Putting Down Roots

Photo credits: Jim Hanson

Regenerating Disturbed Soils to Sustain Vegetation

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Soils disturbed by construction or other heavy disturbance can be changed dramatically. Erosion resistance and desirable vegetative cover must be regenerated at the project's end. However, the functioning soil system needed to attain these objectives is usually lost following excavation and removal, or is altered by compaction or burial of preexisting project-site soils. Research into California's resilient native soils and plant communities suggests that appropriate treatments can return disturbed substrates into functioning soils that infiltrate stormwater, resist erosion, and sustain desirable vegetation cover without ongoing supplemental irrigation.

Shoreline native grass and coastal shrubs along roadside at San Francisco Bay. Grasses were seeded after roadside construction, but first the soil was treated to increase rooting depth and provide a minimal amount of organics.

Because native grass and other native plant species have adapted to survive in extreme conditions—from mudflats to mountaintops—native plants may appear to be ideally suited to provide cover on highly disturbed and degraded soils. Yet, the self-sufficiency of these plants is not solely due to inherent plant characteristics, but comes in large part from the ability of native plants to partner with natural soil system processes that start at the surface and extend deep into the earth.

A series of UC Davis Soil and Revegetation Lab research projects, highlighted below, evaluates how robust and regionally appropriate native plant communities are supported by the natural soils on which they grow. The premise of this research is that these plants are sustained by basic, essential soil processes, including soil–water relations, nutrient cycling, and soil biology. If these same processes could be regenerated on a disturbed, barren, erosive substrate, then, logically, a regionally appropriate plant community could also be regenerated.

Although some lab-based tests conducted for the research evaluated individual plant–soil interactions, most of the research tests of soil resource treatments took place on actual disturbed construction sites. The field trials have been installed on sloped sites in Contra Costa, Lake, Mendocino, Mono, Placer, San Diego, Shasta, and Sutter Counties. Commonly available construction equipment and materials were used. In all cases, plants grew to mature size without irrigation.

Soils are complex systems. However, a functioning soil must, at minimum, be able to infiltrate rainwater, store it, allow deep rooting, cycle nutrients, and support microbial activity to allow for sustained plant growth (Singer and Munns 2006). An understanding of these basic soil resources and processes was synthesized into a five-step "Soil Resource Evaluation System" to help guide when and how to treat harsh, drastically disturbed sites (as well as how to know when conditions are adequate and treatment is *not* required) (UC Davis 2008). Field trials using the general strategy outlined below resulted in

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successful revegetation and erosion resistance on a variety of barren, erosive problem slopes in California. Although observations are drawn from highly sloped field trials, the intent here is to evaluate the potential benefits of restoring basic soil processes on common disturbed, degraded soil situations with grades of less than 3:1 (h:v).

Step 1. Identifying the Reference Site: A Functioning Soil–Plant System

A reference site is an indispensable tool to indicate what will grow on a drastically disturbed landscape. It is important to locate reference site examples, walk them, and document how their characteristics relate to the revegetation project plan.

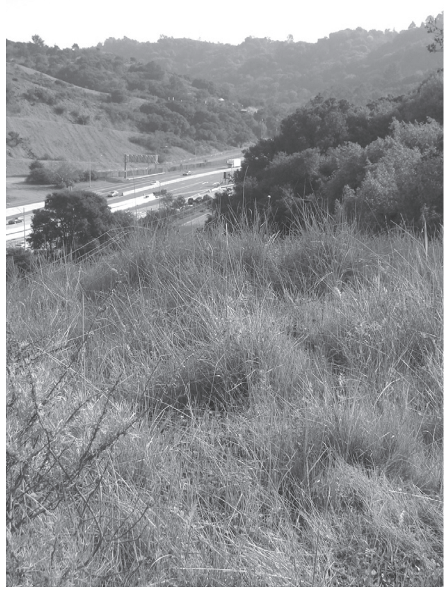
The reference site does not have to represent a fully diverse, undisturbed, intact plant community from a botanical reserve or state park. In fact, the site is especially useful if the area had been previously denuded and had reestablished on its own with native species. This "disturbed-but-revegetated" condition keeps one from trying to copy and re-create a natural soil that may have been centuries in the making.

Although it is possible to build up a harsh, barren site into one of a range of revegetated community types, it is best to take an example of existing, acceptable vegetative types and investigate the soil resources that are needed to support them. Identifying this reference plant community guides expectations to what might be sustainable under regional site conditions because the reference site has, evidently, persisted through a range of good and bad growth seasons.

The practical, empirical example of a working soil–plant system is an invaluable guide for identifying needed soil treatments. Look for a reference site with an acceptable vegetative cover and similar aspect, gradient, and geology to the project site. Then look for signs of successful erosion resistance, such as an accumulated duff layer and evidence of soil regeneration of the upper soil (or "A") horizon. A dark upper layer can be an indicator of soil organic development. Sites that are "bleeding" from erosion will show a bare mineral surface, gullies, or sediment fans. Also, contrast the texture between the two sites (e.g., sandy loam, heavy clay, gravels). Soil texture can be evaluated visually, and by learning to manually "feel" the clay or sand content of different soils.

If the reference site is an acceptable example, start looking for soil characteristics that need to be regenerated on the impacted site, including rooting depth and compaction. If access to a nuclear gauge compaction test, such as engineers would use, is lacking, compaction can be roughly assessed by simply noting the level of resistance on the reference and disturbed sites when swinging a pointed pick into the ground. Soil structure and rooting depth may be difficult to determine without digging a soil pit, but the soil profile can sometimes be observed in nearby excavations or road cuts.

The reference site findings are then compared to soil characteristics on the degraded project site to identify any of the basic soil deficiencies, discussed below, that need to be corrected.



Potential reference site: purple needlegrass (*Nassella pulchra*), coastal sage (*Artemisia californica*), and coast live oak (*Quercus agrifolia*) on a north slope bench cut, Highway 24 near Orinda in Contra Costa County.

Step 2a. Regenerating Site and Soil Hydrology: Soil Water Infiltration and Retention

Natural plant–soil systems infiltrate winter storms and hold moisture that sustains vegetation over the summer. For disturbed soils, the first step to regenerating soil hydrologic processes is to keep exposed soils protected and stabilized while replacement vegetation cover gets established. Surface erosion control measures are typically applied at the completion of construction and development work on disturbed, exposed soils to protect the soil surface particles from dislodging from winter rain impact. Coupling surface erosion-control measures with site-appropriate treatments to restore infiltration, as reviewed below, significantly increases the ability of the site to manage winter storm inputs. This infiltrated soil water also plays a critical role in establishing and sustaining vegetation by providing moisture during the dry summer season.

From short-term erosion control to long-term erosion resistance

Site construction changes the pre-existing site topography. Cutting portions of existing slopes steepens them and removes part of the lower slope. The resulting steeper slope is exposed to the erosive potential of the same flow from above and rainfall on the bare surface. Therefore, the first concern of disturbed site regeneration is diverting "run-on" stormwater from above, away from the exposed, steepened slope. This is typically accomplished by routing the "run-on" through or around the project site in hardened/strengthened flow paths built as coir-lined swales or rock or concrete ditches.

The second concern is protecting any exposed, bare soils from raindrop impact. The most common approach to erosion control is to apply a surface protective layer—compost, seeded grasses, and

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most common approach to erosion control is to apply a surface protective layer—compost, seed, and protective mulch—to the bare soil surfaces. This is usually achieved with seeded and planted vegetation and by moderating surface water flows with straw, wattles, check dams, mulches, and organic blankets. California native grasses and forbs are often used with hydromulching applications because they are adapted to the state's climates and soils and will, if the right conditions are provided, root deeply into the soil profile. Native grasses and forbs also offer social and environmental benefits of habitat, aesthetics, and sequestration of carbon. Container native shrub and tree species may be planted concurrently or later.

On many sites, however, this surface erosion control is not adequate to prevent erosion. Most rains provide enough water volume to more than saturate this hydromulch layer. After the hydromulch layer is saturated, additional rain must either infiltrate into the soil or be shed downslope. A compacted substrate reduces infiltration, generating excess overland flow that gains momentum and mobilizes sediment.

Restoring soil infiltration capacity can begin to take the site beyond short-term control to long-term erosion resistance. Many compacted soils can be treated so that stormwater infiltration into a slope is increased, resulting in no overland flow at all. The objective is to regenerate an infiltration rate in the soil that meets or exceeds the rate of precipitation. Incorporating 1–2 inches of wood chips or shreds into the top 200–250 mm (8–10 in.) of a compacted soil allows many short storm pulses to be retained in the soil horizon. On the test sites, a toothed scarifier (such as a backhoe bucket or short teeth on a toolbar) was used to coarsely mix soils and amendments. After the soils are amended and treated, the soil surface should be covered with another inch of chips, needles, or straw to keep raindrops from splattering the soil surface and forming a surface seal, or crust. These infiltration improvements and surface covers can solve most short storm erosion results, especially if the site is not steep.

Protection through the winter season

Containing larger volumes of stormwater from multiday storm events and accumulation of water late in winter is an additional challenge. Most natural soils are not harmed by this additional water because such soils have developed deep fractures and root channels that allow for deep infiltration. In natural soils, rates of infiltration are slower than at the soil surface, but they are steady enough to drain the soil in time for the next rain event.

The depth of a soil needed to avoid accumulation of water at the surface—and therefore avoid potential runoff—varies, but will be from 2 to 4 feet deep in many areas of California. This depth depends on underlying rock content, texture, water content, and soil structure, as well as the site location and rainfall patterns. Because these variables can be modeled using soil hydrologic modeling software, a set of maps could be developed to estimate general design guidelines for soil treatment depths on various soil types and locations in the state.

Restoring infiltration to a slope may seem counterintuitive, and is not appropriate in all situations, because water has weight, lubrication, and pore pressure qualities. At the same time, the deeper the soil, the greater the level of storm intensity that can be retained without developing saturation and positive pore pressure to form at depth and potentially causing shallow slips. On the test sites, the regeneration of soil–water infiltration capacity was designed to improve surface geotechnical stability in combination with geotechnical and surface erosion control measures. The greater soil capacity holds water with less overland flow, but whenever disturbed soils are at earth surface positions where they may become saturated, they must rest on a horizontal bench to avoid lateral slippage.

On the 2:1 horizontal:vertical (h:v) tests to repair slopes at Lake County, Los Angeles County, and the Sierra foothills, the

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After the farm tour, CNGA's President Wade Belew gave a presentation describing the invaded state of California's grasslands, the high level of grassland species diversity, and the importance of restoring and managing our grasslands.

John Anderson ended the visit with a bit of his own grassland philosophy, urging the Delegation to embrace the use of native species in China, so they do not repeat mistakes that were made in the Western United States with the introduction of non-native species that resulted in species composition change and degradation of rangeland biodiversity.

To learn more about the Delegation and carbon sequestration research in California, go to:

- HTTP://WWW.MARINIJ.COM/MARINNEWS/CI_14517322 "Study in West Marin fights global warming," *Marin Independent Journal,* March 4, 2010;
- WWW.KWMR.ORG/NEWS "West Marin Report." See Monday and Tuesday March 8 and 9 (click the "Listen" Link next to the dates to hear the story.)

John Anderson (right) explains the use of native plantings in weed control while the Delegation was out touring Hedgerow Farms.

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and replacement; back-filled benches; or by hydraulic hammering. Disturbed soils on slopes steeper than approximately 3:1 (h:v) are usually rested on horizontal benches. Claypans, hard sedimentary strata, or volcanic lahar flow substrates are examples of impermeable substrates. Many Coast Range sites will already have natural fractures in the rock that take care of this function, thus it is often not necessary to excavate deeply—just open up the surface a foot or so.

The treatments needed to achieve deep infiltration also provide deep rooting and moisture access. Field plots around the state have shown that plants can be successfully grown only from moisture stored in the soil (Caltrans 2008b). This summer water availability generates increased plant growth, which also creates greater root strength and deeper root anchoring. The increased plant growth and organic matter production, in turn, increases infiltration and increases mulch cover. Such well-vegetated soils saturate less often and become increasingly erosion resistant with time.

Step 3. Regenerating Soil Nutrient Cycling

Soil nutrients on degraded sites are often out of balance, having too low a proportion of slowly available nitrogen (N) and too high a proportion of easily available N. High rates of available N encourage weed growth and can potentially leach to local watercourses. Thus, highly available N should be kept low enough that the native plantings are not overgrown by weeds.

Because N is cycled in and out of organic matter rather than extracted from local geological materials, organic amendments are a good way to address this concern. Yard waste composts are commonly applied to revegetation sites, and they tend to work well because they have a large amount of organically bound N that is only slowly available for release.

The N needs of various types of field sites can be addressed by adding compost products of different ages. A 1- to 2-inch layer of yard waste compost, tilled into the soil, will regenerate much of the nutrient reserves for low nutrient sites. Well-cured composts release their N faster than composts that are mature (thermophilic stage complete) but uncured. The latter hold their remaining organic N in reserve, slowly releasing it over multiple years. For sites where composts are impractical to deliver or apply, blends of wood shreds and commercial organic soil amendments can be selected that provide many of the same nutrient levels.

But, not all sites need nutrient amendment. Sites adjacent to roadways often do not need additional N inputs to support native plant stands because of high levels of N aerially deposited from automobile exhaust. Sites containing residual soil materials that tend to be darker, more friable, and have higher organic content also do not need N input.

Phosphorus, potassium, sulfur, calcium, magnesium, and micronutrients tend to remain in the soil until withdrawn by a root; therefore, chemical-based fertilizers can supply these nutrients if these needs are not met by the compost amendment.

The above-mentioned soil organic amendments and treatments work synergistically. Excavation, ripping, or fracturing to incorporate organics also appear to hold the soils open so storm water can infiltrate. The increased infiltration reduces runoff and stores water for summer plant use. Eventually, the developing soil–plant system takes over the functions of rainwater infiltration and storage, nutrient cycling, and soil biological processes. Within 5 to 10 years, natural soil aggregation gradually replaces the pores held open by the incorporated organics.

Ripping of severly compacted soils on contour for seeding purple needlegrass (*Nassella pulchra*) following construction. "Compost overs" were incorporated prior to seeding.

Step 4. Root and Microbial Biology: A Brief Note on Restrictions

Regenerated soil conditions allow a site to support a wide variety of native species. But, some natural soil conditions are still restrictive to all but a few uniquely adapted plant or microbial types. Some care should be given for special site conditions, such as serpentinite-derived soils, ultramafic substrates, acid or salty areas, or areas of excessive calcium. Commonly, several types of plants (and probably microbes) have adapted to each of these extreme substrate types, but the more extreme the substrate, the more likely it is that locally collected materials or known tolerant accessions should be used. Make friends with a good botanist and pay attention to plants already growing on similar, disturbed-but-revegetated reference sites.

Step 5. Monitoring and Maintenance Treatment Options

The first year of native plant establishment is critical to get right, although even relatively scattered individual plants can expand and fill the ecological space after several years if weed growth is actively controlled. Because access is often limited after a site has established, treatment options are often fewer and involve less intense methods (mainly, there is less opportunity for increasing infiltration and rooting with mechanical tillage). However, most plant growth problems (other than soil hydrology) can be corrected with relatively low-intensity treatments, such as nutrient amendments or surface water

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routing. With adequate site hydrologic treatment, good stand establishment, and active weed control during the first few years, maintenance activities will be vastly reduced. As field successes occur, these demonstrated examples should be communicated with other revegetation workers and entered into easily accessible records.

Conclusion

Although specific prescriptions await further modeling and testing to fit California's widely diverse soil, climate, and geographical conditions, we know that, in general, these critical soil processes can be restored to soils that have been dispersed, stripped, or compacted through disturbance. When soils are adequately regenerated, plant growth can be vigorous, even on previously harsh sites.

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Regionally suited native grasses fill in San Francisco shoreline soils treated for rooting depth and with a few inches of organics prior to seeding. Shown are *Festuca rubra* 'Molate Point,' *Hordeum brachyanterum, Elymus glaucus, Nassella pulchra*, and a small amount of *Bromus carinatus.*

(Left) Weedy, shallow-rooted *Vulpia myuros* (rattail fescue), from the compacted road edge areas remaining after construction. (Right) Native *Hordeum branchyantherum* grass from the shoreline site shown in the adjacent photo. The native perennial's roots appear to be helping to reaggregate the soils.