

VETIVER IN CALIFORNIA'S MOJAVE DESERT A TRIAL FOR APPLICATION IN ECOLOGICAL RESTORATION

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Abstract

Plantings of Vetiver grass have been used in various tropical situations as “nurse” plants to either jump start native revegetation initiatives or to ensure the continued survival of native seedlings in adverse conditions until they are well established. The High Desert of the Mojave, California, presents unique and extreme challenges for the use of Vetiver grass but the potential benefits, should it prove successful, are considerable.

The Mojave River Watershed comprises just over 4,000 km² entirely within San Bernardino County, California and ranges in elevation from 427 to 2,590 m. The Mojave River has been severely impacted by anthropogenic development resulting in severely degraded ecosystems, extreme habitat fragmentation and area loss to urbanization, overuse of groundwater, and introduction and establishment of harmful invasive species.

The *High Desert Tall Pot & Mojave River Native Plant Rehabilitation Project* (HDTP & MRNPRP) near Victorville aims to restore the structure and function of parts of the riparian ecosystem after the removal of non-native invasive species by local authorities, and to replace them with phreatophytic native vegetation transplanted from HDTP & MRNPRP project nurseries. The removal of non-native invasive vegetation is well underway, with Tamarisk or Salt Cedar (*Tamarix ramosissima*), Russian Olive (*Elaeagnus angustifolia*), and Giant Reed (*Arundo donax*) being the most pervasive and harmful species targeted. Accessible riparian sites that can support “islands” of transplanted and seeded native and local plants have been identified in the early stages of the program. A native plants nursery is currently being established on the site of the Mojave River Campus (a high school), which will also provide a significant education and citizen science component to the project. Next, selected riparian sites will be prepared and islands planting and seeding will occur, with intensive monitoring and management, particularly during the establishment phase. Finally, it is hoped that increased involvement from the local community will allow the project to upscale and become sustainable.

Vetiver grass is being trialed as a tool to contribute in at least two stages of this project. The native plants nursery being established at the campus by students is adjacent to a 45 degree slope, raising fears of erosion. Vetiver grass is being trialed for use as cover for this area and to provide Vetiver slips for later use in outplantings. If this is successful, Vetiver grass will be planted in nursery chevrons or wedges about 12 months before outplanting natives in order to develop a semi-protective micro-habitat for outplanting of the other island-guild native plants. It is expected that Vetiver grass will provide some level of

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protection from wind, water erosion and occasional foot traffic, and will also foster helpful environmental conditions by facilitating retention of water and nutrients in the soil. It is also possible that Vetiver may act as an indicator of how suitable the site has become for growth of phreatophytes, since its root system may act in similar ways.

The most serious problem facing this project is the lack of cold-hardiness of Vetiver Grass. The temperature extremes in the High Desert can swing between highs of 46—49° C in the summer months to lows of -9.5—-6.5° C in the winter months, although warming as a result of climate change is already moving plants zones in North America dramatically northward. Initial trials have indicated that Vetiver Grass can survive in the High Desert over a winter with recorded lows of -6° C. Another, more familiar problem to Vetiver practitioners is that of long dry periods, and indications are that some level of irrigation may be required.

We report on the background and technical aspects of the project and present a preliminary progress report focusing on the Vetiver Grass trials to date. We highlight the educational opportunities and those for significant local community involvement and in turn the opportunities for promotion of use of The Vetiver System within the North American context.

Keywords

USA, High Desert, Ecological Restoration, Nursery, Riparian

Introduction

Vetiver Grass, *Chrysopogon zizanioides* (syn. *Vetiveria zizanioides*) has been widely used in erosion control and ecological restoration throughout the tropics and sub-tropics. In the latter application usually involves Vetiver grass being utilized in as “nurse” plants to either help jump start native revegetation initiatives or to ensure the continued survival of native seedlings in adverse conditions until they are well established.

Though its utility in tropical situations is already well established, there is still much to be learned about its use in temperate regions. In temperate zones Vetiver grass can survive temperatures as low as -12°C (10°F) if following daytime temperatures rise well above freezing (pers. com. Dick Grimshaw). Soil temperatures are important—where the crown does not freeze Vetiver utilization may be viable.

As climate change is clearly affecting plant zones by moving them towards higher latitudes³ (Parmesan & Yohe 2003; Peñuelas & Filella 2001; IPCC 2007), it is possible that areas where Vetiver could not survive because of harsh winters could now, or in the near future, support Vetiver applications. The High Desert, at the western border of California’s the Mojave Desert, presents unique and extreme challenges for the use of Vetiver grass but the potential benefits, should it prove successful, are considerable. Temperature extremes in the High Desert can swing between highs of 46—49° C (115-

³ <http://planthardiness.ars.usda.gov/PHZMweb/default.aspx?loc=interstitialskip#>

120°F) in the summer months to lows of -9.5—6.5° C (15-20°F) in the winter months, though winter frosts are generally followed by high solar radiation and highs well above freezing⁴.

The Mojave River Watershed (Figure 1) is located in the arid high-desert region of Southern California and comprises just over 4,000 km² (~1,600 square miles) of total drainage area entirely within San Bernardino County. Approximately 544 km² (210 square miles) of this drainage area is located in the San Bernardino Mountains, which are the headwaters for the Mojave River system. Elevations range from 427 m (1,400 ft) at Afton Canyon near the terminus of the Mojave River to 2,590 m (8,500 ft) at Butler Peak in the San Bernardino Mountains.

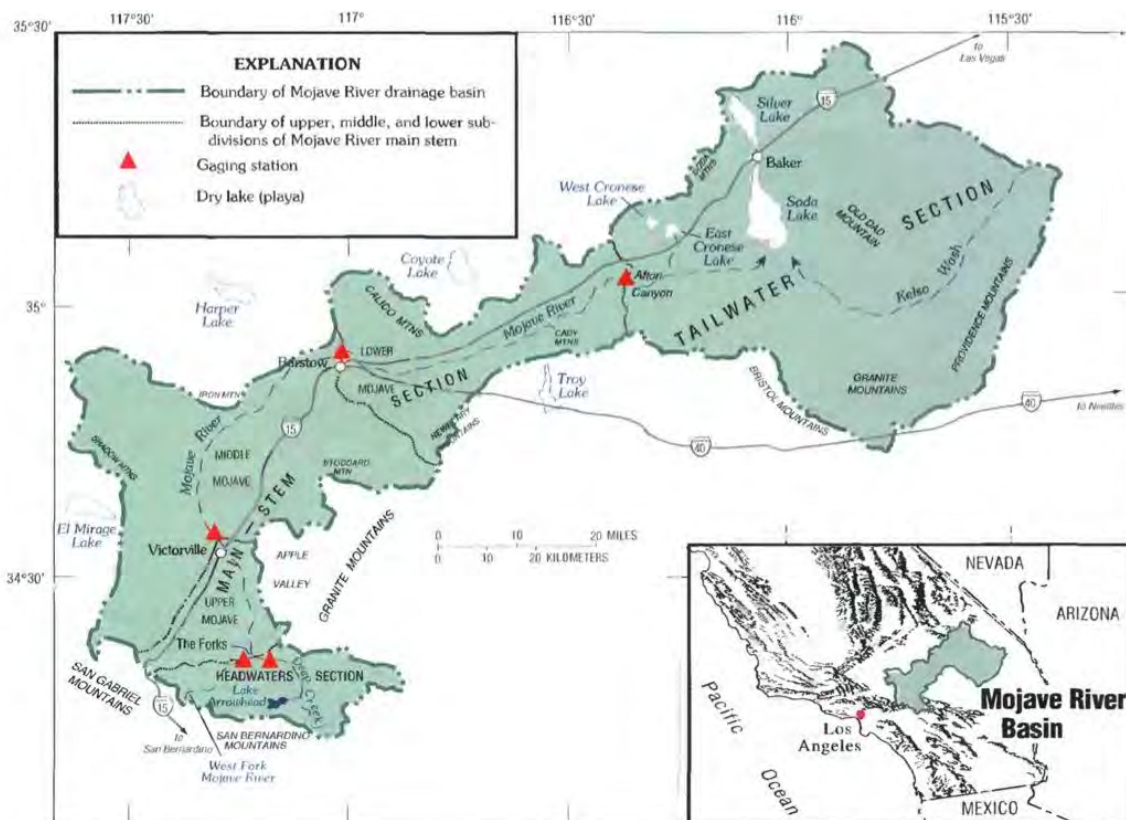


Figure 1. The Mojave River drainage basin.

Deep Creek and the West Fork of the Mojave River are the two perennial tributaries to the Mojave River. Both tributaries have multiple branch tributaries within the San Bernardino Mountains. Deep Creek and the West Fork of the Mojave River converge immediately upstream of the Mojave Forks Dam which was constructed for flood control to protect downstream land and property from damage during peak storm events. The Mojave River channel begins at the Mojave Forks Dam and extends for approximately 193 km. (120

⁴<http://www.ipm.ucdavis.edu/calludt/cgi/WXPCLISTSTNS?MAP=&COUNTY=&ACTIVE=1&NETWORK=&PATH=STNNAME&STN=Victorville>

miles) transecting the communities of Hesperia, Apple Valley, Victorville, Hinkley, and Barstow and finally terminating at Soda and Silver Dry Lakes near the community of Baker.

The Mojave River has been very severely impacted by anthropogenic development resulting in severely degraded ecosystems with compromised structure and function which has led to the loss of biodiversity and provisioning of ecosystem services. Among the causes and impacts are extreme habitat fragmentation and area loss to urbanization, overuse of groundwater, and introduction and establishment of harmful invasive species.

Human caused disruption and invasive species can negatively impact native ecosystems and compromise their functioning. Habitat fragmentation as a result of agricultural intensification, development of road networks, and urbanization can directly cause significant loss of biodiversity and generally have second order effects. This is illustrated in the Mojave River Watershed, as elsewhere, by how these factors have led to greatly increased populations of Common Ravens (*Corvus corax*) which thrive and have undergone large population increases under such impacts. Ravens are effective predators of IUCN-listed vulnerable Desert Tortoises (*Gopherus agassizii*), a species already under great pressure and threatened by the first order stressors.

Overuse of an essential resource like groundwater causes its overdraft, leading to water no longer being available to native vegetation communities and so modifying these ecosystems. Riverine plant communities in the Mojave River Watershed are characterized by the presence of phreatophytes, plants that rely upon ground water that lies within reach of their usually extensive root system for their water supply (Robinson 1958). In this riverine setting available water comprises underground water regulated by the nearby river flows as well as moisture in the soil immediately above the groundwater level (Figure 2.).

Introduced and invasive plant species are another factor contributing to the demise of local ecosystems and their functions. Three species in particular are near ubiquitous to riverine areas of the Mojave River Watershed and a targeted for control. Tamarisk or Salt Cedar (*Tamarix ramosissima*) is a deciduous woody shrub or small tree native to Europe and Asia. Russian Olive (*Elaeagnus angustifolia*) is a thorny shrub native to western and central Asia and is capable of Nitrogen fixation, so can drastically change soil conditions so as to disfavor native plants. Giant Reed (*Arundo donax*) is native to parts of southern Europe, eastern and southern Asia and parts of Africa and forms dense monoculture stands in riparian areas, wetlands and disturbed areas, excluding native plants. These invasive species are well-established and have overwhelmed native vegetation along more than 193 km (120 rivers miles) below the Forks Dam. Native phreatophytes, mostly willows and cottonwoods, have been under significant pressure from these invasives and the native character of Mojave River's riparian habitat is now vastly different from historical states.

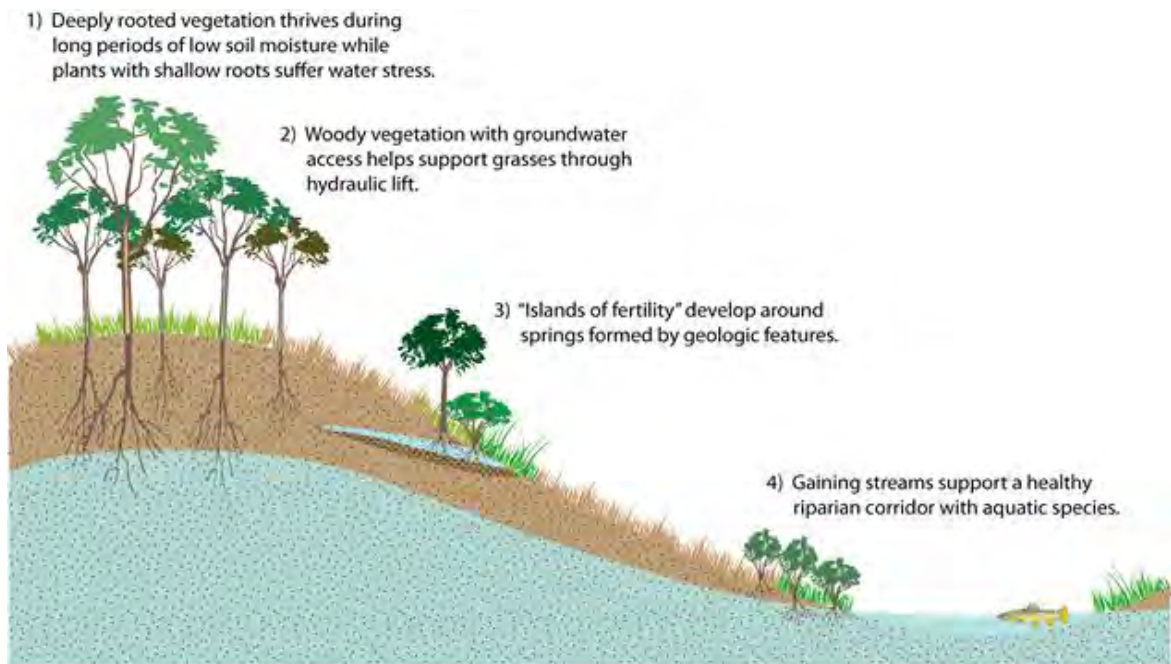


Figure 2. Phreatophytic vegetation services.

<http://www.geography.hunter.cuny.edu/~tbw/wc.notes/15.climates.veg/veg.images/desert/phreatophytes.diagram.png> Accessed 2/5/2015.

Once introduced, non-natives can become naturalized and can outcompete native species and are hard to control due to predator release. A high profile example is the Zebra mussels in the Great Lakes or North America, an invasive species which has been highly publicized about and studied. However, most people calling the Mojave Desert home are ignorant that the High Desert's Mojave River is experiencing comparable impacts from invasive plants. In addition to the usual invasive plant consequences, these species compete with native species for essential groundwater, they may increase soil and water salinity (an impact associated with Salt Cedar and its habit of dropping salt saturated foliage), they increase sedimentation rates within the river channel, leading to an increase in the potential destructiveness of floods, and they greatly increase the probability of wildland fire due to their dense growth habit and subsequent rapid biomass accumulation.

Local government institutions are active in management and restoring lost and compromised ecosystem services. As their primary public mission, the Mojave Water Agency (MWA) is addressing the monitoring and management of our watershed's groundwater. The Mojave Desert Resource Conservation District (MDRCD) is seeing to the removal of non-natives and has focused treatment on the three most serious species, mentioned above. However, prior to this restoration project there has been no effort for active ecological restoration and no interventions to facilitate the reestablishment native plants in areas that have been cleared of non-native invasive species.

The removal of non-native invasive vegetation (Tamarisk or Salt Cedar (*Tamarix ramosissima*), Russian Olive (*Elaeagnus angustifolia*), and Giant Reed (*Arundo donax*)) is well underway. As a first step, from 2003 through 2013 the MWA has funded the

MDRCD to remove the three invasive species within the Mojave River's floodplain from the Forks Dam, near the River's confluence with Deep Creek to just south of Silver Lakes. Subsequent surveys to identify and remove regrowth is a good and necessary second step, a process is also being supervised by the MDRCD. Accessible riparian sites that can support small mixed-species "islands" of transplanted and seeded native and local plants have also been identified in the early stages of the program.

The *High Desert Tall Pot & Mojave River Native Plant Rehabilitation Project* (HDTP & MRNPRP) is located near Victorville and aims to restore the structure and function of parts of the riparian ecosystem after the removal of non-native invasive species by local authorities, and to replace them with phreatophytic native vegetation transplanted from HDTP & MRNPRP project nurseries. The main component of this project, and Stage three of the greater restoration project, therefore, is to grow appropriate native plant species to out-plant to areas where invasive species have successfully been removed (see the Appendix for list of native plant species used in the project).

The primary native plants nursery is located on the Mojave River Campus (MRC) of the Academy for Academic Excellence (a K-12 public charter school under the oversight of the Lewis Center for Educational Research), approximately two river miles south (up-stream) from the Victorville/Lower Narrows Gaging Station above the Upper Mojave River Narrows between Apple Valley and Victorville (see Figure 1). Critical to this strategy is the school's Honors Environmental Science and Mojave River Conservationist class and its instructor, senior author Matthew Huffine. This will also provide opportunity for significant education and citizen science components to the project. Funding has been provided by the MWA and a one-time grant from Southern California Edison. Plants raised at the Mojave River Campus (MRC) Tall Pot Nursery will be out-planted at various pre-identified locations along the Mojave River.

Goals of Stage Three of HDTP & MRNPRP

The *first* goal of the project is to identify accessible sites along the river that can support small mixed-species "islands" (*sensu* Holl *et al.* 2011) of transplanted and seeded native plants specifically selected for the region. This was completed during the 2013-2014 school year by Ethan Sockwell, a Lewis Center Alumni and Graduate student at the University of Redlands. Later, selected riparian sites and "islands" will be prepared and planting and seeding will proceed.

The *second* goal is to create a site on the Mojave River Campus where these native species can be propagated using various sustainably innovative processes and tall pots that will allow the roots of selected native plants to grow longer roots which they will need after being transplanted to aide in the acquisition of surface soil moisture and groundwater. This was partially completed during the 2013-2014 school year. Lewis Center students have prepared the Nursery site, however, the tall pot growing area still needs to be established and is currently in progress during this 2014-2015 period.

Vetiver grass is being utilized as the nursery site is being established and developed. 120 slips of Vetiver grass were planted out in rows to stabilize a highly erodible slope adjacent to the nursery and irrigated by a drip system until well established. Part of this strategy is to determine whether Vetiver grass can grow and thrive in the High Desert, which will probably depend upon whether it can survive through winters. If successful, some Vetiver grass in this area will be carefully harvested as stock for goal three activities.

The *third* goal is to prepare the selected Mojave River sites and to plant and seed them with specifically selected species to form “islands” of vegetation. This will involve planting Vetiver grass slips in the form of protective ‘chevrons’ as part of a vegetative ‘guild’⁵ approach when establishing “islands” of native vegetation along the Mojave River. In this, Vetiver may have two uses. If the deep root structure of Vetiver grass allows it to utilize riparian-maintained groundwater, then native phreatophytes should also be able to survive in the site. Secondly, it is expected that Vetiver grass chevrons will nurture an immediate microhabitat favoring increased runoff and nutrient capture resulting in higher levels of moisture and nutrients in the soil and will facilitate the quicker establishment of a beneficial soil microbiota.

This period will demand intensive monitoring and management, particularly during the establishment phase, estimated to be six to nine months. Irrigation of the Vetiver grass and native seedlings” using ‘DriWater’⁶ will be important for the first six weeks or so. Since the overall strategy of the restoration project is to implement an Applied Nucleation regime (Corbin & Holl 2012; Holl *et al.* 2011), where initial clumped or ‘nucleated’ plantings are the catalyst for ongoing low-intervention restoration, monitoring will also focus on the time for native seedlings themselves to become important sources of seed for subsequent native plant recruitment up and down the river.

The *fourth goal* is to provide opportunities for and encourage “Citizen Science” participation, that is, to garner the support of the general public and/or specific resource conservation groups by allowing them to “adopt” a future *island* site, help prepare it, plant it and monitor it until the island’s vegetation is established. With local support, it is hoped that the ongoing efforts of this project will be able to assist the ecosystems along the Mojave River ‘renature’⁷ them back to a more natural state, thus getting the community involved in their natural surroundings as well as putting the eco-system back to rights.

⁵ The horticultural techniques used by permaculturists rely heavily on plant combinations. A guild is a harmonious assembly of plants (but it could be plants and animals) the essential characteristic being a diverse mixture (polyculture) whose elements all have a purpose. The plants are chosen to be beneficial to each other, and so it is similar to companion planting. http://www.self-willed-land.org.uk/permaculture/plant_guilds.htm

⁶ <http://driwater.com/professionals/>

⁷ Renaturing or reestablishing running water bodies means to restore the ecological system consisting of source-brook-river-riverbed-floodplain-groundwater and to remove transverse and longitudinal structures. At the same time, water retention is improved which also serves the targets of flood prevention. <http://greenallianceblog.org.uk/2013/12/17/dont-call-it-rewilding-renaturing-is-how-to-help-wildlife-survive/>

“Citizen Science” integrates public outreach, ecological restoration and scientific data collection (Cooper *et. al.* 2007). Involving citizen participants and specific resource conservation non-government organizations directly in creating, monitoring and management of specific “island” sites can foster a sense of ownership and pride, contributing to the social sustainability of the restoration project. Thus, increased involvement from the local community may allow the project to upscale to include larger areas of the Mojave River system with the eventual goal of renaturing the river, i.e., nurturing it back to a more natural state, restoring lost ecosystem services and as well as encouraging a healthier relationship between community and nature.

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Preliminary Results

Project managers began to integrate Vetiver grass into the project in March 2014 after consultation with David Price and after being convinced of its possible utility and non-invasive nature. At that time a small shipment of >130 slips from [Alberto Rodriguez](#) of *Agriflora* was received and two areas were planted for winter trials with drip irrigation being provided initially (@ 1 min. using 3 GPH emitters) from a 35 m (110 foot) long, ½ inch black above-ground polytube line (Figure 3).



Figure 3. Vetiver plants at the nursery site.

In February, after the harshest winter weather was past, with lows of -6°C recorded, grass tops were almost entirely brown though there were still some green shoots just above the unharmed crown. By early February the clumps had increased in diameter from between 35 mm (~ 1.5 inch) on average to between 75 and 150 mm (3 to 6 inches) and foliage had attained an average height of over 75 cm (30 inches). As previously stated, soil temperatures are an important factor determining whether Vetiver will survive overwintering or not. The recorded low for soil temperature for the local station is 7.5°C (45.5°F), well above freezing (Figure 4).

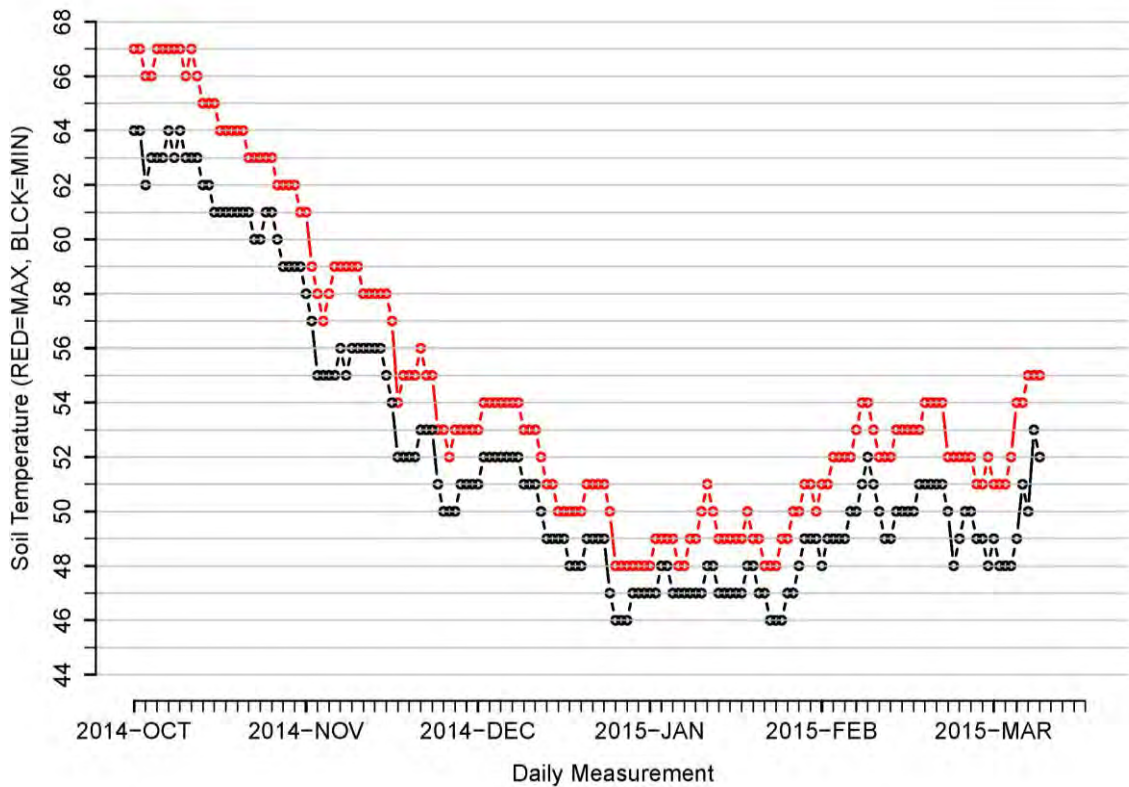


Figure 4. Soil temperatures recorded from Victorville station, downloaded from <http://www.ipm.ucdavis.edu/calludt.cgi/WXPCLISTSTNS?MAP=&COUNTY=&ACTIVE=1&NETWORK=&PATH=STNNAME&STN=Victorville>.

At the MRC Nursery site Vetiver plants also received daylight passive solar heating or reflection from the side of an adjacent 15 m (50 feet) tall neutral-colored west-facing stucco wall of a school building. This creates a stifling summer heat but since the site is located at the bottom of a flood plain, it acts as a cold air sink in the winter months, dropping the air temperature lows $9\text{--}12^{\circ}\text{C}$ ($10\text{--}15^{\circ}\text{F}$) below that of the surrounding higher ground. This microclimate effect shortens the growing season for most plants in this area to less than 7 months.

A few slips were also planted in Matthew Huffine’s garden to determine their survival rate in the expected $43\text{--}^{\circ}\text{C}$ ($110\text{--}^{\circ}\text{F}$) summer heat and -4°C (25°F) winter temperature. This site is about 760 m (2,500 feet) in elevation. The growing season is longer here than at the MRC Nursery with temperature generally not as extreme as at the school. The Vetiver

slips at this sight produced foliage that measured around 165 cm (5 ½ feet), with each slip producing a clump that averaged 15-20 cm (6 to 8 inches) in diameter from their 35 mm diameter beginnings.



Figure 5. Home site plantings after winter.

Several potential problem areas have been identified. The area, like almost every other place on earth, experiences extreme years at both end of the temperature scale. A rare, particularly cold winter could kill existing Vetiver installations. Some nursery Vetiver plants could be maintained in temperature-protected conditions as a contingency against this.

Second, Vetiver certainly requires significant irrigation during the establishment phase of the plantings. Rainfall in the area is extremely low, water is a highly valued, “precious” resource, and is likely to become even moreso with California’s present extreme drought and through climate change impacts. Last year the immediate area received only 47.18 mm of rainfall (Figure 6).

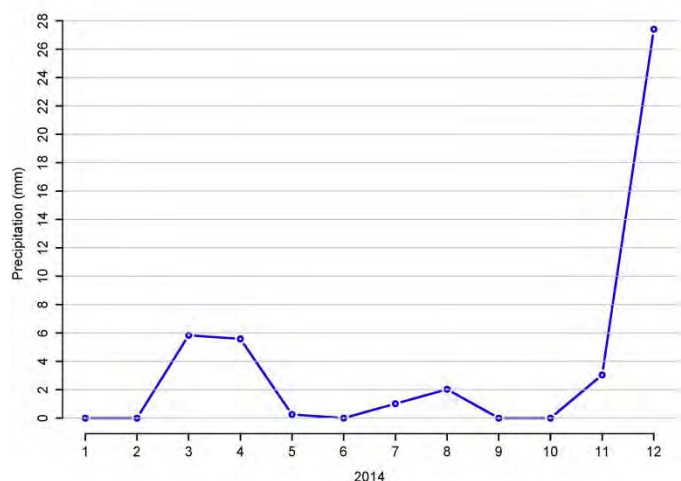


Figure 6. Rainfall records for Victorville station for 2014, downloaded from <http://www.ipm.ucdavis.edu/calludt.cgi/WXPLISTSTNS?MAP=&COUNTY=&ACTIVE=1&NETWORK=&PATH=STNNAME&STN=Victorville>.

Finally, there is the question of social acceptance of yet another introduced, or alien, plant, especially in a context where such are viewed with extreme distrust due to the invisibility issue. This is entirely justifiable since globally, as well as in the United States, invasive, introduced organisms exact a massive toll economically, environmentally and in human health impacts. In fact, the economic cost to the United States alone of invasive species is estimated to be in the order of \$1.2 billion annually (Pimental *et. al.* 2005). Though “Sunshine” *Vetiver zizanioides* has been “certified” as sterile and non-invasive by the USDA⁸, and so legal considerations may not be an issue, California has very active non-government environmental interest groups and lobbies, including such worthy organizations as CalIPC, the California Invasive Plants Council. Opposition from such groups, even though not fact-based, could eliminate Vetiver as a useful tool in the project. Having project managers and participants educated about this issue and concerning Vetiver’s sterility and non-invasive nature may be an answer to this.

Conclusions

Based on the survival of Vetiver grass in the trial plots during winter we are optimistic that Vetiver will contribute many benefits to the overall restoration project. The next priority is to propagate Vetiver to ensure enough slips will be available when the native seedlings are ready for outplanting.

The potential for community involvement with such a project is just being tapped with students and we anticipate many opportunities for wider citizen participation in implementation of the restoration project as well as monitoring. Actively involved community members could also become advocates to answer invasive species control groups in properly informed or educated.

Cautiously, we recommend that Vetiver grass be considered for use in other restoration projects in California where appropriate and where winter temperatures are similar or warmer.

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⁸ http://www.vetiver.com/USA-USDA-NRCS_Sunshine.pdf

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Appendix—List of native plants for revegetation

TALL POT ISLAND DEMONSTRATIONS -- LCER							
		PRIMARY (INITIAL) SHRUB LAYER		SECONDARY UNDERSTORY FORB/SHRUB LAYER		TERTIARY OVERSTORY TREE LAYER	
		COOL-SEASON	WARM-SEASON	COOL-SEASON	WARM-SEASON	COOL-SEASON	WARM-SEASON
Fall Planting		Fourwing saltbush	Quailbush Bladderpod Creosotebush	Indian ricegrass Desert needlegrass Brittlebush	Alkali sacaton ¹ Big galletagrass Desert broom	Fremont cottonwood Goodding's willow Black willow	Honey mesquite
	Late Winter / Early Spring Planting (recommended)	Desert saltbush	Screwbean mesquite	Evening primrose Anderson wolfberry Desert globemallow Mojave buckwheat		Desert willow Arizona ash	Blue palo verde

² finer soil textures only.

SUGGESTED PLANT PALETTE (ALPHA BY SCIENTIFIC NAME)

- 1 Indian ricegrass (*Achnatherum hymenoides*)
- 2 Desert needlegrass (*Achnatherum speciosum*)
- 3 Fourwing saltbush (*Atriplex canescens*)
- 4 Desert saltbush (*Atriplex polycarpa*)
- 5 Quailbush (*Atriplex lentiformis*)
- 6 Desert broom (*Baccharis sarothroides*)
- 7 Desert willow (*Chilopsis linearis*)
- 8 Bladderpod (*Cleome isomeres*)
- 9 Brittlebush (*Encelia farinosa*)
- 10 Mojave buckwheat (*Eriogonum fasciculatum*)
- 11 Arizona ash (*Fraxinus velutina*)
- 12 Creosotebush (*Larrea tridentata*)
- 13 Anderson wolfberry (*Lycium andersonii*)
- 14 Evening primrose (*Oenothera deltoides*)
- 15 Blue palo verde (*Parkinsonia florida*)
- 16 Big galletagrass (*Pleuraphis wrightii*)
- 17 Fremont cottonwood (*Populus fremontii*)
- 18 Honey mesquite (*Prosopis glandulosa*)
- 19 Screwbean mesquite (*Prosopis pubescens*)
- 20 Goodding's willow (*Salix gooddingii*)
- 21 Black willow (*Salix nigra*)
- 22 Desert globemallow (*Sphaeralcea ambigua*)
- 23 Alkali sacaton (*Sporobolus airoides*)