into a basin where it was collected. A rectangular piece of synthetic pond liner was cut and riveted to the vinyl gutter. This prevented simulated rainfall from entering the erosion collection system. The collection system was secured to the box with screws. The basin consisted of an eight quart Rubbermaid container, trimmed to accept the curve of the gutter

Hydroseeding Design

Hydroseeding was performed to specifications standard for the District 5 Central Coast region. The specifications were obtained from past projects that were installed within the last five years in District 5. KarlesKint-Crum, Inc., Licensed Landscape Erosion Control Contractors, performed the application.

Treatments included eight boxes sprayed for each individual treatment listed below. The rate of fiber was applied at 896 kg/ha (800 lbs/acre. The fertilizer was applied at 45 kg/ha (40 lbs/acre) of 15-15-15. The tackifier was applied at 168 kg/ha (150 lbs/acre). The treatments were:

1. fiber, seeds, and crimped straw
2. fiber, seeds, and tackifier
3. fiber, seeds, fertilizer, and crimped straw
4. fiber, seeds, fertilizer, and tackifier

Boxes were placed in a random design before hydroseeding. Prior to hydroseeding, straw was crimped into sixteen boxes for treatment 1 and 3. The first pass was loaded with fiber and seed for treatments 1 and 2 and sprayed sixteen boxes in total. Fertilizer was then added for a second pass and the mixture was sprayed on treatments 3 and 4, sixteen boxes in total. The equipment was then cleaned out with water and set up for the third pass which was fiber for treatments 1 and 3, 16 boxes in total. Tackifier was loaded for the fourth pass on treatments 2 and 4, 16 boxes in total.

Rainfall Pattern

The average rainfall pattern for the District 5 Central Coast region is 55 cm (21.6 inches). To simulate low and high rainfall years, the low was set at 27.5 cm (10.8 inches) and 110 cm (43.3 inches) for the high rainfall years.

To evaluate the relationship of vegetation establishment with simulated rainfall, a set of natural rainfall boxes with the same hydroseeding treatments were grown under the natural rainfall for the 2000-01 season.

A data logger and rain gauge were set up directly above the natural rainfall boxes as well to determine any differences from the simulator boxes. The weather monitoring station was then linked to a computer that logged the information throughout the experiment.

Rainfall Simulators

Two Norton Ladder Type variable sweep rainfall simulators were purchased for use in this study. They were developed at the USDA Erosion

Research Center at Purdue University. Advanced Design and Machine (Clarks Hill, IN) manufactured the simulators.

The rainfall simulator is a pressurized nozzle type simulator, the most frequently used simulator in erosion research. It consists of a boom oscillating side to side by way of a cam. A small motor drives the cam at one end of each simulator. Intensity of rainfall is determined by how many times the nozzles of the boom sweep past the box opening. The boxes are configured to regulate spray pattern and return non-effective rainfall to the water supply system.

Veejet brand nozzles were used on this simulator. These are the most common types of nozzle used on previous rainfall simulation studies. At 41 kPa (6 psi), the drop size should be about 2.25 mm in diameter. This drop size corresponds to the average drop size of erosive storms in the Midwest. The nozzles are industrial spray nozzles used in high-pressure spray applications. They have an optimum range of 5 to 300 psi and for rainfall simulation purpose, the pressure was set at 6 psi.

Water Quality Measurements

Water samples were assigned a bottle identification number, and a data sheet was completed indicating all necessary information on bottle. Each sample was checked for loss of water and sediment caused by leakage and accuracy of sample identification notes. Any additional remarks regarding sample were made on assigned data sheet. After above sample preparations were made, a total sample weight was obtained using a digital balance for all samples. Samples were then analyzed according to either Test Method A (Modified Evaporation) or Test Method B (Evaporation) described below.

<u>Test Method A: Modified Evaporation.</u> This method was utilized when most of the solid material in the liquid had settled down from a state of suspension. Two measurements were obtained: final filter weight and final evaporation weight. The summation of these two measurements yielded the total sediment weight. This sediment weight divided by total water volume yielded Suspended Sediment Concentration (SSC) for given sample.

The supernatant water (clear, overlying water which contains mainly fine sediment) was slowly filtered through a vacuum-filtration manifold. The supernatant water was decanted onto oven dried, pre-weighed Whatman 934AH filter paper. The filter was then oven dried for a minimum of eight hours at a temperature of 115 degrees Celsius. After oven drying, filters were placed into a desiccator. A desiccator prevented air-borne moisture from collecting in the sediment specimens while filters were cooling. After filters were at room temperature, an analytical balance was used to obtain the final filter weight.

Once the supernatant water was filtered, the remaining water –sediment mixture was flushed from the storage container into a pre-weighed Nalgene evaporation beaker. The additional water amount used to flush the water-sediment mixture did not affect final calculations for any data analysis. Multiple evaporation beakers were needed for most samples. Evaporation beakers were then oven dried at a temperature of 115 degrees

Celsius until all water was evaporated. Since most of the evaporation beakers were over 2 liters in volume and too large for the desiccator, a desiccator was not used for the evaporation beakers. After evaporation beakers were at room temperature, a digital balance was used to obtain the final evaporation weight. The final filter weight combined with the final evaporation weight yielded the total sediment weight for given sample. This sediment weight divided by total water volume yielded SSC for given sample.

Test Method B: Evaporation.
This method was utilized when most of the solid material in the liquid had not settled from a state of suspension. One measurement was obtained: final evaporation weight. The final evaporation weight yielded the total sediment weight. This total sediment weight divided by total water volume yielded SSC for given sample.

An entire sample was poured into a pre-weighed Nalgene evaporation beaker. Multiple evaporation beakers were needed for most samples. Evaporation beakers were then oven dried at a temperature of 115 degrees Celsius until all water was evaporated. Since most of the evaporation beakers were over 2 liters in volume and too large for the desiccator, a desiccator was not used for the evaporation beakers. After evaporation beakers were at room temperature, a digital balance was used to obtain the final evaporation weight.

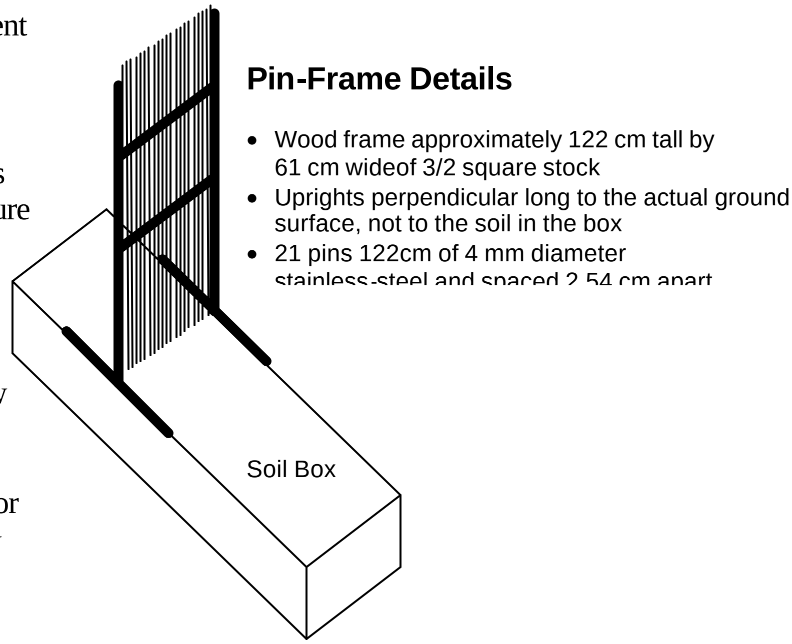
The final evaporation weight yielded the total sediment weight. This total sediment weight divided by total water volume yielded SSC for given sample.

The partitioning of coarse- and fine-fragments was important for at least two reasons. From observations of runoff in the early stages of this study, some samples appeared to have relatively clear water (low turbidity) with a fair amount of coarse-grained material and other samples with seemingly little coarse-grained material, but large amounts of fine-grained material (high turbidity). There was concern that if a method analyzing only total sediment concentration was used there might not be a clear enough understanding of differences among boxes due to inaccurate test results.

A second reason for partitioning sediment is that the coarse- and fine-fractions negatively impact waters in different ways. For example, coarse-fraction materials tend to settle out of the water-column relatively quickly and in so doing cover gravel on stream bottoms that provide spawning beds for salmon or provide habitat for various invertebrates. Conversely, fine-fraction materials have less direct impact on bottom gravel, but negatively affect the water column by increasing turbidity and thereby reducing the light available to primary producers (Clark, et al 1985).

Vegetation Measurements

The three primary measures of vegetation are: density, the number of individuals of a species, lifeform, or structural class per unit area; ***biomass***, the quantity of herbaceous or woody tissue produced by individuals of a species, lifeform, or structural class per unit area; and ***cover***, a two-dimensional perpendicular projection onto the ground surface of the three-dimensional aerial vegetation above (Bonham 1989; Interagency Technical Team 1996; Kent and Coker 1992; Mueller-Dombois and Ellenberg 1974).



For this first rainfall simulation experiment plant cover was measured to assess the affects on soil erosion of vegetation established under different hydroseeding treatments and rainfall regimes. Cover is the most logical and time-efficient measure in that the interception of raindrops by aerial plant parts is fundamental in retarding water-driven soil erosion processes. Although plant density can provide important information about how many individuals of a given species in a seed mix germinated and established, obtaining plant counts are extremely labor intensive and time consuming, especially in a multi- species mix.

The oldest, most objective, and most repeatable measure of plant cover is by *point intercept* whereby a theoretically infinitely small point projected from above onto vegetation surfaces contacts individual plant structures, soil surface litter, rock, or bare soil. Each contact is termed a "hit" for each category scored. Rules must be established beforehand regarding exactly what constitutes a "hit" for each purpose-dependent investigation.

A custom pin-frame using wood stainless-steel rods as pins was designed and constructed. The frame is designed such that the uprights are perpendicular to the actual ground surface, not to the soil in the box, because the vegetation in the boxes is growing perpendicular to the actual ground surface owing to plant phototropism. The frame contains 21 independently operated pins, each approximately 122cm (4 ft) long and spaced 25.4 mm (1 in) apart in a single row. This length accommodates increasing plant height as plants grow through the season. Pin spacing reflects the finely textured, mostly grassy, nature of the vegetation growing in the soil test boxes, and the need to include as many potential sample points as possible in the randomized sampling scheme.

The design rendered 100 observations per vegetation layer for overstory and understory per 2 boxes per treatment. Thus, 3200 observations of overstory, and 3200 observations of understory, for a total data set of 6400 observations on 32 boxes. For consistency, the same experienced observer made scoring decisions for all 6400 observations over approximately 32 hours of scoring time. Plant identifications were made based largely on observer knowledge of the flora. Verifications of some preliminary identifications were made using the most recent taxonomical manual (Hickman, 1993), and specimens in the Hoover Herbarium at Cal Poly. Data were then entered into a computer spreadsheet and verified for accuracy and completeness.

For sampling purposes, each soil test box was conceptually divided into an upper and a lower half to assess whether differences in plant cover exist between the two halves. This effect would have been due to greater gravity water flow and retention in the lower end of each inclined box. A computer spread sheet was generated to develop random numbers to select the five transects per box. Ten sample points were randomly selected for each transect with five in the upper half and five in the lower half.

Statistical Methodology

Proportion cover will be analyzed by three methods, logistic regression, a weighted analysis of variance (ANOVA) and ANOVA on arcsine root transformed data. Although the conceptual model of how rainfall, treatment and other factors affect each of these response variables is the same with each method, each makes a different set of assumptions before the results can be accepted. If all three methods produce largely similar results, both in terms of estimated effects of each treatment factor and in terms of the estimated proportion cover, it should be viewed as confirmation of our conceptual model (Fortin et al., 1989). While proportion cover estimates are informative and perhaps the easiest method for comparison between treatments (light- versus heavy rainfall, etc.) they do not allow for formal conclusions. Therefore, formal statistical tests appropriate to each method will be used for any hypothesis testing (Agresti, 1996).

Percent cover was measured in each box-half by determining cover or no cover for each of 50 points. If the presence or absence of plant matter is considered at each sampled location as the response variable of interest, then this is related to the experimental factors (Montogomery, 1991). Logistic regression is a method by which one can model the presence of plant matter at any point in the box as a function of rainfall level, treatment and other factors. If any location with a fixed rainfall regime, fertilizer level, treatment (straw versus tackifier) and box-half (upper versus lower) is considered, then we model the probability that there is plant material at this location. For example, the probability of cover at a location in the l^{th} box division with the i^{th} rainfall level, j^{th} level of fertilizer, k^{th} level of treatment (straw or tackifier) is p_{ijkl} which was then modeled.

According to these models, percent cover is affected by the rainfall level, fertilizer, treatment (straw versus tackifier) and box division. The two-way interaction terms allow for the effects of fertilizer on percent cover to depend on the rainfall level, etc.

Vegetative Results and Discussion

Overall, vegetation present in the treatment boxes consisted largely of non-native species present in the non-sterilized soil purchased for this experiment. This mimics typical soil seed bank conditions present along most highway roadsides, especially within District 5.

Species Present in Vegetation

Lifeform	Seeded	Not-Seeded
Annual Forbs	2	19
Perennial forbs	1	7
Annual Grasses	1	9
Perennial Grasses	2	0
Shrub Seedlings	3	0

In total, 44 species were observed including 9 intentionally seeded and 35 not seeded but present in the soil. Five of the species intentionally seeded were not observed anywhere in any box. A breakdown of species numbers by life form is presented at right. Annual ryegrass (*Lolium multiflorum*) constituted 64 percent absolute cover (plants + non-vegetated soil) and 70 percent relative cover (plants only) overall. As noted above, these values are likely underestimates. Notable also is that an estimated 9 percent of the surface among boxes was not vegetated at all, and an estimated 51 percent of the understory was not vegetated either. This indicates that other measures (e.g., fi ber, straw, tackifier) would be necessary to achieve 100 percent cover of the soil surface and reduce effects from raindrop impacts.

Of the species used in the seed mix, five were of notable presence in the overall vegetation (Table 1). In the overstory, California brome (*Bromus carinatus*) and Arroyo lupine (*Lupinus succulentus*) made reasonable showings. The understory had

Table 1. Native Seed Mix Cover after 150 days for All Treatments Combined.

				Overstory			Understory				
Vernacular Name	**Scientific Name**	**Family**	**LF**	**Hits**	**%AbsCov**	**%RelCov**	**Hits**	**%AbsCov**	**%RelCov**	**%PLS/Mix**	**PLS/ft2**
California Brome	***Bromus carinatus***	Poaceae	*Gp*	**479**	**14.97**	**16.46**	**7**	**0.22**	**0.45**	25.0	24
Arroyo Lupine	***Lupinus succulentus***	Fabaceae	*Fa*	**173**	**5.41**	**5.95**	**41**	**1.28**	**2.63**	5.0	1
White Yarrow	***Achillea millefolium***	Asteraceae	*Fp*	**7**	**0.22**	**0.24**	**256**	**8.00**	**16.40**	2.5	63
California Poppy	***Eschscholzia californica***	Papveraceae	*Fa*	**3**	**0.09**	**0.10**	**449**	**14.03**	**28.76**	5.0	13
Pin-Point Clover	***Trifolium gracilentum***	Fabaceae	*Fa*	**2**	**0.06**	**0.07**	**64**	**2.00**	**4.10**	12.5	58
Small Fescue	***Festuca microstachys***	Poaceae	*Ga*	0	0.00	0.00	**141**	**4.41**	**9.03**	2.5	23
California Sagebrush	***Artemisia californica***	Asteraceae	*S*	0	0.00	0.00	**21**	**0.66**	**1.35**	2.5	127
Coyote Bush	*Baccharis pilularis*	Asteraceae	*S*	0	0.00	0.00	3	0.09	0.19	2.5	116
Purple Needlegrass	*Nassella pulchra*	Poaceae	*Gp*	0	0.00	0.00	2	0.06	0.13	2.5	5
Black Sage	*Salvia mellifera*	Lamiaceae	*S*	0	0.00	0.00	1	0.03	0.06	2.5	14
Blue Wild Rye	*Elymus glaucus*	Poaceae	*Gp*	*0	0.00	0.00	*0	0.00	0.00	12.5	15
Foothill Needlegrass	*Nassella lepida*	Poaceae	*Gp*	*0	0.00	0.00	*0	0.00	0.00	5.0	15
California Buckwheat	*Eriogonum fasiculatum*	Polygonaceae	*S*	*0	0.00	0.00	*0	0.00	0.00	12.5	52
Deerweed	*Lotus scoparius*	Fabaceae	*S*	*0	0.00	0.00	*0	0.00	0.00	5.0	21

cover of California Poppy (*Eschscholzia californica*), White Yarrow (*Achillea millefolium*), and Small Fescue (*Festuca microstachys*), not unlike local native stands. California Sagebrush (*Artemisia californica*) was the only seeded shrub to emerge with any success at about 1.4 percent cover and 216 total seedlings counted, 178 occurred among only 8 of the 32 treatment boxes under average to high rainfall simulation (Table 2). No sagebrush seedlings were observed among any of the boxes that received natural rain even though the total precipitation for the season was just above the 50-year average.

Table 2. Overstory Vegetation Cover after 150 days for All Treatments Combined

Vernacular Name	Scientific Name	Family	LF	Origin	Hits	%AbsCov	%RelCov	%PLS/Mix	PLS/ft2
Annual Ryegrass	*Lolium multiflorum*	Poaceae	***Ga***	Alien	2043	**63.84**	**70.21**	ns	?
California Brome	***Bromus carinatus***	**Poaceae**	***Gp***	**Native**	**479**	**14.97**	**16.46**	**25.0**	**24**
Arroyo Lupine	***Lupinus succulentus***	**Fabaceae**	***Fa***	**Native**	**173**	**5.41**	**5.95**	**5.0**	**1**
Black Mustard	*Brassica nigra*	Brassicaceae	***Fa***	Alien	37	**1.16**	**1.27**	ns	?
Common Wild Oat	*Avena fatua*	Poaceae	***Ga***	Alien	28	**0.88**	**0.96**	ns	?
Pigweed	*Chenopodium murale*	Chenopodiaceae	***Fa***	Alien	27	**0.84**	**0.93**	ns	?
Field Mustard	*Brassica rapa*	Brassicaceae	***Fa***	Alien	22	**0.69**	**0.76**	ns	?
Tumble Mustard	*Sisymbrium altissimum*	Brassicaceae	***Fa***	Alien	21	**0.66**	**0.72**	ns	?
Common Vetch	*Vicia sativa*	Fabaceae	***Fa***	Alien	19	**0.59**	**0.65**	ns	?
Ripgut Brome	*Bromus diandrus*	Poaceae	***Ga***	Alien	15	**0.47**	**0.52**	ns	?
Yellow Sweet Clover	*Melilotus officianalis*	Fabaceae	***Fa***	Alien	14	**0.44**	**0.48**	ns	?
Milk Thistle	*Silybum marianum*	Asteraceae	***Fa***	Alien	10	**0.31**	**0.34**	ns	?
White Yarrow	***Achillea millefolium***	**Asteraceae**	***Fp***	**Native**	**7**	**0.22**	**0.24**	**2.5**	**63**
Poison Hemlock	*Conium maculatum*	Apiaceae	***Fp***	Alien	4	**0.13**	**0.14**	ns	?
California Poppy	***Eschscholzia californica***	**Papveraceae**	***Fa***	**Native**	**3**	**0.09**	**0.10**	**5.0**	**13**
Pin-Point Clover	***Trifolium gracilentum***	**Fabaceae**	***Fa***	**Native**	**2**	**0.06**	**0.07**	**12.5**	**58**
Soft Chess	*Bromus hordeaceus*	Poaceae	***Ga***	Alien	2	**0.06**	**0.07**	ns	?
Bur Clover	*Medicago polymorpha*	Fabaceae	***Fa***	Alien	1	**0.03**	**0.03**	ns	?
Wall Barley	*Hordeum murinum*	Poaceae	***Ga***	Alien	1	**0.03**	**0.03**	ns	?
Spanish Brome	*Bromus madritensis*	Poaceae	***Ga***	Alien	1	**0.03**	**0.03**	ns	?
Rattail Fescue	*Festuca myuros*	Poaceae	***Ga***	Alien	1	**0.03**	**0.03**	ns	?
No Vegetation					290	**9.06**	N/A		
					3200	**100.00**	**100.00**		

LF = lifeform (***Fa*** = Annual Forb; ***Fp*** = Perennial Forb; ***Ga*** = Annual Grass; ***Gp*** = Perennial Grass; **S** = Shrub)
Mix = whether species was intentionally seeded onto soil boxes
Hits = number of times species was encountered by a pin; ***** = species was not observed anywhere in any box
%AbsCov = (number of hits / 3200) x 100; includes hits for both vegetation and no vegetation (surface mulch layer)
%RelCov = (number of hits / 2910) x 100; includes hits for vegetation only
%PLS/Mix = percent of total pure live seed applied to each treatment box; ns = not seeded (present in purchased soil)
PLS/ft2 = seeding rate per square foot of pure live seed applied to each treatment box; ? = unknown quantity for spp. ns

For the Overstory the logistic regression implies that there is an effect of rainfall on percent cover along with a rainfall fertilizer interaction, and rainfall treatment (straw or tackifier) interaction. The effect of rainfall on percent cover depends on whether fertilizer was applied to the box as well as if straw or tackifier was applied. For the overstory it appears that little else effects percent cover. Eliminating the insignificant terms from this logistic regression does not change the parameter estimates very much so we leave them in for consistency between the overstory and understory analyses.

Rainfall, rainfall fertilizer interaction, rainfall treatment (straw versus tackifier) interaction and rainfall box-division interaction affect the percent cover in the understory. In addition, there are significant interactions between fertilizer and treatment, fertilizer and box-division and finally treatment and box division.

Water Quality Results and Discussion

The trend for SSC was a general increase as the rainfall increased. The high rainfall boxes with fertilizer, regardless of the straw application, had greater SSC. The natural rainfall boxes with fertilizer had total higher runoff than any other treatments and the most SSC.. The bare/unseeded boxes that were freshly disturbed to represent a recently finished site had more runoff and SSC. when compared to the bare unseeded boxes that were stable for six months representing a site that was finished late spring.

Conclusions

The main goal of the project was met by achieving at least 70 percent cover in a short period of time. The overstory cover was at 91 percent within 150 days for all treatments. However, the dominant vegetation was Annual Ryegrass at 63 percent, which was not a planted species. The native planted species accounted for just over 20 percent of the overstory. The understory was at 49 percent plants and 51 percent bare ground. Just over 30 percent were native plants, of which 22 percent were the native forbs of California Poppy (*Eschscholzia californica*) and yarrow (*Achillea millefolium*).

The boxes treated with straw and fertilizer showed higher percent cover than those treated with tackifier and no fertilizer. The ANOVA results indicated that this effect statistically significant to a high degree (p=.001). The effect on runoff was marginally significant (p=.048). Runoff volume was greatest on the heavy rainfall treatments. Higher rainfall treatments showed an increase in native plants of yarrow (*Achillea millefolium*), lupine (*Lupinus succulentus*), and California brome (*Bromus carinatus*). Shrubs and deer lotus (*Lotus scoparius*) were the least common species under all rainfall regimes.

As the rainfall increased, the amount of runoff increased. However the treatments with fertilizer had a higher amount of SSC. when compared to other treatments. The straw treatments had the overall least amount of SSC. compared to all the treatments.

This project demonstrates using hydroseeding that includes tackifier and fertilizer is not as effective in establishing native plant cover as treatment with straw. Therefore, the secondary goal to establish native vegetation using common hydroseeding practices is not likely. The project will be monitoring the vegetation in the test boxes for the next two years to document plant composition changes over time. Future studies will include varying hydroseeding techniques and field trials to correlate to the field.

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