Vetiver Grass
The Hedge against Erosion

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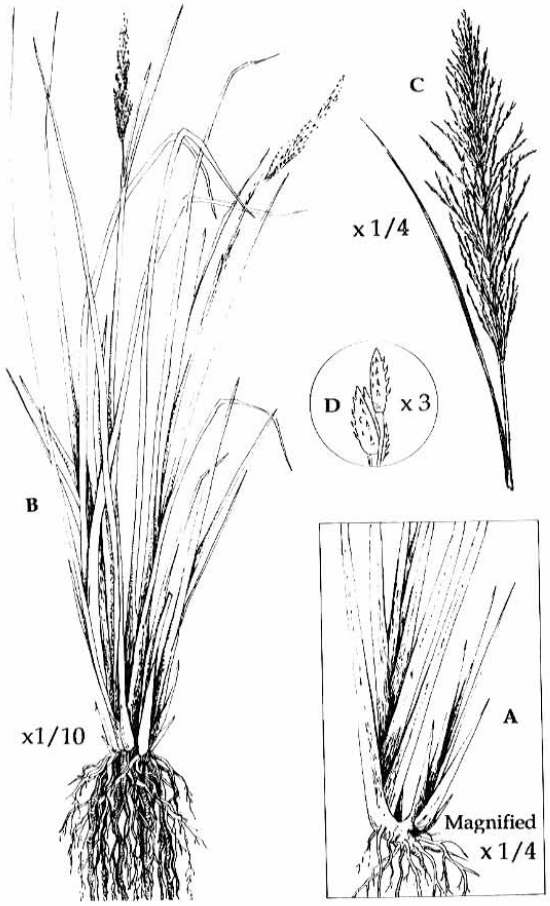


Vetiveria zizanioides

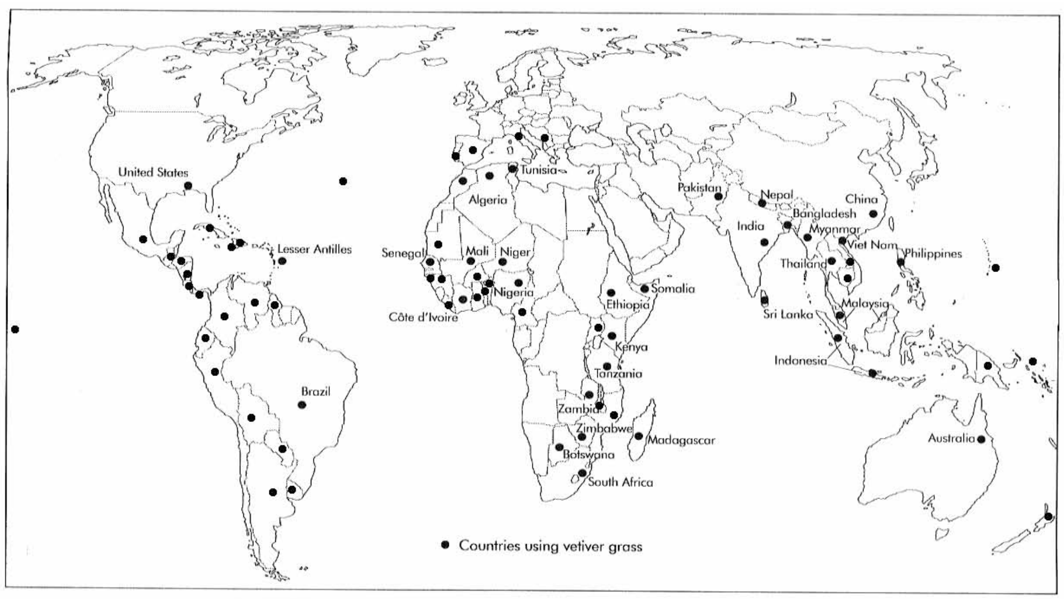
Vetiveria

Of the ten species of coarse perennial grasses found in the tropics of the Old World that belong to the tribe Andropogoneae, Vetiveria zizanioides has proven ideal for soil and moisture conservation.

V. zizanioides (L) Nash (2n = 20) Khus; vetiver grass; a densely tufted, awnless, wiry, glabrous perennial grass that is a "shy breeder" and is considered sterile outside its natural habitat of swampland. It has no rhizomes or stolons and is propagated by root divisions, or slips. The plant grows in large clumps from a much-branched "spongy" root stock (view A) with erect culms 0.5-1.5 meters high (B). The leaf blades are relatively stiff, long, and narrow—up to 75 centimeters long and no more than 8 millimeters wide—and although glabrous are "downward rough" along the edges. The lower glume is muriculated. The panicle is 15-40 centimeters long (C); joints and pedicels, glabrous. Spikelets are narrow, acute, appressed, and awnless (D). One spikelet is sesile, hermaphrodite, and somewhat flattened laterally with short sharp spines. It has *a glabrous callus, three stamens, and two plumose stigmas. The other spikelet is pedicelled and staminate. Some cultivated forms rarely flower.*

Both a xerophyte and a hydrophyte, V. zizanioides can withstand extreme drought—perhaps owing to the high salt content of its leaf sap as well as long periods of inundation (up to forty-five days has been established in the field). It has an exceptionally wide pH range, seems to be able to grow in any type of soil regardless of fertility, and has been found to be unaffected by temperatures as low as -9° Centigrade.

<u>V. zizanioides</u> does not produce seeds that germinate under normal field conditions. <u>V. nigritana</u> (the Nigerian species) does seed, but the seedlings are easily controlled .



Preface

For at least the next decade environmental issues will dominate the agricultural and natural resource sectors. Already the focus of much attention are the problems of deforestation, increased flooding by major rivers, and reduced dry-season water flows for irrigation and urban and industrial supplies. Not enough attention, however, has been given to the massive problem of soil erosion and, more specifically, to the need to reduce soil and water losses caused by excessive rainfall runoff. Of the 11 million hectares of forest cut down each year, one-half is estimated to be needed to replace cropland that has gone out of production owing to erosion and the consequent loss of fertile soil. At the same time, many millions of hectares of land once deemed cropland with high potential are annually being downgraded to land with low potential and high risk, even in areas receiving substantial rainfall. This is because excessive runoff prevents the land from making effective use of the rain that falls. The prime cause of soil erosion and excessive rainfall runoff is the removal of vegetative ground cover by human and livestock populations—one of the dire consequences of our continuing and accelerating overuse of the world's land resources.

Topsoil losses in the past have brought down whole civilizations. The Mayas of Central America are one example, and North Africa used to be the "granary of the Roman Empire." Soil erosion is truly a global problem, and the need for conservation has become critical in many countries. For example, more than half of India's cropland is losing productivity because topsoil is being washed or blown away faster than natural forces can replace it. Reducing the topsoil layer means reducing plants' access to essential soil nutrients and water.

Changes in farming practices have made the problem worse in recent years. In response to the growing need for grain for exploding human and livestock populations, farmers switched from traditional rotations and multiple cropping to continuous-row cropping, a practice that encourages rainwater to run off the land at a faster and more destructive pace. As a result crops are denied the moisture they need for optimum growth.

Recognizing the problem, top-level policymakers in many countries have devoted substantial portions of their budgets to finding a solution. But the sums allocated are often insufficient, costs are too high, and many of the conservation techniques attempted have been ineffective and are inappropriate for small farmers. Soil erosion continues at an accelerating and alarming rate. Governments have only limited access to public funds. Many think that farmers should bear the cost of soil conservation, but most cannot afford to unless cheaper methods—preferably linked to direct income benefits—can be identified that are acceptable to farmers.

This handbook has been prepared to support fieldworkers and farmers in developing vegetative systems of soil and moisture conservation that will meet the requirements of small farmers in developing countries, most of whom reside in the tropics and semitropics. Experience has shown that conventional systems of earth bunds or terraces on small farms are expensive and in many cases, especially in modern times, ineffective. When applied correctly, vegetative systems of soil and moisture conservation—particularly the system of hedges of vetiver grass described in this handbook—have proved cheaper and more effective.

Since the publication of the first edition of this handbook in 1987, we have learned that Indian farmers near Mysore have been using vetiver grass as hedges for perhaps as long as two hundred years. This fact has given the new users of vetiver grass more confidence in the technology. Since 1987 the technology has been tested in the field in many countries—India, China, Philippines, Indonesia, Nigeria, Madagascar, Brazil, and Australia, to name a few. Soils and climate vary tremendously within this group. For example, in China vetiver is being grown as hedges on 60 percent slopes to protect tea and citrus crops on low pH (4.1) red soils. In India it is being used successfully on black cotton soils (severely cracking vertisols) on slopes of 2 percent or less. In other countries such as Trinidad, it has been used for years to stabilize rock-based roadsides. In every case this unique grass has displayed the same extraordinary characteristics that make it an ideal low-cost, non-site-specific system for controlling soil loss and improving soil moisture.

We have learned during the past few years that the introduction of a new technology requires persistence and patience. We believe that the effort and persistence of the many new promoters of vetiver technology are paying off; both the demand for and use of the technology are accelerating. If the system is adopted to the extent that we hope, two landmark objectives will be met in the effort to help more and more of the developing world reach a sustainable basis for rainfed agriculture and land resource conservation; namely, soil stability and in-situ moisture conservation. We are indebted to many workers active involved with this technology. We have to realize the early users of the technology: farm such as those in south India whose ancestors have used the grass for centuries; sugar companies in the West Indies and Fiji that have successfully used the technology for more than fifty years; and West African farmers such as the Hauser of Nigeria, who know well the merits of the grass farm boundary markers. We must recognize the dedication of John C. Greenfield, who renewed the use of the technology in India during the 1980s and was responsible for the preparation this handbook. We must also acknowledge the contribution of the agricultural staff and scientists in the Indian states of Andhra Pradesh, Karnataka, Madhya Pradesh, and Maharashta who have dedicated part of their work to establishing this technology for farmers in these poverty-stricken areas of India. Most recently we must acknowledge efforts by the management and staff of China's Red Soil Project who have taken the lead in testing and demonstrating the technology in their country in the hope of aiding the millions of farmers who live on the badly degraded soils of south China. Finally we have to thank the World Bank staff in New Delhi and Washington, D.C. who have been responsible for editing this handbook and the two earlier editions published under the title, Vetiver Grass (Vetiveria zizanioides): A Method of Vegetative Soil and Moisture Conservation.

This handbook is intended primarily for practitioners and users, and as in previous editions we ask for your views and ideas so that they can be incorporated in future editions.

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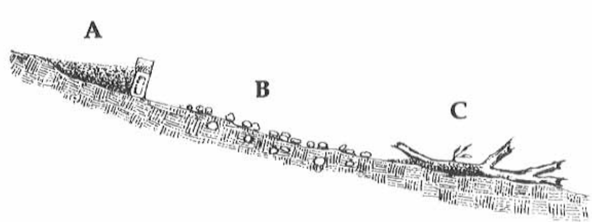
Contents

Vetiver Grass: The Hedge against Erosion

Sheet Erosion

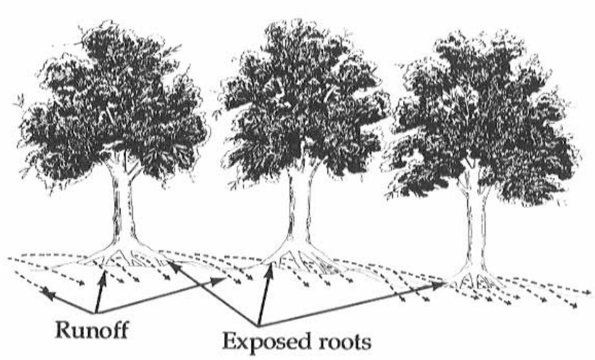
Sheet erosion is the most damaging form of erosion, mainly because it is often not recognized and therefore seldom treated. Triggered by rainfall, sheet erosion accounts for the loss of billions of tons of soil every year. As raindrops pound the ground, particles of soil are knocked loose and then carried away by the runoff. This runoff further strips unprotected areas of their valuable topsoil and becomes the muddy water that ends up in drains, streams, and rivers. sheet erosion leads to more striking forms of erosion—rills and gullies, for example, the focus of most conservation efforts to date. Although not as spectacular, sheet erosion does leave visible marks, as shown in Figure 1: soil collecting behind obstructions on a slope (such as the brick in example A); stones left behind by the runoff because they were too heavy to be carried away (B); or moldy mounds of soil and other debris trapped under branches, twigs, or even clumps of straw (C).

Figure 1. Signs of Sheet Erosion



The effects of sheet erosion are more readily apparent in forest areas that are devoid of ground cover—and in fields or wastelands with a few standing trees—where the loss of soil exposes the roots of the trees (Figure 2). Water can then easily pass beneath the trunks of the trees and between their roots. Once all the soil that supported them and gave them life is washed away, the trees will be washed out of the ground as well.

Figure 2. Sheet Erosion and Trees



Trees by themselves do not prevent soil losses caused by sheet erosion; forests do, with their thick litter and low-growing vegetation. In areas where forest cover is not possible or practicable, vegetative barriers can be used to stop the loss of soil. Fibrous-rooted shrubs and grasses planted as hedges along the contour of the land slow the runoff, spread the water about, weaken its erosive power, and cause it to deposit its load of valuable soil behind the hedgerows. As a result the runoff proceeds gently down the slope, and, if the hedges have been planted at the correct vertical interval (see page 40), without further erosive effect.

The amount of soil lost through sheet erosion is alarming. Figure 3, which depicts two surviving plants whose roots prevent sheet erosion, shows how the amount can be measured. In this case a layer of soil 50 centimeters deep—as measured by the distance between the top of the plant mounds and the present soil surface—has been lost across the entire area of the field since the plants became established.

Rainfed Farming

The traditional way of farming in rainfed areas, no matter how flat the land may seem, is along the slope, or up and down the hill (Figure 4). This system encourages runoff and soil loss and thus makes sheet erosion worse. Often more than 50 percent of the rainfall is lost as runoff and thereby denied to the crops, and the steeper the slope, the faster and more erosive the runoff. Rainfall is less effective because the water is not given a chance to soak in. By plowing along the slope, the farmer in Figure 4 is unknowingly encouraging the rainfall to leave his field.

Figure 4. Traditional Rainfed Farming

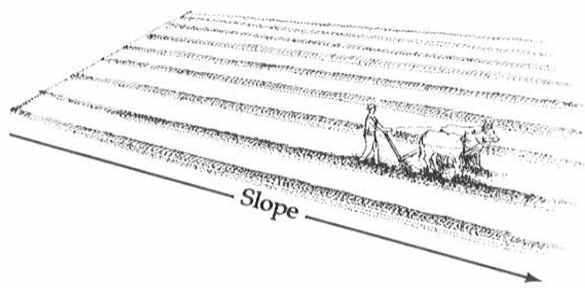
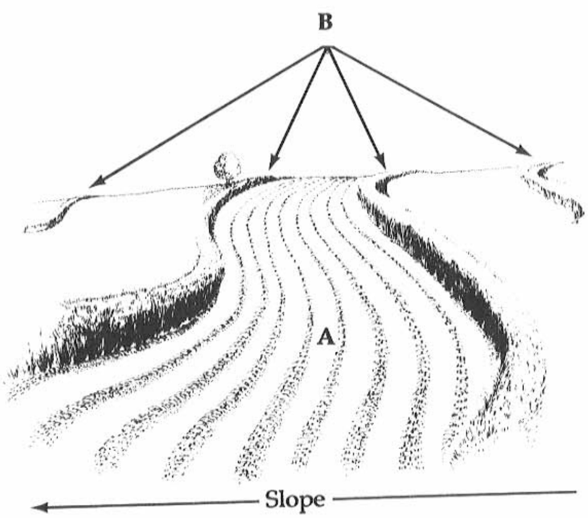


Figure 5 illustrates the method advocated in this handbook—the use of vegetative contour hedges to prevent erosion and conserve natural moisture in the soil. Once established, such hedges need no maintenance and will protect the land from erosion for years, as they build up natural terraces. In contrast to the planting furrows in Figure 4, those at 'A' in Figure 5 follow the contour of the land as laid out by the vegetative hedges (B).

Figure 5. Farming with Vegetative Contour Hedges



Constructed earthen embankments, or contour bunds, have slowed erosion throughout the world since the 1930s. But this method of soil conservation creates an unnatural system of drainage and is no longer considered appropriate for small holders. The embankment in Figure 6 was constructed with topsoil taken from point A, which was thereby transformed into a channel to convey the runoff sideways.. But the bank is made of the same soil it is supposed to protect, and because its construction makes the slope steeper, over time the bank will erode and "melt" away. Then it will have to be replaced—at great cost to the farmer. Moreover, to collect sufficient soil to make the bank and channel shown in Figure 6, a 5-meter-wide strip of land must be taken out of production over the entire length of the bank. This represents a loss of 1 hectare of productive farmland for every 20 hectares of land treated with embankments or bunds.

Figure 6. Constructed Method of Soil Conservation

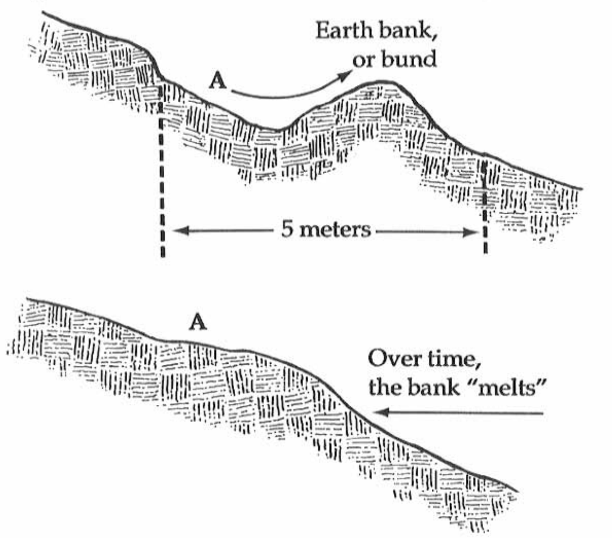
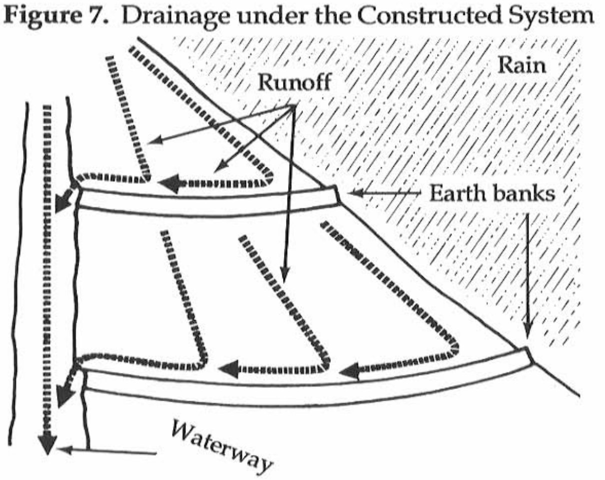


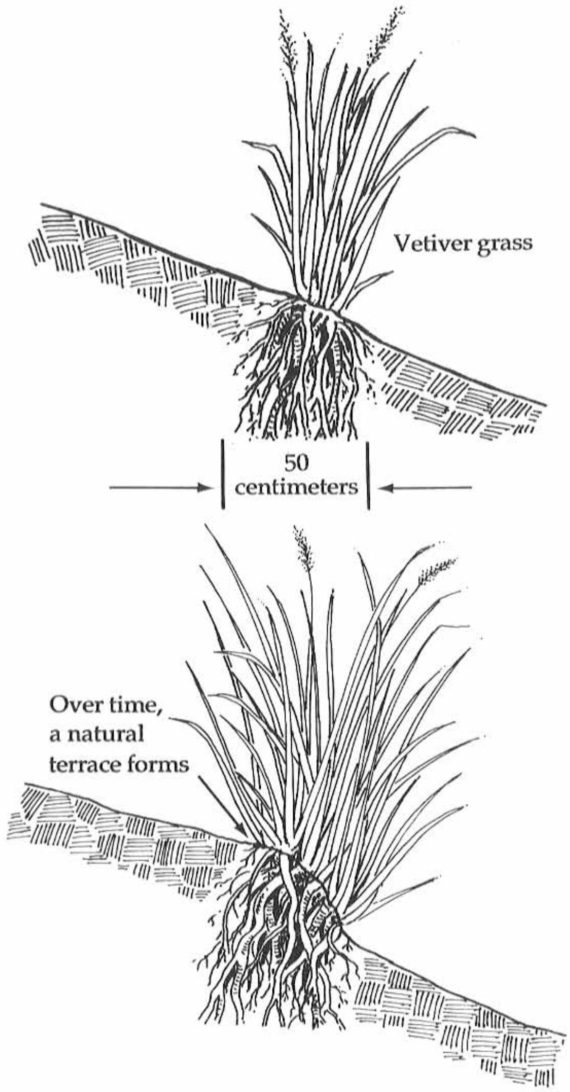
Figure 7 shows the unnatural way the land is drained by this system. All of the runoff is channeled sideways and dumped into a waterway that no small holder would want running through his or her farm. This system makes the areas below the banks too dry, and the channel areas too wet, for optimum crop production.

Figure 7. Drainage under the Constructed System



In contrast, the vegetative method of soil and moisture conservation uses nature to protect itself. In the system demonstrated in this handbook with vetiver grass (Vetiveria zizanioides), only a 50-centimeter strip—or one-tenth of the land occupied by earthen embankments or bunds—is taken out of production (Figure 8). Because the grass root divisions, or slips as they are called, are planted in a single plowed furrow, little soil is disturbed. And whereas earth banks have to be made with bulldozers or by hired labor, the vegetative system requires no special tools or labor beyond that which a farmer would already have.

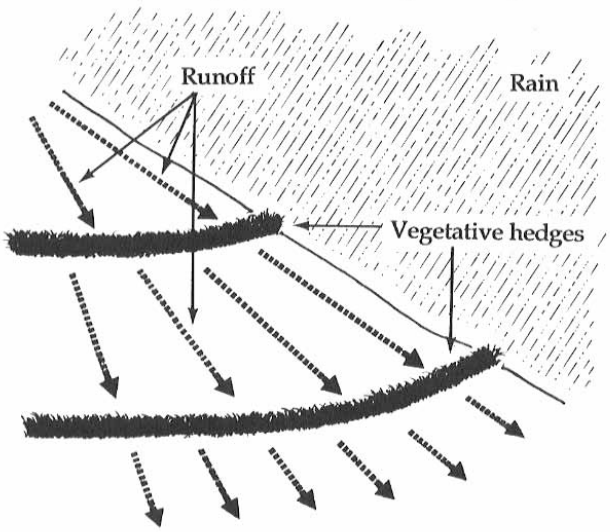
Figure 8. Vegetative System of Soil Conservation



The bottom illustration in Figure 8 shows what happens over time in the vegetative system: the runoff drops its load of soil, the grass tillers up through this silt, and a natural terrace is created. The terrace becomes a permanent feature of the landscape, a protective barrier that will remain effective for decades, even centuries.

When the runoff reaches the vegetative hedges, it slows down, spreads out, drops its silt load, and oozes through the hedgerows, a large portion of the water soaking into the land along the way (Figure 9). No soil is lost, and there is no loss of water through the concentration of runoff in particular areas. The system requires no engineering—the farmers can do the whole job themselves.

Figure 9. Drainage under the Vegetative System

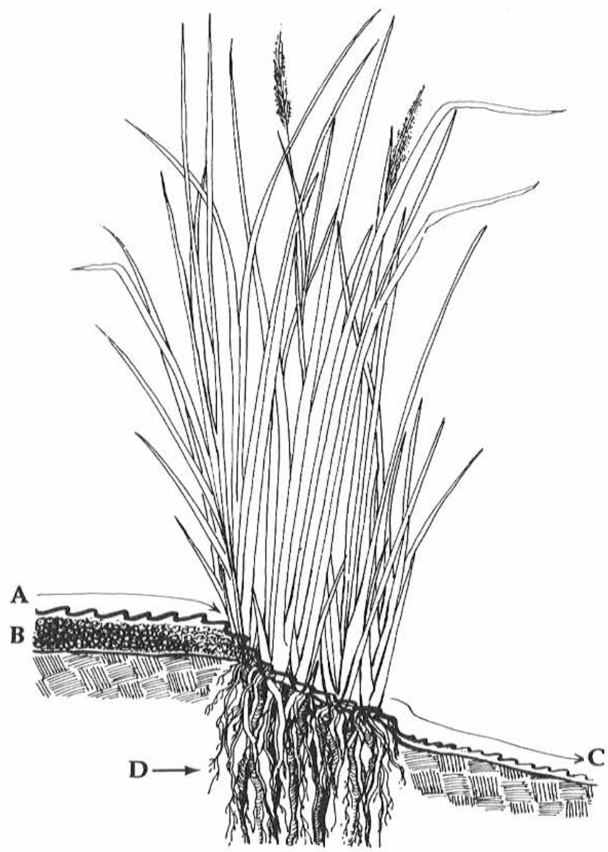


Near Mysore in the southern Indian state of Karnataka (in the villages and hamlets of Gundalpet and Nanjangud, for example), farmers have been maintaining vetiver hedges around their farms for more than a hundred years. To keep the hedges narrow, the farmers simply plow around the edges of the hedgerows whenever they plow the rest of the field for cropping. The hedges are in perfect condition and provide permanent protection against erosion.

Vegetative Control Hedges

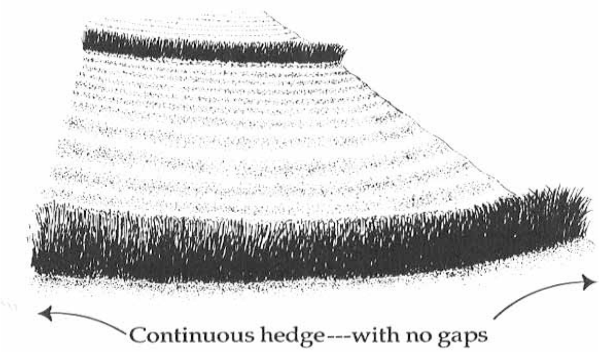
Figure 10 presents a cross-sectional view of a vegetative contour hedge at work. The leaves and stems of the vetiver plant slow the silt-loaded runoff at A and cause it to deposit the silt behind the plant at B while the water continues down the slope at C at a much slower pace. The plant's spongy root system, pictured at D, binds the soil beneath the plant to a depth of up to 3 meters. By forming a dense underground curtain that follows the contour of the land, the roots prevent rilling, gullying, and tunneling. The strong aromatic oil they contain makes the grass unpalatable to rodents and other pests; many Indian farmers report that it also keeps rats from nesting in the area. Because the dense root system repels rhizomes of grasses such as Cynodon dactylon the hedgerows prevent them from entering the farm field and becoming a weed. And according to the farmers near Mysore the plant's sharp, stiff leaves keep snakes away as well.

Figure 10. Cross Section of a Vetiver Hedge



To be effective as a method of soil conservation, the vegetative system must form a hedge, as shown in Figure 11. Although under certain circumstances thick hedges can be formed in one year, it generally takes two to three growing seasons to establish a hedge dense enough to withstand torrential rains and protect the soil. During the first two seasons, and sometimes the third, the plants need protection, and any gaps in their line have to be filled. (During the first two seasons it should also be easy to see the silt being trapped behind the plants as they are establishing, a phenomenon that extension workers should try to point out when explaining the system to farmers.) Although the earth banks used in the conventional method of soil conservation are effective immediately, they break down over time and frequently burst open in heavy rainstorms. Once the hedge has been established, it will neither wear out nor require further maintenance, other than periodic trimming.

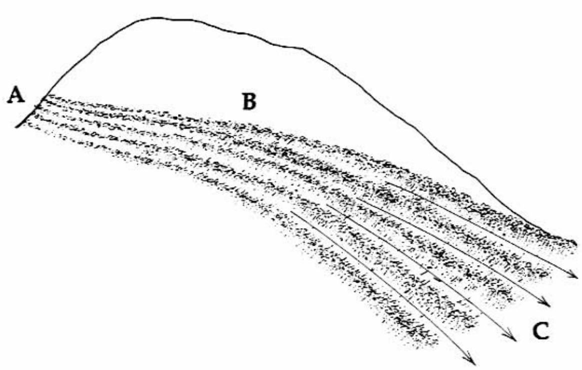
Figure 11. Vegetative System



Trimming the hedges to a height of 30-50 centimeters prevents them from seeding, makes them thicken up, and thereby increases their effectiveness in filtering runoff. In several villages and hamlets near Mysore, the farmers trim their hedges every two weeks throughout the year and feed the young palatable leaves to their livestock. They are thus ensured a year-round supply of stock fodder regardless of rainfall.

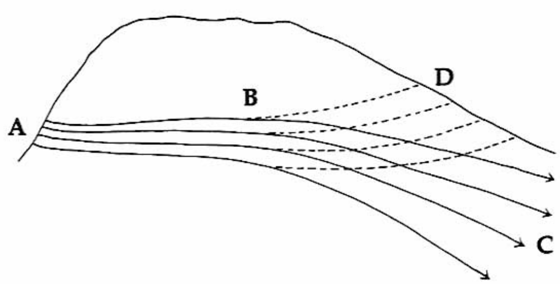
It has become evident that many fieldworkers—and even research workers—lack a clear understanding of what is meant by "the contour." Figure 12 illustrates a common misconception: that a furrow plowed along "the main slope" follows the contour.

Figure 12. False Contour



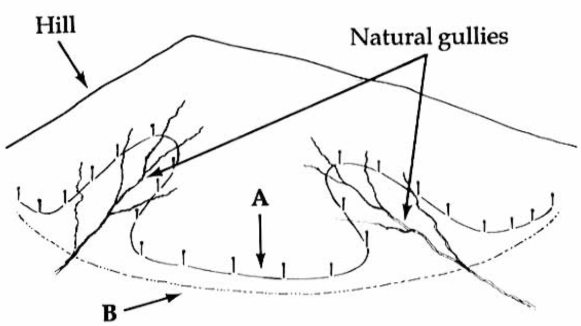
This is incorrect. A true contour embraces all slopes, major or minor; it is a line of equal elevation around a hill. The furrows in Figure 12, which starting from point A follow the main slope straight down to point C instead of curving around the hill, are not on the contour and therefore will neither conserve moisture nor prevent erosion. The true contour, pictured in Figure 13, runs from A to B to D and continues around the hill, maintaining equal elevation all the way.

Figure 13. True Contour



Because the earth banks conventionally are used to control erosion must convey the runoff to a waterway off to the side of the field, they have to be constructed on the exact contour. As shown in Figure 14, such a line (marked with pegs at A) can be difficult for the farmer to follow when plowing.

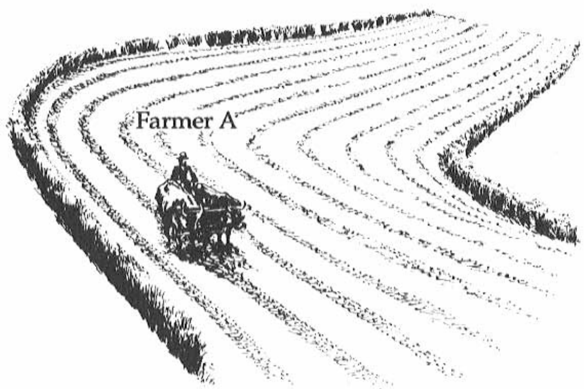
Figure 14. Averaged Contour



The vegetative hedges, however, do not have to be exactly on the contour to provide effective soil and moisture conservation since their purpose is to reduce the velocity of the water as it passes through them and not to channel the water elsewhere. Once the contour line has been pegged in (see page 30), the extension worker can smooth it out to make it easier for the farmer to follow. In Figure 14, contour line A has been "averaged" into the smooth curve of line B. To control sheet erosion, the hedges and plow furrows (crop lines) need only follow line B. The silt filtered from the runoff will build up behind the hedges and eventually form a natural terrace. Because the hedges run across the slope, the ends of each hedgerow should be turned up the slope to prevent runoff from spilling around the sides—this will encourage natural terraces to form more readily and prevent erosion at the ends of the hedgerows, especially in steep lands.

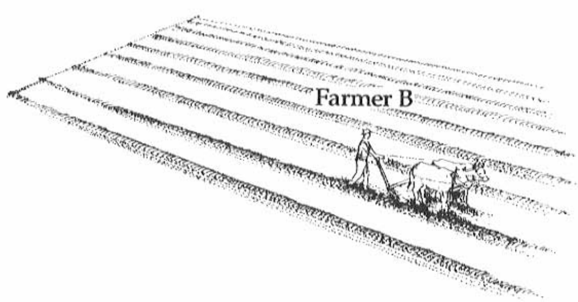
In Figures 15 and 16 we see two farmers, A and B. Both are good farmers, but A in Figure 15 is a wise farmer; he has protected his land against soil loss by planting vegetative hedges on the contour, and he is using the hedgerows as guidelines to plow and plant on the contour.

Figure 15. Protected Farm



The furrows created in this fashion will hold rainfall and store extra moisture in the soil, thus allowing crops to withstand long periods of dry weather. What farmer A is doing costs no more than what farmer B in Figure 16 is doing. All that is involved is a change in management.

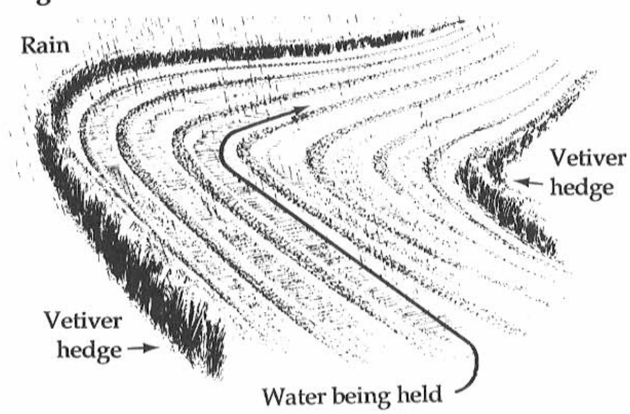
Figure 16. Unprotected Farm



Farmer B is a good farmer, but he is not farming wisely; he is not thinking. By plowing just straight up and down the slope he is encouraging the rainfall to run off his farm, taking his farmyard manure and an irreplaceable layer of topsoil along for the ride. The rainwater runs off so quickly it does not have a chance to soak into the soil, and thus his crops have no protection against dry spells.

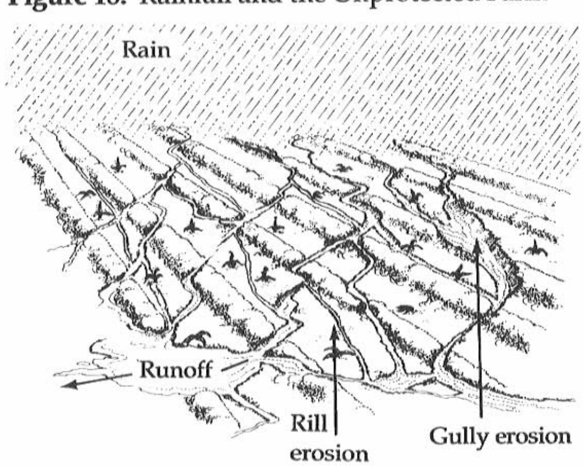
Figures 17 and 18 illustrate what happens when the two farming systems are exposed to heavy rainfall. Farmer A's field is protected by the vegetative hedges, and there is no loss of soil (Figure 17). The contour furrows store all the rainwater they can hold. Any surplus rainfall runs off, but the vetiver hedges control the flow—slowing it down, spreading the water about— and cause the silt to be deposited. As a result the runoff is conducted down the slope in a safe, nonerosive manner.

Figure 17. Rainfall and the Protected Farm



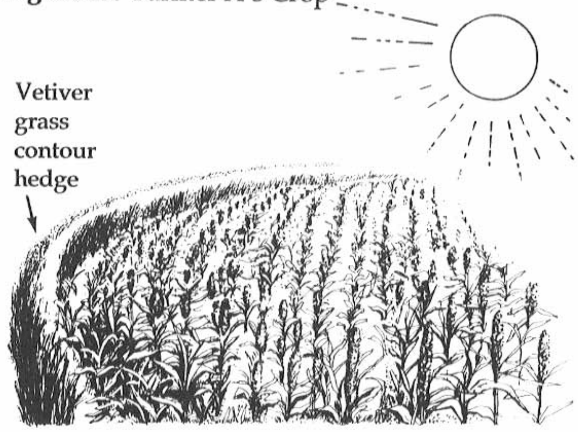
On Farmer B's unprotected land, the rainfall runs off at great speed, taking along his fertilizers and topsoil. The uncontrolled ride down the slope causes unnecessary and damaging erosion (Figure 18). Because the runoff races by so quickly, no moisture is stored. Rainfall is only 40-50 percent effective, and farmer B is always complaining about droughts. Ultimately he will have to abandon his farm because there will be no soil left in which to grow crops. Farmer A will never have this problem; his yields will increase over the years.

Figure 18. Rainfall and the Unprotected Farm



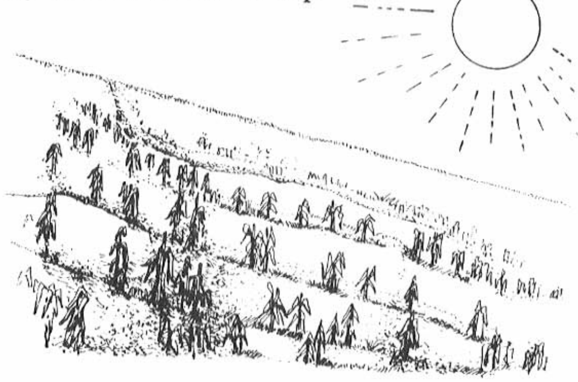
Thanks to his vetiver contour hedges, farmer A obtains an excellent crop (Figure 19). Because the soil has retained ample moisture from earlier rains, his crop is benefiting from the warm sunshine, all the grains are filling, and the crop stand shows even growth. Farmer A will reap a high yield.

Figure 19. Farmer A's Crop



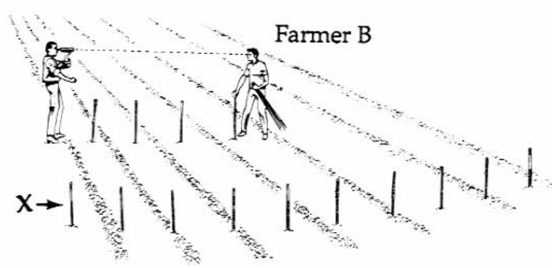
In contrast, farmer B has a disappointing harvest (Figure 20). His crop has all but failed, and what little remains—growing in patches where some moisture was trapped—is being dried out by the sun. Only a small percentage of the grain will fill, and the resulting crop is uneven. Farmer B can expect a low yield. Yet he planted the same crop as farmer A and used the same fertilizer; both crops were planted at the same time and received the same amounts of rainfall and sunshine. Unlike his neighbor, however, farmer B lost most of his fertilizer, together with 60 percent of his rainfall and a layer of soil from his farm possibly a centimeter thick—all because he did not plow on the contour and use vegetative hedges to protect against erosion and help his cropland retain moisture from the rain. If he had taken the advice of his extension service and plowed and planted on the contour, farmer B could have obtained the same high yields as farmer A.

Figure 20. Farmer B's Crop



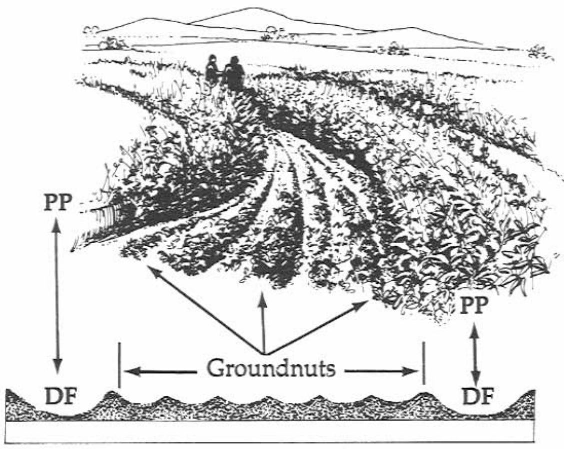
Having learned his lesson, farmer B contacts his extension worker, and together they mark, or peg out, contour lines across the old furrows (Figure 21). This simple process requires virtually no engineering skills—only the use of a small hand-held level. The extension worker stands at the edge of the field and, sighting through the level, has farmer B move up or down the slope until the two men are standing level, at which point the farmer marks the spot with a peg. In Figure 21, the contour line (X) has already been pegged out, and the farmer has but to follow the line of pegs with his plow (as shown in Figure 22) to create the furrow in which to plant the slips of vetiver grass that will eventually form a contour hedge. This is all that has to be done to establish the vegetative system of soil and moisture conservation.

Figure 21. Marking the Contour



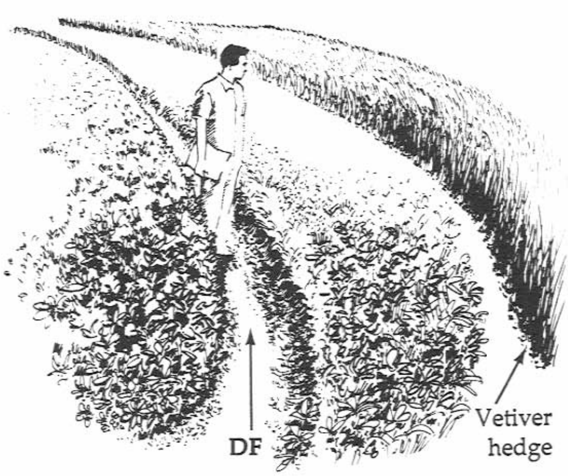
Like any long-lived plant, however, the vetiver hedge system normally takes two to three seasons to become fully effective. You cannot plant a mango tree today and expect to pick mangoes next month! But it is possible to get some immediate effect from the system by using dead furrows until such time as the vetiver grass can be established. This preliminary stage of the system is depicted in Figure 23.

Figure 23. Initial Setup



While waiting for vetiver planting material to be produced in the nursery, the farmer laid out the contours, prepared seedbeds following the contour furrows, and every 5 or 6 meters double plowed a dead furrow. The two dead furrows in the figure have been planted on the contour to pigeon peas and intercropped with six rows of groundnuts. The shape of each seedbed is shown beneath the crop illustration: DF marks the deeper dead furrow, PP the row of pigeon peas it supports. Eventually, vetiver grass will be planted in some of the dead furrows, but in the interim these furrows themselves will provide a bit of protection against runoff. Planting the vetiver grass will stabilize the whole system, as shown in Figure 24, where a vetiver hedge has taken the place of one of the dead furrows.

Figure 24. Stabilized System



Establishing Vetiver Hedges.

The next few pages provide step-by-step instructions on how to establish a vetiver hedge. Also included are tips on handling the planting material, the best time to plant, and what to expect after the grass is planted.

The first step is to obtain the planting material, usually from a vetiver nursery. If vetiver grass is unknown in your area, check with the nearby botanical gardens. Ask them to look up Vetiveria zizanioides. If it has been collected, the herbarium sheet will show what the plant looks like, note where the specimen was found, and provide the local name of the plant. Vetiver is found throughout the tropics and has been grown successfully as far north as 42° latitude. Vetiver nurseries are easy to establish. Inlets to small dams or water holding tanks make the best nursery sites because water en route to the dam or tank irrigates the vetiver grass, which in turn removes silt from the water. Large gullies protected with vetiver grass also make good informal nurseries. For best results, the vetiver root divisions, or slips, should be planted in a double or triple line to form parallel hedges across the streambed. The hedgerows should be about 30-40 centimeters apart.

To remove a clump of vetiver grass from the nursery (Figure 25, illustration A), dig it out with a spade or fork. The root system is too massive and strong for the grass to be pulled out by hand. Next tear a handful of the grass, roots and all, from the clump (B). The resulting piece, the slip, is what gets planted in the field (C).

Figure 25. The Planting Material

A

B

C

Before transporting the slips from the nursery to the field, cut the tops off about 15-20 centimeters above the base, and the roots 10 centimeters below the base. This will improve the slips' chances of survival after planting by reducing the transpiration level and thereby preventing them from drying out. As shown in Figure 26, all that is needed to prepare the slips for planting is a block of wood and a knife—a cane knife, machete, cutlass, or panga will do. The finished planting piece is shown in Figure 27.

Although vetiver grass can be planted from single tillers (when planting material is scarce), this practice is not recommended for grass to be planted in the field because it takes too long to form a hedge. Fertilizing the slips with diamonium phosphate (DAP)

Figure 26. Preparing the Slip

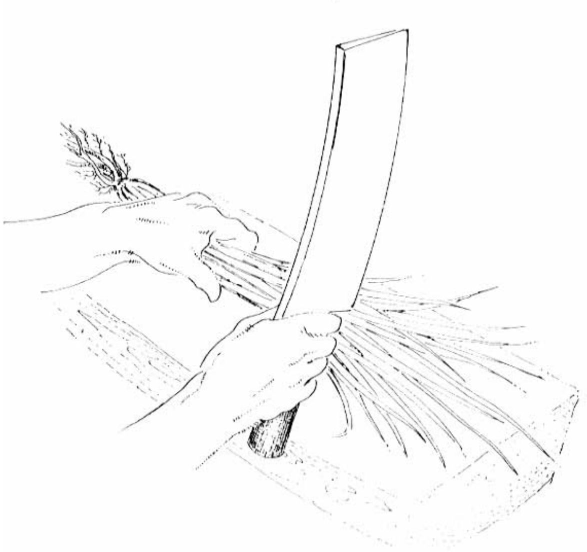
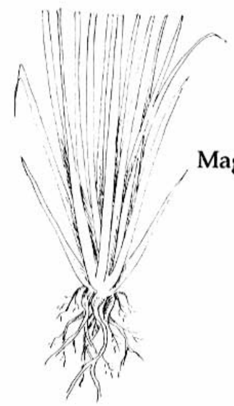


Figure 27. The Planting Piece



encourages fast tillering and is helpful both in the nursery and in the field. To do this in the field, simply dibble DAP into the planting furrow before planting the slips.

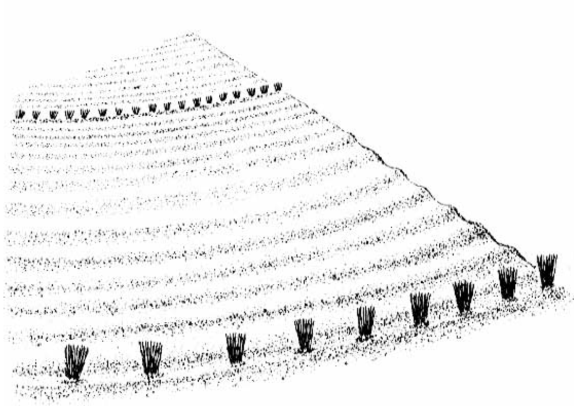
Always plant the slips at the beginning of the wet season to ensure that they get full benefit of the rains. Planting vetiver slips is similar to planting rice seedlings. Make a hole in the furrow that was plowed to mark the contour. Push the slip into the hole, taking care not to bend the roots upward. Then firm the slip in the soil. Ten to fifteen centimeters from the slip, along the same contour furrow, plant the next slip, and so on (Figure 28).

Figure 28. Planting the Slips

Only a single row of slips need be planted. If planted correctly, the slips can withstand up to one month of dry weather. Some slips may die, however, and leave gaps in the hedge line. These gaps should be filled by planting to new slips. In some instances it may be possible to use the live flower stems, or culms (see the illustration on page 14), of neighboring plants—simply bend the culms over to the gap and bury them. The live stems will produce roots and leaves at the nodes.

Of course for this or any vegetative system to work, the plant must form a hedge; otherwise the system cannot act as a barrier against soil loss. Planting the slips too far apart (Figure 29) would render the system almost useless because they would take too long to form a hedge and would provide little protection.

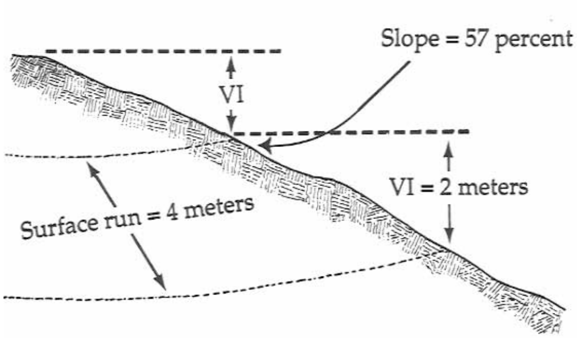
Figure 29. What to Avoid



Moreover, without the extra support of a hedge to hold the soil, fertilizer, and moisture against the vetiver grass, the plants would not be able to survive the worst droughts. Even in arid areas that receive less than 200 millimeters of rain a year, an effective vetiver contour hedge could ensure its own viability. The combined effect of contour cultivation and the hedge's performance in slowing and spreading the runoff is to increase infiltration of water into the soil. Thus the hedge can help itself to what might be the equivalent of half again as much rainfall.

For the system to provide maximum protection against erosion, the hedgerows should be spaced apart at the proper vertical interval (VI). The VI is the vertical distance from one hedgerow to the next one down the slope. The actual distance measured along the ground, called the surface run, depends on the steepness of the slope. With a vertical interval of 2 meters, for example, the hedges on a 5 percent slope would be about 40 meters apart whereas those on a 2 percent slope would be about 100 meters apart. As shown in Figure 30, the surface run between hedgerows planted on a 57 percent slope with a VI of 2 meters is about 4 meters. For a more comprehensive look at the relationships among slope, surface run, and vertical interval, see Table 1 at the back of this handbook. In practice, a VI of 2 meters has generally been found to be adequate.

Figure 30. The Vertical Interval

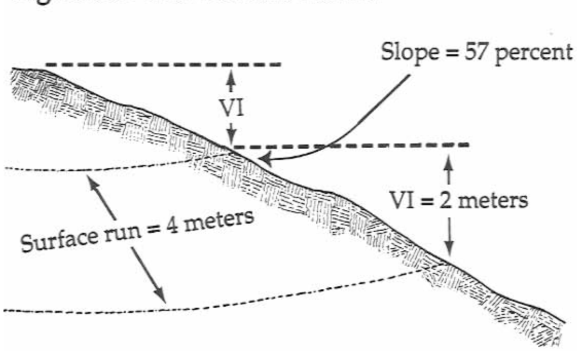


Once the hedges have been established in the farm field, the only care they will need is annual trimming to a height of about 30-50 centimeters to encourage tillering and prevent shading of the food crops. Plowing along the edges of the hedgerows will remove any tillers that encroach upon the field and will thus prevent the hedges from getting too wide.

Moisture Conservation

Although measures to retain natural moisture in the soil are essential to all rainfed farming systems, the art of in-situ moisture conservation, as it is called, is rarely practiced and not widely understood. There is no such thing as flat land; water runs off all land. No matter how flat it may seem, all land must be contoured if it is rainfed. Earthshaping, land leveling, and similar techniques are required in irrigated areas only; rainfed areas must be contoured. Figure 31 shows what happens when land is planted on the “flat” without the benefit of contour furrows.

Figure 30. The Vertical Interval



In view A the rain runs straight off the field. View B shows the results: because no moisture has been stored, the plants wilt and die in the sun. View C shows the same area planted to contour furrows, with a pair of dead furrows taking up the surplus runoff until such time as the vetiver can be planted. Rain caught and held in each furrow’s microcatchment has the chance to soak in. Each furrow can hold 50 millimeters of rainfall, so in most storms there is no runoff. Thanks to this natural system of water storage, the plants can benefit from the sunshine, as shown in view D. In view E one of the dead furrows has been planted to vetiver grass to stabilize the system.

A vetiver grass hedge is the key to the in-situ moisture conservation system. Once established, it serves as a guideline for plowing and planting on the contour, and in times of heavy storms it prevents erosion from destroying the farmer's field. The beauty of the plant is that, once it has established the hedge, the hedge is permanent.

Figure 32. Vetiver System

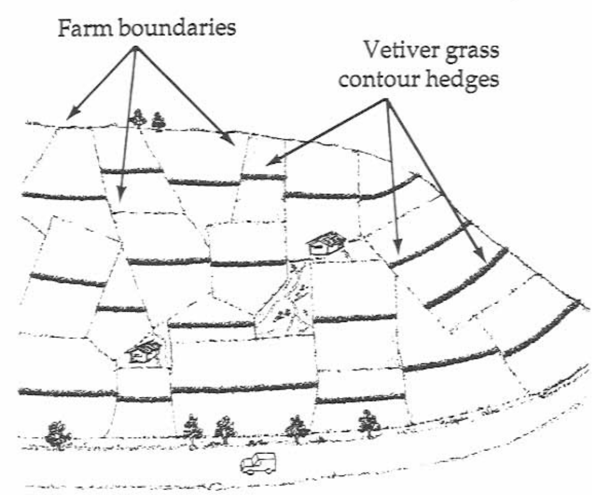


Figure 32 is a diagrammatic representation of what a vetiver grass system would look like in a small holder farming area. As can be seen, it fits into the individual farm systems perfectly. There are no waterways, no earthworks. Most farmers have one line of vetiver roughly in the middle of their fields, no matter what the shape; long fields may need two lines to stabilize them. Although each field has its own line or lines of vetiver, the entire hillside is protected against erosion because each line protects the ones farther down the slope. Under this system, once the hedges have established, no further protective work is needed, and maintenance is minimal. The farmers each have their own supply of vetiver planting material. Should a gully start to form anywhere, vetiver can be obtained from an existing hedge and planted across the incipient gully to prevent its spread—permanently and at no cost except for the farmer's own labor.

Why Vetiver Grass Is the Ideal Plant for the Vegetative System of Soil and Moisture Conservation

Although many grasses and trees have been tried over the years as measures to prevent erosion, to date only vetiver grass has stood the test of time. As made clear by the following list of its characteristics—derived from observations of Vetiveria zizanioides throughout the world—this truly remarkable plant is ideally suited for the vegetative system of soil and moisture conservation. No other grass is known to rival its hardiness or diversity.

- When planted correctly, V. zizanioides will quickly form a dense, permanent hedge.
- It has a strong fibrous root system that penetrates and binds the soil to a depth of up to 3 meters and can withstand the effects of tunneling and cracking.
- It is perennial and requires minimal maintenance.
- It is practically sterile, and because it produces no stolons or rhizomes it will not become a weed.
- Its crown is below the surface, which protects the plant against fire and overgrazing.
- Its sharp leaves and aromatic roots repel rodents, snakes, and similar pests.
- Its leaves and roots have demonstrated a resistance to most diseases.
- Once established, it is generally unpalatable to livestock. The young leaves, however, are palatable and can be used for fodder. (In Karnataka, India, a cultivar of V. zizanioides selected by farmers has softer leaves and is more palatable to livestock. This cultivar is also more dense, less woody, and more resistant to drought than some of the other available cultivars.)
- It is both a xerophyte and a hydrophyte, and once established it can withstand drought, flood, and long periods of waterlogging.
- It will not compete with the crop plants it is used to protect. Vetiver grass hedges have been shown to have no negative effect on—and may in fact boost—the yield of neighboring food crops.
- It is suspected to have associated nitrogen fixing mycorrhiza, which would explain its green growth throughout the year.
- It is cheap and easy to establish as a hedge and to maintain—as well as to remove if it is no longer wanted.
- It will grow in all types of soil, regardless of fertility, pH, or salinity. This includes sands, shales, gravels, and even soils with aluminum toxicity.
- It will grow in a wide range of climates. It is known to grow in areas with average annual rainfall between 200 and 6,000 millimeters and with temperatures ranging from -9° to 45~ Centigrade.
- It is a climax plant, and therefore even when all surrounding plants have been destroyed by drought, flood, pests, disease, fire, or other adversity, the vetiver will remain to protect the ground from the onslaught of the next rains.

Other Practical Uses for Vetiver Grass

Apart from its success as a system of soil and moisture conservation, vetiver grass has proved effective for a variety of other purposes. One of the most important is to stabilize the terrain as well as such structures as dams, canals, and roadways. Figure 33, for example, shows how vetiver can be used to stabilize a typical paddy field that relies on earth banks to keep irrigation water at the correct level. These banks (top illustration) can be worn down by the action of wind-churned water (lap erosion) and the activities of rats, crabs, and other hole-burrowing pests. The subsequent large-scale erosion, not to mention the loss of expensive and in some cases irreplaceable irrigation water, could lead to loss of the crop.

Vetiver can be planted on top of the paddy banks to stabilize them. Vetiver grows well under these conditions and does not suffer from the occasional inundation. In addition, its roots contain an essential oil that repels rodents. Furthermore, because its roots grow straight down and not out into the crop, the grass has no effect on the rice or its yield. Each year the vetiver can be cut back to ground level to prevent shading of the crop.

In an analogous example, vetiver can be used to maintain river levees by preventing them from being eroded back into the fields (Figure 34). It can also be used on river flats to prevent silt from entering the watercourse from the runoff from surrounding fields.

Vetiver's stabilizing influence is especially useful in steep and rolling country, where the distribution of moisture cannot be controlled. Unsuitable for the cultivation of cereal or other annual crops, such areas can be successfully planted to perennial tree crops on the contour when stabilized by vetiver grass. Most attempts to grow tree crops on steep hillsides are abandoned because the resulting poor, uneven stands are not worth the cost of maintenance. Figures 35-37 show a method of establishing tree crops on such hills using contour vetiver hedges. First the contours of the hill are pegged out. Next, by hand or with a bulldozer and ripper unit, the farmer digs shallow V ditches along the contour lines. A row of trees is planted close to the edge of each ditch, and vetiver grass is planted in the ditches (Figures 35 and 36).

Under this arrangement of planting, the runoff between one row of trees and the next one down the slope collects in the vetiver-lined ditches. (There is usually sufficient drainage on the slopes to preclude the possibility of waterlogging.) Thanks to the effects of such water harvesting, the rows of trees do not have to be planted as close together as the trees within a row. Initially, the V ditch will provide a measure of runoff control, thereby increasing the soil's moisture content, and both the vetiver and the planted trees will benefit. By the time the ditch "melts" away after a couple of years, the vetiver hedge will be established and performing its function of increasing the infiltration of runoff, halting the loss of soil and soil nutrients, and creating a natural terrace.

Because the collection of runoff in the contour ditches has the effect of doubling or tripling the amount of effective rainfall, fruit trees planted by this method need no irrigation in the first three years of establishment. The whole system is stabilized by the vetiver grass lines.

After the vetiver hedges have properly established, the vetiver grass can be cut down to ground level when the dry season sets in and its leaves used as a mulch at the base of the fruit trees to help retain stored moisture (Figure 37). The advantage of using vetiver for this purpose is that its leaves harbor few insects and last well as a mulch. Vetiver hedges also protect the young trees in the hot summer months by providing some indirect shade and in the colder winter months by acting as windbreaks.

Forest trees should be planted by the same method. Where this has been done, the results have been spectacular: more than 90 percent of the seedlings so planted survived the 1987 drought in Andhra Pradesh, India, whereas 70 percent of the other seedlings died.

In the Himalayan highlands, where farming is carried out on terraces, vetiver grass is now being used to stabilize the masonry risers that have been erected over the centuries. Without some form of vegetative support, these ancient structures require continual maintenance. If one riser washes out during a heavy storm, other terraces farther down the slope often suffer considerable damage because of the domino effect. Figure 38, which depicts a typical terrace system in the hills, shows the type of damage frequently sustained. To allow for drainage between the stones, the masonry risers are not bound together with mortar. If the walls were solid, instead of just a small section falling out the whole wall might collapse and trigger a landslide that could destroy the entire farm. Although these terraces have done an excellent job through the years, they do exact a toll in the form of crop losses, and they require a lot of hard work in repairs.

When the vetiver system of stabilization was explained to the hill farmers, they wanted to plant as many areas as possible. In a World Bank project begun in 1986, vetiver grass was planted along the edge of the terraces during the rainy season in the hope that its strong root system would reinforce the masonry risers.

Figure 39 shows what the vetiver grass-protected terraces should look like once established. The grass is planted only at the extreme edge of each terrace, so as not to impede the essential drainage between the stones. According to the farmers, what causes most of the damage during heavy storms is the cascading of water down the slopes and over the top of the masonry terraces, especially if the water has a chance to concentrate into a stream. Once established, the vetiver hedges should take most of the erosive power out of this runoff as well as protect the edge of the terraces.

As shown in the close-up in Figure 40, the masonry risers are vulnerable because they are simply stones stacked on top of each other and are usually 2 to 3 meters high. Because its strong root system can easily penetrate to the bottom of the risers, vetiver grass can be used to protect the entire rock face.

In another project in the Himalayan highlands, in areas with no masonry terraces to halt massive sheet erosion, vetiver grass contour lines are being established to determine whether the natural terraces that build up behind the hedges will form a base of stable land for the production of fuelwood and fodder crops. In China in the provinces of Jiangxi and Fujian, vetiver grass hedges are being used to protect the edges of citrus and tea terraces.

Vetiver grass is also used to protect road cuttings, as shown in Figure 41. In the West Indies, the plant has been used extensively for the stabilization of roadsides and has completely prevented erosion for years. People in St. Vincent use it to line the outer edge of the tracks to their houses. The grass has exhibited a remarkable ability to grow in practically any soil. In Andhra Pradesh, India, for example, it was observed growing at the Medicinal and Aromatic Research Station at the top of a bare hill. Even though the soils there are skeletal—granite boulders had to be bulldozed to make a plot for the grass—and are deprived of most of the benefits from rainfall (since they are located at the very top of a hill), and supported no other form of growth at the time, the vetiver grass showed no signs of stress. A plant that can thrive under these extreme conditions should be able to do an excellent job of stabilization almost anywhere.

The use of vetiver grass in wasteland development has recently been tested, and vetiver has proved effective as the initial stabilizing plant. In the Sahel region of Africa (in the state of Kano in Nigeria) and in Bharatpur in central India, under the extreme conditions of constant fire and drought, Vetiveria nigritana and Vetiveria zizanioides, respectively, have survived as the climax vegetation for hundreds of years. When planted as contour hedges in wasteland areas—the first stage in the stabilization of such areas—V. zizanioides reaps the benefits of any surplus runoff and harvests organic matter as it filters the runoff water through its hedges. Because the foothills of the Indian Himalayas are very young geologically, they are highly erodible; planting vetiver contour hedges around these slopes and then across the short erosion valleys will stabilize these areas. A masonry plug at the end of the system allows silt to build up and give the grass a basis of establishment (Figure 42). The same would apply to normal gullies as shown in Figure 43. Once established, the grass would terrace the gullies.

Using vetiver grass to stabilize riverbanks and canal walls is another recommended practice. In an experiment in Tanzania, on the road to Dodoma, a road engineer used vetiver grass to protect the wing wall of a bridge on one side of the river and constructed the usual concrete wing wall on the other side. Some thirty to forty years later, the concrete wall had already collapsed into the river, and the bank it was protecting was eroded. On the other side, the vetiver grass was still holding the bank in perfect shape. Figure 44 shows how vetiver grass can be used to protect the river approaches to a bridge.

Figure 45 shows how vetiver grass can be used to protect the banks of a major irrigation canal.

The contour irrigation aqueducts that lead back from the main canal around the foothills to the upper reaches of a command area suffer from siltation and erosion as they wind their way round the slopes. The typical problem is depicted in the top illustration in Figure 46: the concrete conduit is undercut by erosion at point A and fills with silt at point B.

To overcome this problem, vetiver grass should be planted parallel to the upper and lower sides of the concrete conduit. As shown in the bottom illustration, the upper hedge will prevent silt from entering the canal, while the lower two hedges will prevent erosion and thereby keep the concrete structure from being undermined by rills or gullies.

A similar approach can be taken to protect dams. Small dams are silting up at an alarming rate throughout the world. Once they become filled with silt, they are of no further use—and in many cases there is no other site suitable for a new dam. If vetiver grass is planted around the sides of the dam, as shown in the top illustration in Figure 47, the silt carried by runoff from the surrounding hills will be trapped before it reaches the dam. And vetiver hedges planted across the inlets (A) of small dams on intermittent streams will protect the dams from siltation. In time these hedges will form stable terraces that can be used for cropping or tree planting.

In the bottom illustration, vetiver has been planted on the walls of a dam to protect them from being worn down by rill erosion, a problem afflicting many unprotected earth dams around the world. To make it easier to spot seepage along the toe, or bottom, of dam walls and canal banks, vetiver should not be planted in those areas.

The versatile vetiver plant has numerous more common applications as well. It makes good bedding for livestock because it soaks up the urine and stays dry longer. Ultimately, it makes good compost. In countries with strong winds, vetiver grass hedges make good windbreaks to protect young fruit and timber trees. The grass also serves as a firebreak. Vetiver is used as thatch for roofs of houses, sheds, and shelters and as mulch for tree crops. The grass is woven into baskets, and the leaf midribs and flower stems make excellent brooms.

Management Tips

In the preface of the first edition we asked users to give us their views and share their experiences. Below are some of the responses we received.

General observations

- Well-grown vetiver hedges result in less runoff and improved groundwater supplies. Dry-season streamflow improves under the hedge system of in-situ moisture conservation.
- In most instances on slopes of up to 5 percent, about 10 centimeters of silt is deposited behind the hedges annually.
- In addition to its use for soil and moisture conservation, vetiver is being used for fodder, thatch, mulch, livestock bedding, windbreaks, roadside protection, and brooms.
- Where hillside crop drainage is required— as in the case of tobacco ridges on a graded slope—vetiver hedges act as an excellent buffer against erosion if placed on the contour at fixed intervals on the hillside.
- The majority of a vetiver plant's roots grow straight down for at least 3 meters. Other roots will grow out into the field for up to 50 centimeters, but they do not significantly affect crop growth—probably because of the high moisture content of the soil associated with the hedge.
- Vetiver hedges take about three years to be fully effective under low rainfall conditions. If vetiver slips are planted 10-15 centimeters apart, the hedge will form

more quickly. Even where there are gaps, interplant erosion does not seem to be a problem because the roots join together in the first year to form a subsurface barrier.

- Where vetiver is planted along the edge of terraces, forward-sloping terraces are better than backward-sloping terraces because less runoff is removed by the terrace back channels. Also, because one can dispense with the back channel—and also in some instances the front channel, where constructed—more land will be available for cropping. The ultimate objective should be to dispense with terracing, where possible, through the use of vetiver hedges, so that the topsoil can remain relatively undisturbed.
- Vetiver has been observed growing under conditions ranging from 200 to 6,000 millimeters of rainfall annually and at 2,600 meters above sea level. It survives snow and frost and grows on most types of soil. It obviously grows better where the soil is moist and fertile, but even under adverse conditions it grows extremely well compared with other grasses.
- Vetiver in many countries has been infected with brown spot. The disease does not seem to have an adverse effect on its growth, however. A few instances of black rust have been observed but are not significant. In India the rust seems to be vetiver-specific and does not cross infect other plants. In China vetiver has been attacked by stem borers, but in most cases the borer dies once it gets in the stem. Farmers are generally unconcerned and tend to respond by selecting plants that are more pest- and disease-resistant.
- Some early results from India, on both alfisols and vertisols, indicate that rainfall runoff was reduced from 40 percent to 15 percent (compared with the control), and silt loss was reduced from 25 tons per hectare to 6 tons per hectare (all for two-year-old hedges on 2 percent slopes). The time to wilting in one demonstration on alfisols increased from seven days to twenty when in-situ moisture conservation measures were applied.
- An interesting technique observed in China was the plaiting, or interlacing, of vetiver leaves and stems from separate, neighboring plants to create a temporary barrier until the full hedge could be established.
- The cost of vetiver hedges depends on the availability and cost of planting material. In India the initial cost of hedge establishment is estimated at US$8 per 100 meters of hedge, $6 of which goes for planting materials and other inputs. Once the live material, in the form of a hedge, is on the farm, the cost to produce new hedges is relatively low—it may be as little as $2 per 100 meters. Under such conditions the economic rate of return is more than 100 percent. Where the slopes are less than 5 percent and the hedges are spaced about 40 meters apart, 250 meters of hedge is required per hectare at a cost of between $5 and $20 (see Table 2 at the back of this handbook).

Selection of planting material

- In Karnataka, India, to date six cultivars have been identified. One cultivar selected over the years by farmers exhibits superior characteristics for hedge formation, fodder, and insect-, disease-, and drought-resistance.

- When selecting material, choose plants that exhibit resistance to pests and diseases and that tiller well.
- Where winters are cold, select material that is more tolerant of cold temperatures.

Nursery establishment

- Vetiver planted densely in large gullies can be used for replanting elsewhere. Gullies make good informal nurseries because often they are permanently moist and have conditions good for growth.
- Stem and root cuttings grown under plastic may be a cheap way of vegetative propagation.
- For optimum tillering, nurseries should be fertilized (150 kilograms per hectare of nitrogen) and irrigated (especially in very dry areas).
- Nursery plants should be cut back to about 30-50 centimeters to encourage tillering.
- The best nurseries seem to be in loamy sands to sandy-clay soils where the drainage is good and where it is easy to dig up the plants for transplanting. We have seen excellent nurseries (when well watered) in sandy areas near perennial rivers.

Field Planting

- As long as the vetiver is planted when the ground is wet, it can survive a long period of drought after planting.
- On very small farms and fields where land is scarce and where farmers are reluctant to plant across their fields, vetiver should be planted on the field boundaries.
- On nonarable lands that are heavily eroded, vetiver should be planted first in the gullies and around the gully heads. The material from the gullies can then be used for planting across the slopes in subsequent years.
- Gap filling is essential and should be done at the beginning of the wet season. The possibility of "layering" live stems across the gaps should be tried as a gap-filling measure.
- To encourage tillering and hedge thickening, the grass should be cut back to 30-50 centimeters after the first year. Cutting in the first year does not seem to have any incremental impact on tillering.
- White ant infestation (attacking dead material) can be controlled by applying 1 kilogram of BHC for every 150 meters of hedge line.
- Once the vetiver has established (one month after planting), plowing a small furrow immediately behind the vetiver hedge line helps to capture runoff and results in better growth of the plant.

Common Names for Vetiver Grass

China: Xiang-Geng-chao

Ethiopia:
- **Amharic**: Yesero mekelakeya

Ghana:
- **Dagomba**: Kulikarili

India:
- **Hindi**: Bala, Balah, Bena,
- **Ganrar**: Khas, Onei, Panni
- **Urdu:** Khas
- **Bengali:** Khas-Khas
- **Gujarati:** Valo
- **Marathi:** Vala Khas-Khas
- **Mundari:** Birnijono, Sirum, Sirumjon
- **Oudh:** Tin
- **Punjabi:** Panni
- **Sadani:** Birni
- **Santali:** Sirom
- **Telugu:** Avurugaddiveru, Kuruveeru, Lamajjakamuveru, Vettiveeru, Vidavaliveru
- **Tamil:** Ilamichamver, Vettiver, Vilhalver, Viranam
- **Kannada:** Vettiveeru, Laamanche, Kaadu, Karidappasajje hallu
- **Mysore:** Ramaccham, Ramachehamver, Vettiveru

Indonesia: Aga wangi, Larasetu, Larawestu, Raraweatu

Sudanese: Janur, Narawastu, Usar

Iran:
Persian: Bikhiwala, Khas

Malaysia: Nara wastu, Nara setu, Naga setu, Akar wangi (fragrant root), Rumput wangi (fragrant grass)

Nigeria:
- **Hausa:** Jema
- **Fulani:** So'dornde, So'mayo, Chor'dor'de, Ngongonari, Zemako

Philippines: Ilib, Mora, Moras, Moro, Muda Narawasta, Raiz de moras, Rimodas, Rimora, Rimoras, Tres-moras,Vetiver, Amoora, Amoras, Anias de moras, Giron

Sahel:
- **Bambara:** Babin, Ngongon, Ngoko ba
- **Songhai:** Diri
- **Fulani:** Kieli, Dimi, Pallol
- **Sarakolle:** Kamare
- **Mossi:** Roudoum
- **Gurma**: Kulkadere

Senegal:
- **Wolof:** Sep, Tiep
- **Fulani:** Toul
- **Tukulor:** Semban

Sierra Leone:
- **Mende**: Pindi
- **Susu:** Barewali
- **Temne:** An-wunga ro-gban

Sri-Lanka:
- **Sinhalese:** Saivandera, Svandramul

Thailand: Faeg

Table 1. Slope, Surface Run, and Vertical Interval

Slope degrees	Slope percent	Gradient	Surface Run (a) meters
1	1.7	1 in 57.3	57.3
2	3.5	1 " 28.6	28.7
3	5.3	1 " 19.1	19.1
4	7.0	1 " 14.3	14.3
5	8.8	1 " 11.4	11.5
6	10.5	1 " 9.5	9.6
7	12.3	1 " 8.1	8.2
8	14.0	1 " 7.1	7.2
9	16.0	1 " 6.3	6.4
10	17.6	1 " 5.7	5.8
11	19.4	1 " 5.1	5.2
12	21.3	1 " 4.7	4.8
13	23.1	1 " 4.3	4.5
14	25.0	1 " 4.0	4.1
15	27.0	1 " 3.7	4.0
16	28.7	1 " 3.5	3.6
17	30.6	1 " 3.3	3.4
18	32.5	1 " 3.1	3.2
19	34.4	1 " 3.0	3.1
20	36.4	1 " 2.8	3.0
21	38.4	1 " 2.6	2.8
22	40.4	1 " 2.5	2.7
23	42.5	1 " 2.4	2.6
24	44.5	1 " 2.3	2.5
25	46.6	1 " 2.1	2.4
26	48.8	1 " 2.0	2.3
27	51.0	1 " 2.0	2.2
28	53.2	1 " 1.9	2.1
29	55.4	1 " 1.8	2.1
30	57.7	1 " 1.7	2.0
31	60.1	1 " 1.7	2.0
32	62.5	1 " 1.6	1.9
33	65.0	1 " 1.5	1.8
34	67.5	1 " 1.5	1.8
35	70.0	1 " 1.4	1.7
36	72.7	1 " 1.4	1.7
37	75.4	1 " 1.3	1.7
38	78.1	1 " 1.3	1.6
39	80.1	1 " 1.2	1.6
40	84.0	1 " 1.2	1.6
41	87.0	1 " 1.2	1.5
42	90.0	1 " 1.1	1.5
43	93.0	1 " 1.1	1.5
44	96.6	1 " 1.0	1.4
45	100.0	1 " 1.0	1.4

a. The figures for the surface run are based on a vertical interval (VI) of 1 meter. To use this table, multiply the surface run by the VI: for example, with a VI of 2 meters on a 70 percent slope, the surface distance between vegetative barriers = 2 x 1.7 = 3.4 m

Table 2. Cost of Land Treatment with Contour Hedges of Vetiver Grass by Slope Classification and the Cost of Labor (U.S. dollars per hectare)

Slope	Daily labor Cost US $ per Day					
(%)	**$0.50**	**$1.00**	**$1.50**	**$2.00**	**$2.50**	**$3.00**
0-1	2.43	3.44	4.45	5.46	6.47	7.48
1-2	7.29	10.32	13.35	16.38	19.40	22.43
2-5	17.02	24.08	31.15	38.21	45.28	52.34
5-10	36.46	51.60	66.74	81.88	97.02	112.17
10-15	60.77	86.00	111.24	136.47	161.71	186.94
15-20	85.08	120.40	155.73	191.06	226.39	261.72
20-30	121.54	172.01	222.48	272.95	323.42	373.89
30-40	170.15	240.81	311.47	382.12	452.78	523.44
40-50	218.77	309.61	400.46	491.30	582.15	672.99
50-60	267.38	378.41	489.45	600.48	711.51	822.55
60-70	316.00	447.22	578.44	709.66	840.88	972.10
70-80	364.61	516.02	667.43	818.84	970.25	1,121.66
80-90	413.22	584.82	756.42	928.02	1,099.61	1,271.21
90-100	461.84	653.62	845.41	1,037,19	1,228.98	1,420.77