Notes on Erosion and Its Counter-measures

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Contents

Nature and Erosion Control

1. Erosion Cycle

Nature is constantly in a state of motion. The surface of the earth is always changing. Although on the whole very slow in taking place these changes sometimes are rapid and great in some localities. High mountains are created by the earth mass movement and later they are graded down by weathering and erosion. The topographical degradation is called "erosion cycle" by Prof. DAVIS of Harvard University. Landslides, landcreeps, mudflows and all kinds of other movements of weathered materials are only accidents in the erosion cycle. When the above movements threaten mankind, they are called "natural disasters."

The degradation does not always cause disaster ; it sometimes proves favorable. For example, the fertility of the Nile delta in Egypt is a contribution of the erosion in the upstream region. "Hanshin" district between Osaka and Kobe, one of the famous groups of cities in Japan, has been developed on neighbouring many fans formed along the foot of Mt Rokkō. Even good forests stand on deposits of mud and debris.

In ancient periods when our ancestors lived with nature, they did not suffer from natural disasters as we do now, because primitive men followed nature's will. At least they made their dwellings outside of dangerous areas. As population increased and scientific knowledge developed, men began to utilize nature and invaded areas where natural disasters might occur. They did not anticipate periodical natural happenings or, when they did, the probabilities of the happenings taking place were estimated to be very small. Worst of all, some men were short-sighted in seeking to make temporary fortunes. Civil engineering projects and reclamation measures were nothing but artificial deformations of natural topographies which were indirect or even direct causes of erosion. Also cutting of forests for fuel and construction was a strongly contributory cause of erosion, if it exceeded the allowable limit.

In short, we are exposing ourselves to danger by

(i) living in areas where the movements of sand and debris are likely to happen.

(ii) following ways and means which accelerate erosion cycle.

These bad practices are due to our ignorance or neglect of natural laws. If we wish to be out of danger, we should not live in places mentioned in (i) ; and we need to prohibit acts mentioned in (ii). In actuality, however, since the population increase necessitates (i) and (ii), we have to take some positive measures to control or mitigate the possibility of natural disasters, that is, erosion control.

2. Naturalism or Anti-naturalism ?

Japan has a long history of erosion control. Old Japanese were naturalistic in repairing denuded hillsides. The principal part of the work was tree planting. Since the European way of stream control was introduced in the earlier part of Meiji Era, civil engneering erosion control methods prevailed very extensively. The expenditures spent by engineers were much greater than those by foresters. Many people had the belief that building check dams was the only effective measure which could protect us from flood disasters. Anti-naturalistic opinion was supported by not a few scientists.

After the recent war, however, we have had successive, terrible typhoons. Heavy rains brought by these typhoons have caused repeated floods. It should be remembered that reckless cutting of forests during the war time has contributed greatly to flood ravages. A number of engineering constructions were destroyed showing how small human power was compared to natural force. What happens then ? Most people are very simple in changing their opinions. Now they are naturalists again shouting loudly, "We should come back to nature and plant trees."

The naturalistic method of erosion control has been supported by some specialists even during the period of anti-naturalism. This writer also was one of the naturalists who tried to systematize the erosion control theory in a purely naturalistic way. In doing so, he encountered many difficulties and in the end he found it impossible to make every plan of erosion control entirely subject to natural laws. This, however, does not mean anti-naturalism or overrule of nature. It means that pure naturalism cannot be applied in maintaining our modern civilization which has already been developed and is existing against nature in many ways.

Let us take a city which has frequently suffered from flood. It is understood that the basic cause of inundation is attributed to the expansion of the city over the old river bed. Should a part of the city be moved out of the old river bed, it would be the best measure to avoid disasters. But the actual situation makes impossible this evacuation from the standpoint both of economy and love of land. Now if we do not like the retrogression of our present civilization, some positive measures should be taken to protect ourselves against natural disasters. Levees, reservoirs, check dams and hillside repairs are ways which can change or control the natural erosion cycle. Strictly speaking, there are on the earth only a few districts that have not been touched by humans. Most of our lands, especially productive lands, have lost their original features. Therefore, we can hardly go along with the natural movement. Some foresters say that by planting trees and making good forests we can reduce the speed of erosion which has been accelerated by human mis-use of land. But, the problem is not so simple, because we can not

estimate how much the natural erosion cycle has been hastened by humans.

3. Harmony between Nature and Human Efforts

Again we repeat that our present civilization does not want to go back to the stage of thousands of years ago. We must therefore protect our daily lives against natural disasters. But, in doing so, we cannot fight against nature. Human power is much weaker than nature's power. What should we do, then? Harmony is the only answer. To harmonize human efforts with nature we should know the laws of nature.

It has often been said that the development of science has made mankind more and more anti-naturalistic. This is not always true. The more we know about natural science, the better we understand nature. As we study and learn of the enormous energy of nature, we find it silly to fight gainst nature. The only thing we can do is to guide the erosion cycle in such a way that it gives us as little misfortune as possible. Our knowledge of natural science is still imperfect. We know but little about complicated natural phenomena. It is often reported that some large engineering structures are damaged in spite of plan and execution by excellent specialists. These are the proofs of the insufficiency of human scientific knowledge.

When we are convinced of the limitation of our ability, we have to be prudent. Over-estimation of human power should be forbidden. It is important for us to know that the less we do in changing natural features, the less punishment we receive when our plan does not fit nature's will. The general public is not so generous as to overlook the breakdown of disaster-prevention projects. From this we might say, "Plan in such a way that natural features are changed as little as possible." Low check dams are preferable to high ones. It is not wise to carry out too elaborate grading on denuded hillside. Generally, the spending of too large sums on a single construction or for a small area should be avoided in view of the fact that, though we may aim well toward a certain preventive goal by spending much money, our expectation is often betrayed by the ever changing natural phenomena. It is better to be thrifty in carrying out the first trial of the plan and to wait for some period of observing natural changes carefully. When necessary, additional steps of the plan should be carried out and then there should be a period of waiting again. Following this plan we would be able to give the least change to nature on the one hand and to save much expense on the other.

Erosion control of today can not be purely naturalistic; however the effectiveness of anti-naturalistic efforts does not last long. Only efforts well harmonized with nature, even if they are simple and small, can exist forever.

Does a Forest Give Unfavorable Influences ?

If so, it is foolish to spend large sums for planting which take a long time before yielding profitable results. Nowadays some people (even some scientists) have an opinion that some forests accelerate the possibility of natural disaster. Setting this problem aside for a while, let me stress the importance of propaganda for carrying out a country-wide planting program.

The forest is like water or air. Its benefit is beyond human conception. Most

people have believed in its protective power against natural disaster, but they have been idle in carrying out any real planting program. Far-sighted leaders of Japan have made great efforts in demonstrating the necessity of forests. We have many proverbs, such as "A mountain is noble not because it is high but because it has trees." Why hasn't such a program of planting been considered important ? The answer is quite simple. The method of propaganda has been old and lacked vigor and imagination.

Extensionists in the future should study ever-changing new methods of demonstration. They should be like ministers of Christianity but not priests of Buddhism. The general public knows the value of forests. An ordinary lecture will not attract people. Repeated old stories, however true and good they may be, will only cause people to turn a deaf ear. The effective way to present fresh and attractive propaganda is to tell newly-found truths about forest influences. Many a forest scientist is looking for new facts, but epoch-making discoveries are quite few in number.

Nevertheless, extensionists are forced to have new stories to show the importance of forests. Here, let us come back to the first paragraph of this paper. It is true that in these days not a few people are listening to unusual opinions of "unfavorable forest influences." If we can contradict these opinions they will be used as data to prove forest benefits. Some examples will be shown below.

(1) Forests increase flood quantity.

A heavy rain is usually followed by a heavy wind. Rain water retained by tree crown is blown down on the ground causing the increase of runoff, or flood quantity. The above opinion was once given by some forester. The explanation seems somewhat scientific and it is true in certain differential parts of a forest.

Now I wish to ask the following question : Does a heavy wind blow over a wide area at a time ? Any wind has a wave. When some parts of a forest are suffering under heavy wind other parts are resting. Retained rain water falls in the former but rain is caught in the latter. When a tree crown loses rain water retained on it at a given moment, it begins to catch rain at the next moment. As a result, during a period of considerable time and throughout an area of considerable size, the increasing ard decreasing effects on runoff are canceled.

(2) Forests decrease low water level.

When red pine forests grow on hillsides, irrigation reservoirs have less water. This has been a serious problem in Okayama prefecture. There they have little rain, annual average being about 1,000 mm. Soil condition on hillside is poor composed of weathered granite or liparite which is the most unfavorable rock for water conservation. Extreme circumstances some times produce exceptions. Before giving a conclusion, we have to think this situation over again.

How do they measure the water storage ? Without exception a water gaging rod is used. In other words, they measure water depth. Then, if a reservoir gets silt and bottom level changes, the depth of water observed by gaging rod does not give the correct amount of water. The more siltation, the less water for the same reading.

When a hillside is bare, much silt comes down. It causes the rise of the reservoir bed. Then, the gaging rod gives a larger depth. On the contrary, when a good forest cover is established on a hillside, less silt is produced and the rise of

the reservoir bed is very slow. In such a case, a comparatively low level has a comparatively large quantity of available water. Without more accurate measures, we cannot say which produces more water, a bare watershed or a forest-covered watershed.

If a bare condition supplies more water, it is almost certain that it also supplies much silt. Then, the area of water surface becomes larger and the amount of evaporation is increased. Worst of all, reservoirs loose their water storage capacity much more rapidly. The work involved in taking silt out of reservoirs requires much money. From the economical view point, a forest cover can compensate the weak-point in lessening the run-off, if it exists.

(3) Forested hillsides sometimes slide.

It is true in time of extraordinary heavy rain. It is more correct to say that landslides in unusual rain have a closer relation to soil and underground geological formation than to the difference in ground surface condition, bare or covered.

The forest is not almighty. Its function of preventing erosion has limits. With regard to surface erosion the forest is absolutely effective, but in the worst of conditions, forests sometimes fail to stop deep erosion and slide. Nevertheless, it is true in most cases that land slides are caused when hillsides are cut at their bases. What makes the base cut ? Much running water from bare hillsides does. What is the origin of the base cut ? It is rills or gullies on the bare hillside.

Even though we admit some slides on forested area in emergent climatic conditions occur, we should not forget the immeasurable benefits given by forests while they are standing. Dams and levees in down streams are often broken by flood water. Those constructions occupy large areas of productive farm land and produce nothing. They cannot be compared to forests which have produced timber and other forest products.

It is deplorable that we have spent so little on measures to protect good forest areas which are predicted to be broken in the near future. There has been a considerable amount of money spent for farm land protection. Erosion on farm land results in loss of fertile soil, but erosion on forest land results in losses of forest and farm lands.

Please remember that an inch sheet erosion on a vast bare hillside produces much more silt than ten feet deep erosion on a small forested hillside. However skillfully an explanation might be made, a few exceptional cases can never make a general rule.

Erosion Control as a Counter-measure for Timber Shortage

Depletion of forest resources is progressing all over the world. Japan cannot expect timber import to the extent she could in the past. Self supply of wood materials is one of the most urgent and important problems for us.

Increased planting, proper forest management and more efficient wood utilization are necessary to solve this problem. These measures have been discussed repeatedly for a long time, yet the results have not been satisfactory. Some epoch-making measures should be taken. The control of fuel wood consumption is an item to pay great attention to. In Japan more than two thirds of the total wood produc-

tion has been used in getting heat energy for heating and cooking while the average amount of wood used for fuel in the world is fifty per cent. This situation should be changed.

Considering the present condition of natural resources in Japan, we would say that hydro-electricity is the only substitute for fuel wood. Our greatest resource is rainfall. We are now letting much water flow down in the form of floods causing inestimable damages. It is only natural that hydro-electric dam construction has been regarded as the best measure for both flood control and power production. The more hydro-electricity that is produced, the greater percentage of it can be used for heating purposes thus saving on the use of fuel wood.

The reason why the plan of hydro-electricity production has not been carried out extensively is that some dams do not pay. The water in most rivers carries a great deal of silt which fills up reservoirs rapidly. In order to prolong the lives of hydro-electric reservoirs, their watersheds should be well taken care of. Every exposed ground surface should be covered with vegetation. Erosion control planting in watersheds is the first thing to be done followed by proper management after completion of forest cover.

Well managed watersheds produce more electricity making possible a greater chance to use electricity for heating purposes. The more electric heat energy we get, the more forests, especially coppice, are left uncut. In this way annual increments of forests are increased and forest land erosion is decreased. Moreover, many forests established for the purpose of erosion control can be converted into commercial forests from which we can get timber.

Planting should be carried out on a wide scale.

Some Notes on High Dams

High dams are very common structures for hydro-electric power production. They are also often built for the purpose of erosion control in wild streams especially in Japan, where streams have quite steep gradients. Their primary object is to check sand and stone flow produced by landslides in heavy rain. The designers of high dams say, "This dam can check so many million cubic meter of silt, thus preventing the down stream area from being attacked by sand and stone flow and being covered by deposit". This propaganda has great demonstrative value to the people living down stream. A greater number of people and more well-to-do people live in the down stream area of a river than in the up stream area. Thus, huge constructions get stronger support by the general public. At the same time it is true that large engineering projects have the backing of public works contractors which have a close relation with political parties.

The above being the customary situation in Japan, the general public has had little doubt in spending lots of money for high dam construction. High dams are effective when they are built at the right spots, but a policy of "Nothing-but-high dams" should be abolished. In order to develop more perfect and sound erosion control plans for the future, it is important to impress upon the general public the weakpoints of highdams. The following discussion is also applied to hydro-electric high dams.

(1) A high dam requires large expenditure. It is said that the cost of a high dam is proportional to the square of dam height and even more so when the dam is built on the river bed of sedimentary structures.

(2) When broken, a high dam causes serious damage down stream and its repair requires much money.

(3) Although a high dam checks a large amount of silt, the quantity of the silt can not be compared to the large amount of weathered materials coming down from the denuded watershed.

(4) Where weathering is serious, the function of a high dam is soon lessened under ordinary weather condition, thus showing little or no effect at the time of climatic emergency.

(5) If a high dam is very effective in checking silt from the up stream, there occur severe undercuts along the down stream river bed. Therefore, it is necessary to carry out river bed fixation in order to prevent bank slides as well as to protect the foot of the dam itself. This work requires emergency funds.

(6) A high dam sacrifices a good many acres of productive land and brings about a bad drainage condition in the up stream area. In order to minimize the economical loss, we have to choose a denuded watershed where there is little productive area. Here, however, we cannot expect the dam to last long. If we desire a dam of long duration we have to choose a well managed watershed—that is a watershed covered with good forests. Here, as a rule, we find a great area of well developed productive land drowned under water behind the dam. The above two conditions are contradictory to each other. The only way to remedy this contradiction would be as follows : Choose devastated watersheds where industrial development has not yet been started. Carry out hillside erosion control plans throughout the watershed parallel to the progress of dam construction. It is wiser to begin watershed control with tree planting much earlier than the execution of dam construction.

Idea of the Dam Plain

Erosion is quite severe everywhere in Japan owing to the sharpness of topography and abundance of rainfall. Most rivers have a wild nature. Most streams carry much silt in flood times. Check dams, even though they are built on large scales and have large pockets behind them, are filled up with silt very soon. Even worse, many hydro-electric reservoirs are choked up in short periods. Both check dams and hydro-electric dams are necessary for us, but they require high expenditures.

To clean out the silt behind dams is difficult from the technical standpoint. The larger the dam, the more difficult the cleaning work. Even if this were possible, in some special cases the washed out silt would do great harm to the land down stream. No better way has been found than to leave the dams in silted conditions.

An engineer told to the writer that in the Tennessee Valley the amount of siltation was still negligible about fifteen years after the dam establishment. How is the situation in Japan ? Many reports showing the condition of reservoir siltation indicate much worse conditions than we imagine. It is important to find the means to utilize silted reservoirs for which huge amounts of money have been

spent.

Behind large dams siltation plains of large areas have been established. When the surface of the silt deposit reaches the bottom of the spillway, the water reserving function of the dam is choked. What is the best way to utilize the dam plain ? Let us make a water way to regulate the stream on the plain. By doing so, can we not have farms on the remaining area ? Silt from the up-stream sometimes is quite fertile. If stream control works are established along the newly-built canal as well as in the up-stream, the dam plain could be utilized as pretty good farm land.

When it is predicted how soon the dam is filled up, we do not need to make the construction so firm as we have done in the past. Ordinarily the lateral pressure of silt is smaller than that of water. A dam receiving water pressure for a comparatively short period does not require a very large strength. Thus, to give the construction a sufficient minimum of strength, much money can be saved. This plan does not mean that we anticipate the collapse of the dam sometime in the near future, but it is hoped that it will stand forever. What measures should be taken, then ?

When a dam is filled with sediment, let us make a spillway of a proper size. Then, establish in front of the dam a pair of apron sidewalls. The tops of these walls should have a slope less than 45 degrees. The next step is to move the depositing earth from behind the dam into the front yard of the dam. When the pocket of the dam is filled with deposite, this operation can be easily done with a small amount of expenditure. The only thing to do is to carry the soil to the top of the dam and let it go down in front. When the level of the deposit surface is lowered, it is better to wait for the new deposit. In this way we can make a earthen dam with a strong concrete core in it. While we wait for the new deposit, the dam displays the function of checking sand and debris. It is correct to say that the earthen dam thus established is much stronger than the dam of concrete alone.

Now, the dam plain is given a firmer foundation. Farms on this plain can meet the demand of producing food for the nation. At the same time, the slopes in front of the dam are utilized for tree planting.

Forestry and Stream Works Should Go Together to Control Flood

The principal cause of erosion is heavy rain. However, there is evidence of other direct or indirect causes, which may be classified into two categories :

One is natural cause. Under a stabilized climatic condition, forest grounds can keep thick layers of soil covered with humus and litter. When an unusually heavy rain attacks such a forest area, the thick soil layer absorbs excessive rain water to the saturation point, thus causing land slide. Forest cover can prevent sheet erosion, but it sometimes fails to prevent deep erosion.

The other is artificial cause which accelerates the deep erosion mentioned above. That is the overcut of forest. As a rule, land slides of large scale have a closer relation to geological, topographical and climatic conditions than to ground cover. But it is also true that the removal of trees makes rain water run much faster thus producing rills which are rapidly deepened and widened into gullies. The greater the amount and speed of flow of running water there is in a stream, the severer

the erosion on the bed as well as the sides of the stream. This is an essential cause of hillside sliding. Moreover, disturbed ground surface due to careless lumbering gives the surface flow more chance to intrude into the ground.

Some landslides of large scale as episodes in the geological cycle cannot be prevented by human power. Their energy is far beyond our scientific knowledge. Modern civilization—the development of cities and farmlands—has continuously driven forest areas into steep mountain districts. Foresters have done very little in changing topographical and soil conditions excepting some forest engineering constructions and short sighted overcuttings. As a whole, forestry could be said to be an industry most faithful to the natural law. Therefore, foresters are not responsible for the occurrence of landslides. It is true that we have had landslides from time immemorial. Their frequency is closely related to climatic change. If we could have a statistical record over a very long period, we would find no increase in the frequency of landslides. However, the amount of damage has been increasing. Why ? It is because humans have developed their civilization over areas which are vulnerable to attacks by natural disasters.

According to this writer's investigations, a new theory is advanced as regards the movement of mud flow produced by landslide in many flood damaged areas. Excepting very fine silt, sand and debris of appreciable size are not sent so far down stream as has been generally presumed. They easily deposit where the stream widens out. At the mouths of the valleys we often observe well-formed bebris fans and a little siltation on the paddy fields down below.

When forest land slides, the mud flow carries much timber thus increasing its destructive force. The floating timbers sometimes are stopped by piers of a bridge and dam up the running water, causing inundation. From this, the value of forests is disputed by civil engineers. But, it is doubtful that the timber carried down a long way with debris and bowlders can keep such big crowns and roots as easily stopped by bridge piers. Are most of the harmful floating timbers not those produced by side erosion in the plane field ? A precise investigation is desirable in the future as regards the source of floating timbers.

In conclusion the following summaries are proposed. To keep forests in good condition, the avoiding of destructive overcutting is the most important measure for erosion control as well as economical stabilization. Good forest covers will prevent flood damages under ordinary heavy rains. However, we should not forget that there will be some landslides on forest areas under extraordinary heavy rains, although the frequency is very small. Even in districts where no flood damage has taken place for a long period, the people should always be prepared for natural emergency. It is true that in Japan there is no place absolutely free from natural disasters in the long run. The main thing to do is to keep their forests in healthy condition, otherwise they will suffer under rains of ordinary intensity with no question about heavy rains. The erosion control works in wild streams are effective to some extent. Their function is strengthened by good conditions of forests in the watersheds.

If we desire to lessen the destructiveness of unavoidable natural disasters which happen rarely, the writer recommends a seemingly drastic measure as follows : That

is to utilize widened parts of stream channels or small delta plains in mountains as sites for stopping or checking mud flow. In many of these areas there live villagers with small acreage of farm land. The sacrifice of such sites will benefit more highly developed and industrialized villages, towns and cities located down stream. If it is natural that we must have some landslides and resulting mud flows in the course of many years, it is also natural that some mountain villages will suffer damages.

The recent development of reclamation measure in mountain villages should be said to be short-sighted. Because if reclamation is carried out on steep hillsides, it accelerates erosion and increases the mass of mud flow. When delta plains are reclaimed, newly established paddy fields must be protected by levee works. The levee works together with channel regulation works will offer a smooth passage to mud flow. Thus more valuable lands and other properties downstream will be lost. From the national view point it is much wiser to stop mud flow at places as far upstream as possible. By doing so the damage loss can be minimized and the government can save money that will need to be spent on repairing.

The Budget Should Be Elastic for Erosion Control

Erosion control is one of the efforts being carried out in places where the geological cycle is proceeding very rapidly. The ground surface is always moving on eroded hillsides and river beds are always changing in wild streams. These are the fields where erosion control measures are being carried out.

It is a great mistake to expect the absolute control of natural phenomena. We can follow the natural law, but we can never overrule natural progression. When we build some projects on hillsides or in streams, "will-be-established" conditions are always different from what we expect. For example, even carefully graded slopes or well made terraces will have some rills, big or small, after some heavy rains. High check dams, although they check a considerable amount of silt behind them, often cause undrained floods upstream as well as river bed and bank erosion downstreams. Thus, the resulting conditions do not meet the expectations in the plan.

We should always watch the changing conditions of nature after erosion control works are carried out. If there is found any unexpected sign of destruction on the field, it should be remedied as soon as possible. Otherwise, small rills on a repaired hillside sometimes grow into big gullies owing to the softness of cut soil. As regards a check dam, care should be taken not to cause down cut at its front base. This is a very common situation because the water increases its erosive power after it deposits behind the dam most of the sand and debris it has carried down. An auxiliary dam should be built without delay in order to protect the dam for which much money has been spent. "An ounce of prevention is worth a pound of cure."

Any government project has a year's budget. For erosion control measures the budget includes only enough funds for the completion of certain projects, but little or none for supplementary needs. From the nature of erosion control measures, the budget should be large enough so that certain projects can be completed but also so that emergency needs can be met even though they occur some years later.

There is a way to request special funds for repairing once-completed works. But

ordinarily it takes a long time, and the natural destructive forces are not likely to wait until the budget is given.

In short the budget allocation system should be more elastic in meeting public works needs such as erosion control.

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