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RECLAIMING BARREN LANDS

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ABSTRACT: Land reclamation, usually known as reclamation, and also known as land fill (not to be confused with a waste landfill), is the process of creating new land from oceans, seas, riverbeds or lake beds. The land reclaimed is known as reclamation ground or land fill.

In some jurisdictions, including parts of the United States,^[1] the term "reclamation" can refer to returning disturbed lands to an improved state. In Alberta, Canada, for example, reclamation is defined by the provincial government as "The process of reconverting disturbed land to its former or other productive uses."^[2] In Oceania, it is frequently referred to as land rehabilitation.

KEYWORDS: reclamation, barren, lands, rehabilitation, government

I. INTRODUCTION

One of the earliest large-scale projects was the Beemster Polder in the Netherlands, realized in 1612 adding 70 square kilometres (27 sq mi) of land. In Hong Kong the Praya Reclamation Scheme added 20 to 24 hectares (50 to 60 acres) of land in 1890 during the second phase of construction. It was one of the most ambitious projects ever taken during the Colonial Hong Kong era.^[3] Some 20% of land in the Tokyo Bay area has been reclaimed,^[4] most notably Odaiba artificial island. Le Portier, Monaco and Gibraltar are also expanding due to land reclamation. The city of Rio de Janeiro was largely built on reclaimed land, as was Wellington, New Zealand.

Methods

Land reclamation can be achieved by a number of different methods. The simplest method involves filling the area with large amounts of heavy rock and/or cement, then filling with clay and dirt until the desired height is reached. The process is called "infilling"^[5] and the material used to fill the space is generally called "infill".^{[6][7]} Draining of submerged wetlands is often used to reclaim land for agricultural use. Deep cement mixing is used typically in situations in which the material displaced by either dredging or draining may be contaminated and hence needs to be contained. Land dredging is also another method of land reclamation. It is the removal of sediments and debris from the bottom of a body of water. It is commonly used for maintaining reclaimed land masses as sedimentation, a natural process, fills channels and harbors.^[8]

Agriculture



Land reclamation in progress in Bingzhou (丙州) Peninsula (formerly, island) of the Dongzui Bay (东咀港). Tong'an District, Xiamen, China

Agriculture was a driver of land reclamation before industrialisation.^[25] In South China, farmers reclaimed paddy fields by enclosing an area with a stone wall on the sea shore near a river mouth or river delta. The species of rice that are grown on these grounds are more salt tolerant. Another use of such enclosed land is the creation of fish ponds. It is commonly seen on the Pearl River Delta and Hong Kong. These reclaimed areas also attract species of migrating birds.

A related practice is the draining of swampy or seasonally submerged wetlands to convert them to farmland. While this does not create new land exactly, it allows commercially productive use of land that would otherwise be restricted to wildlife habitat. It is also an important method of mosquito control.

Even in the post-industrial age, there have been land reclamation projects intended for increasing available agricultural land. For example, the village of Ogata in Akita, Japan, was established on land reclaimed from Lake Hachirōgata (Japan's second largest lake at the time) starting in 1957. By 1977, the amount of land reclaimed totalled 172.03 square kilometres (66.42 sq mi).^[26]

Artificial islands

Artificial islands are an example of land reclamation. Creating an artificial island is an expensive and risky undertaking. It is often considered in places with high population density and a scarcity of flat land. Kansai International Airport (in Osaka) and Hong Kong International Airport are examples where this process was deemed necessary. The Palm Islands, The World and hotel Burj al-Arab off Dubai in the United Arab Emirates are other examples of artificial islands (although there is yet no real "scarcity of land" in Dubai), as well as the Flevopolder in the Netherlands which is the largest artificial island in the world.

Beach restoration

Beach rebuilding is the process of repairing beaches using materials such as sand or mud from inland. This can be used to build up beaches suffering from beach starvation or erosion from longshore drift. It stops the movement of the original beach material through longshore drift and retains a natural look to the beach. Although it is not a long-lasting solution, it is cheap compared to other types of coastal defences. An example of this is the city of Mumbai.^[10]

Landfill

As human overcrowding of developed areas intensified during the 20th century, it has become important to develop land re-use strategies for completed landfills. Some of the most common usages are for parks, golf courses and other sports fields. Increasingly, however, office buildings and industrial uses are made on a completed landfill. In these latter uses, methane capture is customarily carried out to minimize explosive hazard within the building.

An example of a Class A office building constructed over a landfill is the Dakin Building at Sierra Point, Brisbane, California. The underlying fill was deposited from 1965 to 1985, mostly consisting of construction debris from San Francisco and some municipal wastes. Aerial photographs prior to 1965 show this area to be tidelands of the San Francisco Bay. A clay cap was constructed over the debris prior to building approval.^[27]

A notable example is Sydney Olympic Park, the primary venue for the 2000 Summer Olympic Games, which was built atop an industrial wasteland that included landfills.

Another strategy for landfill is the incineration of landfill trash at high temperature via the plasma-arc gasification process, which is currently used at two facilities in Japan, and will be used at a planned facility in St. Lucie County, Florida.^[28]

Environmental impact



Parts (highlighted in brown) of the San Francisco Bay were reclaimed from wetlands for urban use.

Draining wetlands for ploughing, for example, is a form of habitat destruction. In some parts of the world, new reclamation projects are restricted or no longer allowed, due to environmental protection laws. Reclamation projects have strong negative impacts on coastal populations, although some species can take advantage of the newly created area.^[29] A 2021 global analysis estimated that 39% of losses (approximately 5,300 km² or 2,000 sq mi) and 14% of gains (approximately 1,300 km² or 500 sq mi) of tidal wetlands (mangroves, tidal flats, and tidal marshes) between 1999-2019 were due to direct human activities, including conversion to aquaculture, agriculture, plantations, coastal developments and other physical structures.^[30]

Environmental legislation



A map of reclaimed land (grey area) in Hong Kong. Many of the urban areas of Hong Kong are on reclaimed land.

The State of California created a state commission, the San Francisco Bay Conservation and Development Commission, in 1965 to protect San Francisco Bay and regulate development near its shores. The commission was created in response to growing concern over the shrinking size of the bay.

Hong Kong legislators passed the Protection of the Harbour Ordinance, proposed by the Society for Protection of the Harbour, in 1997 in an effort to safeguard the increasingly threatened Victoria Harbour against encroaching land development.^[31] Several large reclamation schemes at Green Island, West Kowloon, and Kowloon Bay were subsequently shelved, and others reduced in size.

Dangers

Reclaimed land is highly susceptible to soil liquefaction during earthquakes,^[32] which can amplify the amount of damage that occurs to buildings and infrastructure. Subsidence is another issue, both from soil compaction on filled

land, and also when wetlands are enclosed by levees and drained to create Polders. Drained marshes will eventually sink below the surrounding water level, increasing the danger from flooding.

II. DISCUSSION

Barren vegetation describes an area of land where plant growth may be sparse, stunted, and/or contain limited biodiversity. Environmental conditions such as toxic or infertile soil, high winds, coastal salt-spray, and climatic conditions are often key factors in poor plant growth and development. Barren vegetation can be categorized depending on the climate, geology, and geographic location of a specific area.^[1]

Pine barrens, coastal barrens, and serpentine barrens are some of the more distinct ecoregions for barren vegetation and are the most commonly researched by scientists. Often referred to as "heathlands", barrens can be excellent environments for unique biological diversity and taxonomic compositions.^[1]

Serpentine Barrens

Biological diversity

Serpentine barren habitats include grasslands, chaparral, and woodlands as well as some areas that are very sparsely vegetated. Areas of sparse vegetation are often characterized by annual and perennial herbaceous plant species.^[2] The flora of the serpentines is recognized globally for its high level of biological diversity which includes over 1600 taxa of plants occurring in serpentine areas of the eastern U.S., with as many as 2000 taxa considered to be endemic to serpentine rich soils.^[3]

Geology

Serpentine barrens are distinct due to the serpentine-rich soil produced by the hydration weathering and metamorphic transformation of ultramafic igneous bedrock.^[4] Serpentine barrens are often characterized as high-stress environments with low water and nutrient availability. These areas are often depleted in basic nutrients such as nitrogen and phosphorus. The soil is often shallow and can be toxic due to high heavy metal concentrations such as nickel, cobalt and chromium.^[4] As a result of the harsh conditions and unique edaphic properties presented by serpentine barrens these environments support stress-tolerant plant communities characterized by distinct and locally defined plant species.^[4]

Pine barrens

The Pine Barrens comprise 550,000 hectares of a heavily forested area of coastal plain and are home to at least 850 species of plant life, including many which are endangered or threatened.^[5]

The Pine Barrens are primarily formed on unconsolidated, acidic, medium-to-coarse grained sands and gravel. The mature soils are considered to be true podzols and are siliceous and highly permeable.^[5] The low moisture holding capacity and nutrient status of the soil create low vegetation growth rates throughout much of the Pine Barrens.^[6]

Coastal barrens



A heathland in Botany Bay National Park, Sydney, Australia.

Coastal Barrens are characterized by short vegetation, sparse tree cover, exposed bedrock, and bog pockets. Often, coastal barrens exhibit stressful climatic conditions and are subject to consistently windy conditions and salt-spray.^[1]

Coastal Barrens typically host low growing shrub communities with sparse tree cover and are often dominated by ericaceous species such as the black huckleberry (*Gaylussacia baccata*) and low bush blueberry (*Vaccinium angustifolium*).^[7] The coastal barrens of Atlantic Canada host a variety of taxonomic species such as macro lichens, mosses, and vascular plants.^[1] Studies have recorded 173 different species in various coastal barren regions of the province of Nova Scotia.^[1] This number included 105 vascular plants, 41 macro lichens, and 27 moss species with six provincially rare vascular species that were found predominantly in nearshore areas that contained high levels of substrate salt and nutrients, variable substrate depth, and short vegetation.^[1]

In Sydney, Australia, the coastal area is mostly dominated by mallee or stunted forms of eucalyptus trees, and scrubby vegetation such as *Allocasuarina distyla*, *Angophora hispida*, *Banksia ericifolia* and *Grevillea oleoides*, among other species, typically in an exposed coastal sandstone plateau with infertile, shallow, fairly damp soils. Unique to New South Wales, such vegetation is found from Gosford to Royal National Park, with southern outliers at Barren Grounds and Jervis Bay.^[8]

Climate zones

Although barren lands are generally located in areas associated with arid, semi-arid, polar and tundra climates, they can also be extensively found in milder, temperate, and/or humid climates as well, such as:



Avalon Peninsula Newfoundland Canada August 2012

- The Buck Creek Serpentine Barrens in North Carolina received around 1770 mm of precipitation in the last ten years.^[9]
- The Nottingham Serpentine Barren are very humid and has an average temperature of 11 degrees Celsius. Here, the average precipitation averages at 1200 mm and is spread out evenly throughout the year.^[10]
- Another region of barren vegetation is located in the Appalachian Mountains. In the low elevation of the northern part of this mountain chain, the annual precipitation is a little lower than on the southern Appalachians high peaks. In this location, precipitation falls mostly as rain rather than snow; and also precipitation occurs mostly in the summer.^[11]
- The ecoregion known as the Pine Barrens are found to spread across much of the northeastern United States, primarily in the state of New Jersey.
- Along the Atlantic coast of Nova Scotia and northeastern United States, there are patches of unforested coastal barrens spread throughout areas that contain exposed bedrock and/or little soil cover within a forested landscape.^[7] More extensive barrens can be found in much of Newfoundland and Labrador and further north in mainland Canada.
- In 1819, during the early European colonization of Australia, Sydney's landform was described by English explorer William Wentworth as "extremely barren, being a poor hungry sand, thickly studded with rocks".^[12] Moreover, Adelaide Plains, a region with a Mediterranean climate, was described by as "barren" by early settlers.^[13]
- Calcareous glades are sometimes described as barrens. They occur on dolomite and limestone in humid climates.^[14]

Anthropogenic relationships

Anthropogenic interactions have been used over the years to help change and drive vegetation in the eastern US. Meaning that the actions of human-beings will play a role in what type of vegetation will grow in some locations. This

is including things like fires and fire suppression, grazing, logging, and agriculture clearing. Research has been done and anecdotal evidence has been shown to suggest vegetation structures and composition in the eastern serpentine barrens may have also been influenced by local disturbance regimes associated with these events as well as mining^[10]

Savannahs and barrens are ecosystems that are rare in North America. This is due in part to human impacts, such as agriculture, urbanization, and altering the natural fire regimes.^[15] Over the past 50 years, the area of savannah-like openings and pine woodland has been continuously reduced over the years, a tendency opposite to that of hardwood forests. These changes in vegetation structures along with the composition are caused by, in part to anthropogenic changes in the fire regime.^[10] Following the burning of vegetation there is a release of inorganic nutrients into the ecosystem caused by the combustion of the plants biomass and therefore, releasing the nutrients. This release of nutrients, after the occurrence, is thought to be a reason for an increase in plant productivity.^[16]

Global distribution and geography

Regions on the earth's surface where soils are dominating the ecosystems with little to no plant cover are often referred to as "Barren". These places are areas like deserts, Polar Regions, areas of high elevation, and zones of glacier retreat. For barren zones that are situated in mountain ranges, they are often called the "Subnival Zone", and are found at elevations between the upper limit of the vegetation zone and the lower limit of the ice-covered zone. Subnival zones in places like the Rockies, Andes, and Himalayas have increased greatly in the past few years due to the retreat of high elevation glaciers and the ice caps.^[17]

One area for study is The Nottingham Serpentine Barrens, which covers 200 ha in southern Chester County, Pennsylvania on the Pennsylvania-Maryland border.^[10] The typical serpentine barren is either a prairie or savannah grassland. The soils here in this location are a section of the Neshaminy-Chrome-Conowingo association. These soils are deep and are derived from the serpentine bedrock. This series of soils are well-drained and also moderately sloping. With this, these specific locations have been under heavy erosion forces and have a depth to its parent bedrock within a distance of 15–75 cm. Here, there is also low permeability which makes it difficult for plants to have availability to water and therefore hard to collect moisture.

Mean elevation and elevation range limits both vegetation zones and individual species should be defined with increasing latitude. For example, in the southern Appalachians, high-elevation outcrops, composition gradients are a function of elevation, potential solar radiation, a geographic gradient that corresponds to broad geological differences (mafic rocks to the northwest vs. felsic rocks in the southwest direction), and surficial geomorphology (bedrock surfaces that are less fractured in the southeast).^[11]

III. RESULTS

Land reclamation, the process of improving lands to make them suitable for a more intensive use. Reclamation efforts may be concerned with the improvement of rainfall-deficient areas by irrigation, the removal of detrimental constituents from salty or alkali lands, the diking and draining of tidal marshes, the smoothing and revegetation of strip-mine spoil areas, and similar activities.

Reclamation of arid land

In the United States, the most extensive reclamation activities are those concerned with irrigation, particularly in the western United States. The United States Bureau of Reclamation, an agency of the Department of the Interior, has as its central purpose the construction and maintenance of dams, canals, and pumping systems to bring irrigation water to arid, semiarid, or subhumid lands in the 17 western states. Among the more than 600 dams constructed by the Bureau of Reclamation are Grand Coulee Dam on the Columbia River and Hoover Dam on the Colorado River.

Other extensive areas reclaimed from a desert or near-desert status by irrigation are found in Israel, Egypt and other countries of the Middle East, India, Mexico, Peru, Russia, and China. Irrigation of arid lands has been practised in the Middle East for thousands of years and extensive irrigation projects were developed in what is now southwestern United States by American Indians long before the arrival of Europeans. The real impetus to reclaim the arid western United States by irrigation, however, came about the middle of the 19th century when the Mormons established settlements in the Great Salt Lake basin, and settlers drawn to California by the discovery of gold turned to irrigation in order to supply themselves with food.

The extent to which land is improved by irrigation is related to the aridity of the land in its natural state. The deserts of the Middle East, the alluvial valleys of the Central Asia, the Imperial Valley of California, and the Columbia basin are examples of areas reclaimed from a near-desert state to a highly productive intensive agriculture. Land reclamation by irrigation is, however, not limited to desert regions. Much of the land irrigated in humid areas throughout the world is used for the production of paddy rice, although irrigation of vegetable crops, usually with overhead sprinkler systems, also is practised on a considerable acreage.

Many irrigation projects have failed because of salt accumulations in the irrigated soils or the silting in of reservoirs and irrigation canals. It is essential, therefore, that provision for drainage of the irrigated lands be considered in the planning of all irrigation reclamation projects and that water relatively free from dissolved salts be used.

Reclamation of land by irrigation was extensively developed by the Soviet Union. By the late 1950s the Soviets reported a total of about 27 million acres (11 million hectares) under irrigation, about one-half of this being in the Central Asian republics. The Syr Darya and Amu Darya rivers were the principal sources of irrigation water in this area. These rivers discharged into the Aral Sea, and diversion of these rivers from their natural course caused an ecological disaster in the region. With its primary sources of inflowing water gone, between 1960 and 2010, the Aral Sea shrank to a tiny fraction of its former size. The collapse of the Soviet Union left the now-independent Central Asian republics bordering the Aral Sea struggling to coordinate a response to the crisis. The loss of the world's fourth largest body of inland water led to more-extreme temperature swings in the region, and wind storms carried contaminated dust from the exposed seabed across the region. Populations living in the region subsequently experienced a range of diseases and disorders at markedly high rates.

In the arid regions of the world, and along coastal areas subject to periodic inundation by sea water, soils may have such a high content of soluble salts that production of economic plants is not possible. The salts found in soils are generally the chlorides, carbonates, bicarbonates, and sulfates of sodium, with lesser amounts of potassium, magnesium, and calcium salts.

Normally, the salt is carried into the soil by water, either by upward moving saline groundwater or by saline irrigation or flood waters. As the water evaporates from the soil or is transpired by plants, the salt is left behind. Unless provision is made for removing it from the soil by flushing with nonsaline waters, the salt will accumulate until plant growth is inhibited. Thus, salts tend to accumulate in poorly drained soils where water does not move down through the soil profile and out in the drainage water and in soils of arid areas where the annual addition of nonsaline water to the surface soil in the form of rain is insufficient to wash the salts downward. Since all irrigation waters carry at least some salt, irrigation may hasten the process of salt accumulation in soils, and reclamation of arid lands by irrigation may be followed by a need for reclamation of salty lands by drainage and leaching.

The salt in soils dissolves in the soil water and damages plant growth by preventing the plants from getting needed water from the soil, since the energy required to remove a given quantity of water from a salt solution increases as the salt concentration of the solution increases. In some cases, the dissolved salts may be toxic to plants when taken up by the roots. In addition to their detrimental effects on plants, sodium ions from the dissolved salt may become adsorbed by the clay particles of the soil and render the soil very sticky when wet and hard and cloddy when dry. Soils containing significant amounts of adsorbed sodium are nearly impervious to water and roots. These detrimental accumulations of sodium are formed through a process called cation exchange.

Most productive soils have calcium cations adsorbed on the surfaces of the clay particles. But when such a soil is treated with a salt solution high in sodium and low in calcium, sodium cations from the salt solution replace the calcium cations held by the soil, and a so-called "sodic soil" results. These cations of sodium remain adsorbed by the soil after the salt solution is drained away. Whenever sodium cations are in excess of about 10 percent of the total amount of cations held in adsorbed form by the soil, a sodic soil of undesirable physical properties results. The Food and Agriculture Organization (FAO) uses the term solonetz (from the Russian sol etz "strongly salty") to describe sodic soils.

The reclamation of salt-affected soils follows the exact reverse of the process by which they are formed. The first step is to improve the drainage so that upward movement of ground water to the soil surface ceases and water applied to the surface can move down through the soil profile. Then fresh nonsaline water is applied to the surface by irrigation. This fresh water washes out the excess salts, which are carried away in the drainage water. In the case of sodic

soils, amendments that will supply a fresh source of soluble calcium to replace the sodium adsorbed by the soil are added, and leaching is carried out until the replaced sodium is removed. Gypsum (calcium sulfate) is the most common amendment used to supply calcium for the reclamation of sodic soils.

Procedures for the diagnosis and reclamation of salt-affected soils are generally used for planning this type of reclamation activity throughout the world. Saline and sodic soils are found in extensive areas in Russia, Pakistan, the Middle East, North Africa, Spain, and in the western United States. Deep tillage to break up the horizons high in adsorbed sodium is a common technique used for the reclamation of these soils.

Reclamation of swampy lands

Where excess water accumulates in and on the soil, the land is rendered unfit for production of many crops. Even where the wet condition is of fairly short duration, cultural operations required for crop production may be delayed past the optimum planting date or crops already planted may be drowned out. The reclamation of such wet areas is centred on means of removing the water from these areas more rapidly than it is removed in their natural condition. This process is termed drainage.

The first requirement of a drainage project is an outlet for the water. One of the most common means of providing this outlet is to dig a ditch from the swampy area to a river, sea, or other natural body of water. The size of the ditch is determined by the amount of water to be carried and the gradient of slope along the ditch. The topography of the land, the amount of water to be removed in a given time (called the drainage coefficient), and the distribution and nature of underlying strata are factors determining the design of the drainage systems for moving the water from the land to the outlet.

Of particular importance is the permeability, or ability to transmit water, of the soil and underlying strata. If the soil and underlying strata have a low permeability, a quality frequently found in clay soils, the excess water must be removed by surface flow. This may require regularly spaced small ditches throughout the area to be drained and a land forming or grading operation to provide slopes toward the field ditches and to eliminate low spots between ditches. If the soil is permeable, the excess water may be removed through tile lines installed beneath the surface of the soil. The tiles are traditionally made of fired clay or concrete, although corrugated plastic tubing is also commonly used. The spacing of the tile lines is governed by the permeability of the soil. The more permeable the soil, the farther apart the tile lines. The tile lines may be installed in a regular pattern in large wet areas or in a random pattern where critical wetness is confined to scattered spots in the area. Tile drains have the advantage over open ditch drains in that farm operations can be conducted across the tile lines, making it possible to use larger and more efficient fields, with no loss of land occupied by ditches.

Occasionally, underground drains are constructed without use of tile by drawing a bullet-shaped tool through the soil at a depth of 18–36 inches (46–91 cm). This tool leaves a channel through the subsoil that may serve the same drainage function as a tile line. The practice of forming unlined underground drains is called mole drainage. After a period of time, depending upon the stability of the soil, the unlined channels collapse and the mole drainage operation must be repeated. With the development of low-cost flexible plastic materials, devices for lining mole drains with perforated plastic liners to increase the life of the drains were developed.

If a permeable strata such as gravel underlies the area to be drained, widely spaced open ditches dug into the permeable strata usually provide effective drainage. Frequently, poorly drained swampy areas are occupied by soils very high in organic matter, called peats and mucks. When these organic soils are drained, the improved soil aeration brings about an increase in the rate of oxidation of the organic material, resulting in a loss of the soil material itself. This leads to a subsidence of the land surface, and, in some cases, the land surface may sink several feet. Subsidence of drained organic soils is more rapid in warm climates than in cooler areas. Appreciable subsidence has taken place in the reclaimed organic soils of the Everglades of Florida.

Some areas are too wet for crop production because of recurrent flooding from adjacent rivers and creeks. Reclamation of this type of wetland is usually effected by building levees along the stream to keep it confined in its channel. If necessary, excess water originating in the protected area is lifted over the levee by pumps. An extensive area of land is protected by levees in the lower Mississippi valley of the United States.

Projects for the reclamation of land by drainage are found in England, Europe, and the eastern United States. Large areas of organic soils have been reclaimed by drainage near Minsk, Belarus. Mole drainage is used in England, in New Zealand, and in Australia. Reclamation of wetland by drainage is an ancient practice, having been used by the Romans along the Tiber River.

Reclamation of coastal areas

Where offshore lands or tidal marshes are covered by shallow water and additional land is critically needed, the land can be reclaimed by construction of dikes roughly parallel to the shoreline, followed by drainage of the area between the dikes and the natural coastline. Where a sediment-laden stream can be diverted into the area between the dikes and the shoreline, the sediment from the stream may be used to build the diked-off land to a higher level, thus facilitating the drainage operation.

Occasionally, reclamation of tidal marshland can be accomplished by closing the mouth of tidal estuaries by dikes. Where the land surface is above low-tide level, a dewatering system based on tide gates which discharge water into the sea at low tide and automatically close to prevent reentry of seawater at high tide may be used. In other instances, pumps have been used to lift water over the dikes. The use of pumps permits the reclamation of lands that are below low-tide level. The most notable example of reclamation of coastal lands is the polder (tract of artificially drained land) system developed adjacent to the Zuiderzee in the Netherlands.

Other examples of this type of reclamation are found in England. During the colonial period, extensive areas of tidal marsh were reclaimed for rice production in the Carolinas and Georgia in the United States. The systems of dikes used in reclaiming marshlands in the Carolinas and Georgia were not maintained and most of the diked-off land reverted to tidal marsh. Areas newly reclaimed from inundation by seawater contain so much salt that most plants will not grow. For this reason the procedures for reclamation of salt-affected soils must be used in addition to diking and draining in order to develop productive agricultural land.

Some marshlands formed in brackish water are very high in sulfides. As long as air is excluded from the soil because of saturation with water, these sulfides are stable and the soil will produce marsh plants. When the soil is drained, the improvement of soil aeration brings about an oxidation of the sulfides to sulfates, and if the soil is low in basic constituents free sulfuric acid is produced, making the soil too acid for any plants to grow. Marsh soils high in sulfides are termed cat clays by the Dutch. Very large quantities of lime are required to neutralize the sulfates and make the soil suitable for crop production. Unless the sulfide-containing sediments naturally contain sufficient lime to neutralize the potential sulfate content, drainage and reclamation are rarely attempted, and these areas are left as wildlife preserves.

The only feasible method of producing crops on cat clays is to grow rice using methods that provide for planting and harvesting the rice without draining the land. Inasmuch as these methods preclude the use of modern machinery, the use of cat clays for rice production is confined to Southeast Asia and other areas where the supply of farm labour is abundant in relation to the supply of available land.

Reclamation of mine spoils

Where mineral deposits are near the surface of the earth, frequently they are exposed for mining by excavating the entire overburden with power shovels. This process is called surface mining and was widely used as a method for extracting coal in the Ohio River valley and in England. This technique is also used for mining phosphate deposits, gypsum, gravel, limestone, copper, iron, and other minerals. The overburden removed to expose the mined deposit is dropped by the power shovel in a series of generally conical mounds.

In strip mining, the operation is conducted so as to deposit the overburden material in a previous excavation left after the mined deposit is removed. The final excavation is not filled. The strip-mined area is then left as a series of piles of overburden, called spoil banks, with a deep trench at the side where operations ceased. The piles of overburden are generally loose and porous but barren of plant life and only slowly revegetated by natural processes. Historically, when the mineral deposits in an area were exhausted, the site was abandoned, leaving a lunarlike landscape that was unsuitable for development. This led to an increased interest in the problem of more rapidly reclaiming and revegetating the spoil-bank areas. By 1950 the states of Pennsylvania, West Virginia, Ohio, and Indiana had enacted

legislation requiring strip-mine operators to replant or smooth and replant strip-mined areas. A similar wave of reclamation of surface mines took place in Eastern Europe after the fall of the Soviet Union.

The problem of revegetation is complicated by the irregular, frequently steep topography of the spoil-bank area and the raw, infertile nature of the spoil material. Smoothing of the area is likely to result in excessive compaction of the spoil material, rendering it less suited to plant growth. For this reason, reclamation of spoil banks is generally confined to reforestation, to development of grazing land, or to reclaiming for recreational areas. Reclamation to the point where cultivated crops can be produced is rare. Materials overlying coal deposits are often high in iron sulfides. Under the well-aerated conditions present in loose spoil-bank material, these sulfides are oxidized, and highly acid conditions may develop in the spoil. The process is similar to the development of acidity in cat clays in reclaimed tidal marshes. In mine spoil, however, drainage is generally good, and the acid constituents will be removed by leaching in a period of years. In some states of the U.S., the legislation governing strip mining requires grading of the spoil areas to form water-retaining benches to hasten the leaching process. Pine trees are frequently used to reforest spoils high in sulfides because of the acid tolerance of the pines.

IV. CONCLUSION

Where soil erosion is severe, a land area may be denuded of topsoil and interlaced with a dendritic, or branched, system of steep-sided watercourses called gullies. These areas are generally devoid of vegetation, and sediment eroded from them may menace lower-lying lands or water retention structures.

In humid regions these eroded areas are usually reclaimed by reforestation accompanied by exclusion of livestock from the area. If the gullied area is not large and topographic conditions permit, a diversion ditch to prevent runoff from higher lying areas from entering the gullied area may hasten the reclamation process. Native plant invasion and succession may revegetate eroded areas if they can be protected from the cause of the accelerated erosion. Where the subsoil material is friable and fertile, the land may be graded to obliterate the gullies and permit production of pasture or other close growing crops.

In the southeastern United States, kudzu, a leguminous vine, was frequently used to stabilize gullied areas and prevent erosion. The introduction of this aggressive invasive species led to its own problems, however, as kudzu overran native plants and trees, earning the nickname "the vine that ate the South." In the 21st century such missteps, as well as growing environmental concerns, led developers to consider sustainability alongside purely economic concerns when reclamation projects were undertaken.

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