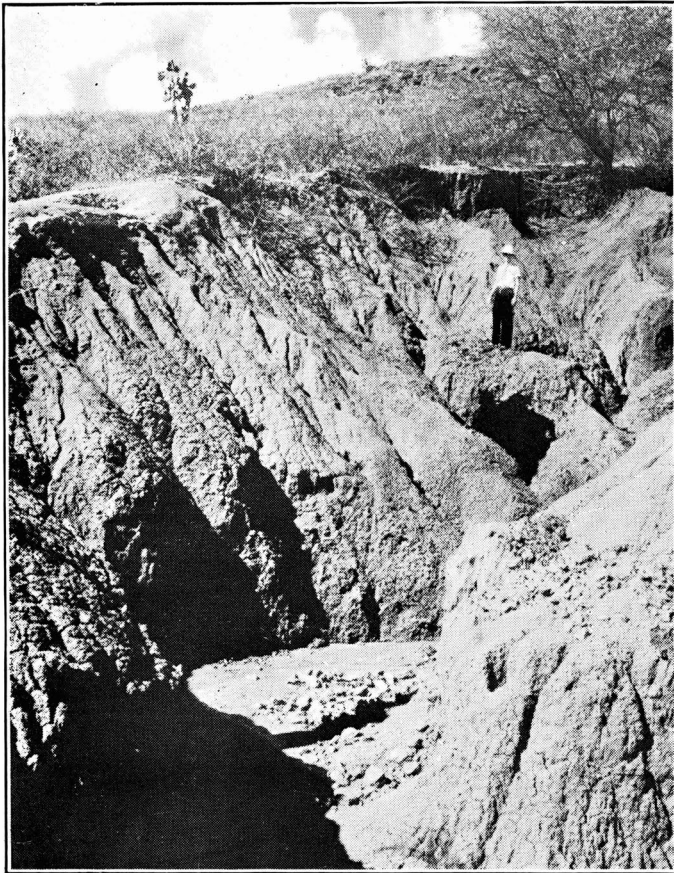


THE PROBLEM OF SOIL SAVING IN THE HAWAIIAN ISLANDS



A New Gully in Pasture Land

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TABLE OF CONTENTS

President Roosevelt on Soil Conservation.....	4
Summary	5
A Recommendation	5
Present Soil Conditions	
Definitions	7
Damage From Gullyng	8
Soil Losses Costly	8
Erosion Injures Others	9
Erosion In Grazing Land.....	9
History of Erosion	10
Causes of Present Erosion	10
How To Prevent Erosion	
Helping Rain Water To Soak In.....	13
Regulating Surface Run-off	14
Ditches To Catch Run-off	14
Tree Planting To Check Run-off	15
Broad Base Terrace	15
Laying Out Plant Rows	20
Control Of Gullies	22
Tree Planting To Control Erosion in Grazing Land.....	22
Using Erosion	25

President Roosevelt on Soil Conservation

Extracts from the address of President Roosevelt at the opening of the Governors' Conference, May 13, 1908.

"We began with soils of unexampled fertility and we have so impoverished them by injudicious use and by failing to check erosion that their crop producing power is diminishing instead of increasing. In a word, we have thoughtlessly, and to a large degree unnecessarily, diminished the resources upon which not only our prosperity but the prosperity of our children must always depend

"The son of the farmer of the past moved on to new land The son of the farmer of today must make his living on his father's farm. There is no difficulty in doing this if the father will exercise wisdom. No wise use of the farm exhausts its fertility"

SUMMARY

Prevention is better than cure, hence a part of this bulletin is devoted to the harm done by erosion to the land itself and to the consequent loss to land owners. Some space is taken up by a consideration of ways of preventing erosion in agricultural land, on the theory that it is better to save farm land now than to plant trees on waste land. The methods of saving the top soil include better tillage, the use of cover and green manuring crops, broad base terraces and the laying out of plant rows and ditches in such a way as to handle surface runoff more effectively.

Erosion in grazing land can be prevented by planting grasses, forage plants, shrubs and trees.

The more extensive use of trees and brush, in soil binding and in catching soil to build up land, is worth considering by landowners.

A RECOMMENDATION

In many European countries, it is a well established principle supported by law that no man has the right to misuse his land. This policy is based upon the fact that land, especially fertile agricultural land, is held as a trust that must be passed on to our descendants as we, in turn, received it from our forefathers. The State should regard this as the first duty of the landowner. Those owners who impoverish their land are unfaithful to this trust and, therefore, are enemies of the State. This idea may be new to many, but until every landowner adopts this policy, the agricultural area of Hawaii will become smaller and smaller, as it has in many another region where there was no definite land policy or no strong public sentiment against the waste of the top soil.

Present Soil Conditions in the Hawaiian Islands

Definitions. Erosion is the process by which soil from weathered rocks on slopes is carried down hill and dropped along stream banks and at the mouths of streams. In nature, this process is very slow because the trees, ferns, plants and the dense mat of grass, which cover the ground, protect the soil from washing. When man removes this soil cover and loosens the surface by plowing, or turns his stock loose on mountain sides, then erosion becomes destructive. It is this unnecessary and destructive erosion which will be considered in this bulletin.

The two forms of erosion most often found on farm lands in the Hawaiian Islands are sheet erosion and gullying. Sheet erosion is the washing of soil from the surface of the field or slope. It takes place on overgrazed pasture lands as well as on other land, plowed or unplowed, that is without a dense covering of plants. The amount of erosion during a storm depends on the looseness of the soil, the intensity of the rainfall and the steepness of the slope. The loss of soil, whether much or little, is permanent.

Gullying is caused by water flowing downhill in channels, with enough force to make the channels deeper and wider by washing away the soil. Gullies start wherever there is a stream of water flowing over ground, such as in furrows plowed downhill, in cattle trails, in wheel ruts of dirt roads, and where water draining from pineapple fields, from roads, or overflowing from ditches, flows down a hillside.

Sheet erosion does the following things to farm land on which it takes place:

1. It washes away much of the fertilizer that the farmer may have put on the land.
2. It washes away fine soil particles which contain minerals needed by the plants.

3. It removes humus from the soil. Humus is made up of fine particles of rotted plants. It is an important plant food and is a valuable aid in keeping soil porous. Its loss, therefore, injures the soil in two ways: First, the best of the soil itself is washed away, thus leaving the land unfit for farming. Second, water which at one time soaked into the humus soil is lost on eroded land through rapid run-off. That means that the crops on eroded or "thin" land do not have enough soil to grow in nor enough water to keep up any growth that may have been made.
4. Eroded land gradually becomes less suited to produce vegetables and crops and fit only for the coarse weeds and shrubs that take possession of the land.

The Damage from Gullying. The damage that gully-ing does to land can be easily seen.

1. The gullying, slight though it may be, which is found between rows of plants, injures the land by removing soil.
2. In addition, it injures the crop by exposing the roots and the soil around the roots to the drying action of sun and wind.
3. Small gullies hinder the cultivation of the soil.
4. Large gullies break up the land into irregular patches that are hard to reach and are often too small to be worth farming.
5. Large gullies also break up the sheet of underground moisture in the subsoil and hasten evaporation, making the area between gullies dependent on rain for the moisture needed by the crops.

Soil Losses are Costly. A farm that was valued at \$50,000 twenty years ago was recently sold for taxes because erosion resulting from reckless cultivation and poor farming methods had removed so much of the top soil as to make the land worthless.

The common way of judging the farm land is by the value of the crops raised on it during a year. Another way of fixing the price of a thing, say of a house, is by finding out the cost of making another like it. If a man tried to make his farm as good as new by hauling fertile soil and spreading it six inches deep, the top soil would cost him a thousand dollars an acre.

The farms on the slopes of Mt. Haleakala, which supplied the California miners in 1849, and for years after, with wheat and potatoes, have for fifty years been unfit for agricultural crops and are now used as grazing land, because of soil losses. In almost every section of the Hawaiian Islands erosion is causing similar soil losses.

Erosion Injures Others. The loss of the top soil from a farm injures not only the farmer, but it also injures the entire community. The soil that is washed off the farm land is taken down into the lowlands, and, as the stream loses its force, the soil is dropped here and there, doing great damage.

1. The stream bed is filled with gravel and stones and, lower down, it is choked with sand and silt. The stream bed is then too full of dirt to take care of flood water and, therefore, in times of flood, the water cuts a new channel through farm land, overflows its banks and deposits a foot or two of sand and gravel on top of valuable farm land. Over night, land worth \$200 or more per acre can be made absolutely worthless, through no fault of the owner, because other landowners somewhere up stream have plowed their land with furrows running downhill.
2. The flood water that once was safely carried by the stream before erosion started now destroys crops and irrigation ditches and delays agricultural operations.
3. Bridges and culverts once large enough to handle floods are now too small and, as a result, roads are damaged or made impassable.
4. Fish ponds that have been used for centuries are filled with mud brought down from farms that are losing their top soil.
5. The mud deposited in Pearl Harbor has killed the oysters that gave the harbor its name, and recently introduced oysters have also been killed by the mud.
6. Many beaches that were once firm sand are now too muddy for bathing.

Erosion in Grazing Land. Sheet erosion and gullying also occur in land that has been overgrazed. The forage plants are destroyed or have no chance to spread or to ripen seed and, as a result, the surface of the soil is left

bare. Sheet erosion is inevitable, and advanced stages of sheet erosion produce innumerable gullies. In addition, the cattle trails during storms become water courses and then gullies.

History of Erosion in the Hawaiian Islands. Several years ago someone opposed a tree planting project to save the soil of Kahoolawe, giving as his reason that the soil on this island had been blowing away for ten thousand years and he could see no reason to worry about it at this late date. There was little erosion in the Hawaiian Islands a hundred years ago, before the spread of cattle to all the islands. The disappearance of forests, following the inroads of cattle and goats, exposed the soil, and in a few years there was very serious erosion on a large scale. Both forests and the loose forest soil disappeared. Then springs dried up and people were forced to abandon their taro fields. Today, water must be piped for miles to supply the cattle grazing on former taro patches.

During the last thirty years the establishment of forest reserves has led to the exclusion of cattle from most of the steep slopes that were forested at one time. For the last fifty years extensive tree planting by corporations, individuals and the government has steadily improved soil conditions in the forest areas.

Causes of Present Erosion. In the agricultural regions much remains to be done if the top soil is to be kept on the land.

The fields of sugar plantations have been laid out for irrigation and, therefore, erosion is not a problem on cane lands, but the erosion on lands of others is causing trouble for cane plantations because mud from these higher fields chokes irrigation ditches and fills reservoirs. Erosion is far too common on land not planted to cane, and in some localities little effort is being made to prevent it. There are several reasons for this state of affairs.

1. Failure to understand just what agricultural land is, namely; "land which for a long term of years will produce profitable crops by proper farming methods."
2. The chief cause of erosion, according to J. Russell Smith, author of "Three Crops, a Permanent Agriculture," is the custom of using on hillsides and on sloping lands the methods that have proved valuable on the level lands of the valleys.

3. The red soil found on Oahu and on some of the other islands is unusual in that it can be safely cultivated on slopes that are too steep for the cultivation of other soils. Many farmers, not knowing this, have adopted the methods of the pineapple growers who occupy these tenacious soils. The farmers failed to notice that most pineapple land is plowed deeply and is subsoiled in three directions, and they did not see that even in this kind of soil, erosion is forcing the abandonment of steep slopes formerly planted to pineapples. As a result, top soil is being washed off many slopes that should have been kept in grass or should have been cultivated more conservatively.
4. The cultivator of the land, in many cases, is merely the holder of a sublease. In some cases, two or more subleases are in force, thus leaving the occupant of the land without any sense of responsibility to the owner. The result is the cultivation of every foot of land that can be reached. In some cases, land was plowed with the avowed intention of abandoning it after the second crop had been harvested.
5. Faulty lease contracts encourage the misuse of land. The average lease contract follows a fixed form which the lawyer prescribes and one which has proved very satisfactory in the country of its origin, but which is entirely unsuited to Hawaiian conditions. Some of its terms have no application in Hawaii and, as a result, the tenant is legally able to do as he pleases with the land and the owner has no redress. Each lease contract states that the tenant shall cultivate the land according to good farming practice. The lease contract also forbids the tenant to commit any waste. The word "waste" is of no value in so far as it applies to soil erosion in the Hawaiian Islands, because mainland courts have ruled that a tenant is not guilty of waste if he follows the usual farming methods of his community. In other words, if the tenant can show in court that his planting pineapples downhill is the usual way of setting out pineapple plants, then he is not guilty of waste, even though all the soil has been washed away. It, therefore, is necessary for the owner to decide what part of the land should be cultivated, and what portion should be left in grass or brush, and how the land should be cultivated. He should be

very careful to specify how the rows of plants should be set out and to name the grade of the drainage ditches in the fields, as well as the distance between ditches. The lawyer is not supposed to know anything about farming or soil erosion. All that he is expected to do in drawing up a lease contract is to prevent errors and misunderstandings and to put into writing the points upon which the owner and tenant are agreed. The owner, therefore, and no one else, is to blame if he fails to include in the lease the terms which will protect his land from soil losses.

How to Prevent Erosion

The Soil Keeps the Farmer Who Keeps His Soil. There are two ways of preventing erosion. One is to help the soil soak in as much rain water as possible. The other way is to lead the excess water slowly to a prepared channel where it can do no harm. Both of these are used together to get the best results.

Helping the Rainwater to Soak In. There are several ways of helping the rainwater to soak into the ground.

1. In pasture land and in fallow land, the land should be covered with a dense mat of grass or another cover crop. This simple precaution is neglected on many slopes used for grazing, with the result that erosion is turning grazing land into waste land.
2. Plowing the land deeply and, in stiff soils, such as clay, subsoiling in two or three directions will help the soil soak in water. Subsoiling is more important than many farmers realize. A heavy rain showed clearly how proper subsoiling in a stiff soil can help prevent erosion. Two pineapple plots, side by side and as nearly alike as possible, were subsoiled along a gentle grade. The second plot was subsoiled again, the two lines of subsoiling making a diamond pattern. The pineapple plants were then set out in the usual way, with the rows running downhill. A ditch at the upper end of the plots kept out all water coming from the upper slopes. After the hardest rain in several years, the plot that had been subsoiled once had considerable surface washing, that is, sheet erosion was evident and the running water had cut channels a few inches deep in the lower ends of the rows. The second plot soaked up so much water that the run-off was not large enough to start soil washing.
3. The plowing under of green manuring plants is a well established farming practice. The vegetable matter added to the soil not only is a fertilizer

but it helps to make stiff soils more porous, thus allowing a larger amount of rainwater to soak into the soil. The decayed vegetable matter in the soil also prevents the pattering rain drops from forming a water-tight film over the surface.

4. By plowing the land along a contour, that is, along the slope, the numerous ridges made by the furrows will give water more time to soak in than would be the case if the furrows were plowed up and down the hill or along a steep grade.

Regulating Surface Run-off. Running water can do a great deal of harm in a very short time. For example, a heavy down pour lasting only an hour and a half cut a gully nearly four hundred feet long and eight feet deep at the upper end, ruining that much pasture land and covering plowed land with gravel to such a depth that it cannot be used for agriculture. It has been shown that a certain quantity of water, flowing at the rate of one foot per second, will carry a certain amount of dirt. The same quantity of water, flowing twice as fast, will carry sixty-four times as much dirt. It, therefore, is very important to regulate the run-off of surface water on farm land. As one writer has expressed it, "Make Running Water Walk." Many of the states in the Union are working on this problem and they not only have developed successful methods of controlling the flow of water from the land, but, in their education of the landowners and others as to the needs of such control, they have also worked out effective publicity methods. One slogan could be adopted here—

"Keep Hawaii at Home, ever remembering that
When the Top Soil Goes to Sea
The Farmer Goes Broke."

Ditches to Catch Run-off From Upper Slopes. To prevent soil losses caused by running water, it is necessary to take care of all water from higher slopes before it enters the field. Then it will be easier to regulate surface run-off starting in the field itself. The sole purpose of these ditches is to force the water to move slowly to a prepared channel where it can do no harm. There are laws dealing with such ditches and the landowner should find out what the law requires and he should also get the consent of all owners affected by the water coming from these ditches. No ditch should be built to drain into a public road without first consulting the County Engineer and getting his written consent to the project, even though

the natural drainage crosses the road or uses the roadside ditch.

The ditch at the upper end of a field must be large enough to take care of all water coming from the higher slopes. To be safe, the ditch should be twice as large as seems necessary, in order to safely handle the unusual cloudbursts. The bottom, as well as the sloping sides of these ditches, should be planted to grass because grass lined ditches require far less attention than those with steep sides not protected by grass. Kikuyu, buffalo and Bermuda grass are recommended for this purpose. They are listed in their order as stock feed, for they are equally good as soil binders. However, Bermuda grass is better for dry sites than either of the others. Elephant grass and Uba cane are too tall for this purpose, because they choke the channel.

If the grade of the ditch is too steep, then stone walls, low in the middle and with stone platforms on the downstream side, should be put in.

Tree Planting To Check Run-off. The amount of soil coming from the higher slopes can be greatly reduced if the higher slopes are planted to elephant grass, uba cane or to various forage plants if the land is used for grazing; or to useful trees if it is better suited to trees. A windbreak, a shelter belt six to twelve rows wide, or a woodlot could be planted, using black wattle and turpentine trees at elevations of 2,000 feet or more and black butt, lemon gum and turpentine and brush box in guava regions. All except the black wattle will make excellent fence posts. The roots of these trees will help hold the soil in the drainage ditch, and the litter in a grove of trees will stop most of the dirt that otherwise might be washed into the ditch.

A shelter belt between cultivated and grazing or waste lands will serve as a windbreak, as a source of fence posts and firewood and as a shelter for stock.

The next thing is to handle the water that flows off the field. This can be done by using broad base terraces or by laying out plant rows and ditches on a gentle grade.

Broad Base Terraces. In the first place, do not confuse the broad base terrace with the dikes and bench terraces seen in rice and taro fields. The broad base terrace is a low ridge about twenty feet wide which slopes gently toward the middle where it is eighteen inches high. This terrace permits the farmer to plow and culti-

vate his field as before and crops can be grown on the terrace itself. The terraces have a gentle grade and they are spaced just far enough apart to take care of all water that falls on the land. The low dike holds back the water and allows it to soak into the ground, an important item in a dry region, and any additional water is led to a grass lined ditch and then to a gulch. The terrace prevents soil washing in plowed land better than any other method, for it is effective whether there is a crop on the land or not.

The broad base terrace requires a fairly deep soil and, therefore, may not be adapted to shallow soils that would leave the subsoil exposed along the terrace ridge. This would not be a serious objection in orchard planting but would affect truck crops. On the other hand, if the soil is too shallow, it should be put to other use if the owner wants to keep it. Possibly the planting of fruit or nut trees or even fence post trees would be the best use for the land.

In Texas, terraces cost \$25.00 per acre if road scrapers or similar machines are used in making the ridge.

DISTANCE IN FEET BETWEEN TERRACES FOR DIFFERENT SLOPES

Slope of Land Fall per 100 feet	Vertical Drop in Feet Between Terraces	Horizontal Distance in Feet Between Terraces
3	4	133
5	5	100
7	6	85
10	7	70
13	8	62
15	9	60

TABLE SHOWING AMOUNT OF FALL TO GIVE TERRACES FOR PROPER DRAINAGE

Distance In Feet From Outlet	Fall In Inches Per 100 Feet
0-100	6
200-400	5
400-600	4
600-800	3
800-1000	2

Fig. 2

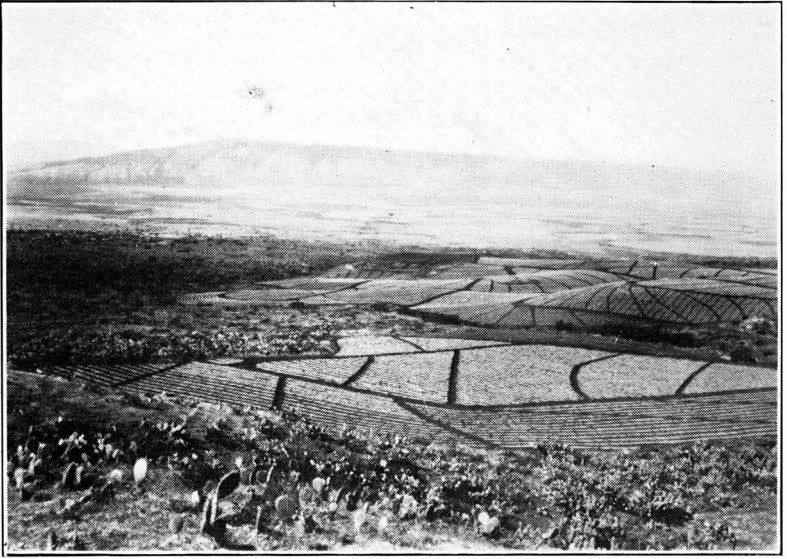


Fig. 3—Two Pineapple Fields in Porous Soil. Note Short Rows and numerous Ditches to Prevent Erosion.

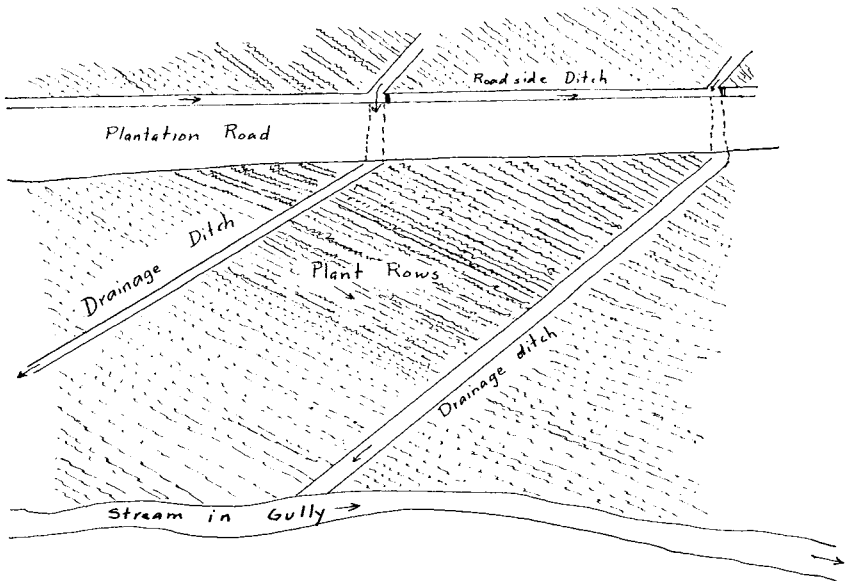


Fig. 4—Diagram showing layout of rows and ditches to prevent rapid run-off of rain water. Compare this arrangement with the usual arrangement in which rows and ditches follow the shortest line from the road to the stream.

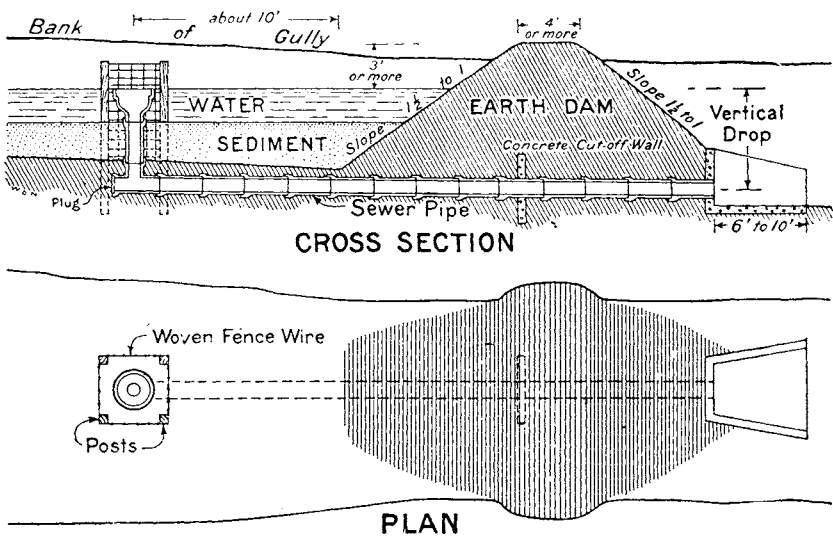


Fig. 5—Plan of an earth dam from Farmers' Bulletin No. 1234

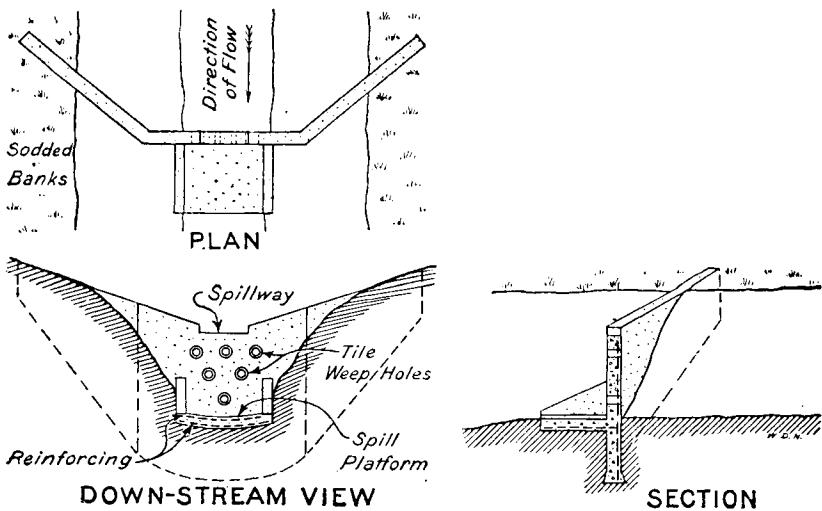


Fig. 6—Plan of a concrete dam recommended for use in deep gullies and where cloud bursts occur. From Farmer's Bulletin No. 1234.

The terracing should start at the highest spot in the field. The first terrace should inclose the top of a knoll or the upper portion of the field. A terrace is set out on a gentle grade, the fall being toward either or both sides of a field. Terraces over a thousand feet long should have outlets at both ends or at depressions. Great care must be taken at depressions to make the ridge high enough or to make the terrace follow the contour closely. Concrete pipes through a terrace will drain away the water that gathers in a depression. In such cases, the depression should be sodded or made into a ditch. The amount of drop to give terraces and the distances between terraces are shown in the accompanying tables. Terracing may be made easier if several farmers combine and terrace their fields at the same time or at least agree upon drainage ditches that two or more may use.

In laying out terraces, a level is needed and, in view of the fact that each sugar plantation has men well skilled in laying out ditches, it should be possible to employ one of these men to set the grade stakes.

The ridge can be made by plowing and using either a road scraper or the ditching apparatus found on all pineapple plantations. A satisfactory scraper can be made at home for about \$12.00, including the cost of

lumber, iron work and labor. However, a regular grader is easier to use. Those who are interested can secure further details from the County Extension Agent whose name and address will be found on the inside front cover of this bulletin.

Laying Out Plant Rows. A change for the better can be made at the next planting season, in case it is not possible to build terraces, by using a better method of laying out rows. In many cases, rows of plants are set out downhill. This means that later subsoiling and cultivation is downhill also. Progressive pineapple growers have found that this is a mistake and they use this method only where the location of roads makes it necessary. Some of them are studying the subject and have about decided that the cultivation of steep slopes is not worth while.

There is a tendency now to plow across fallow plowed land furrows which will serve as ditches before the crop is put in. These furrows are renewed every time the field is cultivated. The rows of pineapple plants are set out on a gentle grade and at the slightest depression care is taken either to send the water down the depression or to lead the water past the low spot. At intervals of thirty to sixty feet, ditches at a gentle grade cross these rows. If the soil is very powdery and is apt to wash away, the ditches are closer together. The same is true of ditches on steep slopes. Care is taken to see that the water keeps moving slowly all the time. The ditches are so placed that, if one is choked up or overflows, an adjacent ditch will take the water. This is illustrated in the accompanying diagram.

The rows slope down the gulch. The ditches crossing the rows slope toward the head of the gulch. This means a shorter ditch and one with less fall than a ditch that leads the water in the same general direction as the gulch.

Roads in fields are also used as ditches. Long roads, such as are found on many pineapple slopes, must have ditches at intervals to lead water to a gulch, lest the volume and force of water do harm. Roads around the hillside, that is, along a contour, have a cut on the uphill side and a high fill on the downhill side, thus making a ditch out of the road. In contour roads and ditches, the uphill side of the cut is about 30 degrees from the vertical. Such a ditch is easier to make and to keep open.

In land used for truck crops, a similar system of rows and ditches will reduce the amount of soil washing, but the cost of making these ditches each year or after every

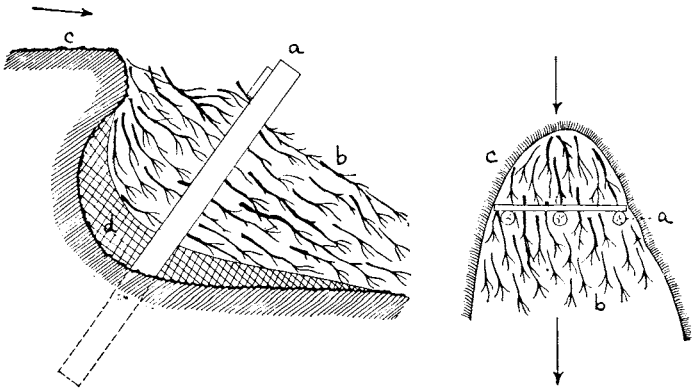


Fig. No. 7—How to Control Gullies. Brush piled into the head of a gully to prevent further caving of the bank. (a) Posts and cross bar to hold brush in place; (b) brush; (c) surface of ground; (d) fine brush or grass.

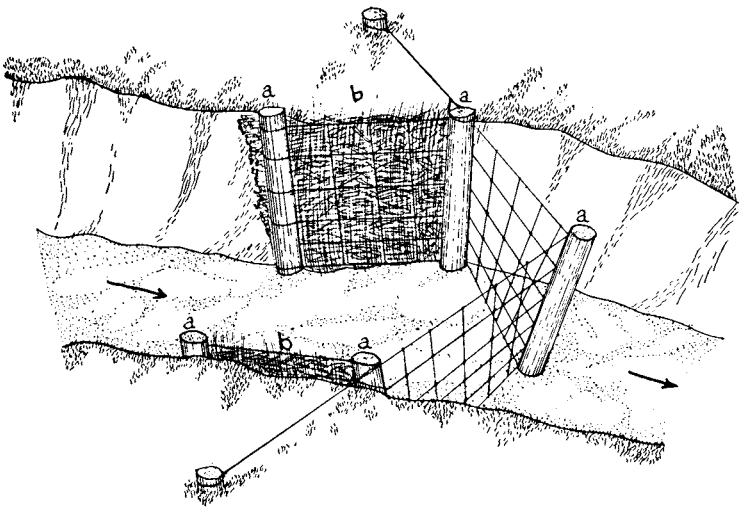


Fig. No. 8—Woven Wire Dam in a Gully. The dam is intended to catch rubbish and then it will hold dirt. Brush may be piled against it. (a) post; (b) brush piled against the bank to prevent washing around the dam.

crop will prove greater than the cost of a broad base terrace system, which requires but little attention to keep it in good condition. However, the farmer is facing the loss of all his soil if he continues planting his crops downhill. One man with two horses and a Fresno scraper spent ten days trying to put back on his field soil that had been washed from the higher part of his truck farm during an hour's downpour.

Control of Gullies. Those who are interested in the control of gullies should study Farmers' Bulletin No. 1234. A gully is never too small to stop, and it is cheaper to stop a small one than to bridge a big one. Small gullies may be controlled by diverting the water to a better channel or by planting the bottom and sides to grass. All gullies, especially those three or four feet deep, must be prevented from growing longer. This is done by packing brush against the bank wherever water falls over the edge of the gully. In the case of deep gullies, it is necessary to make a spillway where water flows into the gully. The next step in the control of a small gully is to put in soil saving dams. These usually are of earth with two or more outlet pipes. The dam is sodded and is protected by an apron from undercutting in case cloudbursts overflow the dam.

Gullies eight feet deep in regions of violent rainfall will require more permanent dams or well made earth dams with a stone facing. The dams must be able to withstand floods that will pour over their tops.

Whether the dam is made of brush, earth or concrete, it must be protected from undercutting. Brush will serve in a brush dam, but a stone or concrete platform with wings must be used in permanent dams. The accompanying diagram will show where these are placed. In case pipes act as an outlet through a dam, a concrete collar should be made to prevent seepage along the pipe. If two or more pipes are used they should be at least as far apart as their diameters. The upstream end of the pipes should slant upward after the pipe has passed through the dam. A screen should be put up two feet from the mouth of the pipe to keep out rubbish.

A soil saving dam will fill up a gully and then the remaining sides can be plowed in, sodded, and the gully can be more readily crossed by farm machinery.

Tree Planting to Control Erosion in Grazing Land. The erosion occurring in pasture lands has been mentioned already. It is obvious that the value of the land

does not justify expensive control measures unless the existence of roads or other improvements is endangered. Therefore, effort should be concentrated on the prevention of erosion by reducing the number of stock to fit the safe carrying capacity of the range, by shortening the grazing period of any given paddock and, most important, by improving the range by planting better forage plants. Australian salt bush (two kinds) meibomia, pigeon peas, kikuyu grass, elephant grass, Natal red top and others are suitable for this purpose. There is one for nearly every type of pasture land.

In pastures where soils are exposed and erosion has begun, it is necessary to plant grasses and shrubs to cover the ground. Any grass that is suited to the locality and spreads by runners is good. For covering gullies nothing is better than the koa haole or ekoa (*Leucaena glauca*). It does well in dry places, and, if given a good start, cannot be destroyed by cattle. This tree is planted by broadcasting the seed at the rate of ten pounds per acre. On wind scars, it should be scattered around the sides and on the face of the scar and the same is true of gullies. If the koa haole is given a fair start, it will gradually control the gully, especially if brush mattresses are built at the points where water flows into the gully.

There are serious objections to the use of koa haole which must be considered. First, it is such a serious pest on agricultural land that it should not be planted where its seed will be carried by wind or storm water into cultivated fields. This danger would be avoided if cattle kept the tops eaten back at all times. A second objection is that it is not suitable as feed for dairy cattle, because it flavors the milk, and, finally, in the case of horses and mules, it causes the long hairs of the mane and tail to fall out. On the other hand, it will grow where cactus does, and dry lantana slopes could be made into good pasture for beef cattle if koa haole were planted and allowed to shade out the lantana. On Oahu, one manager of a cattle ranch has plowed furrows around hills. The furrows are ten feet apart and alternate furrows are planted either to pigeon peas or to koa haole. On Hawaii and Kauai, large areas have been sown to koa haole. This shrub, if given an opportunity to grow, will make an excellent soil binder and, once established, it is a valuable forage plant for beef cattle up to elevations of 1200 feet on Oahu and higher on Hawaii. Koa haole can also be propagated by cuttings. They can be set in a plowed trench or in holes made by a bar. The cutting must not be forced into the ground, for this scrapes away the bark

at the point where roots should form. In a test, nearly sixty per cent of the cuttings thrust into the ground failed to take root, while only ten per cent failed where the cuttings were put into holes made by a bar. The cuttings may be an inch to two inches in diameter and eighteen inches long. They should be set a foot deep in the soil. Short cuttings are not so easily damaged by cattle as are longer ones.

In controlling a gully by tree planting, six or eight rows of black butt should be planted along both sides of the gully to hold the soil, because the steep banks of a gully will cave in for some time. The sides of the gully should be planted with koa haole cuttings three feet apart in rows eight feet apart. These rows should cross the gully in a V shape with the tip of the V down stream.

In guava regions, it will be possible to use cuttings, seedlings or seeds of madre cacao (*Gliricidia sepium*). This small tree is eaten by stock in the Philippines, but no harmful effects have been reported. This tree cannot become the pest that koa haole is. It is sensitive to wind and elevation and is recommended for guava regions not over 600 feet above sea level. By making mass plantings, spacing trees three or four feet apart, protecting the trees from stock and then judiciously thinning them, it will be possible to get straight trunks which will make very durable fence posts. Unless kept crowded, the tree will send out long slender shoots. These ought to make good temporary flume props. A row of such trees, planted six feet apart, can be made into a living fence or hedge by bending the shoots to the ground and pegging them down. They could be used in the same way to make living brush dams across gullies.

When plowing land in the bottom of a grassy gulch, great care should be taken to leave a channel for flood waters. In too many cases, the occupant plows across the gully, and storm waters sweep through the plowed land taking out soil and crops. In one case, a deep gully was started. The water flowed over the grass covered gulch to the soft plowed ground. This ground was washed away, making a waterfall a little over a foot high, but high enough to start back cutting. In less than two hours, the new gulley was over five hundred feet long and eight feet deep, and the plowed field was covered with gravel.

USING EROSION

Many landowners have been taking advantage of erosion to catch soil to fill in their own land. Low stone walls across shallow gullies catch soil and, in time, form benches of green plants when all other vegetation is dry. Other landowners scatter brush in the path of silt laden water and catch soil in that way. On Molokai, the hog fences have raised the level of the land inside the fence. In several cases, the difference in level inside and outside the fence is one foot.

Cooperative Extension Work in Agriculture and Home Economics,
University of Hawaii and United States Department of Agri-
culture Cooperating. Acts of May 8 and June 30, 1914.