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Stabilization of Coastal Dunes with Vegetation

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Introduction

Coastal sand dunes are beautiful land features, but their beauty is often overlooked by coastal property owners whose homes and land are buried by them. From the coasts of the Pacific and Atlantic Ocean, to the coasts of the Gulf of Mexico and the Great Lakes, 90,000 acres of migrating sand dunes are a problem (Brown, 1948). Because of the full exposure to almost constant wind from the ocean, a slight disturbance of the vegetative cover may result in extensive "blow outs" of the unconsolidated soil (Oosting, 1942). Through this process dune fields are formed, engulfing everything in their paths. Migration of sand dunes also occurs when the vegetation on stabilized dunes is seriously damaged or destroyed. Extensive areas of migrating coastal dunes have developed along the Pacific and Atlantic coasts, as well as the gulf coasts and coasts of the Great Lakes. Many of these migrating dunes were formed due to disturbances from fire, logging, grazing, and foot and vehicular traffic (Oosting, 1942). These migrating dunes were a concern of the colonists at Cape Cod as early as 1714 (Woodhouse, 1978).

Formation

Coastal sand dunes are typically formed through the trapping of sand by dune vegetation. The type of vegetation that grows on dunes has special adaptation characteristics that allow the vegetation to establish, grow, and trap sand in the harsh conditions of coastal areas. In the absence of such vegetation, the wind can act on the exposed sand, forming migrating dunes that move back and forth with the wind (Chapman, 1976). The vegetation of coastal dunes usually becomes established when seeds or plants are trapped along shorelines during very high tides (Chapman, 1976). Trapping of seeds or plants is the first step in the sequence of events and circumstances necessary for the development of coastal dune vegetation. The next crucial factor in the process is that the seeds or plants must be suitable for establishment in the area. The establishment of suitable seeds or plants must then be followed by one or two years of favorable growing conditions. However, on most sites the complete sequence does not occur. The early phases occur frequently on many sites, but the embryo dunes are usually destroyed by storm activity before sufficient establishment occurs (Woodhouse, 1978). Consequently, the sequence of events can be bolstered if the area can be stabilized for a long enough period of time with different stabilization techniques.

Restoration Techniques

There are a few different techniques that can be used in the restoration of damaged or incomplete dunes. One technique is to mechanically move sand into place and then to grade it into suitable form (Wilcock, 1977). Mechanically grading sand dunes is a favorable technique because the time requirement is reasonable and the site can be manipulated to the perfect slope and length, which allows vegetation to become established more easily than on very steep, natural slopes (Wilcock, 1977). However, unless the site is well-vegetated, the dune will not last against wind erosion and storm tides. One study done on a coastal dune in Northern Ireland suggested that a smooth dune profile is essential for a stable dune, steep slopes cannot be stabilized through planting alone, and conventional techniques of stabilization were unlikely to be successful within a reasonable time period (Wilcock, 1977). This particular study favored the use of mechanical grading of dune sites as the best stabilization technique.

Another technique is to trap the blowing sand with the use of sand fences. Sand fences slow sand movement by reducing the wind velocity in their immediate vicinity. While sand fences are very effective in trapping windblown sand, once they are filled they have little or no further effect on sand movement (Woodhouse, 1978). However, the advantage of sand fences is that they can be installed during any season and they are fully effective as sand traps as soon as they are installed (Woodhouse, 1978).

Mats and netting are also a useful technique for protecting bare sand surfaces. Coarse netting and mats are useful in protecting dunes while transplanted dune grasses are establishing (Dahl, 1975). This technique does protect the sand surface but does not collect much sand, so the best use of netting and mats is to protect new seedlings (Woodhouse, 1978). But using this technique as a method of protecting new seedlings requires careful protection of edges to prevent the mats or netting from being blown away (Woodhouse, 1978).

Brush is another effective but temporary stabilizer of dune sites when placed over bare sand (Woodhouse, 1978). This method is not commonly used though, since it has high labor requirements and it interferes with subsequent planting (Woodhouse, 1978). Use of this method should be limited to small blowout areas.

The most effective method of stabilizing coastal dunes is through the use of vegetation (Woodhouse, 1978). In many cases, vegetation is the least expensive, most durable, most aesthetically pleasing, and only self-repairing technique available (Woodhouse, 1978). Dune plants are especially effective at stopping and holding wind-borne sand. Their growth produces surface roughness which decreases the wind velocity near the ground, reducing wind erosion at the sand surface. Also, the plant stems and leaves above the sand surface greatly interfere with sand movement by saltation and surface creep (Woodhouse, 1978). As the grass fills and becomes buried, sand spills farther and farther into the interior of the stand of dune grass. A cover of dune plants tends to regenerate trapping capacity by growth even as it fills because the plants are stimulated to grow by the deposition of sand around them.

Vegetation

The coastal environment is typically harsh for plant growth: for plants to be successfully established they must have special adaptation characteristics that allow them to survive such a harsh environment. These plants must be able to tolerate rapid sand accumulation, flooding, salt spray, sandblast, wind and water erosion, wide temperature fluctuations, drought, and low nutrient levels. In spite of the severe limits these requirements place on the plant species, plants capable of stabilizing coastal dunes can be established in most coastal regions with enough rainfall to support plant growth (Woodhouse, 1978).

Degraded or incomplete coastal dunes in the United States are usually stabilized by planting with a small group of pioneer plants, perennial dune grasses (Woodhouse, 1978). The major grasses include: American beachgrass (*Ammophila breviligulata*) along the North Pacific, North Atlantic, and Great Lakes coasts; European beachgrass (*Ammophila arenaria*) along the North and South Pacific coasts; bitter panicum (*Panicum amarum Ell*.) along the South Atlantic and gulf coasts; sea oats (*Uniola paniculata L*.) along the South Atlantic and gulf coasts; salt-meadow cordgrass (*Spartina patens*) along the South Atlantic and gulf coasts (Woodhouse, 1978).

The most common of the above mentioned grasses for dune stabilization are American beachgrass and European beachgrass. American beachgrass is a cool season dune grass native to North and mid-Atlantic and Great Lakes coasts, and probably the most widely used species for initial trapping of blowing sand in these areas (Seliskar, 1995). Some favorable characteristics of this grass are that it is easy to multiply vegetatively and readily available commercially (Woodhouse, 1978). Also, American beachgrass is easy to harvest, store, and transplant with a long transplanting season and a good survival rate (Woodhouse, 1978). This species also grows rapidly and becomes an effective sand trapper by the middle of the first growing season (Woodhouse, 1978).

European beachgrass is a species very similar to American beachgrass and was introduced in the late 1800's to the Pacific coast where it has become widely distributed by planting and natural spread (Zak, 1965). It is the primary grass used along the Pacific coast for the stabilization of large areas of blowing sand. European beachgrass is very easy to propagate and is available commercially (Woodhouse, 1978). This species is also easy to harvest, store, and transplant, but is less tolerant of high temperatures than American beachgrass is (Woodhouse, 1978). Long transplanting seasons with very high survival rates under appropriate conditions are also favorable characteristics of this species (Woodhouse, 1978). Although European beachgrass is an exotic, it does not become invasive on most sites. Because this species does not grow as vigorously, and does not persist as well as other native species of dune grasses, such as American beachgrass, there have not been any problems of invasiveness (Zak, 1962).

Both species of beachgrass, American and European, produce viable seeds and occasionally spread into dune areas by seeds, but direct seeding is not usually a sufficient way of establishing initial cover on coastal dunes. In bare sand, seeds will often become uncovered or buried too deep before they can germinate and the seedlings become established (Wilcock, 1977). Therefore, with few exceptions, planting of most coastal dunes is done vegetatively (Wilcock, 1977).

Sources of Dune Grasses

Adequate supplies of healthy planting stock are essential to any successful dune planting, and to get these plants is usually a major cost in planting projects. There are two primary sources of dune grasses: (1) nursery-grown plants, usually produced for the purpose of dune stabilization projects, and (2) plants obtained by thinning or cultivating established stands (Dahl, 1975).

American beachgrass is relatively easy to produce under nursery conditions (Seneca, 1968). American beachgrass can be multiplied either vegetatively or by seeds. The vegetative method is normally preferred since direct seeding is uneconomical due to unreliable seed supplies and difficulties in weed control in seedling stands (Woodhouse, 1978). European beachgrass is the easiest of all the dune grasses to propagate, and can be produced most efficiently in nurseries (Hawk, 1967). Consequently, much of the planting stock for large stabilization projects along the Pacific coast came from the established stands in the region that the plantings took place (Zak, 1965).

Factors of Growth

Even with a sufficient supply of planting stock for stabilization projects, the success of the project is still dependent on several other factors. For instance, sufficient soil moisture is an essential component for the establishment of dune grasses, and the low water holding capacity of sand can cause failure of plantings (Chapman, 1976). However, compensating factors in the dune system such as high water tables often make it possible to work around this problem. Also, dune plants have various specialized adaptations for surviving long periods of low moisture. For these reasons, irrigation of restored sites is not generally worthwhile (Woodhouse, 1978).

Another important factor that can greatly affect the establishment of dune grasses is salinity concentrations. Salinity is a potential inhibitor to dune grass growth along any coast since salt is deposited on dunes in substantial quantities by salt spray or by high tides (Oosting, 1942). Fortunately, the likelihood of salt damage to dune plants is greatly diminished by the rapid leaching of salts from the dune sands. These sands have almost no retentive capacity for salt and only a small amount of rainfall is needed to remove salt from the plant zone (Seneca, 1968). Also, all dune plants are tolerant of moderate salt concentrations and most seeds can withstand salinities as high as full strength sea water (Seneca, 1968).

Fertilization of dune sites can also influence the success of dune grass establishment. Dune sands undergo extensive leaching during accumulation, transport, and deposition of sand grains, leaving them very low in most nutrients essential to growth of plants (Chapman, 1976). While typical dune species are well-adapted to a low nutrient regime, most respond noticeable to nitrogen, phosphorous, and potassium (N-P-K) fertilizers (Brown, 1948). However, studies imply that the use of fertilizers in the dune system is not necessarily desirable, but that fertilization can be a useful management tool. Also, studies show that fertilization is useful for more definite and restricted purposes such as speeding up the establishment of new plantings, increasing growth and increasing sand-trapping capacity (Brown, 1948). Overall, the positive effects of fertilization on the sand dune vegetation improves the chances of survival. Since the initial establishment period is usually the most crucial for dune plantings, even moderate growth acceleration at this point may be the difference between success and failure. However, by the second year, invasion of weeds becomes a problem on fertilized sites (Brown, 1948). The use of perennial legumes, such as purple beachpea (*Lathyrus maitimus*), mixed with dune grass stands can also be effective in providing nutrients to the dune system, but may also result in growth of weeds (Brown, 1948). A study done on coastal dunes along the Pacific coast looked at the effects that mixing legumes in with dune grasses had on planting success. They found that mixtures of legumes and dune grass seedlings were more successful than if only the native grasses were planted (Brown, 1948).

Standards for Planting

Soil moisture, salinity, and fertilization will affect the success of dune grass establishment once the grass has been planted, but there are also certain standards that need to be followed when planting the vegetation. For most species of dunegrasses, planting is typically done by hand on small areas and on rough or steep slopes, and by machine on larger, flatter sites (Wilcock, 1977). The depth and date of planting vary between geographic regions and among species of dune grasses. In general, depth is typically 20 to 30 centimeters, and date of planting is dependent upon favorable soil moisture conditions (Hawk, 1967).

The spacing and pattern of planting is also important to consider. Spacing that is too close is more costly and wasteful, and spacing that is too wide will usually result in total failure (Woodhouse, 1978). The spacing and pattern should be determined by the conditions of the site and the objectives of the planting. In general, plants should be spaced about 18 inches apart, and in a strip pattern with 36 inches between rows (Zak, 1962).

Once stands are fully established, they will require protection from foot and vehicular traffic and any broken or damaged plants will need to be repaired quickly (Wilcock, 1977). Controlled burning may also be an advisable management tool to reduce the chance of wildfire and to control pests (Woodhouse, 1978).

Success of Past Restorations

The success of dune stabilization through the use of vegetation has been studied in depth. Whether revegetation, mechanically grading the sites, or using techniques such as sand fences, mats and netting, or brush to initially establish the stands, is the best technique has still to be decided upon by researchers. One revegetation study done at Padre Island, Texas showed that no one factor accounted for the successful establishment of sea oats, salt-meadow cordgrass, and bitter panicum. Either extreme drought or extreme salinity could cause failure (Dahl, 1975). Other variables such as soil and air temperature and carbohydrate storage did contribute to planting success or failure, but were never responsible for total stand failure. All species tested survived best when soil moisture and precipitation were high, and soil salinity and carbohydrate storage were low (Dahl, 1975). Another study done in Delaware along the Atlantic coast found that the success of American beachgrass plantings was much greater if nitrogen, phosphorous, or potassium fertilizers and limestone were applied to the sites. The application of macro-nutrients and limestone enabled the site to be planted successfully soon after the original plants of the sites had died (Seliskar, 1995). Without such soil amendments a dieout site cannot be successfully replanted for up to five years, leaving the dunes barren of stabilizing plants (Seliskar, 1995).

Conclusion

Although there are several techniques used to stabilize coastal sand dunes, revegetating the sites is probably the best alternative (Woodhouse, 1978). This method is the least expensive, most durable, most aesthetically pleasing, and only self-repairing technique available (Woodhouse, 1978). There are several species of plants to choose from for planting a coastal dune, but the objectives of the planting should be considered before deciding which species is best for the purpose. There are also many factors, such as soil moisture, salinity and nutrient status of the soil, that may determine whether or not the stabilization project will be a success. The success of the stabilization is also dependent on when and how the plants were introduced to the site (i.e. date of planting, spacing, method of planting, etc.).

Coastal sand dunes are complex systems, integrating a harsh environment that requires specialized plant communities. The fragile nature and erodibility of dunes makes their stabilization very difficult, thus management and monitoring programs are an essential part of success in reestablishing sand dune vegetation. Stabilization solutions must be compatible with these fragile ecosystems and efforts must be made to minimize any possible human or natural impacts that could cause the project to fail.

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