Vetiver Grass: a Method of Soil and Moisture Conservation

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Vetiver Grass (Vetiveria zizanioides)

A Method of Vegetative Soil and Moisture Conservation

First Edition

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PREFACE

This handbook has been prepared to support field workers and farmers in developing appropriate soil and moisture conservation measures using vegetative systems. Experience in India and in other countries has shown that conventional earth bunding systems on small farms have been expensive to develop and have in many cases proven ineffective. Vegetative systems of soil and moisture conservation have proved cheaper and more effective *when implemented correctly*. The technical staff of our New Delhi office believes the system described in this field handbook has extensive possibilities in India. The system is being tested in farmers' fields in a number of locations in India. We encourage you to try the system out, and we would like to know your views as to its relevance, based on actual "on-farm" experience.

R.G. Grimshaw
Chief, Agriculture Division
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New Delhi

INTRODUCTION

There is an urgent need to consider soil erosion and water conservation, two long range problems that confront farmers and their governments. 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 conservation is truly a world problem.

Soil erosion has reached crisis proportions in this country. Over half of India's crop land is losing productivity because top soil is being washed or blown away faster than natural forces can replace it. Reducing the topsoil layer causes part of the subsoil to be cultivated, meaning that plants will have reduced access to essential nutrients and water.

Changes in farming practices have accelerated this erosion in recent years, as farmers switched from traditional rotations to continuous row cropping in response to a growing need for grain.

Top level policy makers recognise the problem exists and have already spent Rs.1,200 M on earthworks as preventative measures. But this has only covered a few million of India's 328 M hectares, 90% of which is afflicted with soil erosion.

According to a study made by the Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehra Dun, 5334 million tonnes of soil is being eroded annually, of which 29% is being permanently lost to the sea, 10% is deposited in reservoirs as silt, and 61% is displaced from one location to another. The study further warns that the annual average loss of top soil is approximately 16 tonnes/ha, far above the permissible limits of around 4 tonnes/ha. The problem is, who is going to pay the bill for the necessary controls?

Take a simple case: the construction of diversion banks and waterways, at a low Rs.1,000/ha, needed on say half of the total land mass, or 164 M hectares, would cost on the order of Rs.164,000 M (or about US$14 billion). Conservation construction costs are tremendous and, unfortunately, only provide temporary measures.

The Government doesn't have this money, and the States cannot afford it. Many think the farmers should pay for it, but it is beyond their means, *unless*, they use vegetative methods as outlined in this handbook. The short-term costs of *constructed* soil conservation measures would outrun the short-term benefits by three or four times, and these practices not only cost money, they also *cut* production. Farmers do not look kindly on these practices.

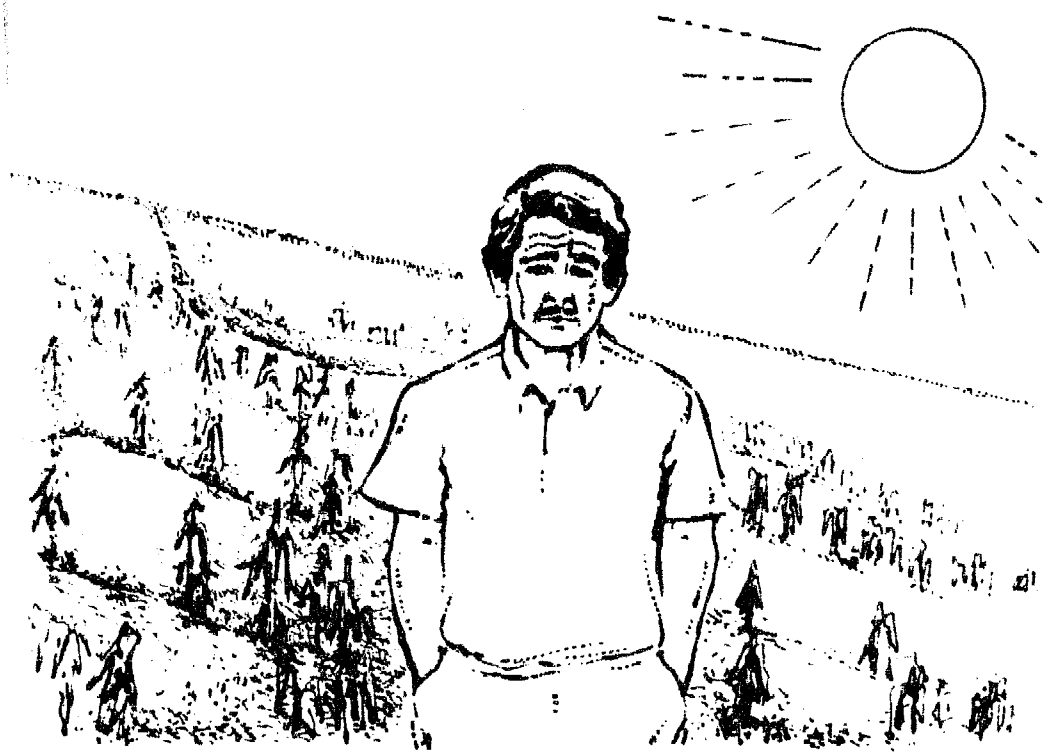
On the otherhand, *vegetative* soil and moisture conservation measures are not only extremely cheap (less than 1/10-1/100 the cost of constructed banks and waterways) but the farmers can do the work themselves, and, if they have the planting material, at no cost. Once vegetative hedges are established (this usually takes two to three seasons) they are permanent. When they are followed as contour guidelines for cultivation and planting, the resulting "in-situ" moisture conservation increases yields by at least 50% over traditional methods.

Now, the other problem: *Water.* The shrinking supply of groundwater – underground reservoirs known as aquifers – are starting to dry up as irrigation wells extract the water faster than it can be recharged. Underground water reserves are *not* inexhaustable. Without conservation, areas will begin to dry up, or the water table will get so low that pumping costs will become uneconomic. Vegetative conservation measures *hold* the runoff on the slopes longer than other methods, giving it a chance to soak in over a wide area and recharge the aquifers. Constructed measures are designed to dispose of runoff as fast as practicable, thus reducing any chance of recharge. Dams rarely recharge aquifers; if they did, it would be considered that they were leaking.

This handbook describes the use of Vetiver grass as the best known plant, *at this time,* that can be used to help prevent sheet erosion and increase moisture conservation. If you can find a better, more appropriate plant, use it – and tell us about it. This is the only system we know that works and has been tested over 30 years under full farming conditions with smallholders.

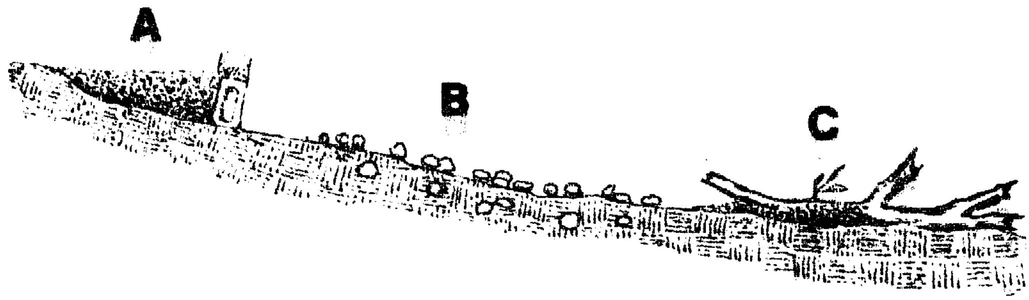
J.C. Greenfield
World Bank
New Delhi
February 1987

RAINFED FARMING



thout moisture conservation in situ, your crops
'l fail as above. But, under the same conditions,
ing moisture conservation, your crops will grow
ll, as below. Why don't you try it?

Fig 1



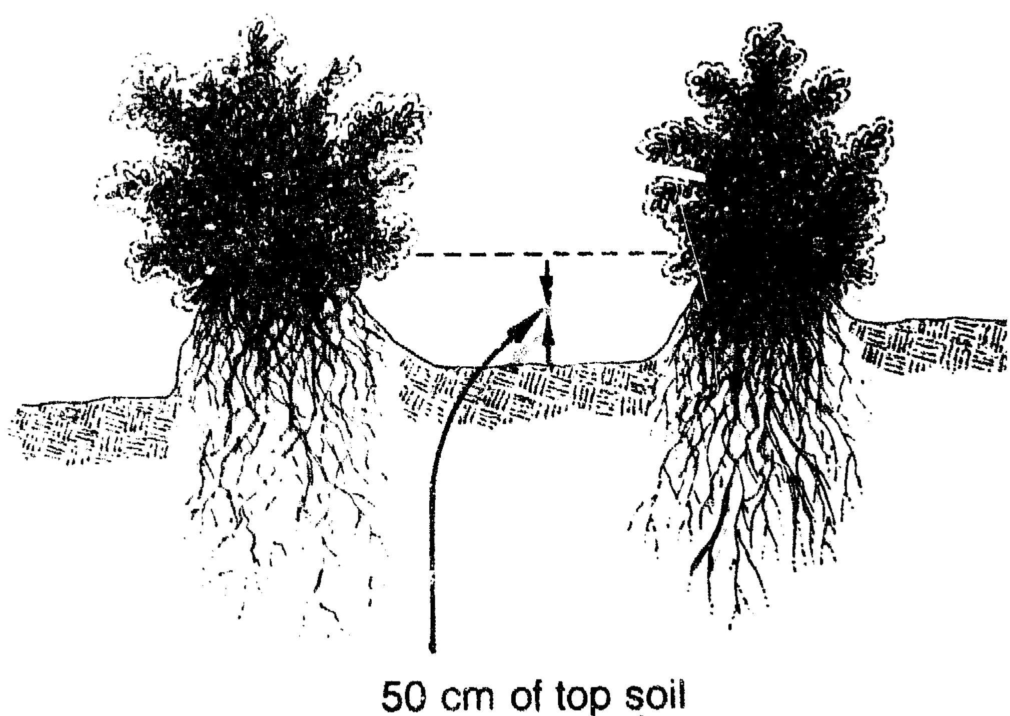


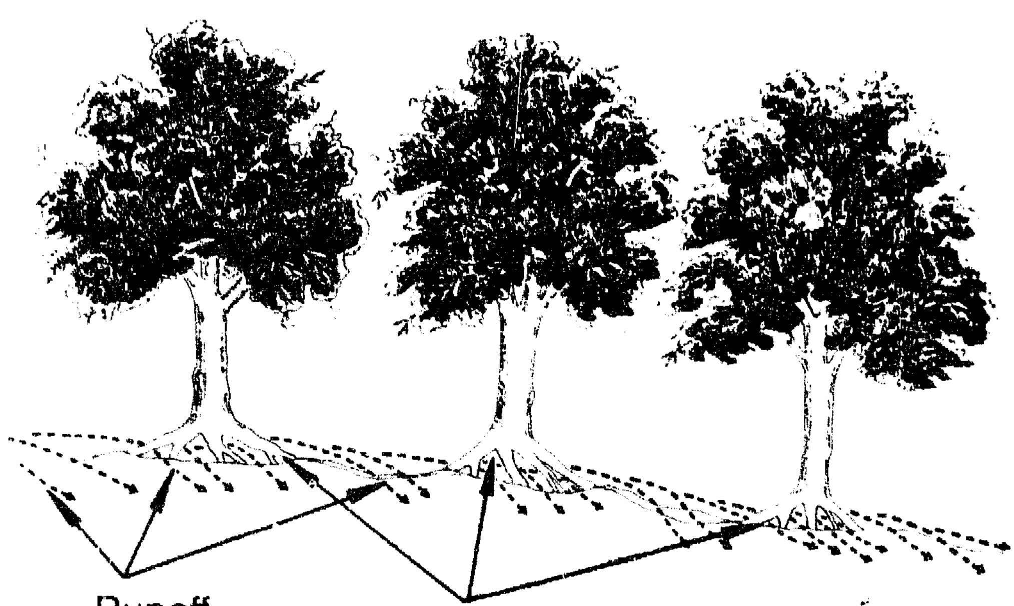
Fig 2

SHEET EROSION

Sheet erosion is the first and most damaging form of erosion, mainly because it is often not recognised and is seldom treated. Sheet erosion strips the soil from the farmers'fields, or any unprotected area, and moves it down the slope mixed with runoff water from rainfall – muddy water in drains, streams and rivers is mostly the result of sheet erosion. Sheet erosion leads to rill and then gully erosion, which are spectacular and easily recognised. Sheet erosion is not spectacular, but it can be recognised as shown in **Figs 1,2 and 3.** At **A** in **Fig 1,** it can be seen as soil collecting behind obstructions in the field, in this case a brick; or in **B,** as stones left on the surface, as they are too heavy for the runoff to carry away; or as in **C,** when you lift twigs or even straws off the surface, they leave a "mold" of soil behind.

In **Fig 2** the actual amount of soil lost can be measured between two surviving plants whose roots prevent sheet erosion. Measuring from the top of the mound to the present soil surface, shows that, in this case, 50 cm of soil has been lost over the whole field since these plants became established.

Fig 3



SHEET EROSION

Fig 3. In forest areas, or even where trees stand alone in fields or wastelands, the effects of sheet erosion can be seen easily when you look at the roots of these trees – the tree seems to be standing on its roots, water can easily pass underneath the stem of the tree and between it's roots. Eventually the tree will be washed right out of the ground, when all the soil that supported it and gave it life has been washed away. Trees do *not* prevent sheet erosion, only fibrous rooted shrubs and grasses planted as hedges along the contour can prevent sheet erosion. They slow the runoff water down, spread it out, take the erosive power out of it, filter out the soil it is carrying, and let the filtered runoff proceed down the slope, gently, and, if the hedges have been planted at the correct vertical interval **VI** for a given soil, without any further erosive effect.

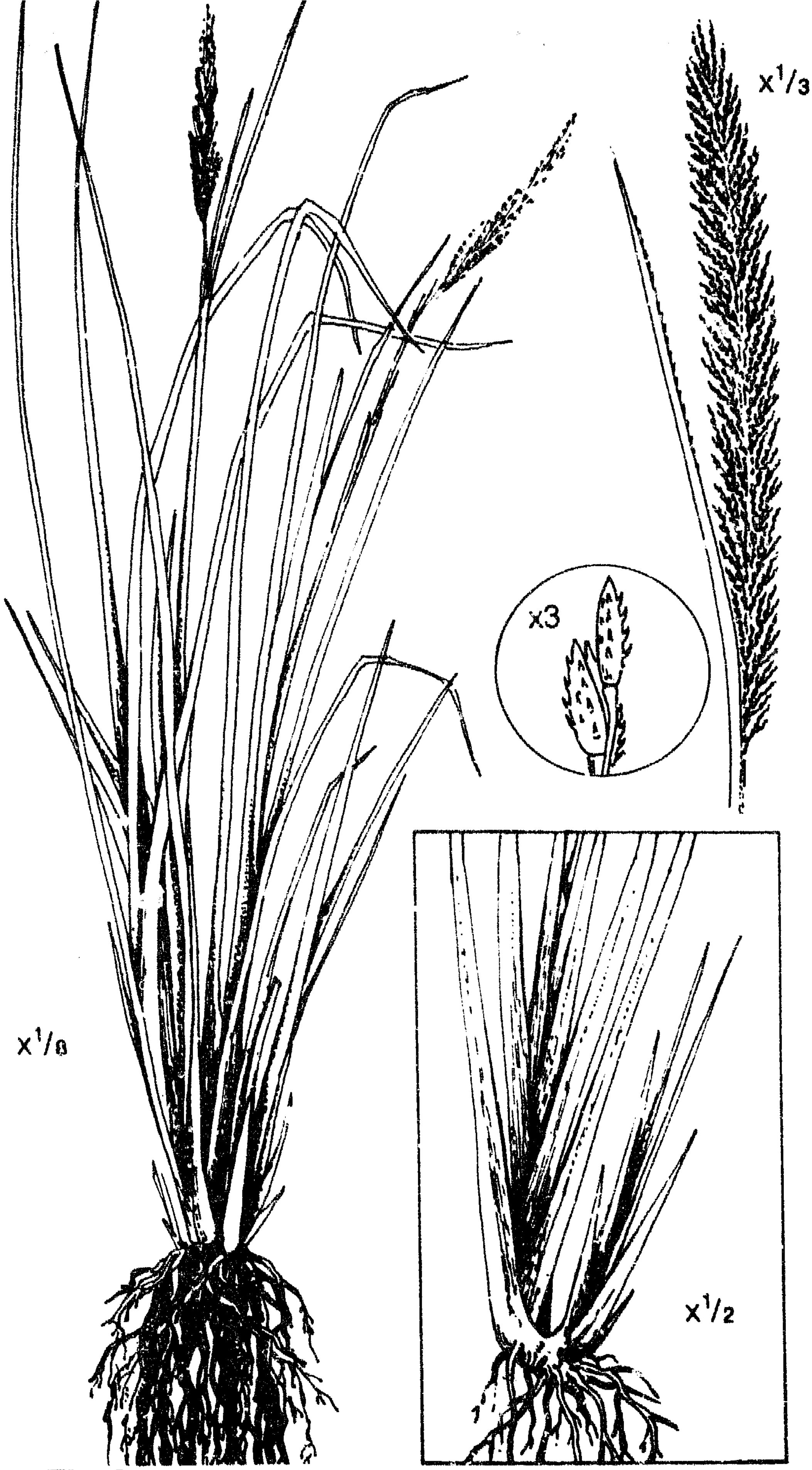


Fig 4

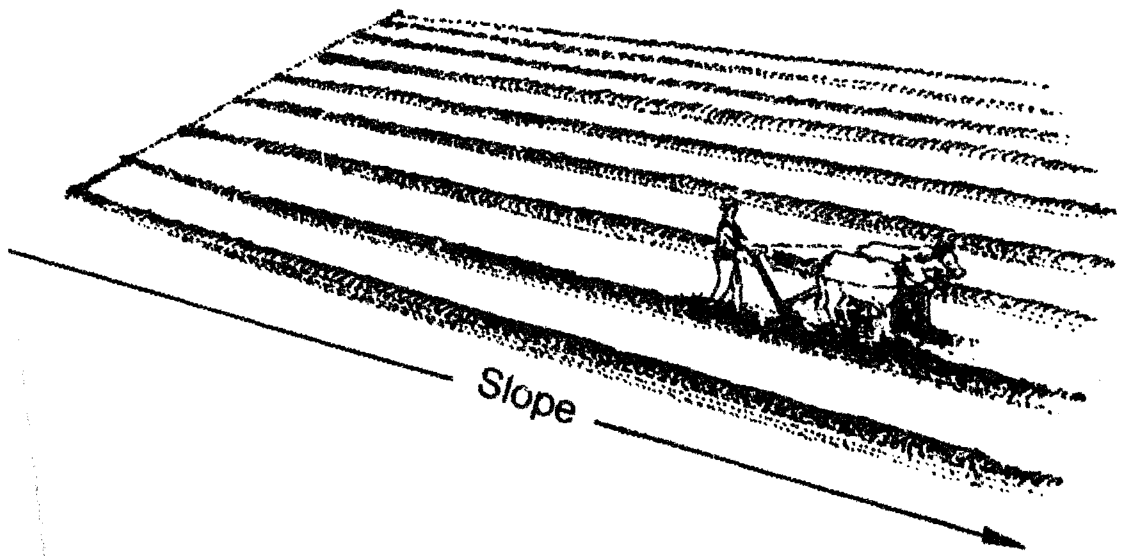
VETIVERIA

Lem.-Lisanc. (x = 10)

Of the 10 species of coarse perennial grasses in the tropics of the "old world", belonging to the tribe Andropogoneae, *V. zizanioides*, has proven ideal for vegetative soil conservation measures.

Vetiveria zizanioides (L) Nash (2n = 20) KHUS, VETIVER GRASS, KHUSKHUS, a densely tufted, awnless, wiry, glabrous, perennial grass, is a "shy breeder" and is considered sterile – no rhizomes, no stolons, propagated by root divisions, or slips. The plant grows in large clumps from a much-branched "spongy" root stock with erect culms 0.5-1.5 m high. The leaf blades are relatively stiff, long and narrow – up to 75 cms long and 8 mm or less in width, glabrous, but "downward rough" along the edges. Panicles 15-30 cm long, narrow, acute, appressed, awnless, one sensile and hermaphrodite, somewhat flattened laterally, with short sharp spines, 3 stamens and 2 plumose stigmas; the other spikelet pedicelled and staminate. Some cultivated forms seldom flower **Fig 4.**

Fig 5



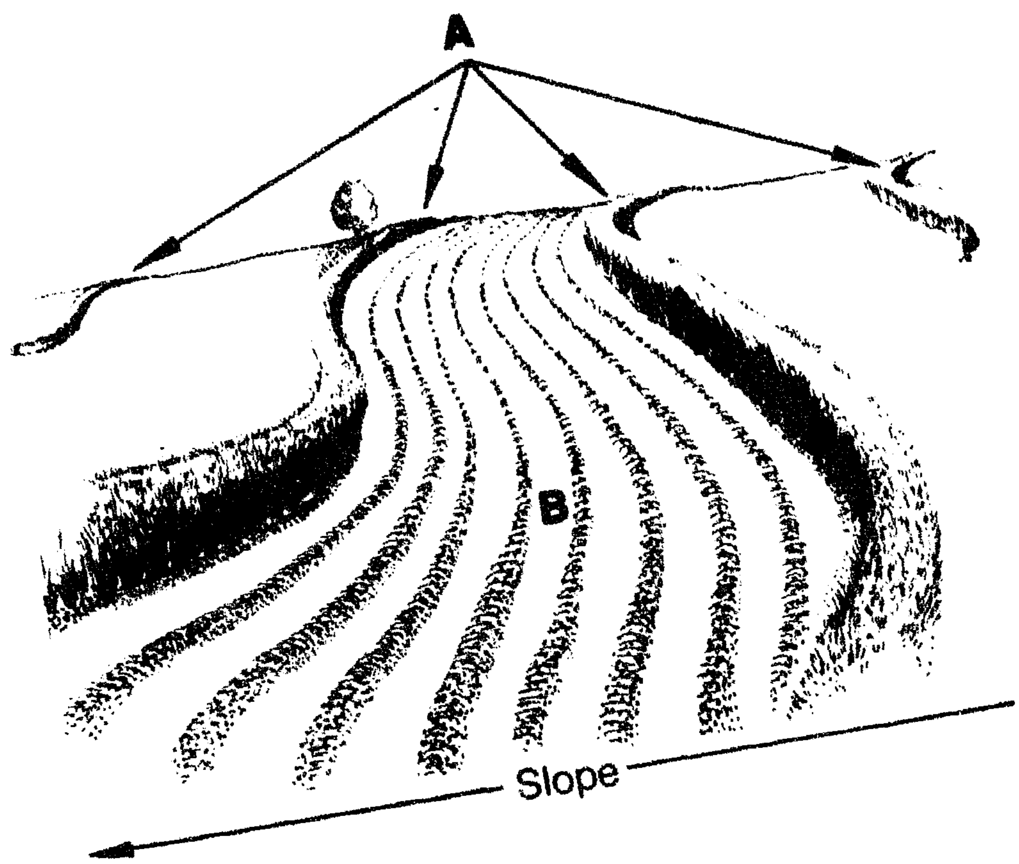


Fig 6

The traditional way of farming in rainfed areas, no matter how "flat" the slope may seem, is "along the slope" or, up-and-down the hill. This system encourages runoff and soil loss; sheet erosion is bad under this type of cultivation. The crops are denied over 50% of the rainfall that is lost as runoff, and as the slopes get steeper, runoff increases and the rainfall becomes less effective. Encouraging rainfall to run off like this does not give the water a chance to soak in. In **Fig 5** you see the farmer ploughing along the slope, unknowingly encouraging the rainfall to leave his field. **Fig 6** is an illustration of the method advocated in this handbook. That is "in-situ" moisture conservation, stabilised and enhanced by *"vegetative contour hedges"*. These hedges, once established, need no further maintenance and will last for years, protecting the farmers' soils from erosion and, at the same time, building up natural terraces. In **Fig 6, A** shows vegetative hedges and **B** shows planting furrows which follow contour guidelines.

Fig 7

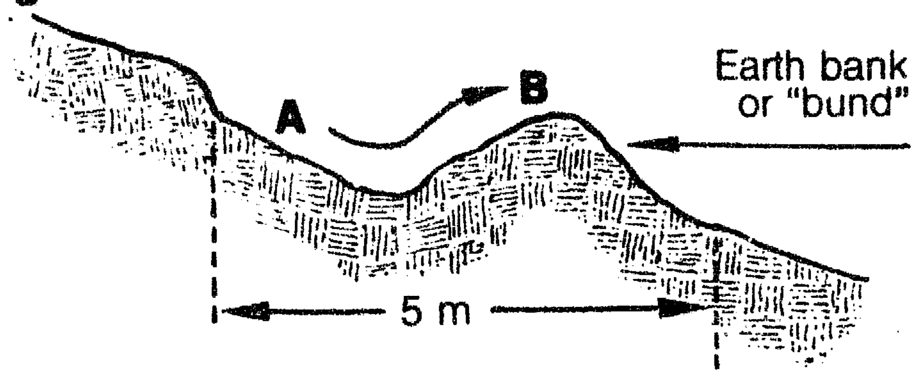
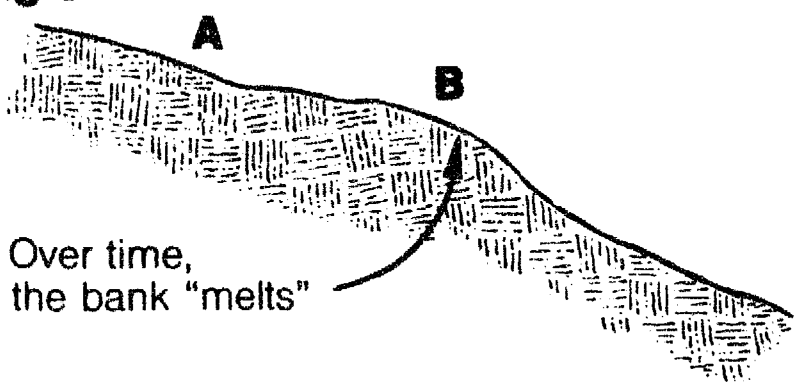


Fig 8



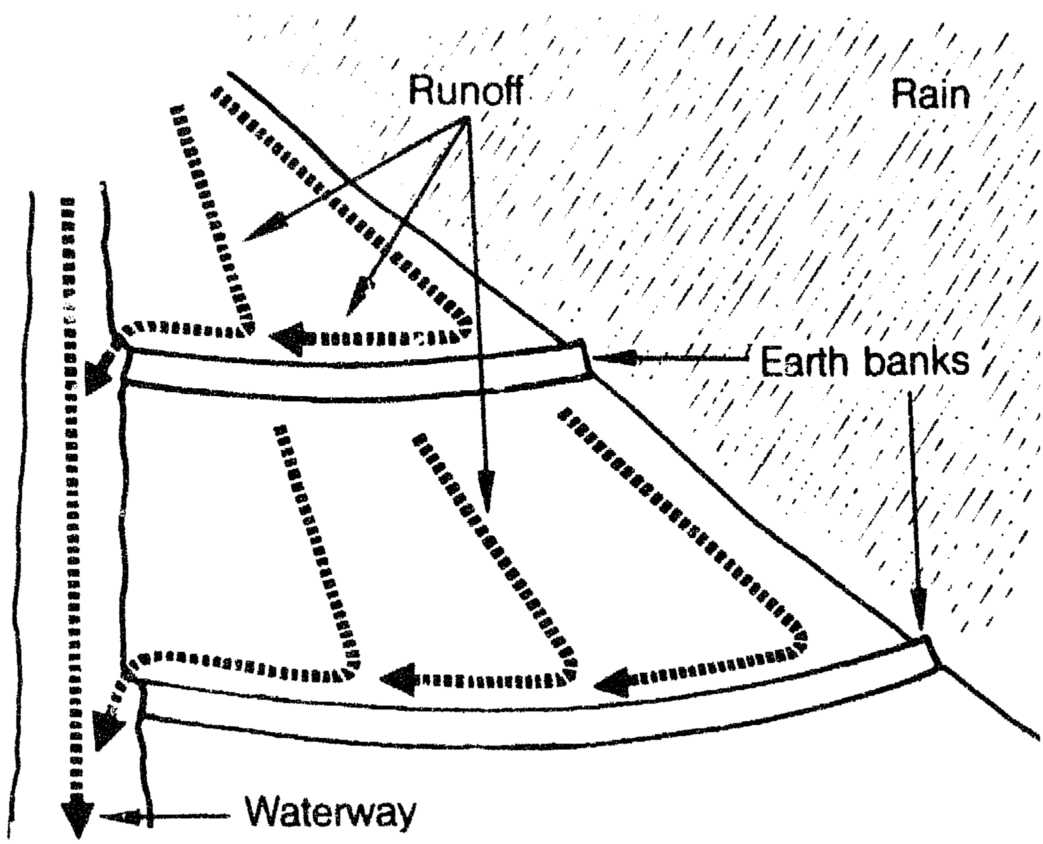


Fig 9

The conventional "Tennessee Valley" constructed earthbanks, or "bunds" as they are called in India, have slowed down erosion throughout the world since the 1930s. However, they are no longer considered appropriate for small holders, since this is a totally unnatural system of "drainage". As can be seen in **Fig 7** top soil is taken from point **A** and heaped up at **B** to make a bank, **A** forming the channel that conveys the runoff sideways. As the bank is made of the same soil it is trying to protect from erosion and is now steeper by being made into a bank, it erodes and "melts" away over time **Fig 8** . Then it has to be replaced at great cost to the farmer. To collect sufficient soil to make the bank and channel, a 5 m strip is taken out of production over the total length of the bank, as in **Fig 7.**

Fig 9 shows the unnatural way the land is drained by this system. All the runoff is channeled sideways and dumped into a waterway that small-holders do not want running through their farms

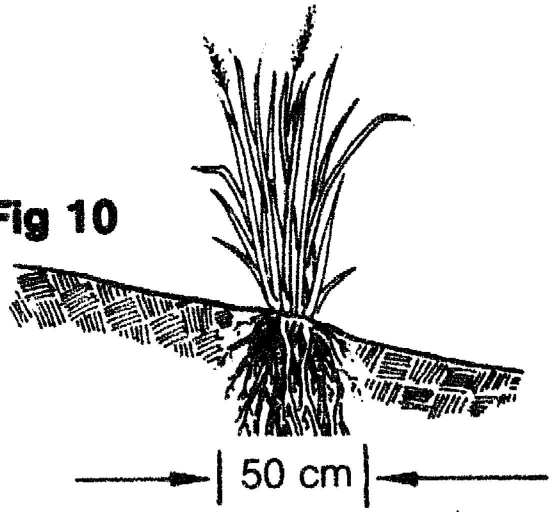


Fig 10

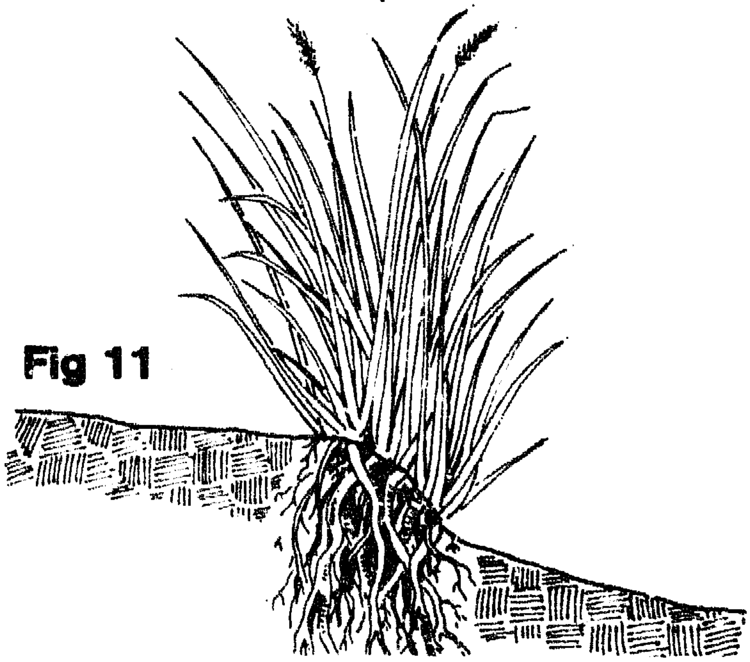


Fig 11

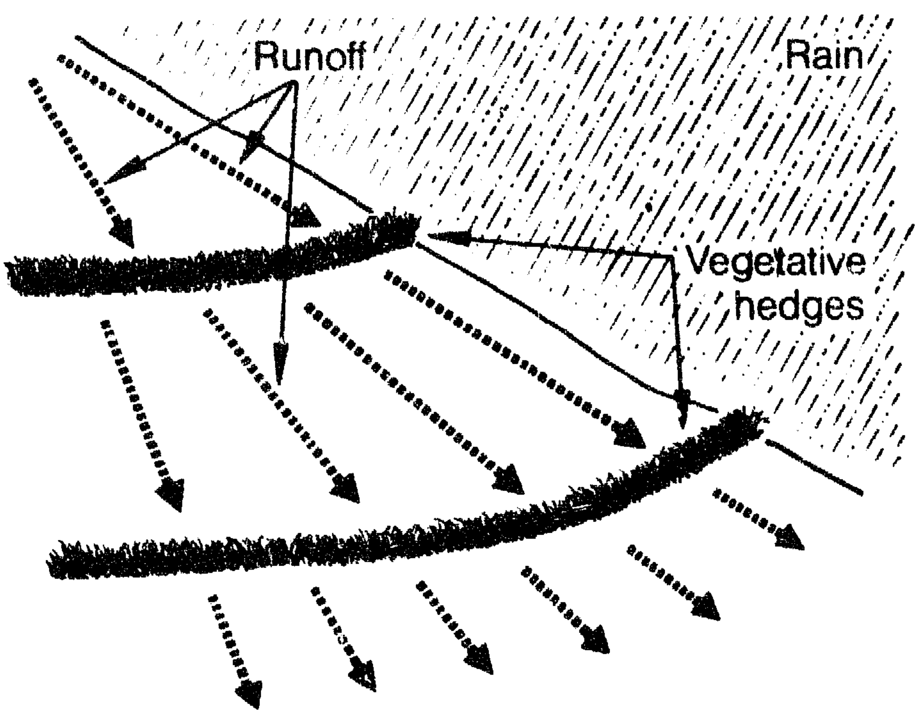


Fig 12

The *vegetative* method of soil and moisture conservation uses nature to protect itself. In this case, Vetiver grass is being used. Only a 50 cm strip is taken out of production **Fig 10.** The grass root divisions (slips) are planted in a single ploughed furrow, so little soil is disturbed. The farmer can do the whole job himself with the "power" he has on his farm. Earth banks have to be made by bulldozers or hired labour.

Fig 11 shows what happens over time with the vegetative system: the soil is filtered out of the runoff, the grass tillers up through this silt, forming a natural terrace that becomes a permanent feature of the landscape, remaining effective for years.

In **Fig 12,** when the runoff reaches the vegetative hedges, it slows down, spreads out, drops its silt load and "oozes" through the hedge in a natural fashion, reaching the bottom of the slope without causing any erosion and without being concentrated in any area. This system requires no engineering – the farmer can do the whole job himself.

Fig 13

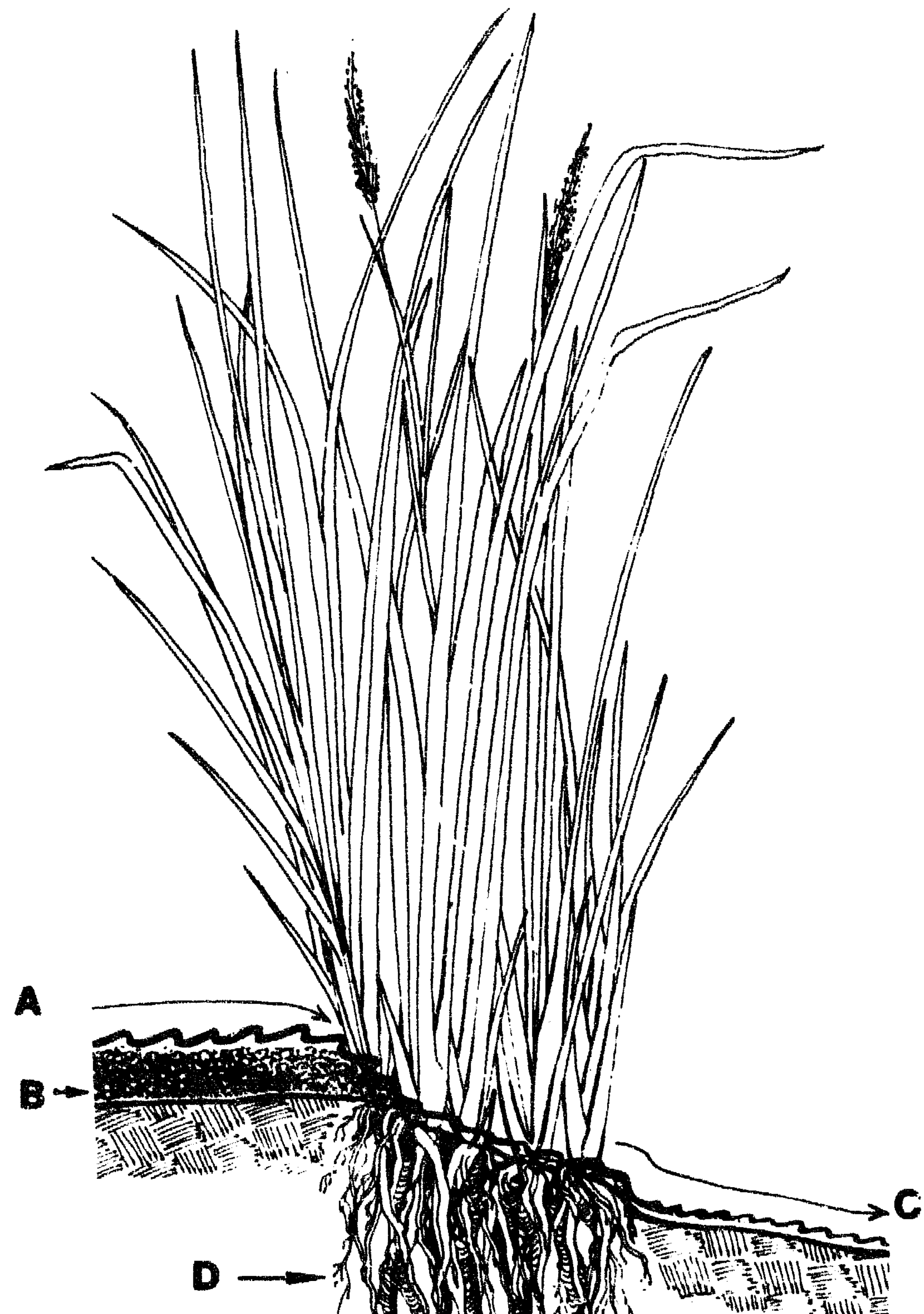
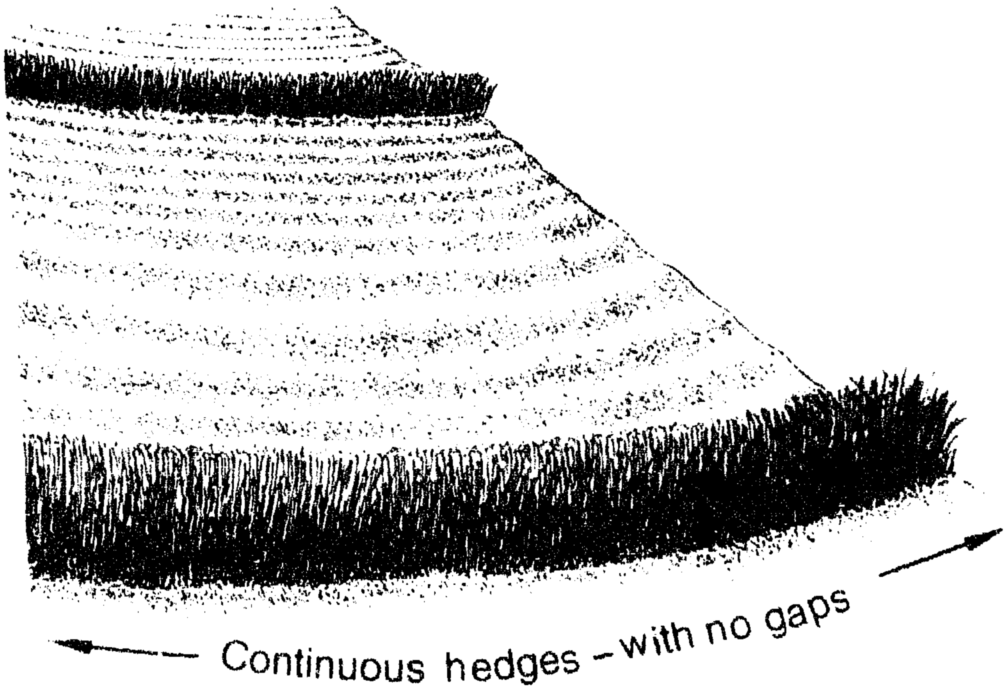


Fig 13 illustrates the essential function of a vegetative hedge being used as a contour soil conservation measure. Here, Vetiver grass has been established and is acting as a filter to runoff, using its leaves and stems, etc. to filter the silt out of the runoff water, slow it down, and take the erosive power out of it as it oozes through the hedge and moves on down the slope. In **Fig 13, A** shows the silt-loaded runoff being slowed down by the plant; **B** shows the silt dropping out of the water behind the plant; and **C** shows the "siltless" water continuing on down the slope at greatly reduced speed. **D** shows the dense spongy root system that binds the soil together to a depth of up to 3 m. It forms a dense curtain of roots underground on the contour. These act like reinforcing steel in concrete, protecting the soil under the plant from rilling, gullying and tunneling. These same roots, because they contain a strong aromatic oil, are repellent to rats and other pests.

Fig 14



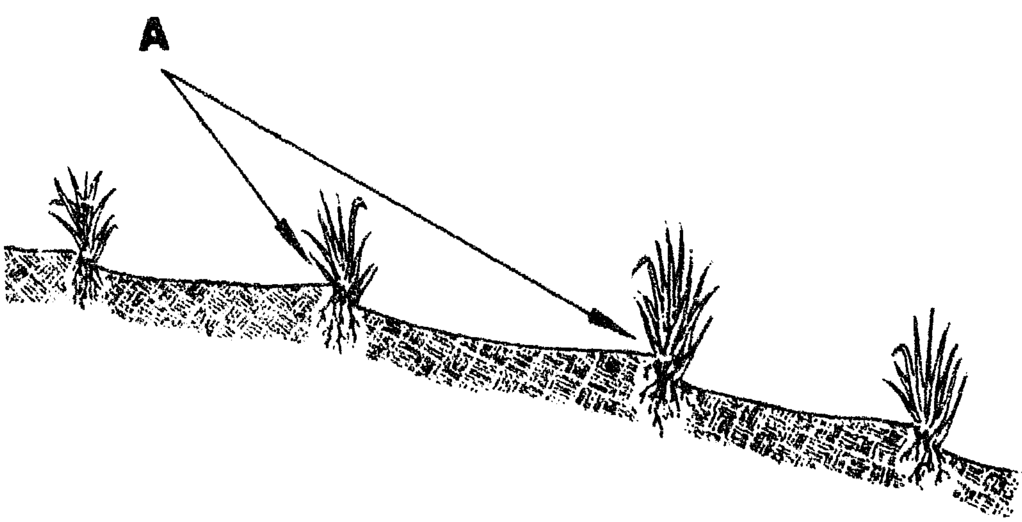
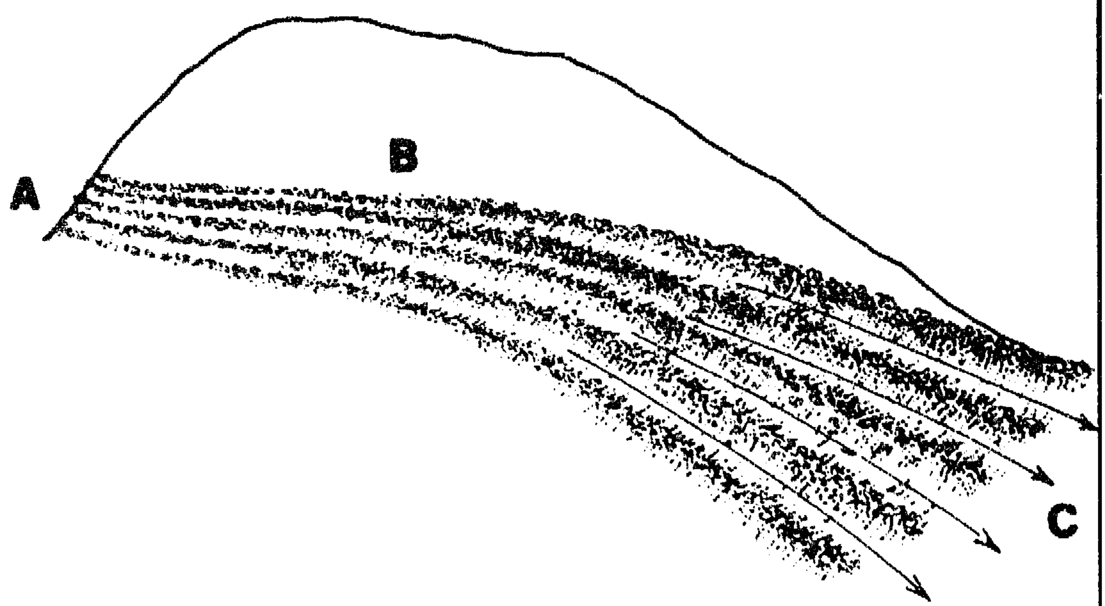


Fig 15

Fig 14 illustrates the essential point of a vegetative system. and that is, ***it must form a hedge*** to be effective. It is unlike the constructed system of soil conservation banks, which are effective immediately following construction, but wear out, break down or simply "burst" in heavy rainstorms. The vegetative system takes from two to three growing seasons to establish as a dense hedge capable of withstanding torrential cloudbursts while still protecting the soil. You must understand that the plants need protection and maintenance/gap filling during the first and second, and possibly the third season. Then they can stand on their own as a hedge with no further maintenance.

In the first, and certainly in the second season, it may be possible for extension workers to show the farmers the silt being trapped behind the plants as they are establishing. as shown by **A** in **Fig 15.** It is an essential task of the extension worker to explain this system to the farmer.

Fig 16



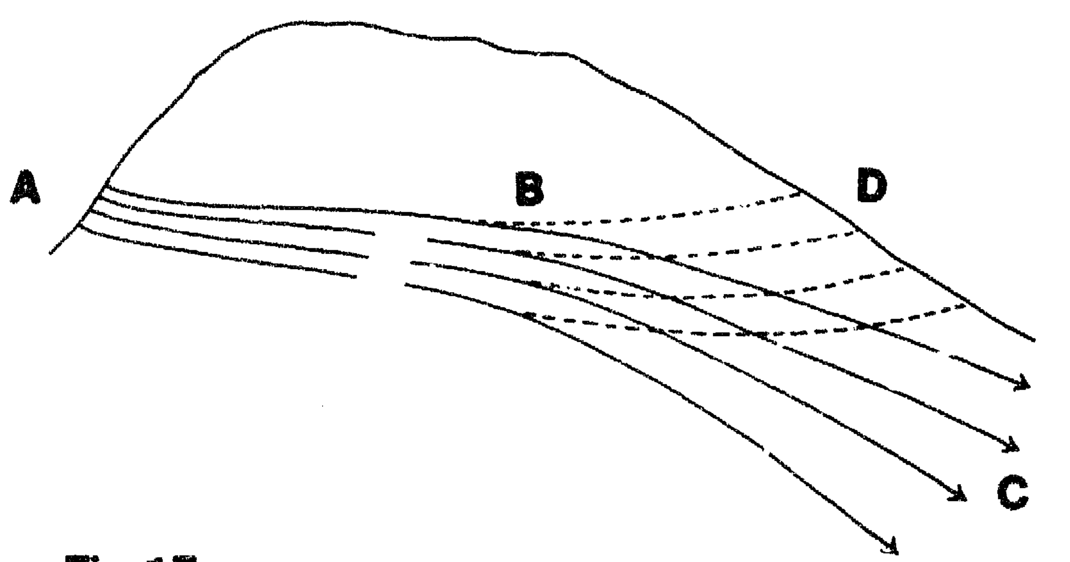


Fig 17

During our field trips and in discussions with many field workers – even research workers – we have noticed there is often misunderstanding as to what a contour really is. **Fig 16** illustrates the concept of a contour in the minds of many of these workers. It is a "furrow" ploughed along "the main slope". This is where the definition breaks down; a true contour embraces all slopes, major or minor; it is a line of equal elevation around a hill. If, as in **Fig 16,** the furrow starts at point **A** following the "main slope" to point **B** but continuing on straight to point **C** instead of following "round the slope" to point **D** as shown in **Fig 17,** then it is ***not*** a contour, will ***not*** conserve moisture ***nor*** prevent erosion. A true contour, as shown in **Fig 17,** runs round the slope from **A** to **D** maintaining equal elevation all the way.

Fig 18

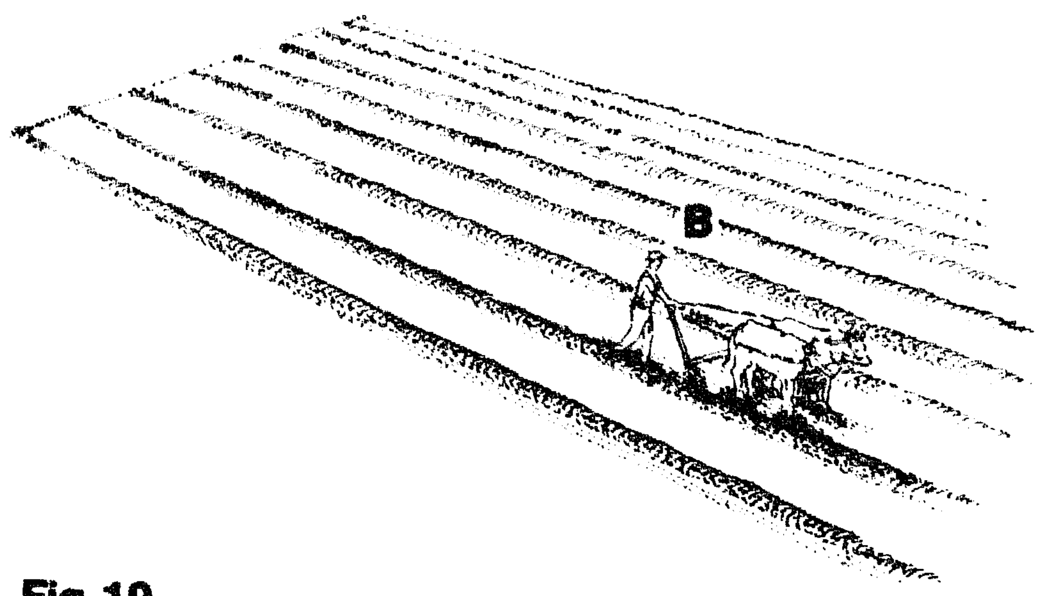
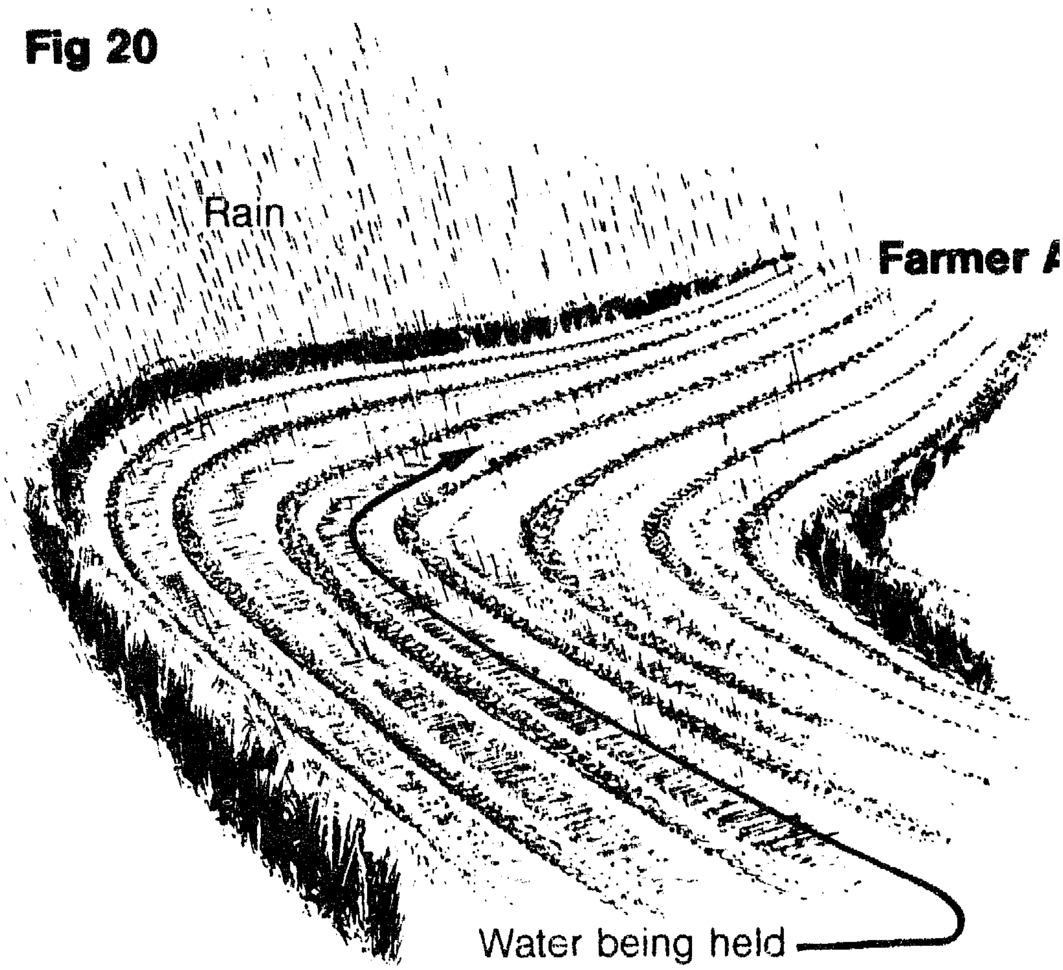


Fig 19

In **Figs18 and19**.we see twofarmers,**A** and**B** Both are good farmers, but **A** in**Fig 18** is a wise farmer; he has protected his land from erosion by planting vegetative hedges on the contour, and he is following these "guidelines" by ploughing and planting on the contour. 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** is doing. All that is involved is a change in management.

Farmer **B** in **Fig 19** is still a food farmer, but he is not wise; he is not thinking. By just ploughing up and down the slope he is actually encouraging the rainfall to run off his farm, taking his farmyard manure with it, plus a layer of top soil that is irreplaceable.Because he has ploughed up-and-down the slope, the rainfall runs off so fast it does not get a chance to soak into the soil and, therefore, his crops have no protection from long periods of dry weather. In nature, nothing grows in straight lines; in rainfed agriculture, full use has to be made of the natural contours, no matter how *flat* the slope may be.

Fig 20


Rain
Farmer A
Water being held

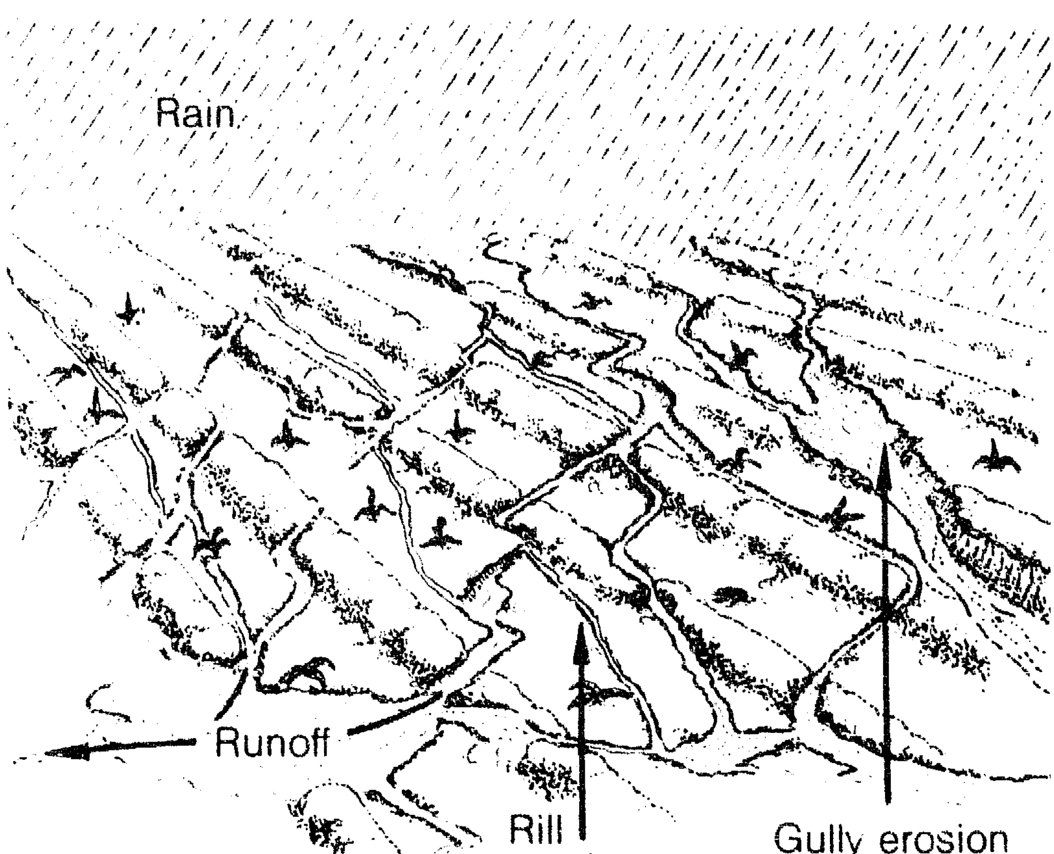
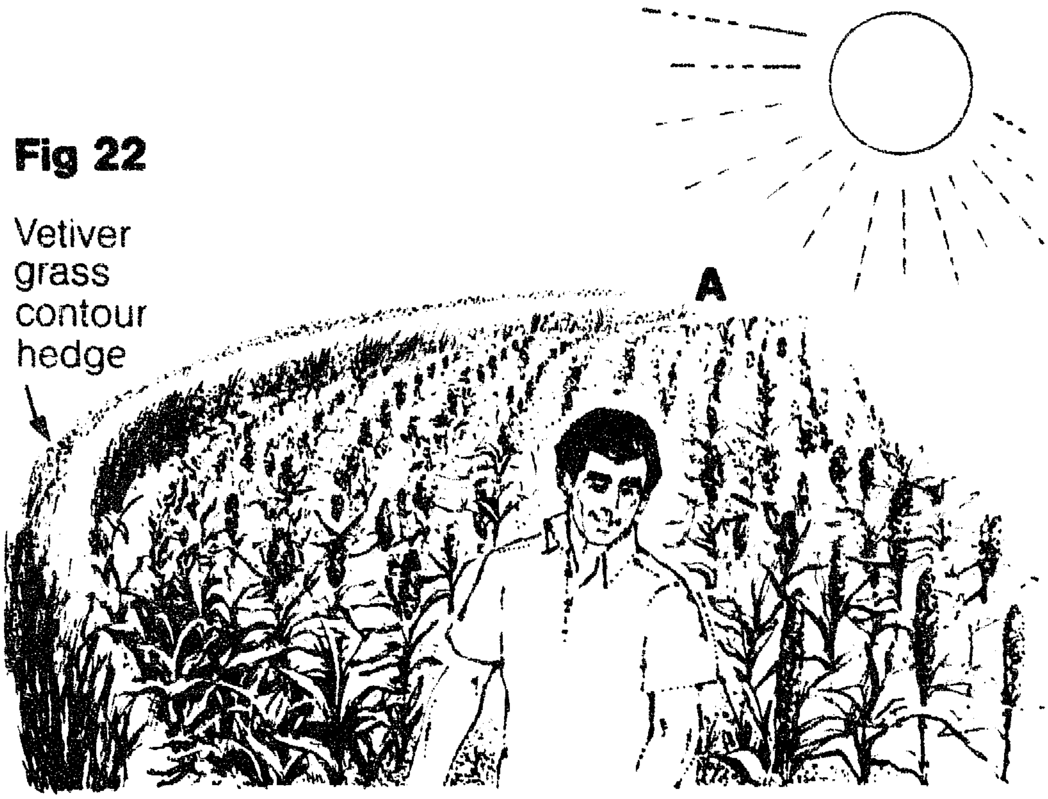

Rain
Runoff
Rill erosion
Gully erosion
Farmer B

Fig 21

Illustrated in **Figs 20 and 21** is what happens when the two systems are exposed to heavy rainfall. **Farmer A**'s contours are protected by the vegetative hedges, and no erosion occurs. The contour furrows store the rainwater to their full capacity. Any surplus rainfall runs off but is controlled by the Vetiver hedges. Any silt this runoff is carrying is filtered out of it. The runoff is slowed down, spread out, filtered through the hedges, and is conducted down the slope in a safe, nonerosive manner.

In **Farmer B**'s land, the rainfall is encouraged to run off at great speed, taking his fertilisers and soil with it. This uncontrolled "ride" down the slope causes unnecessary and damaging erosion. Because the runoff has been so fast in this case, **Farmer B** has stored no moisture, his rainfall has only been 40-50% effective, and he is always complaining about droughts. Ultimately, he will have to abandon his farm as there will be no soil left to grow his crops. **Farmer A** will never have this problem; his yields will be increasing over the years.

Fig 22



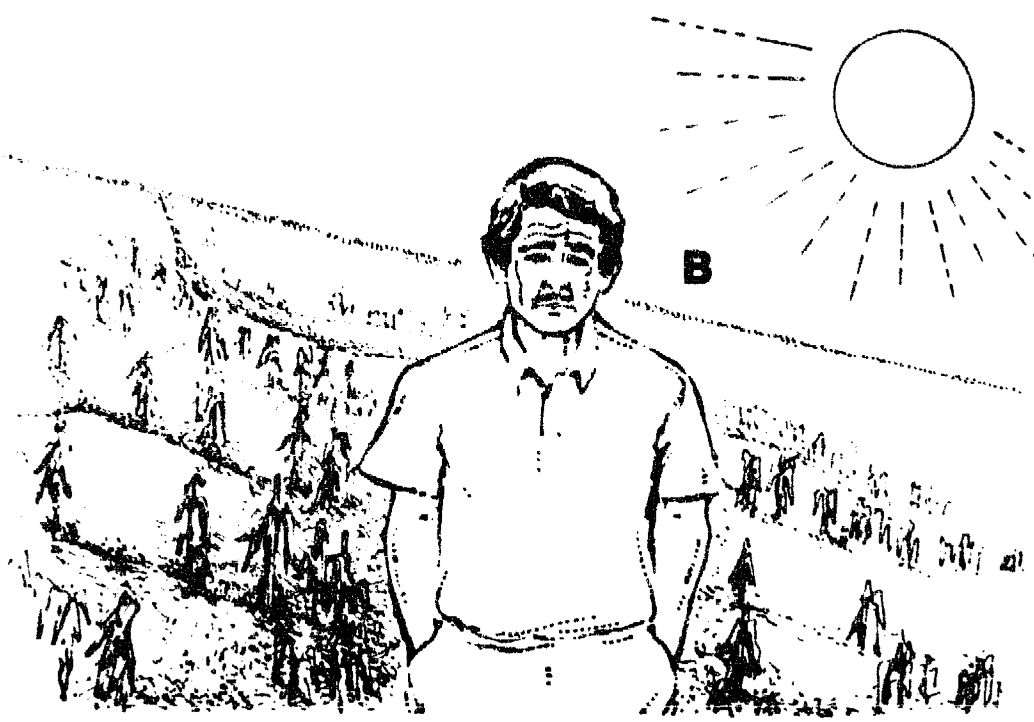
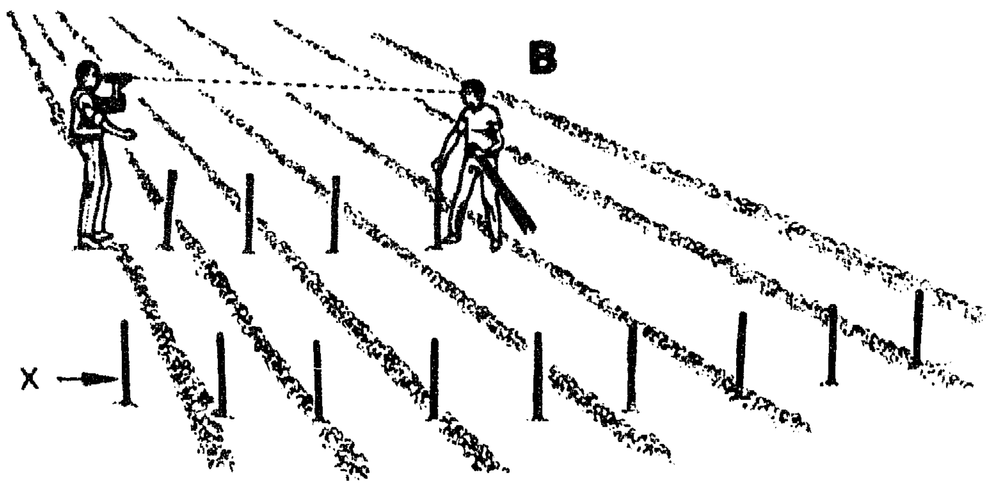


Fig 23

Here we can see the excellent crop farmer **A** has obtained. Because he has stored ample moisture in the soil, his crop is benefitting from the warm sunshine; all the grains are filling and the crop is very even; it will produce a high level yield. His neighbour, farmer **B** is very disappointed. His crop has all but failed, and the warm sun is just drying it out. Only some of the grain will fill, and the resulting crop is very uneven. Patches have grown where some moisture was trapped, but he can expect a low yield. Yet he planted the same crop as his neighbour **A**,used the same fertilser, planted at the same time, received the same rainfall and the same amount of sunshine. Unlike his neighbour, he lost most of his fertiliser, together with 60% of his rainfall and possibly a one centimeter sheet of soil from his whole farm – by not ploughing on the contour and using vegetative contour guidelines to protect his farm from the excesses of runoff. Farmer **B** could also obtain high yields and be just like his neighbour, if he took the advice of his extension service and ploughed and planted on the contour.

Fig 24



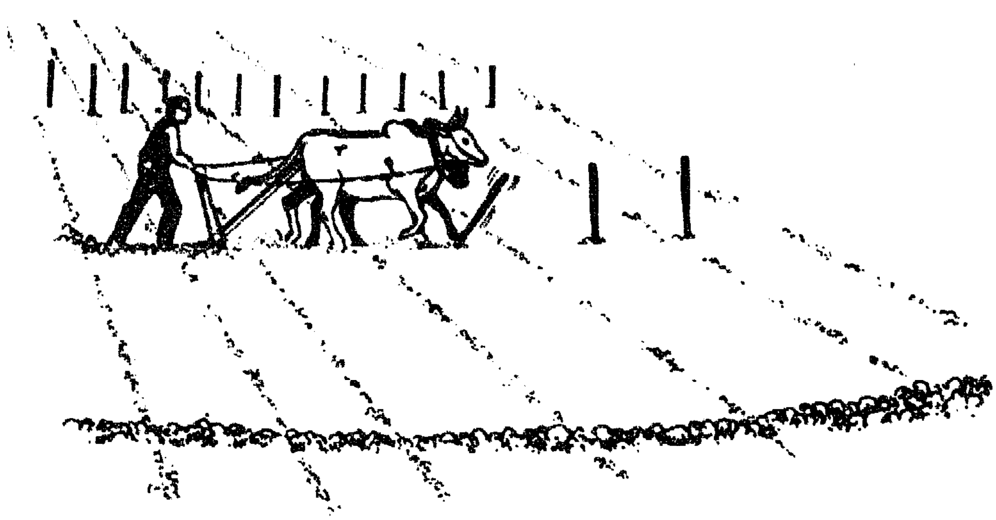
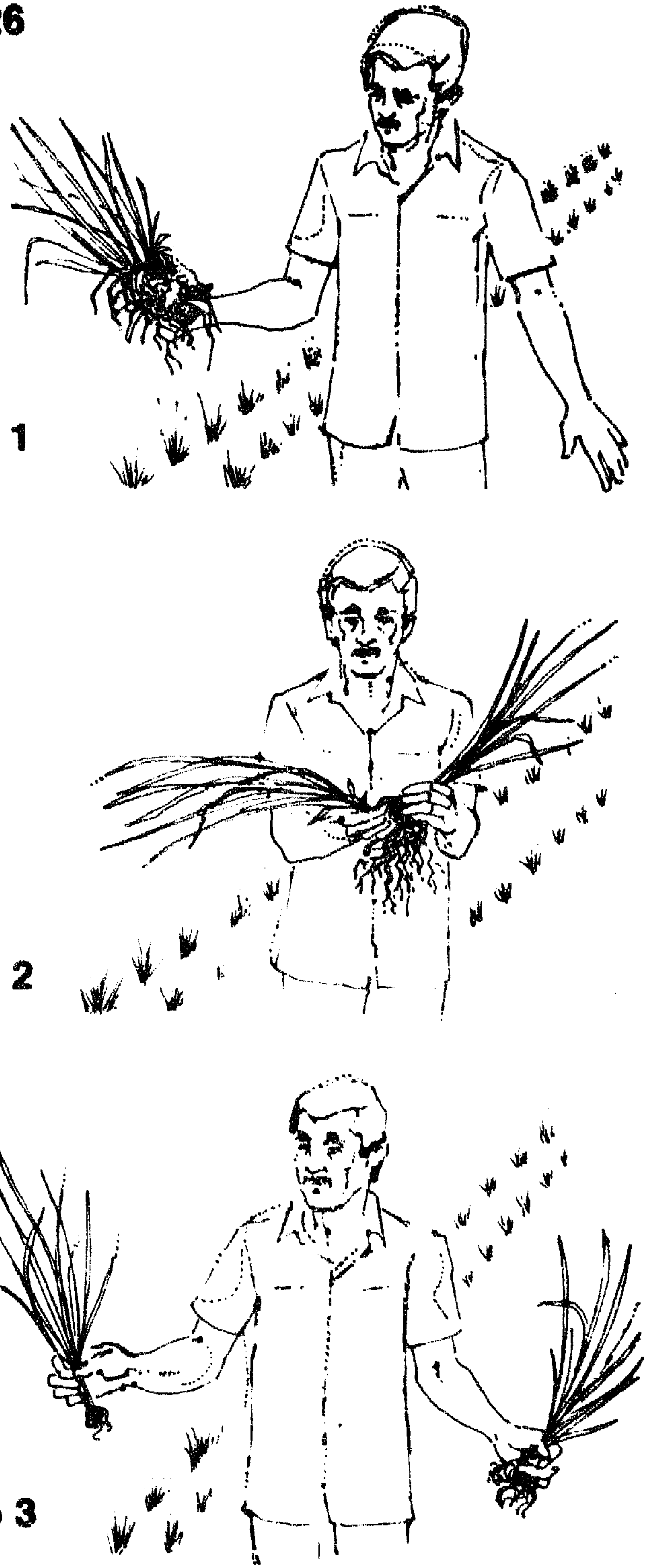


Fig 25

Here, we can see that farmer **B** has learnt his lesson. He has contacted his extension worker and together they are "pegging" out contour lines across his old furrows. This is a simple process, it requires virtually no engineering skills, but only the use of a small hand-held level. The extension worker stands at the edge of the field and, sighting through his level, moves farmer **B** up or down the slope until he finds the right position in the field where farmer **B** is at the same level as the extension worker. There, the extension worker tells him to mark the spot with a peg. The line of pegs at "x" in **Fig 24** have already been "levelled-in" and the contour line they indicate is ready for the farmer to mark with his plough.

Fig 25 shows farmer **B** with his oxen, ploughing a single furrow following the line indicated by the contour pegs. In these furrows, he will plant the slips, or root divisions of Vetiver grass that will eventually form his vegetative contour hedges. This is all that has to be done to establish this simple system.

Fig 26



Step 1

Step 2

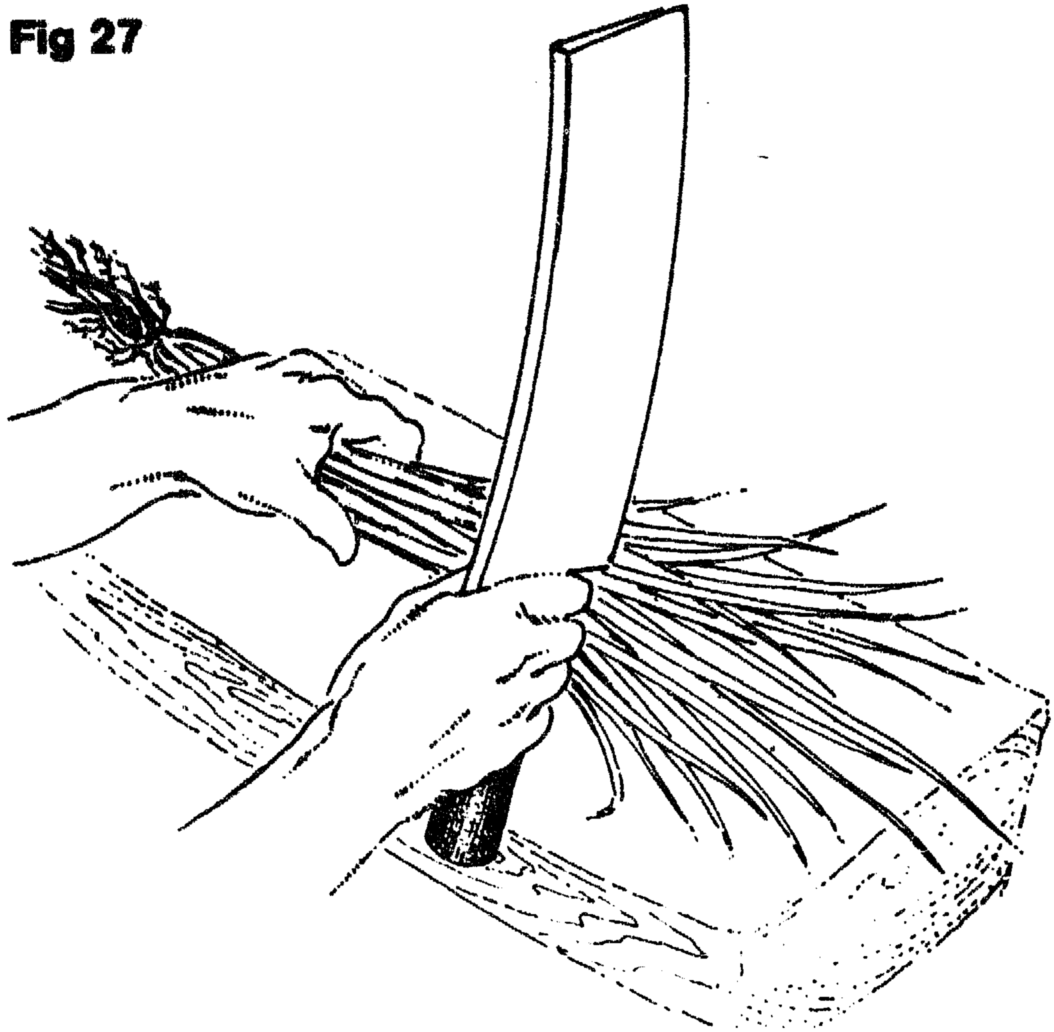
Step 3

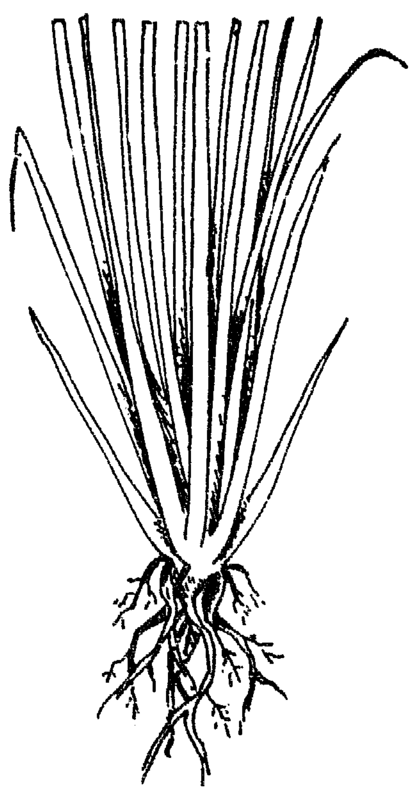
The next few pages should clearly illustrate how Vetiver grass is taken from the nursery and planted in the field. It will also discuss our experience in handling the planting material, the best time to plant and what to expect after the grass is planted.

Fig 26 shows the extension worker or a farmer removing a "clump" of Vetiver grass from the nursery. This has to be dug out with a spade or fork. The root system of this plant is massive and very strong, and the grass cannot be pulled out by hand. In **Step 1** he has removed a large clump; in **Step 2** he tears a "handful" of the grass, roots and all, from this clump; **Step 3** shows the resulting piece, or root division, or slip, that will form the planting material used in the field.

Vetiver nurseries are easy to establish if the planting material can be obtained. The best nursery sites are at the inlets to small dams or tanks. Here the slips are planted as "hedges" across the stream, one meter apart. The water on its way to the dam "irrigates" the Vetiver grass which, in turn, removes the silt.

Fig 27





$\times \frac{1}{4}$

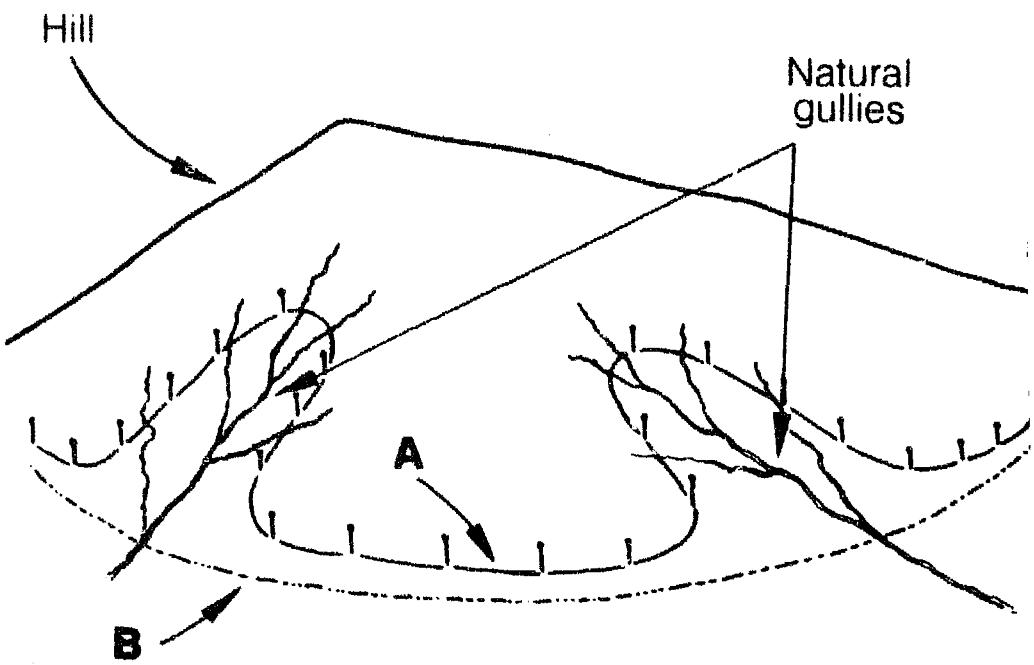
Fig 28

Once the Vetiver grass clumps have been removed from the nursery and the root divisions torn off them, then, prior to transporting them to the field, the farmer cuts the tops off about 20 cms from the base. Below the base, roots of 8-10 cms in length should be left on the plant. **Fig 27** shows the farmer using a block of wood and a simpe knife (cane knife, machete, cutlass or panga), to cut the slip down to the size for planting. The finished "planting piece" is shown in **Fig 28.**

Though Vetiver grass can be planted from single tillers if planting material is scarce, this practice is not recommended in the field, as it takes too long for a single tiller to form a hedge. The reason for cutting the tops off the planting material is to cut down the transpiration level of the slip once it is planted, to prevent it from drying out, thus giving it a better chance of survival. Slips planted in the nursery can be fertilised with DAP (diamonium phosphate) to encourage fast tillering. This would help also in the field. DAP could be dibbled into the planting furrow prior to planting the slips.

AVERAGE CONTOUR

The advantage of using *vegetative* methods of soil/moisture conservation is that the contours do not have to be exact. Once the contour line has been pegged in, it can be smoothed out by the extension worker, to make it easier for the farmer to follow with his plough – the runoff water oozes through the whole length of the vegetative line (hedge) and the soil it filters out of this water forms a natural terrace behind the hedge. A constructed earth bank contour, **A** below, has to convey the runoff water sideways, so it *must* be on the *exact* contour, making it very difficult for the farmer to follow. **B** shows the smooth line of an "averaged" contour, all that is necessary for the control of sheet erosion, using the vegetative method.



VERTICAL INTERVAL

The vertical interval **VI** between the vegetative hedges is the vertical distance from the bottom of one hedge to the middle of the next one, down the slope: e.g. a **VI** of 3 m on a 5% slope means that the "hedges" would actually be 60 m apart horizontally, or, from one hedge to the next, but only 3 m apart vertically. On a 2% slope, with a **VI** of 3 m, the hedges would actually be about 100 m apart.

Below, on a 57% slope the horizontal distance between the hedges would be about 7 m.

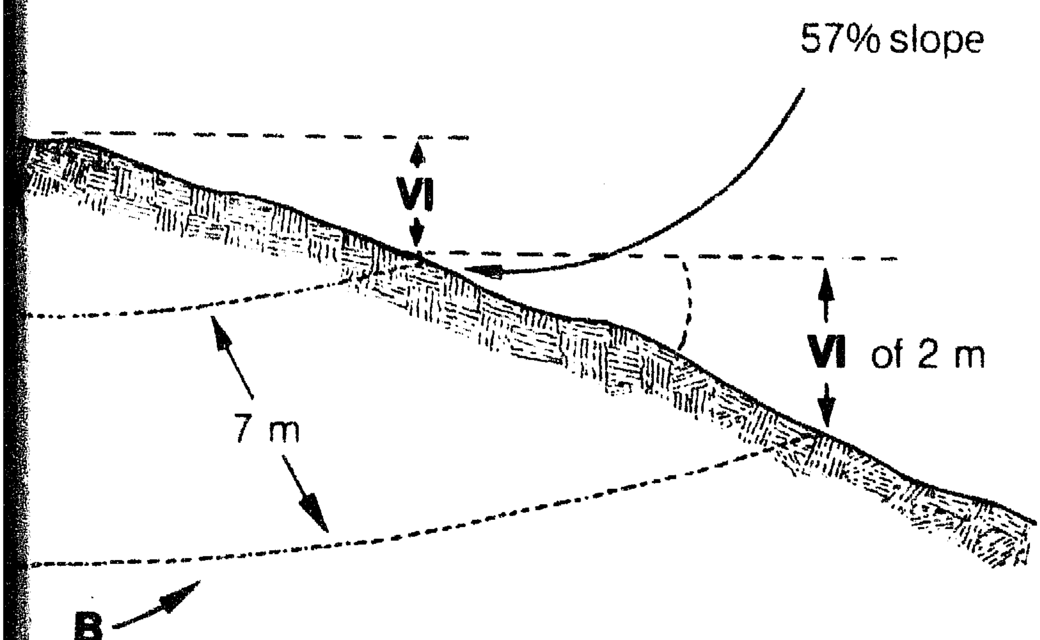
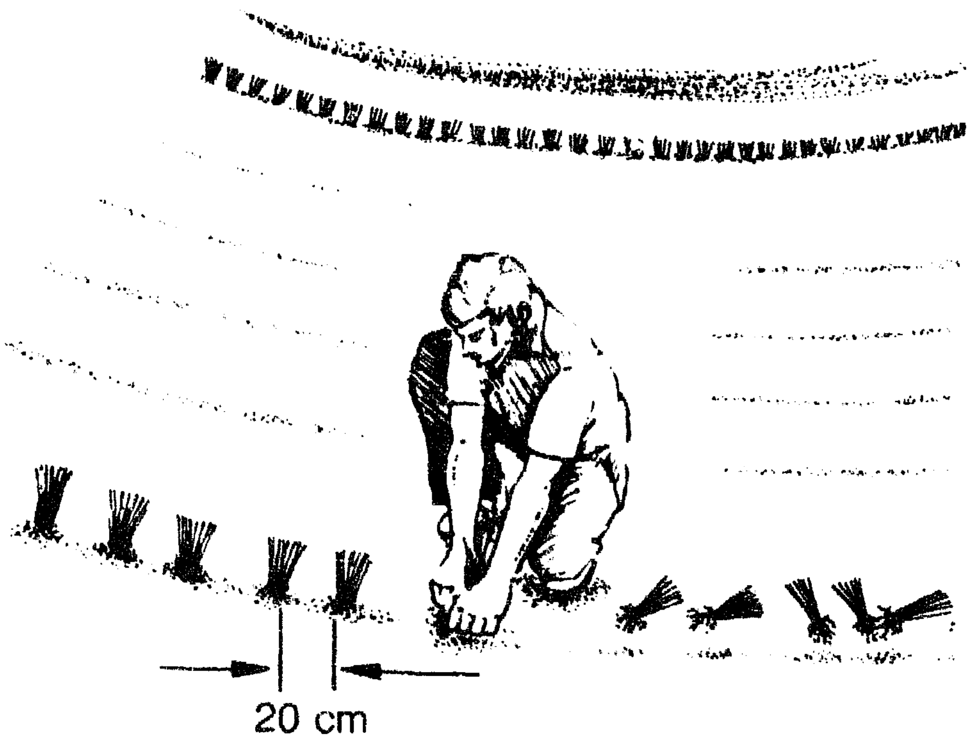


Fig 29 shows the farmer planting the Vetiver slips in the field. This is best done at the beginning of the wet season. They are planted somewhat like rice seedlings as follows: Make a hole in the furrow that has already been ploughed to mark the contour; push the slip in to this, being careful not to bend the roots upwards: then firm the slip into the soil. Twenty centimeters from that slip, on the same contour furrow, plant the next slip, and so on, and if planted well, the slips can withstand up to one month of dry weather and still survive. Only a single row of slips needs to be planted, but, of course, if ample planting material is available, then the slips could be planted as a continous line touching each other. Using this method, they would form a hedge more rapidly. Here, once again, it must be emphasised that for this, or any vegetative system to work, it *must* form a hedge; otherwise the system cannot act as a filter, and would be almost useless. **Fig 30** shows the sort of situation that must be avoided – planting the slips too far apart. In this case, they would take too long to form a hedge, and would give the farmer little protection. Also a very important point is that the hedge holds the soil, fertiliser and moisture against the Vetiver grass, giving it the extra support it needs to help it survive the worst droughts.

Fig 29



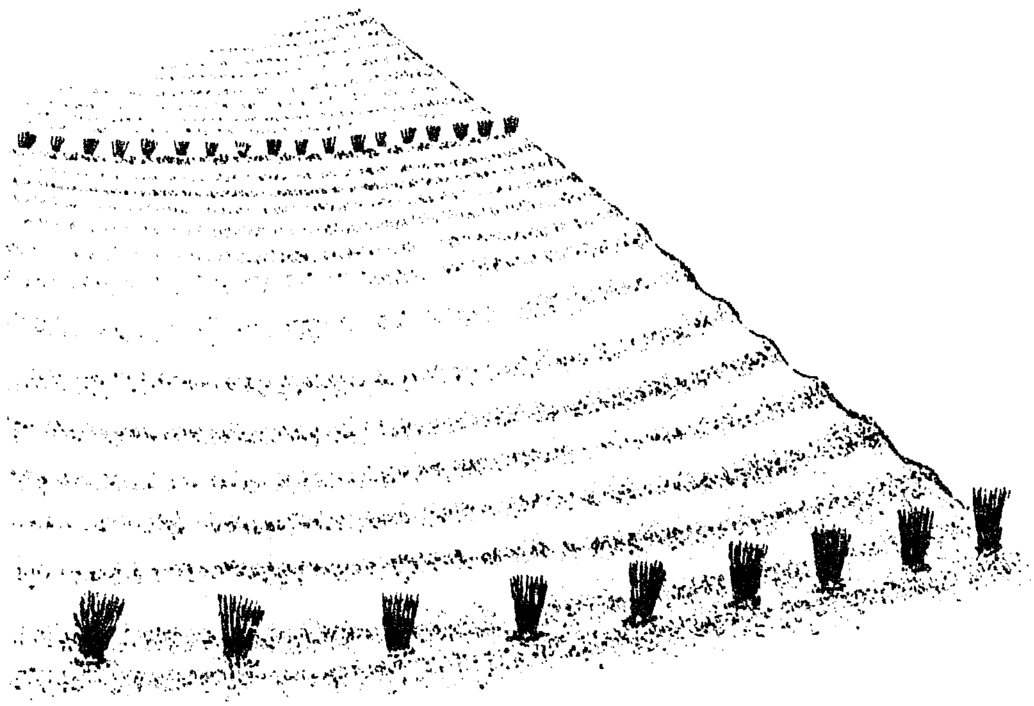


Fig 30

A point that must be stressed is that vegetative soil conservation measures take two-to-three seasons to become effective – like any long-lived plant. You wouldn't plant a mango tree today and expect to pick mangoes next month!

To get some immediate effect from the system, or while you are waiting for the planting material to be produced in the nursery, the extension worker can lay out the contours. You can prepare the seedbeds following the contour furrows and every 5 or 6 meters double plough a "dead furrow". **Fig 31** shows two dead furrows that have been planted on the contour to pigeon peas and inter-cropped with six rows of groundnuts. The shape of the seedbed is shown beneath the crop illustration. Where **DF** shows the shape of the deeper dead furrow, the **PP** shows the row of pigeon peas it supports, etc. The object of the dead furrows is to provide a bit of extra protection against runoff until such time as the Vetiver grass can be established. **Fig 32** shows the Vetiver grass **V** established where a dead furrow was previously. Planting the Vetiver grass stabilises the whole system.

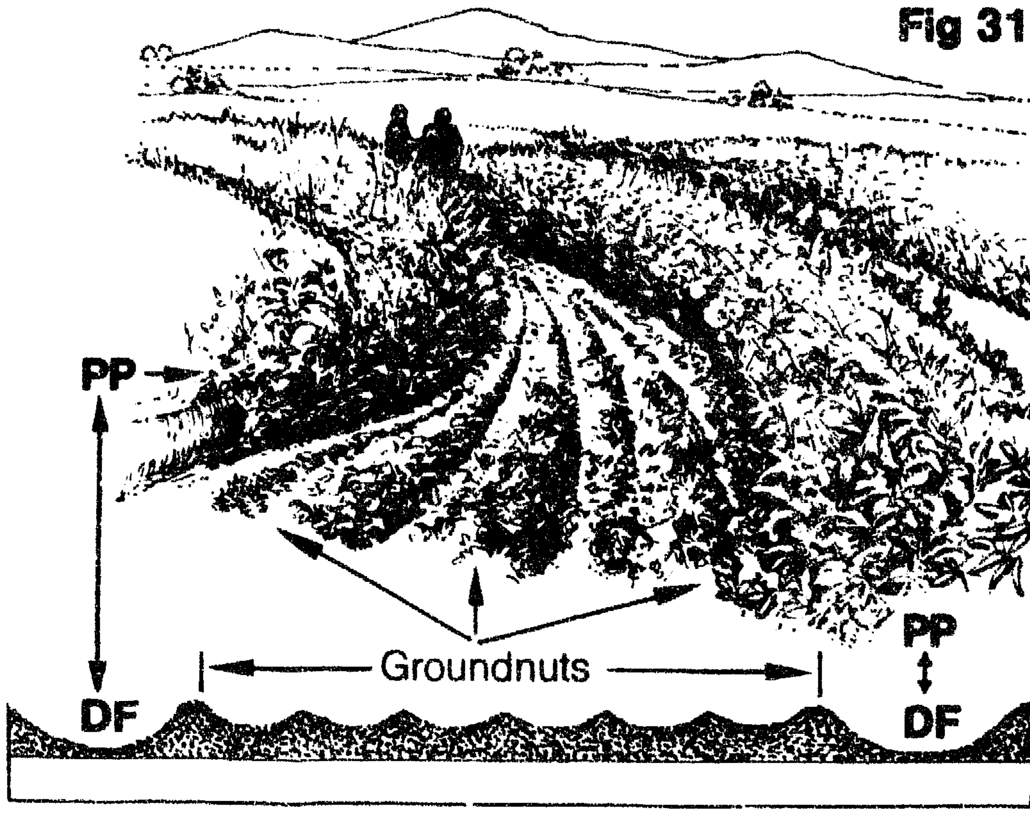


Fig 31

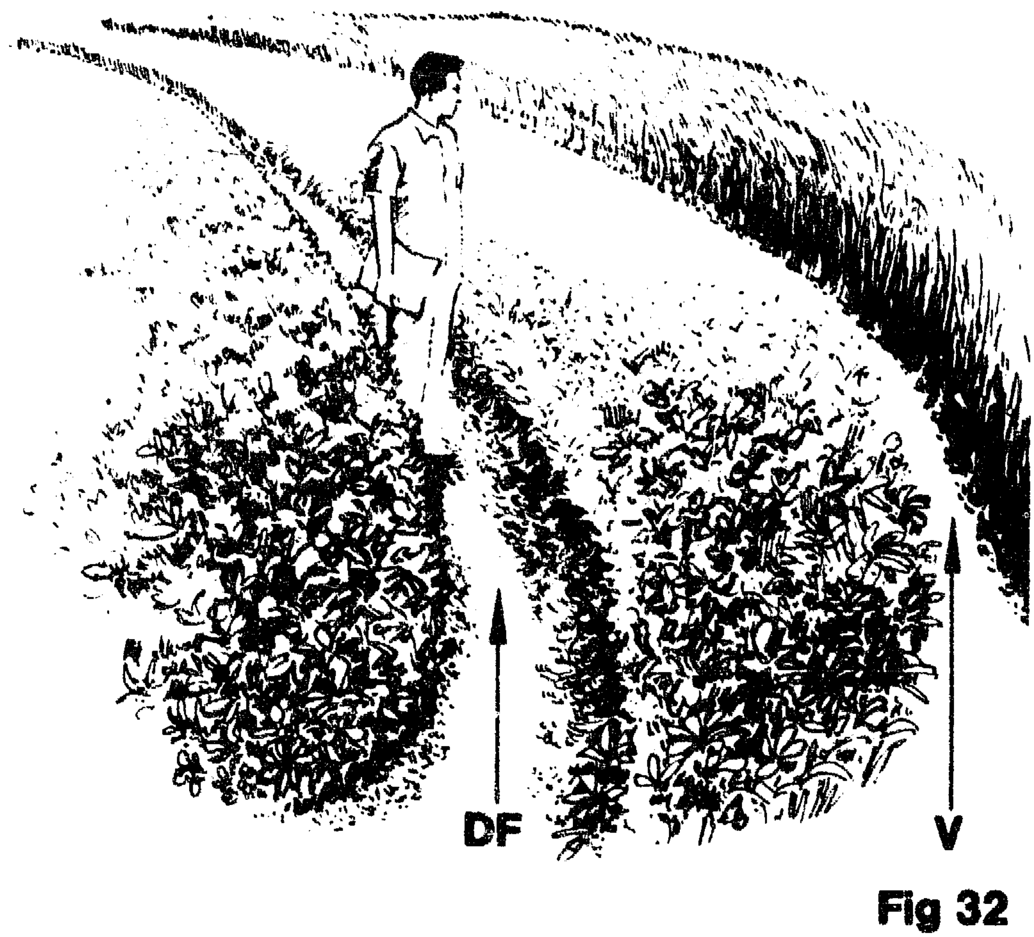
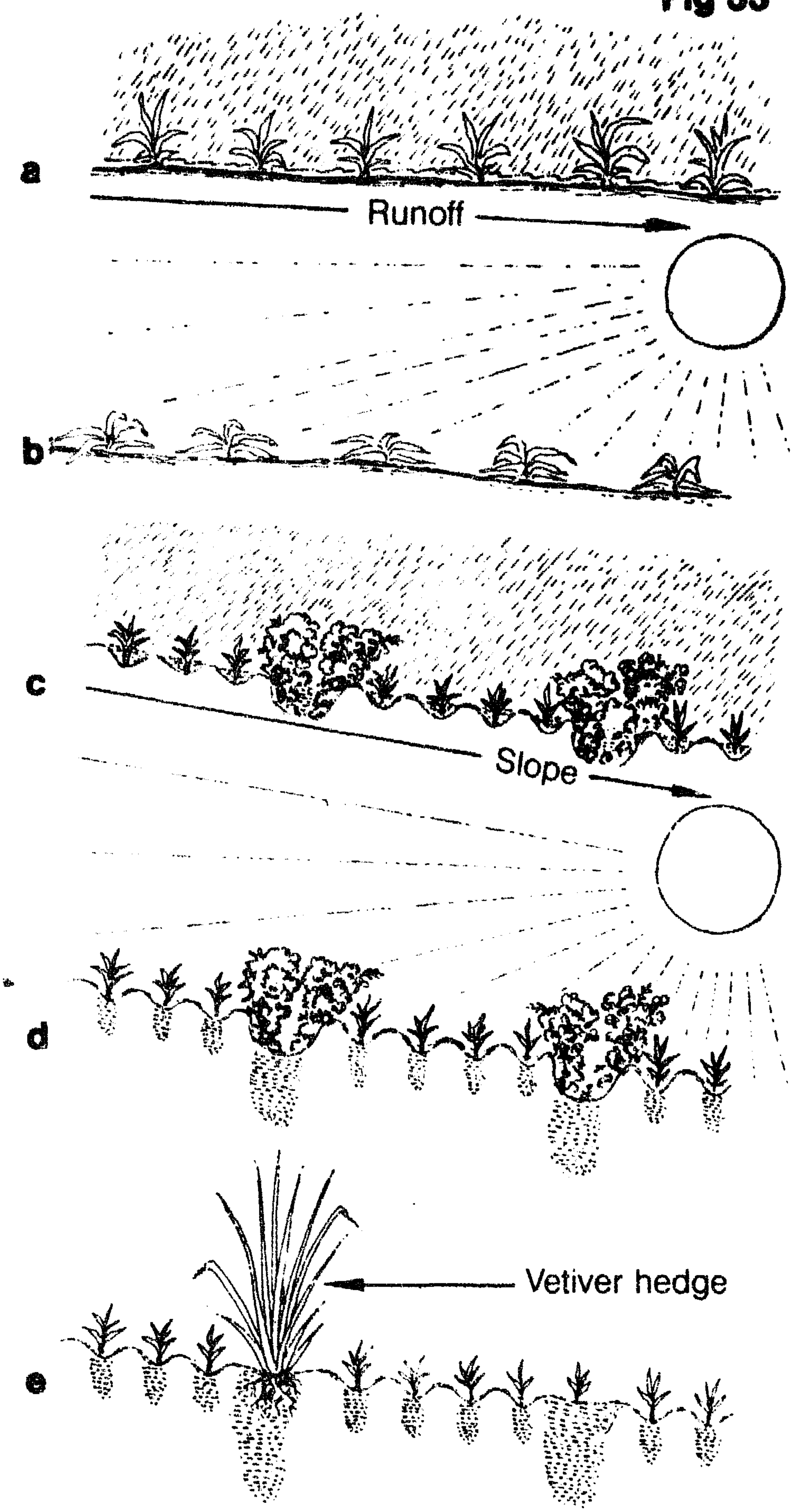


Fig 32

In-situ moisture conservation, associated with vegetative soil conservation measures that stabilise the system, is an essential part of all rainfed farming systems. Yet it is very rarely practiced or 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, smoothing, etc. are for irrigated areas. Rainfed areas must be contoured only. **Fig 33** shows what happens when land is planted on the "flat" without the benefit of contour furrows.

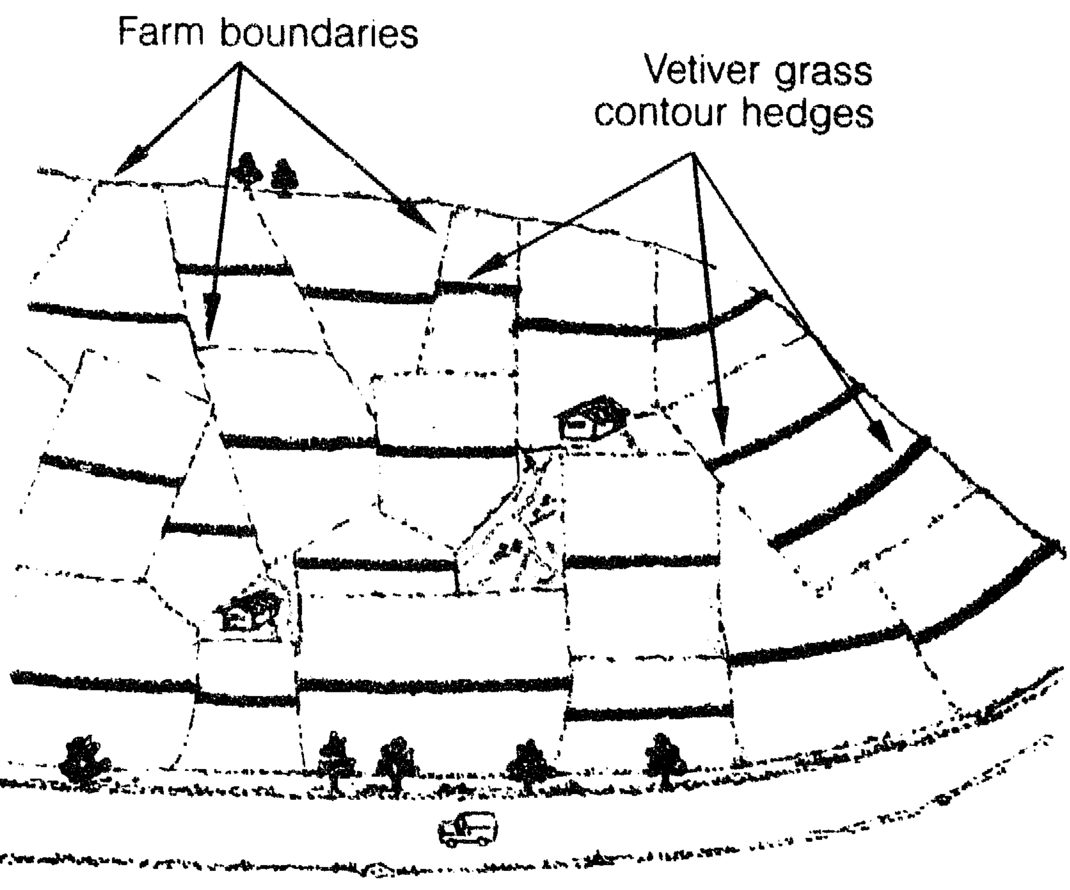
At **a** in **Fig 33,** the rain is falling and running straight off the field; **b** shows the results: No moisture storage, the plants wilt and die in the sun. The same area planted to contour furrows in **c** with the dead furrows taking up the surplus runoff until such time as the Vetiver can be planted. It shows the rainfall being held in each furrow's micro-catchment, giving it the chance to soak in and be stored. Each of these furrows can hold 50 mm of rainfall, so in most storms there is no runoff; the water soaks in and the plants benefit from the sunshine, as in **d**. In **e** one of the dead furrows has been planted to Vetiver grass to stabilise the system.

Fig 33



Finaliy, **Fig 34** is a diagramatic representation of what a Vetiver grass system would look like in a smallholder farming area. As can be seen, it fits into their system perfectly. There are no waterways, no earthworks. Each farmer has one line oi Vetiver roughly in the middle of his farm, no matter what the shape ; long farms may need two lines to stabilise them. Under this system, once the hedges have established, there is no need for any more protective work – maintenance is totally minimal – and yet the whole hillside has now been protected from erosion. Each farmer has his own supply of Vetiver planting material. If he notices a little gully starting anywhere on his farm, he can get planting material from his existing contour line. He can plant across the incipient gully and prevent its spread permanently, at no cost except his own labour. In the diagram you will notice that even though each farmer has his own individual line, all the lines, when looking down the slope, protect each other.

Fig 34



OTHER PRACTICAL USES

The following few pages give additional uses for Vetiver grass that have been noted in some other countries. **Fig 35** shows a typical paddy field with its earth banks constructed by the farmer to contain irrigation water at the correct level. In many cases, wind, causing lap erosion, and rats/crabs, etc., making holes in these banks, can cause their breakdown. This leads to a major erosion problem, not to mention the loss of expensive irrigation water, which in some systems is irreplaceable. The farmer could lose his crop.

In **Fig 36,** Vetiver has been planted on the top of the paddy banks to stabilise them. Vetiver grows well under these conditions, does not suffer from the occasional inundation, and has the added advantage that the essential oil in its roots acts as a deterrent to rodents. The Vetiver, growing so close to the rice has no effect on its yields as its roots go straight down and not out into the crop. Each year the Vetiver can be safely cut right back to ground level – if it should start to have any shading effect.

Fig 35

Fig 36

Fig 37. Vetiver grass can be used on river flats to prevent silt from entering the river from heavy runoff out of the fields alongside. It can also be used to maintain river levees, prevent erosion from cutting them back into the fields. Vetiver grass is the ideal plant for this purpose. *V. zizanioides* has the following characteristics that make it ideal for soil conservation/ stabilisation:

a. It has a deep, strong fibrous root system;

b. Planted at the correct distance, *V. zizanioides* will quickly form a dense hedge, underlain by a dense curtain of roots binding the soil along the contour;

c. *V. zizanioides* is practically sterile; it has to be planted vegetatively, meaning that it will not become a weed in farmers' fields;

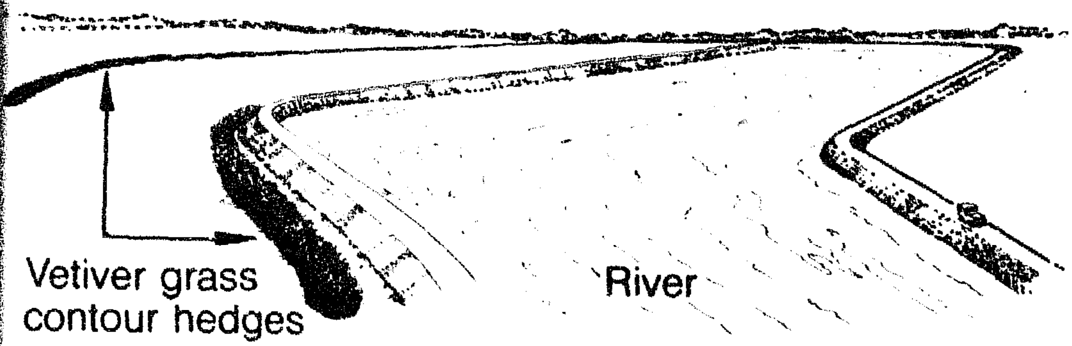
d. Once established, it is generally unpalatable to livestock;

e. It is perennial and will last as a hedge, not requiring maintenance for years;

f. It can withstand fires, droughts, inundation and floods;

g. Its leaves and roots have demonstrated a resistance to most pests and diseases, making the leaves a useful mulch for fruit trees planted in rainfed areas.

Fig 37



Steep and rolling country – too steep, or not suitable for the cultivation of cereal or pulse crops – can be successfully planted to perennial tree crops on the contour when stabilised by Vetiver grass. At present attempting to grow tree crops on rolling country or steep land results in a very poor, uneven stand not worth the cost of maintenance and often abandoned. This is because moisture distribution cannot be controlled. **Fig 38** shows a method of establishing tree crops on these hills. Contours are pegged out and shallow **V** ditches are either dug by hand or constructed by a bulldozer and ripper unit. The trees are planted *near* the edge of the **V** ditch. (See **Fig 39** for a more detailed description of this method.) Under this system of planting, water, nutrients, organic matter, mycorrhiza are all harvested from the inter-row runoff and collected in the trench for the benefit of the tree crop, and the whole system is stabilised by the Vetiver grass lines. Because of this waterharvesting effect, the trees can be planted closer together in the intra-row and a little further apart in the inter-row.

Fig 38

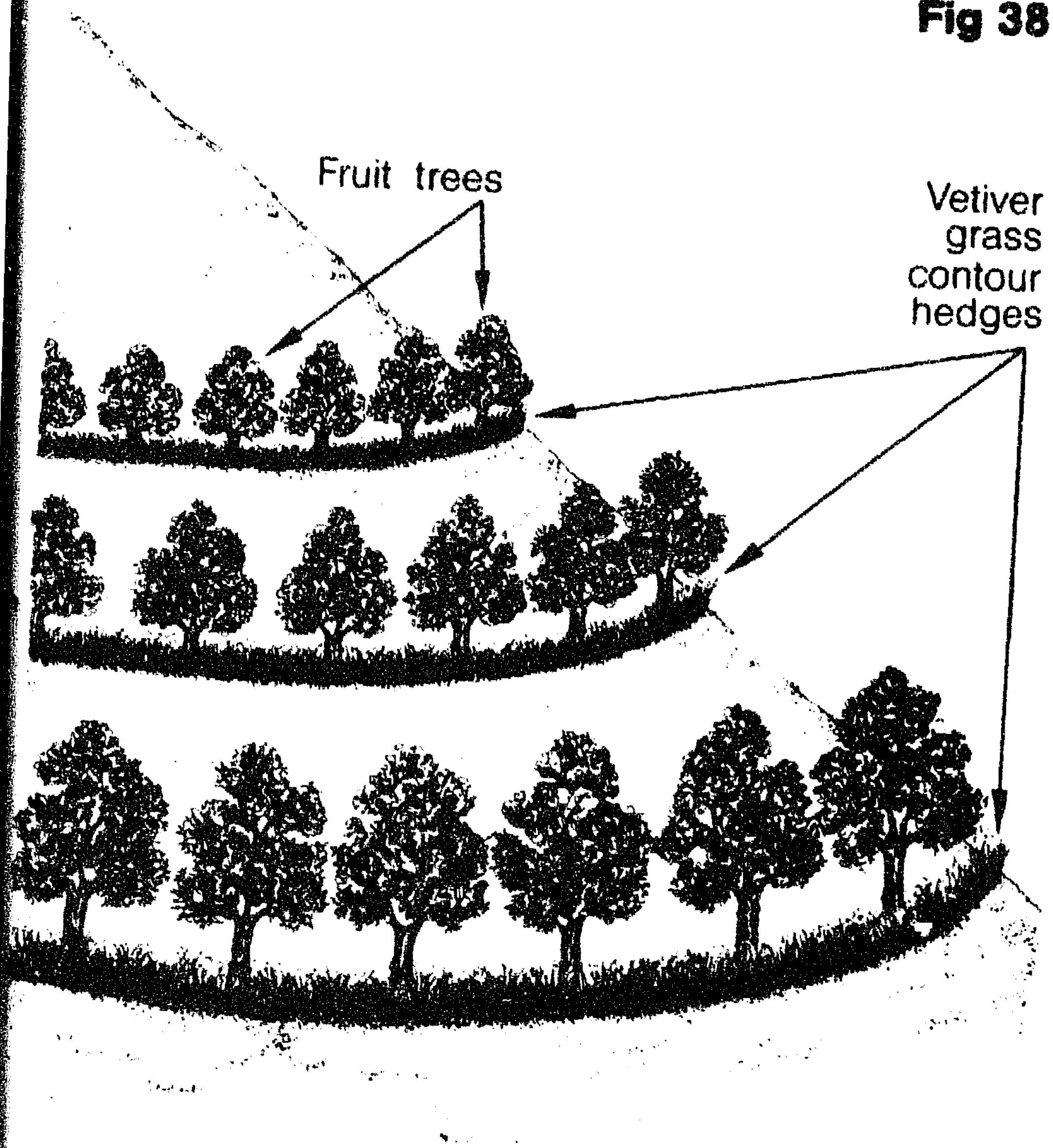
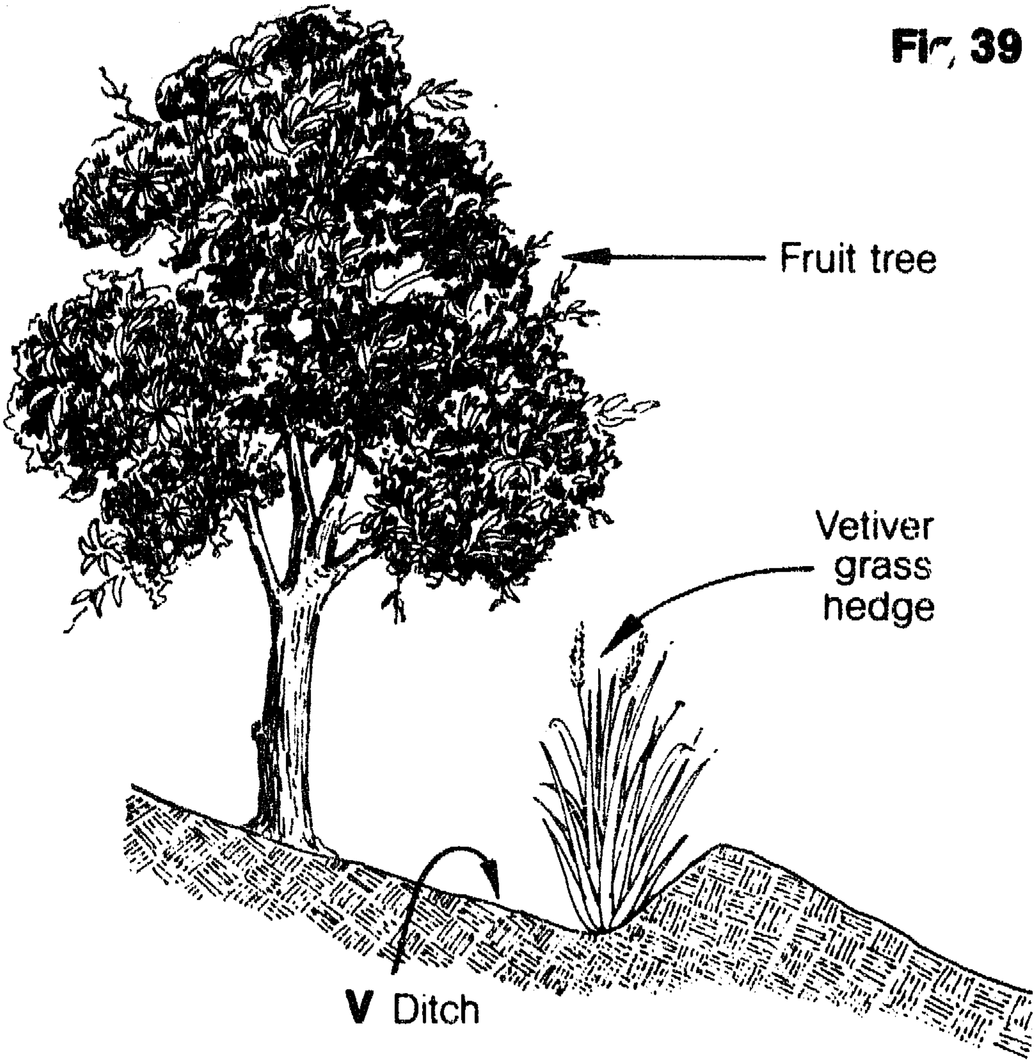


Fig 39 shows in more detail how the trees and the Vetiver are planted in the contour **V** ditches. Using this system enables trees such as olives to be planted without the need for irrigation in the first three years of establishment. The collection of runoff in these contour trenches has the effect of doubling or tripling the amount of annual rainfall. The runoff from the inter-rows between the trees is held in the trench and, ultimately, behind the Vetiver hedge, and it has time to soak right into the soil at the base of the trees. There is little chance of waterlogging since there is usually sufficient drainage on the slopes to take care of that. Once the dry season sets in, and after the Vetiver hedges have properly established, Vetiver grass can be cut down to ground level and its leaves used as a mulch at the base of the fruit trees to help retain stored moisture **Fig 40.** The benefit of using Vetiver for this purpose is that its leaves harbour few insects and last very well as a mulch. Forest trees should also be planted by the same method. Where this has been done, the results have been quite spectacular.

Fi-, 39


Fruit tree
Vetiver grass hedge
V Ditch

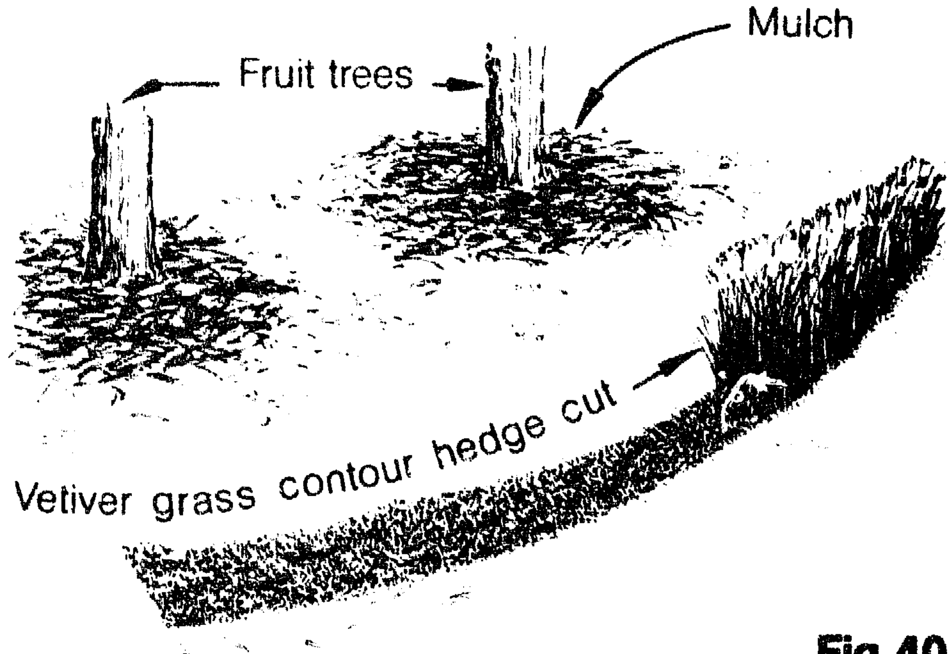
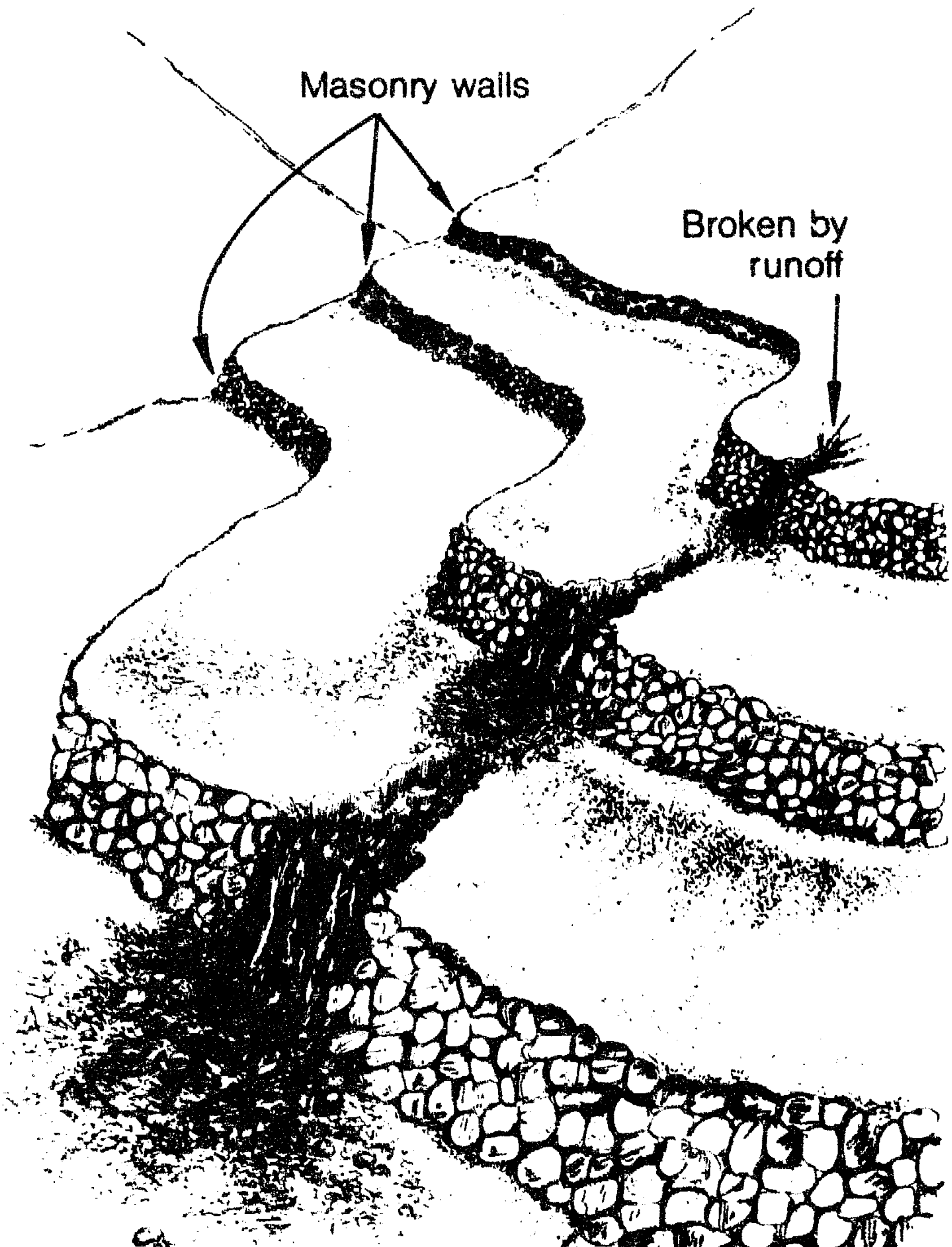

Mulch
Fruit trees
Vetiver grass contour hedge cut

Fig 40

In the Himalayan highlands, farming is carried out on terraces that have been erected over the centuries. These are almost entirely masonry structures that require continual maintenance. Even then they can be washed-out in a heavy storm, causing considerable damage, with a "domino" effect on the other terraces down the slope. We have planted Vetiver grass on the edge of these terraces and hope that the strong root system will act as a support for the masonry risers. We are describing the technique here in the handbook, before we have actually proved that it will work, but the grass was planted in the monsoon of 1986 and the system looked as though it would be successful.

Fig 41 shows the damage typical of this system in the hills. The masonry risers are not bound together with mortar (concrete) since the farmers realise that they must allow for drainage between the stones. If the walls were solid, then instead of a small section falling out, there is a risk that the whole wall would collapse, which could cause a landslide and the loss of the total farm. These "engineered" terraces have done an excellent job over the centuries, but they still cause the farmers a lot of grief in crop losses and a tremendous amount of hard work in repairs.

Fig 41



When the Vetiver system of stabilisation was explained to the hill farmers, they were convinced that it was the answer and wanted to plant as many areas as possible. The results of this project will be carefully observed over the next few years, and hopefully will be reported successful. At the same time, Vetiver grass contour lines will also be established in areas with no masonry terraces to halt massive sheet erosion. This trial will determine whether the natural terraces formed behind the vegetative hedges will form a base of stable land for the production of fuelwood and fodder crops.

Fig 42 illustrates our concept of what the Vetiver grass protected terraces would look like once established. The grass would be planted only at the extreme edge of the terrace, as shown in **Fig 43.**

Fig 42

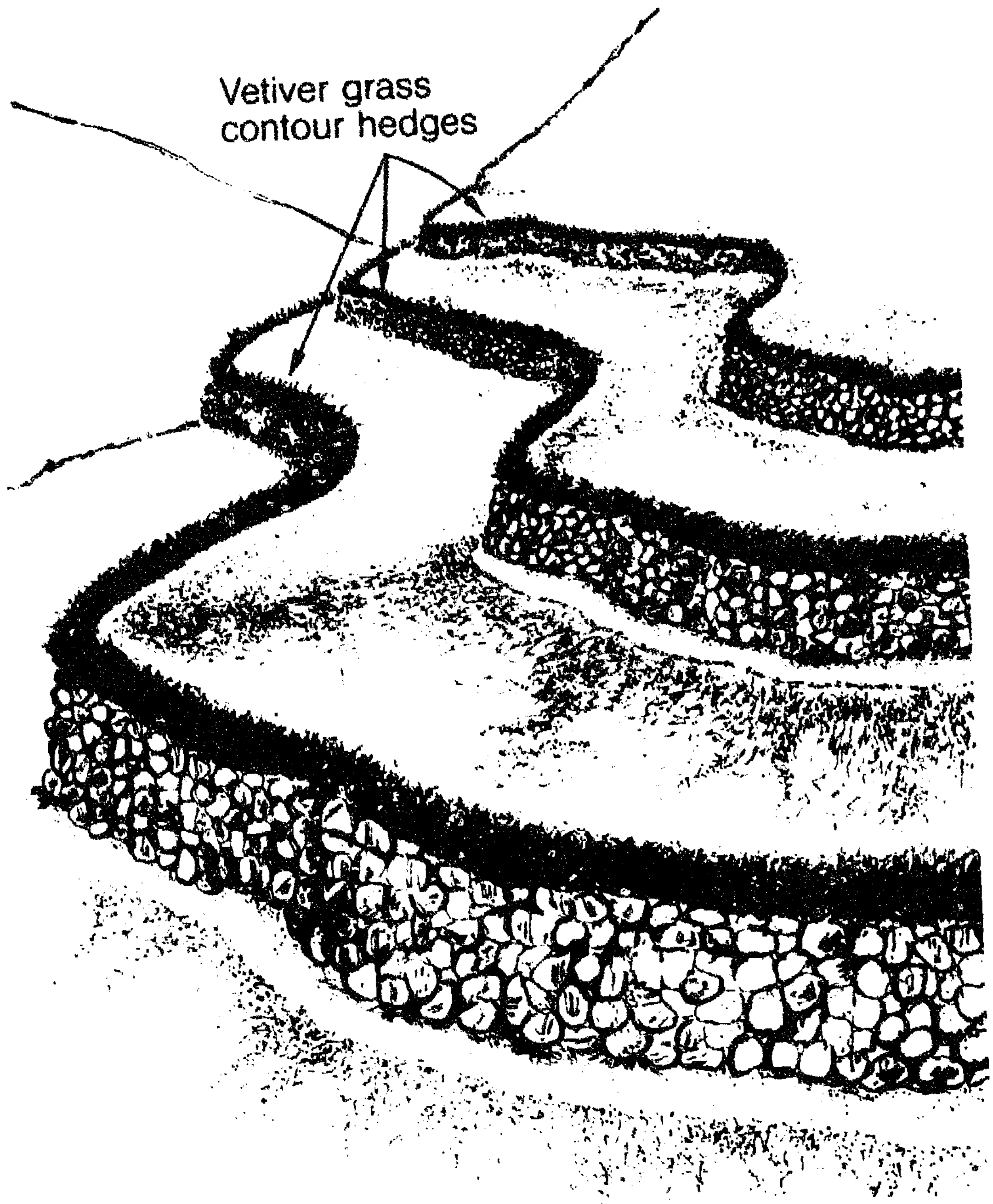


Fig 43 illustrates how the Vetiver would support a masonry terrace without impeding the essential drainage between the stones. In heavy storms, the water cascades down the slopes and over the top of the masonry terraces. This causes most of the major damage, according to the farmers, especially if this water gets a chance to concentrate into a stream. It is anticipated that once Vetiver hedges are established, they will take most of the erosive power out of this runoff and should certainly protect the edge of the terrace.

In **Fig 43** it can be seen that the masonry risers are very vulnerable since they are simply stones carefully stacked on top of each other and are usually two to three meters high. Vetiver grass has a very strong, penetrating root system, capable of protecting the whole rock-face. Its roots will easily penetrate to the bottom of the risers.

Fig 43

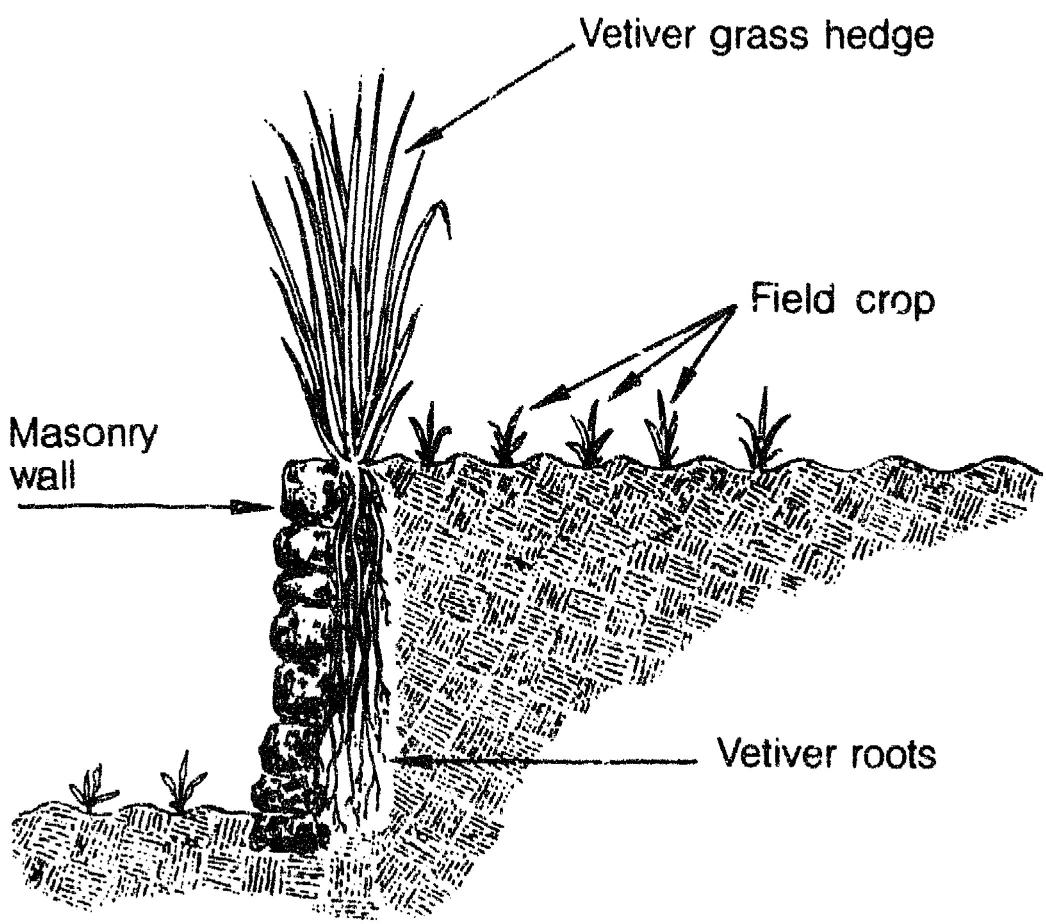
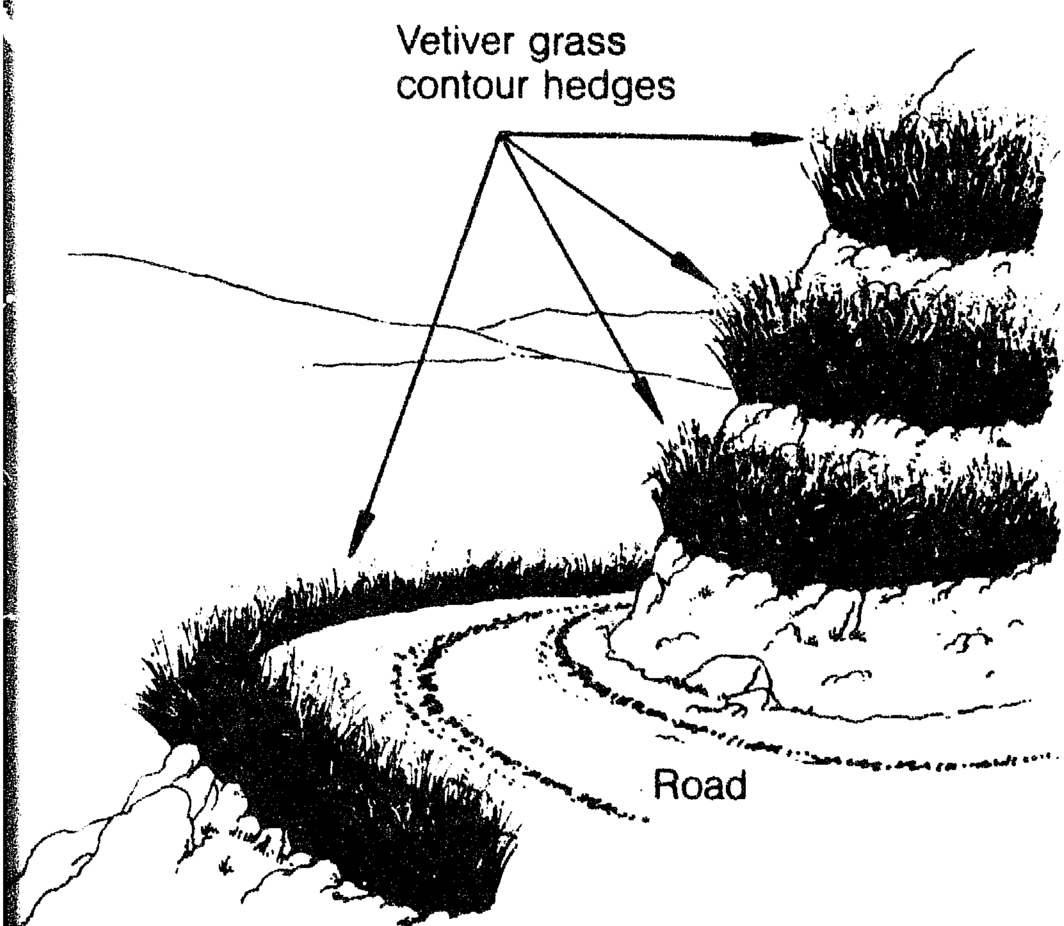


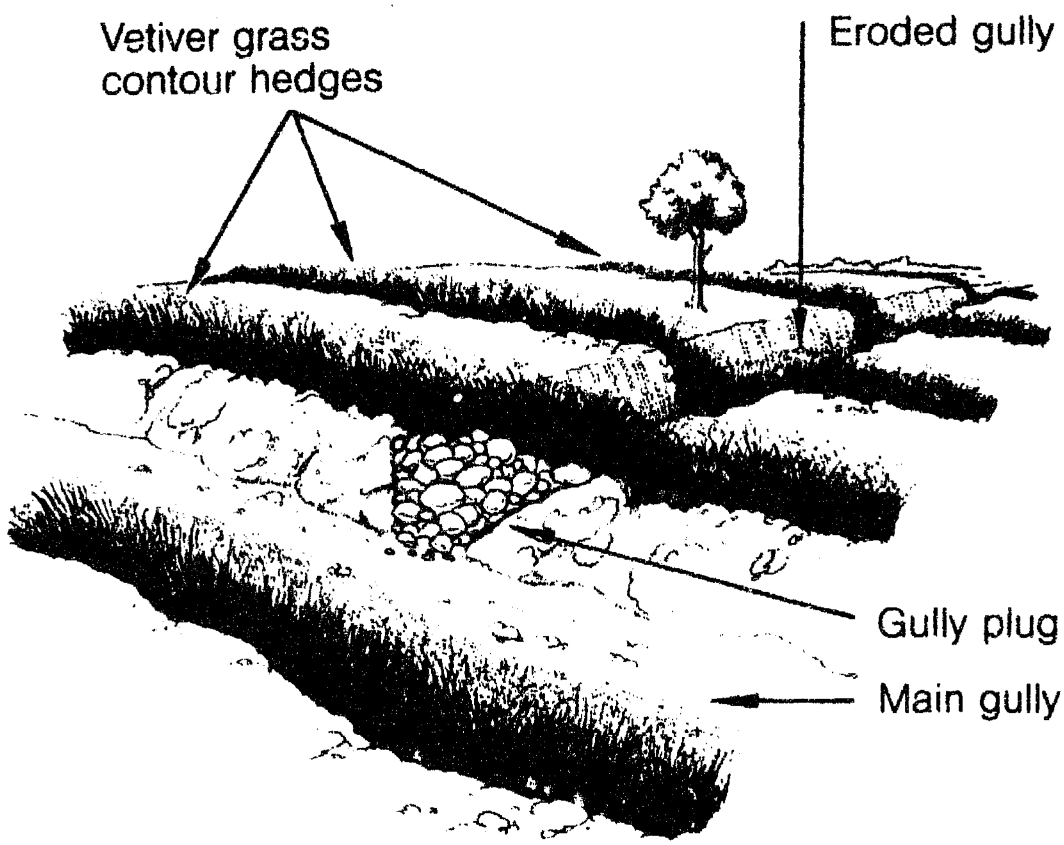
Fig 44 shows Vetiver grass being used as a means of protecting road cuttings. The grass has exhibited its ability to grow on practically any soil. In Andhra Pradesh it was observed growing at the "Medicinal and Aromatic Research Station" on an area of the hilltop where granite boulders had been bulldozed away to make a plot for it. The grass was being deprived of the benefit of rainfall as it was planted on top of the bare hill. The soils it was growing in were "skeletal" and not supporting any other form of growth at the time of observation, yet the Vetiver grass was showing no signs of stress It was decided that if it could thrive under these extreme conditions, it would do an excellent job of stabilisation almost anywhere.

Fig 44



The use of Vetiver grass in wasteland development has yet to be tested, but there is absolutely no reason why it should not be successful as the initial stabilising plant. *Vetiveria zizanioides*, in the Sahel of Africa and in Bharatpur in Central India, has survived as the climax vegetation for hundreds of years under extreme conditions of constant fires and droughts. *V. zizanioides*, planted as contours in wasteland areas, would reap the benefit of extra runoff and "harvest" organic matter as it filters the runoff water through its hedges. It should prove to be a very useful means of commencing the stabilisation of these areas. The foothills of the Shivaliks being very young geologically, are highly erodible; by planting Vetiver contour hedges around these slopes and then across the short erosion valleys, these areas could possibly be stabilised. It would require a masonry "plug" at the end of the system to allow silt to build up and give the grass a basis of establishment. The same would apply to normal gullies shown in **Fig 46.** Once established the grass would terrace these gullies.

Fig 45


Vetiver grass
contour hedges
Eroded gully
Gully plug
Main gully

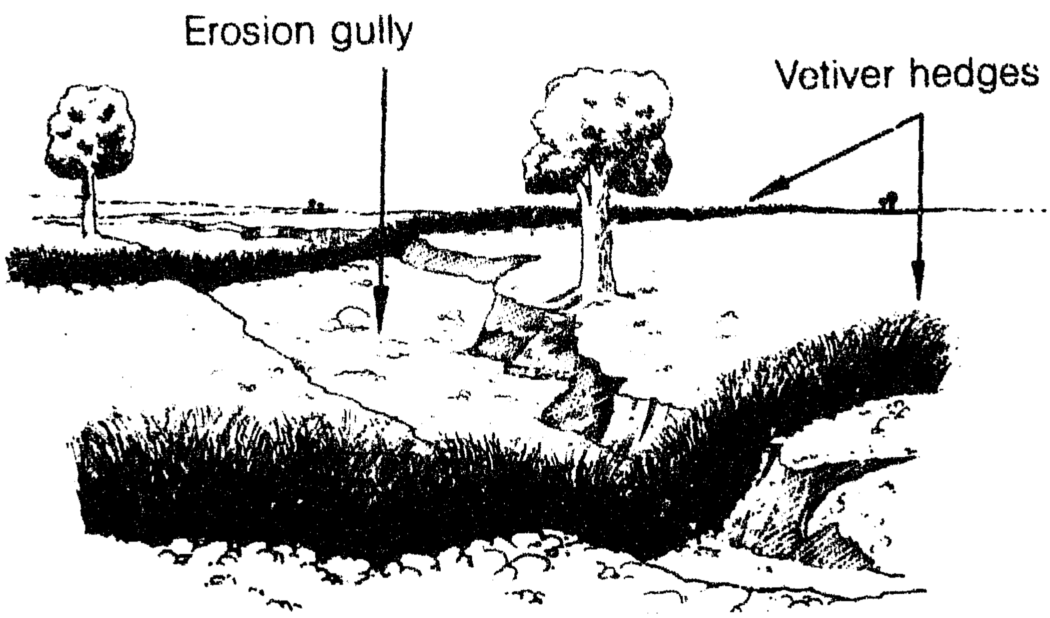
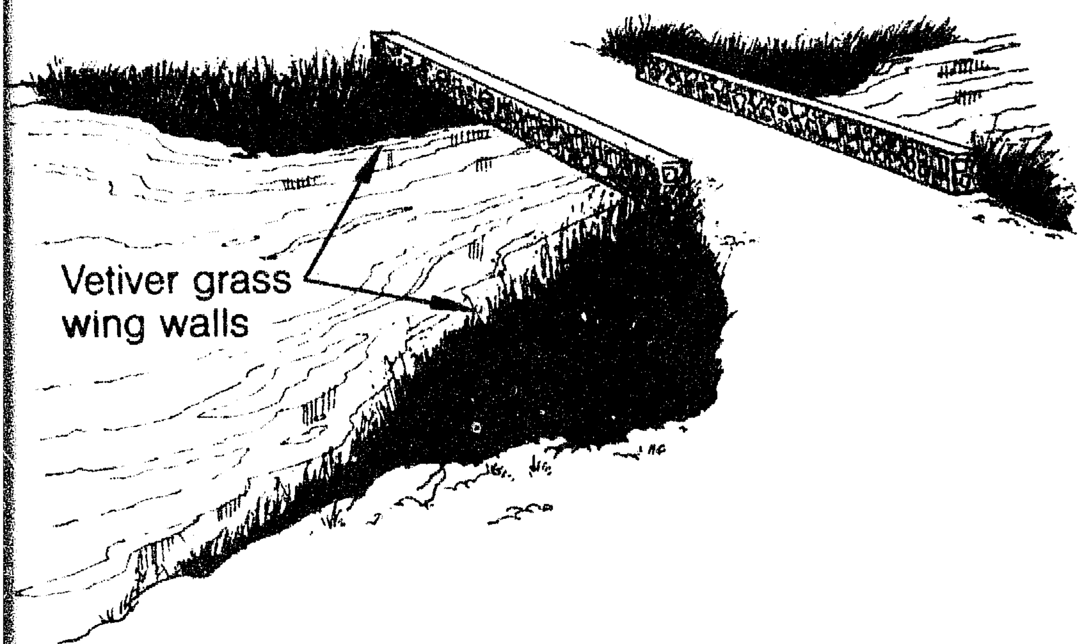

Erosion gully
Vetiver hedges

Fig 46

The use of Vetiver grass for the stabilisation of river banks and canal walls is another area where it could be tried. An experiment was observed in Tanzania, on the road to Dodoma, where a road engineer, 30 or 40 years previously, had used Vetiver grass to protect the "wing-wall" of a bridge on one side of the river. On the other side he had constructed the usual concrete wing-wall. Over the years, the concrete wall had eventually collapsed into the river, and the bank it was protecting had eroded. On the other side, the Vetiver grass was still holding the bank in perfect shape. **Fig 47** shows Vetiver grass being used to protect the river approaches to a bridge.

Fig 48 shows Vetiver grass being used to protect the banks of a major irrigation canal.

Fig 47



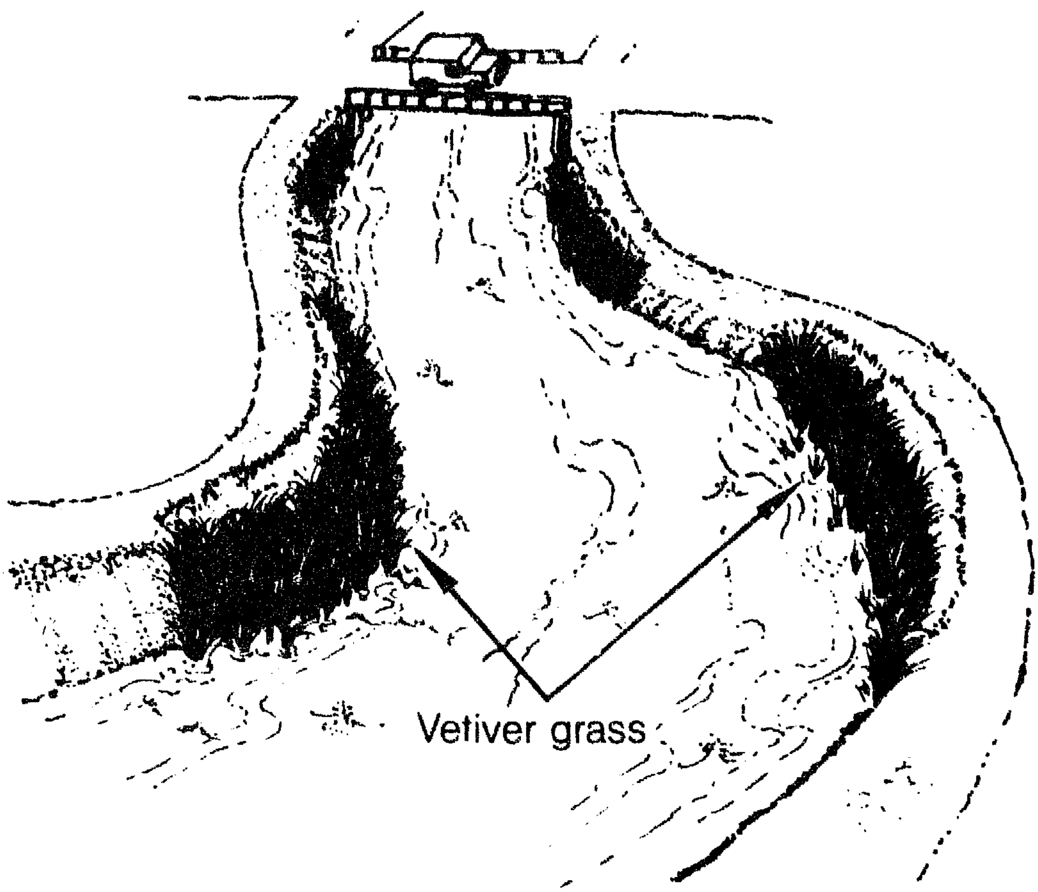
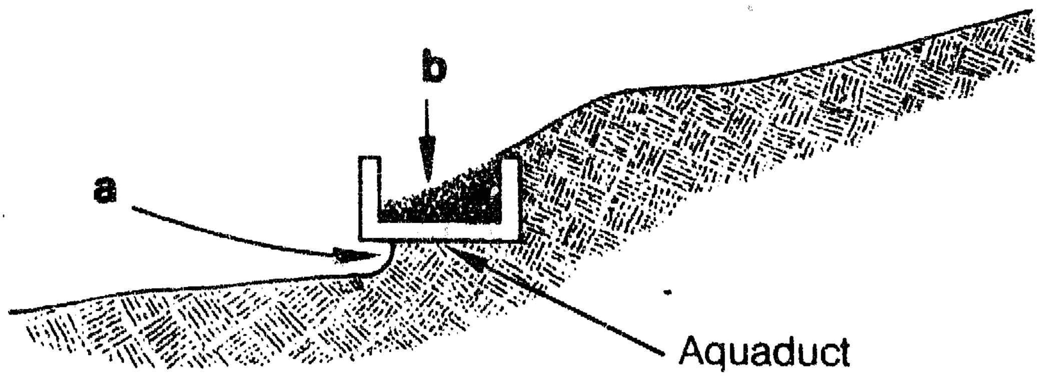


Fig 48

Fig 49 shows a contour irrigation aquaduct leading back from the main canal around the foothills to the upper reaches of a command area. These canals suffer from siltation and erosion as they wind their way round the slopes. In **Fig 49,** the typical problem is illustrated: The concrete conduit is undercut by erosion at **a** and is filling with silt at point **b**.

To overcome this problem, it is recommended that Vetiver grass should be planted parallel to the upper and lower sides of the concrete conduit. As shown in **Fig 50,** the upper hedge will prevent silt from getting into the canal, while the lower two hedges will prevent erosion rills or gullies, cutting up from below and undermining the concrete structures.

Fig 49



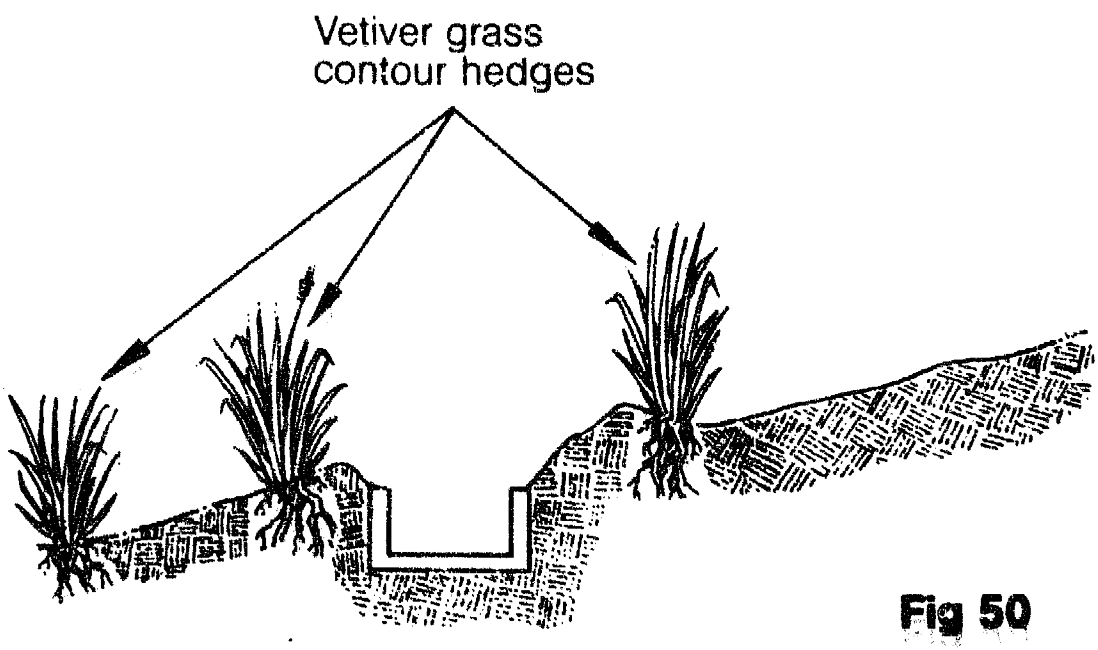
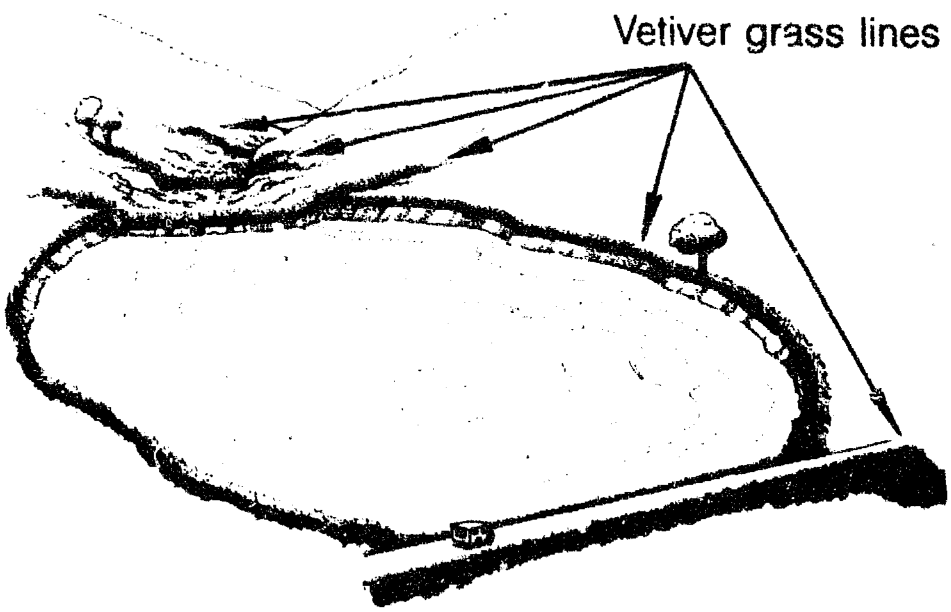


Fig 50

Fig 51



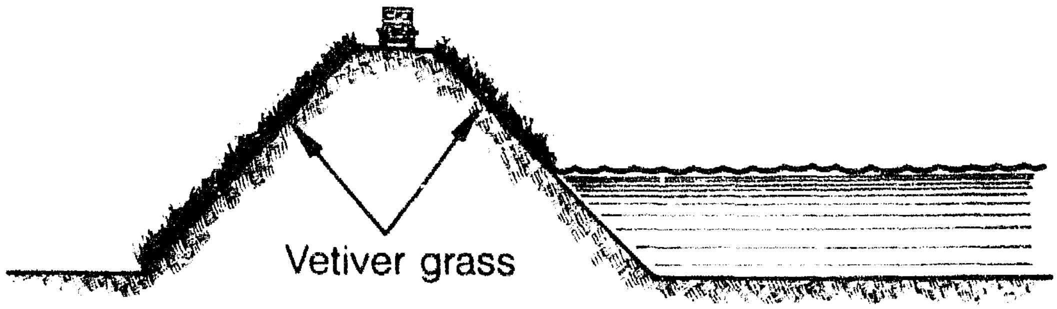


Fig 52

The use of Vetiver grass to protect dams is another approach that should be taken up. Small dams throughout the world are silting up at an alarming rate. As these dams were obviously sited in the best areas in the first place, once they have been filled with silt, they are of no further use – and in many cases there is not another good site for a new dam. By planting Vetiver grass around the sides of the dam as shown in **Fig 51** silt is trapped before it reaches the dam from the surrounding hills. Also, by planting hedges of Vetiver grass at the entrance to the dam, two purposes are well served: this area makes an ideal site for a Vetiver nursery; and, by being planted in hedges across the dam's inlet, the Vetiver filters out all the silt before the water reaches the dam. Over a period of time these hedges will form stable terraces which could be used for cropping or tree planting.

In **Fig 52,** Vetiver has been planted on the walls of a dam to protect them from rill erosion and eventual breakdown. This type of damage can be seen going on unchecked throughout the country.

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