WATER-LOGGING OF IRRIGATED LANDS AND REMEDIAL MEASURES

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WATER-LOGGING and consequent increase of alkali salts in soils is a condition caused either by a rise of the subsoil water table or by inadequate draining of surface water or both. In most of the major irrigation schemes in Ceylon, drainage of aswoddumized* lands is left to the resources and understanding of the proprietor or his tenants. Annually large tracts are being alienated to poor peasants who are given limited aid by Government to establish farms according to their understanding. The peasant, in his eagerness to derive an income from the new possessions, with the minimum of labour within the shortest time, seldom gives any thought to drainage, nor does he prepare the lands according to any predetermined plan to take irrigation water without surface waste. Knowing that new clearings are fertile and the yield is good he soon learns that, unless he has an abundant supply of water, he will miss his opportunity. Irrigation is not only his insurance against failure of crops but also his chance to gather a bumper harvest from a new clearing. Thus he feels that the more water he can apply to the land the more certain is he of his bumper harvest. Such misguided enthusiasm results in over-irrigation and finally spells disaster to crop production under irrigation. In the long run, these practices are attendant with dangers which will prove a menace to profitable agriculture. These dangers are water-logging, spread of aquatic plant pests, and increase of alkali salts in the soil. If these are not perceived early they may result in complete abandonment of large tracts or in heavy expenditure in attempting to overcome them.

A study of soils that precedes all land development schemes may indicate its suitability for agricultural purposes both in texture and in chemical constituents. It may have all the desired qualities of a good soil. But with irrigation a change in these conditions must be expected. And this change may be

* " Asweddumizing " means cultivation of paddy fields by puddling.

caused by the method of applying irrigation water, or by the physical features of the land or by both. Hence the observations made at the time of the soil survey cannot be considered final and permanent, unless such methods as are necessary to conserve and rehabilitate the soil are adopted when the land is brought under cultivation. It is always well to study beforehand how a soil in a particular area will react to irrigation. Though it may be found that the depth, physical texture, and chemical constituents are favourable with the subsoil free from an excess of alkali salts, for crop raising, one must not forget that these conditions were established under natural influences. One could not say that these would continue to be so under altered conditions. Before a land is exploited for agriculture it is often under heavy jungle giving it impenetrable shade ; it has a periodical dry and wet season ; it receives a fairly regular rainfall during the monsoons which has carved out a natural drainage system to deal with the surface run-off. When the cultivator starts his operations for crop raising he denudes the land of its jungle and exposes it to the direct rays of the sun ; he constructs ridges to hold water and channels to deliver it ; he levels and cultivates the soil ; and he applies water year in year out. These are conditions quite different from what they were at the time of the soil survey, and if nature is what it is, there should take place radical changes in the soil under the new conditions. Such changes in the soil may be accelerated with poor subsoils, the presence of an impervious hard-pan close to the surface, lack of an effective drainage system and, last but not the least, continuous irrigation.

Under this erratic method of irrigation, or what is called over-irrigation, the first change to expect is a variation of the subsoil water table. It may rise very close to the root regions, and with improper land preparation, it may even rise to the surface at depressions and low-lying areas which will be lost for crop production. This is what is known as water-logging.

Such an artificial raising of the water table, specially in lands devoid of shade, usually aggravates the alkali condition of the soil which will, in course of time, render it entirely unsuitable for crops. This may happen under irrigation even in areas that had not a trace of alkali salts before. Its early appearance may be observed to a marked degree in low-lying areas. The reason for this and the occurrence of alkali salts in soils free from them before irrigation is that, with the continuous application of water, salts are leached out from higher to the lower lands, by seepage from irrigation channels, and by flushing of lands above due to excessive irrigation. This subsoil flow from higher to the lower regions often gathers large quantities of soluble materials which may get concentrated in low-lying and improperly-drained areas. As time goes on, under these conditions such areas may be rendered hopelessly barren. Another factor, often overlooked by irrigators, is that lands higher up in a water-shed are more porous than those lower down owing to heavy soil erosion under natural conditions. A light porous soil results in an excessive loss of irrigation water by deep percolation—which cannot be entirely avoided. If this fact is not borne in mind when issuing water to the lands lower down, over-irrigation is bound to occur with all its dangers. It is not always necessary for the water table to rise within the root regions to cause injury to plants. Owing to capillary attraction, water from the lower crust of soil is drawn to the surface and there evaporated leaving behind it all the harmful salts which had been dissolved in it. The quantities so left in the soil may not be in sufficient concentrations to cause immediate injury to crops. But this upward and downward movement of subsoil water results in the ultimate presence of salts in the effective soil strata. If this is followed by a prolonged dry season the appearance of salts on the surface soil in the form of efflorescence is not rare. This is a common occurrence in arid or semi-arid regions. It must be remembered that irrigation is essential only in such regions for crop production and one of the main characteristics of soils in arid areas is the presence of sodium salts. This is what causes alkalinity in soils, and irrigation causes this characteristic to vary to the detriment of plant life. The salts which occur most commonly in a natural state in soils are (1) carbonates, bicarbonates, sulphates, and chlorides of sodium, (2) carbonates, sulphates, and chlorides of magnesium, (3) carbonates, sulphates, and chlorides of calcium. Of these salts the most injurious to plant life is sodium carbonate. Though it may not be present in the soil in large accumulations at the commencement of a project there is a chance of its increasing under irrigation by a base exchange with other soluble salts. Also this danger may be present indirectly in the irrigation water if it contains large quantities of calcium carbonate in solution. According to Evershed, the limit of tolerance of vegetation to different alkali salts in the soil is roughly as follows :—

	Per cent.		Per cent.
(1) Sodium carbonate	0·1	to	0·15
(2) Sodium chloride	0·2	to	0·3
(3) Sodium sulphate	0·4	to	0·6

If these percentages are increased owing to any external causes or causes inherent in the soil, lands become unprofitable for agricultural purposes. Therefore every precaution should be taken to keep these figures down. This only emphasizes the need for careful investigation of the soil behaviour before an irrigation project is undertaken. Also it is useful to study what changes may take place in the soil and ground water under irrigation. In summarizing, a soil may said to be rendered alkali owing to the following causes:—

(1) water-logging and blocking of natural drainages;
(2) want of sufficient rain to leach out any soluble salts present in the soil;
(3) excessive evaporation with high temperature;
(4) want of sufficient surface and subsoil drainage;
(5) over-irrigation under condition (4).

It should be clear now why special attention should be paid to the correct preparation of lands before irrigation water is turned on to it. In poorly-prepared lands there will be excessive wastage necessitating over-irrigation. This surplus water and waste will collect in depressions and low-lying areas with inadequate drainage facilities. These are the first steps towards water-logging often of large tracts. Once these conditions have been definitely established the growth of aquatic plant-pests such as Bulrush (*Typha angustata*) and rushes (*Cyperus laevigatus*) follows and this may even gradually spread on to good arable lands. With water-logging, increase of alkali in the surrounding lands is a matter of time.

One should expect to encounter these dangers in the dry zone much more than in the wet zone for the following reasons: In the wet zone, on account of the even distribution of rainfall over the year the natural drainage will have established itself to deal with a perennial flow. Under these circumstances there will be little chance of over-irrigation (if irrigation is necessary at all) and even if it occurs it has very little bearing on the subsoil water table. There will be no significant variations in its level. On the other hand rains are periodical in the dry zone, lasting for about four months at a time. Under these conditions the formation of drainage lines will not be so well defined. Consequently, a good deal of the run-off will collect in depressions and furrows of a rugged terrain. A rise of the water-table is inevitable. During the rest of the year drought conditions with extremely high temperatures and low humidity exist, resulting in heavy evaporation of soil moisture from the surface. A fall in the water-table follows. With this the surplus water collected in depressions, &c., disappears. Whenever an irrigation system is established in such an area without proper drainage ground-water rises, thus upsetting the balance maintained previously under natural conditions. A fluctuation of the water-table occurs which causes the drawing up of soluble salts to the root regions by capillary action—danger No. 1. As the ground-water approaches the surface deeper plant roots get surrounded with water containing a high percentage of mineral salts, assimilation of which is disastrous to plants. Apart from this, roots do not spread in soils where the moisture content is persistently above field capacity. This limits the feeding area of roots with permanent injury to plant—water-logging—danger No. 2. (Field capacity may be defined as the maximum moisture content to which a soil can be wetted under action of gravity in the field).

When these points are considered the importance of efficient drainage in irrigation schemes cannot be overlooked. Partial abandonment of once fertile lands owing to bad drainage is not rare. Drainage of agricultural lands is as closely linked with it as irrigation. And it is impossible, in any irrigation project, to predict the adequacy of natural drainage of the area embodied within it. In this country where a survey of the subsoil water-table or observation of its behaviour under irrigation is considered to be of secondary importance in the preparation of a project, the question of artificial drainage to supplement the natural system must be studied with the channel layout. The effect of bad drainage on plant life will not be perceived during the early life of a project. The explanation of this is that, though the soil in the lower regions of a water-shed may be quite porous, underlaid with light soil and subsoil water far below the surface, yet with the introduction of irrigation and heavy cultivation weathering of soil particles and decay of organic matter will take place with a consequent increase in clay, humus, and organic contents of soil. The tendency of these changes in the soil is to change its permeability which in turn affects subsoil flow. Then excess application of water—an evil to which cultivators are often addicted to in new clearings—together with periodical rains will often render the drainage conditions inadequate and inefficient to deal with the increased water under new conditions. This means that a process of soil deterioration will set in and gradually a new regime will be established in the same way as one was established before irrigation was started. Unless the natural conditions are unusually favourable, water-logging is inevitable in continuously-irrigated lands. In the first instance it will appear in the low-lying areas and as time goes on it will spread to higher regions also.

There are few irrigation systems where natural drainage should not be supplemented by artificial drainage, and the expansion of an irrigation system may ultimately require a complete drainage system. When much attention is not paid to proper land development, the necessity for effective drainage will be felt in a considerably short time. A complete drainage system is not going to overcome water-logging nor the alkalinity of soil entirely. Preparation of lands too must be done in such a way as to facilitate easy drainage when required. Sporadic clearing, ridging, and levelling and the non-observance of any approved plan or method can be considered as factors that accelerate the process of deterioration. Unscientifically prepared lands consume more water than those prepared according to a recognized method. The surplus water taken by the former must find an outlet and, if no drainage facilities are provided, unfavourable soil conditions will be established.

Methods of preventing water-logging.—The first step to be taken in the prevention of water-logging is to discourage waste of irrigation water. It can be done by correct " asweddumizing " with substantial ridges following contours against " fall of land ". In partly-developed lands every effort should be made to keep waste water from flowing into the undeveloped areas as surface run-off. If it cannot be avoided then temporary drains must be cut to drain them or early steps taken to cultivate them. In preparing lands the method of applying water to each field depending on its configuration must be settled first and should precede all other operations. And into this method waste-water drains must be incorporated which should be capable of draining into a field channel lower down ; if this is impracticable, into a natural drainage line. Surface waste should never be allowed to find its own outlet.

Depressions and pockets that are always found in large tracts must be filled up in the process of levelling. If this is too expensive then they should be converted into receptacles for waste water linked with a natural drainage line by a drain connecting with an effective out-fall. This is very necessary to control its water level according to requirements. Below every block of fields, however small they may be, a waste drain must be provided. Any water flowing into this from its fields above can be directed into a field channel lower down for redistribution. Such a procedure will reduce wastage to a minimum.

Over-irrigation should be discouraged. It could be done by adopting a system of rotational issues, *i.e.*, each block of fields should receive water for 3 or 4 days in the week only. Such a method of issues will help to drain any surplus water in the soil. Also it is a good practice to rest tracts of fields periodically during the dry season. This is a method practised by small cultivators under village tanks ; though they may not know the scientific significance of it, yet they follow it regularly more or less by instinct.

To help in the correct functioning of and guidance in the above methods there must be laid down a main system of drainage in the scheme which must be cut and maintained with the same efficiency and in the same condition as irrigation channels. Apart from natural *drains* there must be ditches to receive waste or surplus water from main channels, distributaries and field channels. Such channels may be either obvious drainage lines, cleared, graded, and maintained in good order, or natural water-courses, or a series of depressions used as small collecting ponds but linked to a natural stream so that their water level may be controlled. Where artificial channels are required they should be located between two parallel water-sheds and led into the main drainage line. Such improvements are always necessary to supplement the natural drainage of an irrigation project. It is on the efficiency of the drainage system that the preservation of the soil conditions depends and not so much on the irrigation system. Irrigation is required only to help the plant to wrest its food from the soil.

The local practice of putting in two crops of the same kind twice a year under intensive irrigation without rehabilitating the soil by the application of some kind of manure must also be discouraged. It is not only bad agriculture but also uneconomic expenditure of productive labour which if directed into other channels may give a better yield. If the natural factors are such that rotational crops cannot be raised in the area, then at least rotational resting of the fields must be adopted. In all cases this must be in the dry season. It must be remembered that of the water applied to a field only a fraction is used up in plant transpiration and evaporation compared to the amount absorbed by the soil. This water must be provided with an outlet so that by its prolonged "stay" it may not affect the soil condition.

In the foregoing pages drainage of surface flow has been dealt with. The next problem is to deal with subsoil flow. Before any particular method is decided upon, a thorough knowledge of the soil profile of the affected area must be had as the subsoil flow is dependent on the substratum. If this is not pervious, water will collect dangerously too close to the feeding area of roots on the impervious soil and finally may form into a "secondary water table". On the other hand if the soil has a porous substratum within a reasonable depth the percolated water will pass this and finally flow beyond the reach of the roots. If the substratum is composed of sand or gravel fairly deep (of which the capillary power is low) there is no chance of the soil becoming alkali by this process. Soil profiles of this formation are easy to drain and reclaim. Seldom will these be subjected to water-logging or turn alkali. Light soils form a natural subsoil drain and also act as a cut-off preventing the soluble salts from coming up by capillary action. All the troubles arise when the substratum is impervious within an effective depth of about 3 to 4 feet. Such lands are difficult to drain and the necessity to provide an efficient system of drainage, if the area is to receive irrigation, cannot be over-emphasized. Generally speaking the subsoil water-table may be disturbed by the following causes (*a*) percolation from irrigation works and over-irrigated fields, (*b*) rainfall, (*c*) impervious subsoil formations, (*d*) perennial irrigation. Rain by itself is not harmful but with the other causes will alter the regime established under natural conditions.

Subsoil flow too is dealt with by a system of drains, open or covered. Of necessity these drains must be sufficiently deep to keep the required depth of soil free from excess of water. It will be found that these drains are required much deeper than those excavated for surface drainage. There is no hard and fast rule whereby the depth could be fixed. This depends entirely on the individual characteristics of the area to be drained. However, the following points must be considered in deciding on the depth of drains: (*a*) soil formation, (*b*) depth to which injurious salts are present in the soil and their movement with irrigation, (*c*) method and type of irrigation to be adopted, (*d*) types and nature of crops to be grown, (*e*) possibility of clear out-falls.

The need for covered drains depends on the cost of land to be reclaimed, cheapness of materials required for their construction, comparative costs of maintenance of open drains and covered drains, and finally the purpose for which the reclaimed land will be used.

In this article I do not propose to give the constructional details of various types of drains but I hope to do so in a subsequent article.

Lands already water-logged can be made arable by the provision of an effective system of drainage, both surface and sub-soil, as explained above. In a very short time paddy could be grown in lands so claimed even if the soil is not entirely free from salts which may have been formed with water-logging. According to Tamahane of the Department of Agriculture, Bombay, "Rice is almost the only crop which has sufficient resisting power against salts. Rice requires a clay soil and a large amount of water which dilutes the salts to a considerable extent, thus helping the successful growth of rice in such lands".

Reclamation of alkali lands for crop production is very expensive, often beyond the resources of a local peasant. Methods of reclamation may be grouped into three classes (*a*) physical, (*b*) removal, (*c*) chemical. Under (*a*) where salt has appeared on heavy clay soils it could be removed by "washing the surface" by frequent flooding and then deep cultivation so as to bring the subsoil to the surface to be mixed up with the top soil. This will render the original heavy soil more workable and will improve its permeability. As time goes on surface salts will be dissolved and leached out.

Another method is to give the soil an application of lime and heavy doses of farm yard manure followed by intensive cultivation. Dosage depends on the quality of the soil to be treated. The principle underlying this method is that farm yard manure and lime helps to convert the sodium salts into sodium bicarbonate which is easily leachable and can be drained off. Large areas of heavy clay soils in Hungary have been reclaimed by this method.

A third method—which is more or less designed to preserve soil condition—is to prevent moisture evaporation from surface soils. Evaporation concentrates the soluble salt contents and this is further increased by the replacement of moisture from the subsoil by capillarity. This moisture often brings up with it soluble salts which accumulate on the surface. It could be prevented by shading, mulching or hoeing of the soil. This method is especially successful in orchards where, apart from preventing the deterioration of soil, it helps to conserve the moisture for the crop.

Under (*b*), leaching of the salts into the subsoil and then draining it off is the most common practice. This is done by dividing the area into suitable checks by means of earth ridges, filling the checks with water and then allowing it to stand so that the water percolates to the subsoil. In its downward movement the salts will be dissolved and taken to the subsoil from where it can be removed by deep drains or below the limit of capillarity. This method to be successful the following conditions must be obtained:—(1) A certain degree of permeability, (2) adequate supply of water, (3) water table below limit of capillarity.

A second method is to cut a system of drains so as to lower the subsoil water below the root regions and thus effectively drain the soil together with soluble salts in it. It is not always possible to restore soils to its original state by draining. However, it may improve with cultivation. If the injury to the soil had been caused by sodium salts (sodiumization) reclamation is difficult because, after a certain limit, the presence of sodium salts make the soil impervious and retards movement of water so that the salts cannot be removed entirely. In fact, based on this characteristic of sodium soils, a method has been evolved in India to stop seepage from irrigation channels—known as the sodium carbonate treatment.

If it is further desired to reduce this limiting salt content (0·4 to 0·57 per cent.), heavy doses of farm yard manure should be given at the rate of about 10 tons per acre. The theory is that farm yard manure liberates free carbon-dioxide in the soil which combines with sodium carbonate to form sodium bicarbonate which is easily leachable. Then if the soil is flooded the sodium salt can be washed into the drains. According to Dr. Mackenzie Taylor of Punjab, if paddy is cultivated on soils so treated the soil further improves owing to the action of carbon-dioxide, liberated from the paddy roots, on sodium carbonate which is converted into leachable bicarbonate.

In the chemical treatment of alkali soils the use of the following materials have been experimented upon with varying results: gypsum, bauxite decomposed with sulphuric acid, sulphur, hydrochloric acid, and acetic acid. These processes are expensive, and for us in Ceylon they are only of academical interest. Therefore it is proposed not to discuss them here.

In conclusion it may be mentioned that alkalinity in soils is the worst enemy of agriculture. And unless early measures are taken either to prevent accumulation of salts where it has appeared in small quantities or where it is likely to appear in soils free from it, reclamation later on will prove extremely expensive and difficult. It is an "enemy of agriculture" which can be easily defeated by adopting simple tactics if its presence or its possible appearance is noticed early. It must be remembered that drainage helps the cultivator to get better crops which is the dominant factor contributing towards his prosperity and well being.

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