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Reclamation of Salinized Soils In Arid Regions

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Nearly ten percent of the total land area in the world is affected by soil salinization. Salinization is the accumulation of soluble salts of sodium, magnesium, and calcium in soils. (Mainguet, 1991). These salts can affect soils to the extent that crop production is severely limited. High levels of soil salinity limit plant growth; the increased osmotic pressure of the soil solution reduces the plant's capacity to withdraw water from the soil (Ahmad and Kutcher 1992). The increasing human population of the world makes it necessary for the earth's soil resources to be maintained in order to meet the increasing demand for food (Goudie, 1990). Every continent contains areas with salt-affected soils and at least seventy-five countries worldwide have serious salinization problems (Goudie, 1990).

Many saline regions of the world occur naturally. Saline regions are found in poorly drained low-lying areas within semi-arid and arid climates in which large quantities of salts have leached from regions of higher elevation. These leached salts accumulate in the slow flowing groundwater and are brought to the soil surface, in these low-lying areas, through high evapotranspiration rates (Goudie, 1990).

Salinization can also occur as a result of human activities.In recent decades, the impacts of humans on the circulation of salts in the landscape has been profound. Irrigation of cropland has led to the salinization of many soils. By adding more water, and inevitably more salt, to an area by irrigation, salts stored in deeper soil layers are mobilized. Another effect of irrigation is the raising of the water table resulting in irrigated areas becoming waterlogged and salinized (Goudie, 1990).

Salt Removal Techniques

Since the harmful salts are soluble in water, reclamation can be accomplished through water management. The most common methods of salt removal include the physical removal of salts, flushing, and leaching (Gupta and Gupta 1987).

Physical Removal

One method of desalinating the soil is to remove the top layer of the soil. After this layer is disposed of, the lower salt-free layers of the soil can be utilized. This method is based on the idea that the lower layers of the soil profile have a lesser accumulation of salts than the surface layer. There are several disadvantages to this method, which provides only a temporary, short-term solution. Over time, this method intensifies the problem. By lowering the ground level in relation to the water table, salts accumulate. There is also a high cost associated with disposing of large quantities of highly saline soil. This method is rarely used (Gupta, Gupta 1987).

Flushing

Another method of desalinization is to flush the soil with water. This method is beneficial for soils with very low permeability and for soils that have a high salinity content in their surface layer. After washing the surface of the soil with water, the salts are carried down slope by excess irrigation water and rainwater. A sufficient downward gradient is required to carry the water away, therefore, this method is not practical in landlocked fields. Flushing is most effective initially; however, as salt concentrations diminish, the efficiency decreases (Gupta and Gupta 1987).. While the surface area is being somewhat remedied, the rest of the soil profile is still contaminated

Leaching

Leaching is the process of applying an excessive amount of water onto the soil surface in order to push the salts down through the soil profile along with the water. There are two methods of leaching: continuous ponding and intermittent ponding. The continuous ponding method consists of ponding water at the soil surface, while the intermittent ponding method consists of several small applications of water in intervals (Gupta and Gupta 1987).

Continuous ponding is the preferred method when time is a limiting factor. This method can pass the same amount of water through the soil profile much quicker. As a general rule, this type of leaching will require one centimeter of water for each centimeter unit of the soil profile to be reclaimed. However, the amount of water needed for leaching will vary, depending on the texture of the soil (Gupta and Gupta 1987).

When water is the limiting factor, the intermittent ponding method should be used. This is the better of the two leaching methods for extremely arid regions because it is most water efficient. The amount of water needed is 30-35% lower than the amount needed for continuous ponding. One disadvantage to intermittent ponding is that it is much slower than the continuous ponding method (Gupta and Gupta 1987).

In order to have a successful leaching program it is necessary to first level the land. However, the heavy machinery required for leveling can significantly harden the soil. Therefore, it is necessary to plow, following leveling, before leaching can begin. The necessary depth of the plowing will range from shallow to deep, depending on the severity of the soil compaction. One positive side effect of the plowing is an increased infiltration rate. This will considerably reduce the time required to pass the leaching water through the soil profile. In a few cases, the infiltration rate has increased three to four times after plowing (Gupta and Gupta 1987).

Another important aspect of a leaching program is the timing of the leaching. It is important to wait until just before the rainy season. The water table will be lowest at this time of year, so there will be less upward movement of the salts into the root zone. In addition, the oncoming rainy season will further leach the soil. In very arid regions, rainfall can be an important source of water for leaching. Building 25cm high berms around the field will ensure capture of the rainwater. Without the construction of berms, an estimated 30-35% of the rain water will flow away from the field (Gupta and Gupta 1987).

There are cases in which the limiting factor is not time nor water, but the quality of the available water. The lower the amount of salt in the leaching water, the higher the amount of salt removed per unit of the water applied. However, water with a low salt-content is not always available. In such cases, it has been found effective to use saline groundwater for leaching. Even though these waters contain salts, they still have a much lower salt content than the soil surface. When combined with a limited amount of fresh water, the salt from the root zone can be leached to a permissible level. When mixing the saline groundwater with fresh water, as much as 40% of fresh water can be reduced. There are mathematical formulas for determining the proper quantities of each. One negative aspect of this approach is that a larger overall amount of water is required for leaching than is needed for leaching with the freshwater alone (Gupta and Gupta 1987).

Enhancing Leaching

It is possible to enhance leaching through improved agricultural practices. These practices include the following: subsoiling, subsoiling with inversion, auger hole piercing in the impermeable layer, addition of amendments, and irrigation practices(Gupta and Gupta 1987).

Subsoiling is a tillage operation in which the soil is plowed to a depth of 60 cm or more, using an implement known as a subsoiler. Subsoiling results in a greater storage of water and faster movement to lower depths, therefore leading to a faster reclamation in the upper layers of the soil. It has been shown that the infiltration rate of a subsoiled land is much greater than that of shallow plowed land. Subsoiling with inversion is a process in which, during tillage, the lower layer of soil are placed on top of the upper layers. The inversion is useful before leaching when the lower layers have a lower salinity than the upper layers (Gupta and Gupta 1987).

Auger piercing is used when surface layers are comparatively less permeable with highly permeable layers available at some depth below. Auger piercing consists of making 10 cm diameter holes up to a depth of 2.5m, and then filling the holes with sand. This method results in a greater amount of leaching. One potential means of improving this method further would be to angle the holes rather than to drill them vertically. The disadvantage of this method is the additional time required to dig the holes (Gupta and Gupta 1987).

The addition of amendments (chemical, organic, or sand), can be used to enhance the infiltration rate, therefore enhancing leaching. These amendments are particularly useful on heavy textured soils where it can take a long time for leaching. One example of an amendment is the addition of green manure and sand (Gupta and Gupta 1987).

Irrigation practices and water management can be improved to enhance irrigation. As mentioned above, intermittent ponding, in some cases, is superior to continuous ponding. Similarly, sprinkler irrigation is usually superior to flood irrigation. It is also more efficient to leach with each irrigation, rather than leaching at the end of the crop (Gupta and Gupta, 1987).

There is no set rule to determine which practices under which conditions will improve leaching. The choice of which method will be chosen to enhance leaching will be affected by the following: the type of soil, the variation of soil salinity with depth, the placement of hard pan in relation to ground surface, and the depth to the water table (Gupta and Gupta 1987).

Drainage

In order to permanently improve salinized soil, it is necessary to not only leach the soil, but also to have adequate drainage. The drainage system must provide an outlet for the removal of the leached water as well as keep the water table deep enough to prevent salt-laden groundwater from moving up to the root zone. This is particularly a problem for soils with a shallow, saline water table (Schilfgaarde 1974). For saline soils, provision of drainage is an essential prerequisite of the reclamation. Before reclamation occurs, there are several possible drainage methods to control salinization. The drainage methods include, the lining of canals, the drainage of borrow pits, and the management of on-site water (Gupta and, Gupta 1987).

Lining Canals

It is very important to prevent the water table from becoming too close to the surface of the soil. Shallow water tables are a major contributor to salinized soils. Seepage from canals, distributaries, and field water courses are one of the main sources of excess ground water which results in a raised water table. As much as 25% of the water is lost into the ground through canal seepage. When there is a partial lining of the canal system, there is a substantial reduction in seepage. The most effective and cheapest course is to line the whole canal system when it is initially installed (Gupta and Gupta 1987).

Borrow Pits

Sometimes faulty development schemes can be a contributing factor in salinization. Soil is dug from borrow pits to be used for road and railroad construction. These pits accumulate rain and flood water, which eventually seeps out and raises the water table. The best approach is to avoid digging this pits in an area that is sensitive to salinization. Otherwise they should be dug in a way that allows them to drain into a natural drainage system.(Gupta and Gupta 1987).

On-Site Water Management

Good irrigation management consists of efficiently using irrigation water. As much as half of the water delivered at the field head goes as deep percolation losses and on average, it is presumed that one-third of the water is lost at the field level. By adding this one-third to the 25% of water that is lost through seepage in canals, nearly 58% of the water from a canal irrigation system is contributing to the ground water, raising the water table. To utilize irrigation with minimal losses, the water management should include land leveling, shaping, efficient design and layout of irrigation methods, scientific scheduling of irrigation (under both normal and drought water conditions), and crop planning (Gupta and Gupta 1987).

A Silvipastral System As An Alternative

In the absence of a safe outlet for drainage water, the conventional methods of reclamation through leaching and drainage aren't possible. Sometimes, the cost of the leaching and drainage system is beyond what a community can afford. In some cases, salinized areas belong to village communities or state organizations that can't allow the land to be conventionally cropped because they need the land for grazing of cattle or other purposes. There is a promising alternative for reclamation in these areas. The alternative is known as a silvipastral system. This system utilizes trees in place of traditional crops to reclaim salt-affected soils. By removing water from lower layers of soil, the trees minimize the capillary rise and therefore shift the zone of salt accumulation from the surface to lower layers. This helps to minimize the salt injury to shallow rooted crops and other plants Chhabra, 1996).

Trees, because they use a greater amount of water on a continuous basis compared to annual crops, intercept the seepage from canals and the runoff from higher slopes, which helps to control salinization by preventing a rise in the water table. When a particular area has a shallow water table, the large scale planting of trees can biodrain the excess water and lower the water table. Trees also help to lower the salt content of the soil by absorbing salts from the soil and irrigation water (Chhabra, 1996).

Afforestation of saline soils requires that special attention is paid to site development, species choice, and management level. Although some trees are very tolerant of adverse conditions, it is somewhat difficult to grow plants on inhospitable sites. The stress that the trees face depends on the extent of the soil salinity, the existence of physical impediments (such as hardpan), and the quality of ground water along with its depth. It is essential to understand these stresses in order for a successful plantation on salt-affected soils (Chhabra 1996).

In order for the trees to establish and grow, care has to be taken to provide aeration in the root zone and to prevent excessive salt accumulation. There are several different methods for planting, depending on the given conditions. These methods include digging ridge trenches, planting in sub-surface auger holes, and planting in irrigation channels Chhabra 1996).

In the ridge trench method, the trees are planted on ridges, 50 to 100cm high. The trenches between the ridges are used for draining the excess water. This is particularly useful when there is a shallow, saline water table. However, this method is not feasible in very arid areas. Because of greater evaporation from the exposed areas, excess salts tend to accumulate on the sides and top of the ridges. Also, as a result of greater evaporation, moisture content is also generally lower in the ridges than in the surrounding ground. Therefore, under certain conditions, this method makes it difficult for the trees to grow (Chhabra, 1996).

The next method is the auger planting method. In saline soils, the greatest salt accumulation is on the surface of the soil. Therefore, greater success can be achieved if the young tree's roots are placed below the surface, where there are less salts. Young saplings are planted in the auger holes, 30-45cm below the surface. There are a couple disadvantages to this method. The auger holes sometimes collapse because of runoff from nearby areas, and then the salt collects in these areas. Additionally, even though the holes are much less saline than the surface, the salinity may still kill some plants during the critical establishment stage (Chhabra 1996).

The final method is irrigation channel plantings. Young saplings can be planted in shallow trenches about 30 cm deep, which are also used for irrigation. The water in the trench pushes the salt away from the active root zone and also serves as an irrigation source for the plants. This method has had the most success of these three methods of tree planting (Chhabra 1996).

It is not necessary to add amendments in order to raise trees on saline soil. However, in the case of heavy textured soils, it is beneficial to add sand, silt, or rice husk. These items allow for more efficient leaching of the salts. The application of organic mulch helps to reduce the accumulation of salts on the surface (Chhabra, 1996).

Regular irrigation of trees during initial establishment is essential for afforestation of saline soils. Even though the soil may look moist, and the trees have access to water because of a high water table, the high quality irrigation water leaches the salts from the root zone. During the first year, 8-10 irrigations should be done and 3-6 should be done in the second year. At later stages, irrigation should be provided when possible (Chhabra, 1996).

Conclusion

Salinization is found in all ecozones around the world, due to natural causes as well as human causes such as improper agricultural practices. Silvipastral systems are one possible solution for areas experiencing increased soil salinity; in most cases it will be necessary to reclaim highly saline lands through drainage and leaching methods (Ghassemi et al. 1995).

Several areas are being studied in hopes of learning better methods of soil desalinization. One approach is to formulate a system by which salinized soils can be distinguished and classified. Another is the mapping and territorial evaluation of salt-affected soils. The preparation of large scale, current maps is necessary to determine the required methods, strategies, and tactics in soil desalinization. A final approach is to predict and attempt to prevent salinization in susceptible areas through a thorough study of all environmental factors, such as the geology, climate, and hydrology of the area (Szabolcs, 1979).

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