# PROTECTION AGAINST FLOOD DAMAGE

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## Abstract

Three weather systems which cause heavy rains in southern Africa are described and the frequency of their occurrence is evaluated. Cyclonic rain such as that which occurred as a result of the Demoina and Imboa cyclones in 1984 is discussed. The Natal storms of September 1987, caused by a concentration of very low pressure isolated in a high pressure area are also described. Recorded rains are shown as isohyets over Natal. The Tugela, Umvoti and Nonoti catchments are used to illustrate the role which sugarcane plays in protection. A general assessment of damage caused by the recent floods is given and the relative importance of protection measures for field areas, perennial stream regions, and river floodplains is evaluated. The use of materials, grasses and indigenous trees in an overall protection scheme is discussed.


## Introduction

The storms which occurred in Natal at the end of September 1987 caused death and widespread damage and were described as 'the worst in living memory' and 'once in a lifetime'. The occurrence of this type of storm, has been estimated to be about once in 200 years or more. There are, however, many storms of a less severe nature which happen much more frequently. In this paper the term 'storm' is used to denote a period of intense, mostly continuous rainfall where any cessations do not exceed a period of 8 h.

Henry Brooks wrote about Natal in 1876: "Floods of a very much more serious and disastrous character are, at long intervals, brought about in the coast districts . . . in 1856 the uMgeni rose 28 ft above its usual level . . . The rainfall at the seaport during these three disastrous days amounted to 27 inches". Since that date the recorded climatic data show that a great number of exceptionally heavy storms have occurred in South Africa with surprising regularity. Table 1 (Adamson[1]) lists some of the periods of heavy rainfall since the beginning of 1959.

**Table 1**

**Heavy storms recorded in South Africa from 1959**

| Year | Area/event | Rainfall (mm) | Period (d or h) |
|---|---|---|---|
| 1959 | Natal South Coast | 450 | 1 d |
| 1960 | Uhlenhorst storm | 400 | 12 h |
| 1961 | Karoo floods | 100 | 14 h |
| 1968 | Port Elizabeth storm | 550 | 1 d |
| 1970 | East London storm | 800 | 4 d |
| 1974 | Eastern Cape floods | 200 | 1 d |
| 1978 | Natal cyclones | 550 | 3 d |
| 1981 | Langsberg floods | 350 | 2 d |
| 1987 | Natal floods | 900 | 3 d |

While the extreme cases have had notably disastrous results there are many other storms which annually cause millions of rands of damage to agricultural crops and land. Heavy storms or rainfall must be expected every 3 to 4 years when fields, natural watercourses, and floodplains are likely to be damaged. All agricultural progammes must therefore include some provision to protect the land and crops adequately from flood damage.

*Frequency*

At present, the data on rainstorms comprise daily recordings of rainfall which are totalled to provide annual figures. At the coast a large proportion of the total is made up of rain generated by synoptic systems such as frontal movements, cyclonic circulation, and isolated low pressure cells. These factors contribute in decreasing amounts to the total annual rainfall as distance from the coast increases. Pegram and Adamson[3] have recently suggested that statistical analyses carried out previously, using methods such as the extreme value type 1(EV1) or Gumbel distribution, under-estimate the occurrence of heavy rainfall events in Natal and the rest of the coastal regions of the country. The authors propose a method of analysis which differentiates between two important components which make up the annual rainfall totals. It takes cognisance of the different rates at which two different types of rainfall occur. The large amounts of rain caused by synoptic systems (although these are relatively infrequent) represent a high proportion of the annual totals. With the new method of analysis the data are plotted to provide two curves, one for the 'outlier' or more extreme events, and one for the lesser storms. As a result extremely heavy storms are now estimated to occur more frequently than has formerly been predicted.

From this type of analysis it appears that the rainstorms experienced in September 1987 occur at least once in 100 years. For the Pinetown area it is likely that a one in 10-year storm would be about 255 mm, a one in 20-year storm about 315 mm, and a one in 100-year storm about 540 mm. It is also probable that the area reduction method used to estimate rainfall and runoff, underestimates the flood depths associated with synoptic rains. This means that the river systems are likely to flood more frequently than has been predicted by conventional techniques. The change in predicted frequency of storms is thus the result of a better understanding of rainfall systems and data analysis, and does not reflect any change in weather patterns.

## Weather systems

There are 3 major weather patterns that produce rains of sufficient magnitude to destroy lives, land, and property:

**Cyclonic rain:** during certain periods of the year, swirling air masses are developed along a belt between the south-east trade winds and the monsoons in the Indian Ocean. The cyclones generated by this interaction move in a westerly direction towards the African land mass. Often the precipitation from the cyclones takes place over the ocean or the offshore islands, but occasionally they move in over the mainland and cause very heavy storms. Such storms occurred in Natal in 1984 with the Demoina and Imboa cyclones. The map shown in Figure 1 depicts the isohyets or contour lines of equal rainfall for cyclone Demoina (Kovacs *et al.*[2]).

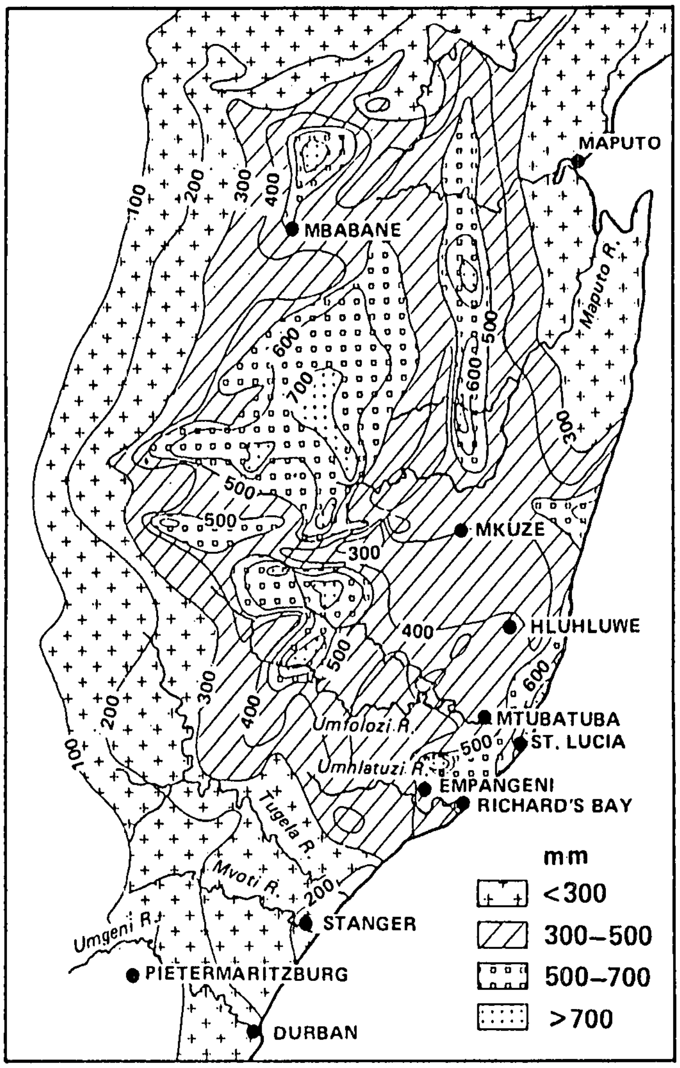


**FIGURE 1** Rainfall isohyets over Natal from cyclone Demoina, January 1984.

**Isolated low pressure cells:** the weather over the southern part of the continent is dominated by the south Atlantic high pressure areas which move into the country from the south-west. Occasionally a very deep cell of low pressure is cut off by the higher pressure front. Cold, moist air from the far south is fed into this cell causing the situation which led to the rains over Natal in September 1987. The movement of moist air from the south-east into these very intense low pressure cells has caused them to become known as 'black south-easters' because thick cloud masses form. The distribution of rains of this type which occurred over the 3-day period from 26 to 29 September 1987 is illustrated in Figure 2.

**Orographic thunder-storms and localised rain:** high temperatures during the summer months with high humidities in the circulating air cause hot moist air masses to rise rapidly. This air is quickly cooled and the moisture condenses as rain or hail. Severe thunder-storms and intense rainstorms can develop like this. While these are generally localised, very large amounts of rain can result. Normal frontal movement of air masses, converging with moist air from the north, causes rain which makes up the bulk of the annual rainfall for the coastal regions. Natal is in a summer rainfall region with the majority of the rain falling from October to March.

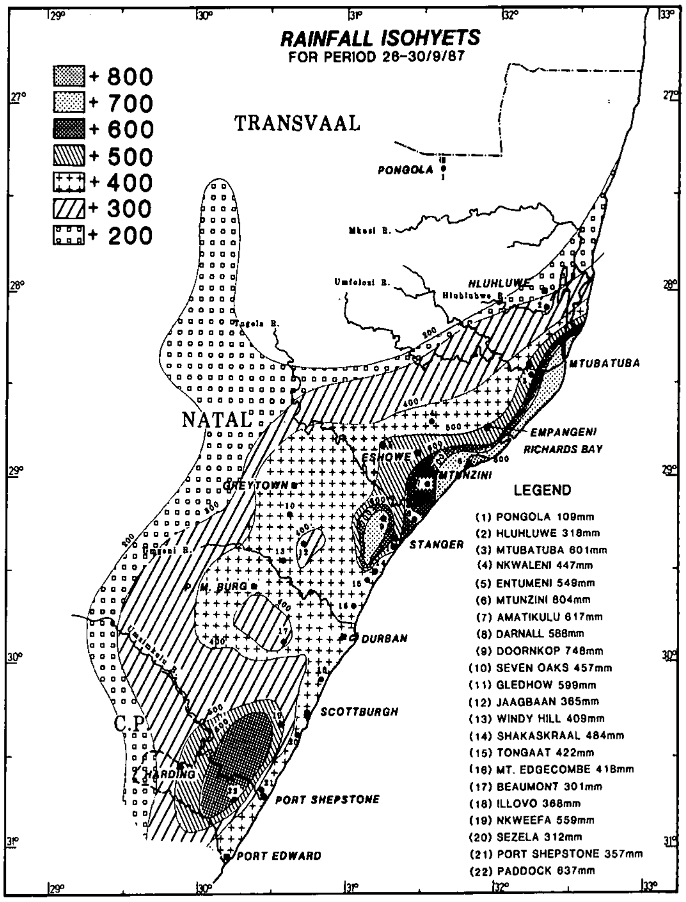


**FIGURE 2** Rainfall isohyets for Natal, September 1987.

*Catchment size*

Large sections of the sugarcane growing area of Natal are situated along or close to the coast. The drainage of the inland parts of Natal takes place by means of large rivers which eventually pass through this cane belt. The major rivers such as the Umzimkulu, Umkomaas, Illovo, Umgeni, Tugela, Amatikulu, Umhlatuzi, and the Umfolozi drain very large areas of land outside the sugarcane belt. However, large areas of sugarcane are found on the floodplains of the Umvoti, Umhlatuzi and Umfolozi rivers.

The other main rivers pass through relatively few cane areas although the Umzimkulu and Illovo rivers do have cane fields adjacent to them in proximity to the mills. The catchments of several of the smaller rivers (Umhlali, Nonoti, Sinkwazi) lie within cane-growing areas and the sediment loads in these rivers are indicative of the amount of protection in their catchment areas. A comparison of various river catchment areas in Natal is given in Figure 3.

## Discussion

*Damage*

The 1987 floods provide an example of severe storm damage to land under cane, which can be divided into 3 main classes:

**Infield damage:** most of the damage occurred in fields where preparations for replanting cane using conventional tillage had been made or where cane had recently been planted. The worst affected areas were moderately steep slopes with shallow, fine-grained sands. Areas with Longlands, Cartref, Mispah, Westleigh, and Kroonstad soil forms were particularly vulnerable. Large landslips often occurred

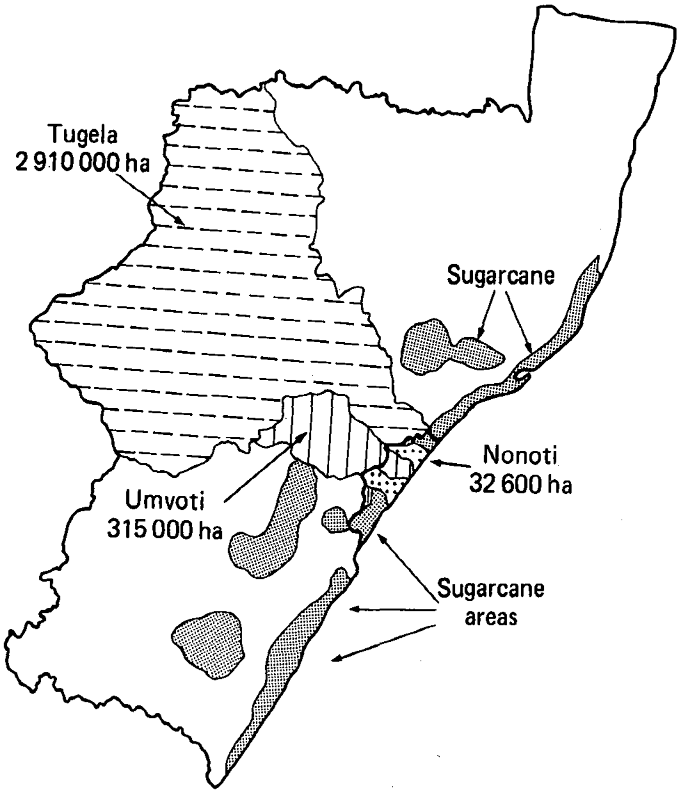


**FIGURE 3** Catchment sizes of 3 Natal rivers.

where saturated topsoil overlay E-horizons or impermeable rock layers. These landslides were often triggered by erosion at the base of the slip. Infield roads, bridges, and crossings were frequently washed away. Massive gullies formed in some fallow fields (Figure 4).

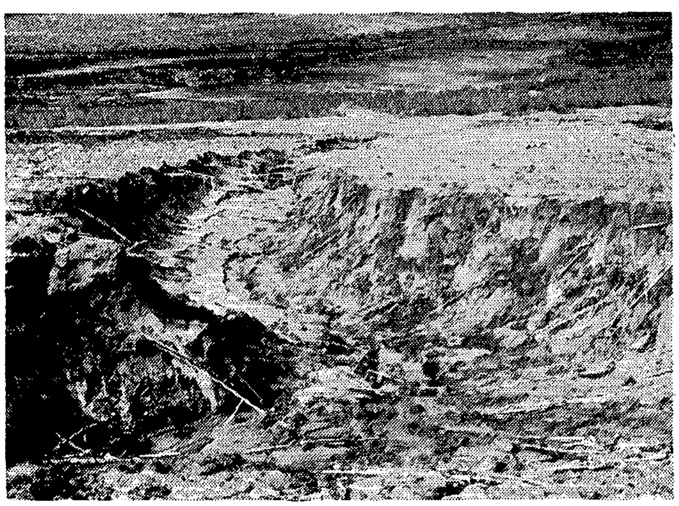

**FIGURE 4** Extreme soil erosion from a recently planted sugarcane field.

**Waterway and streamline damage:** because of the very large amounts of runoff, inadequately protected drainage lines suffered most, especially where the crop had provided little cover and in fields which were ready for replanting. Streambank erosion and undercutting of the banks, followed by further collapsing of the scoured portions commonly took place, but was mostly localised and influenced by the state of the catchment (Figure 5).

**FIGURE 5** Streambank erosion showing banks collapsing due to undercutting action of the stream.

**Riverine damage:** extremely high flow rates occurred in all the main rivers. Damage to banks was severe with existing natural vegetation, often being completely destroyed. Rivers changed their courses, and in many regions where flooding occurred, deposits of sand buried the standing crop and made it uneconomical to recover the fields. This type of damage was particularly obvious and expensive to repair but it comprised a relatively small proportion of the total damage caused (Figure 6).

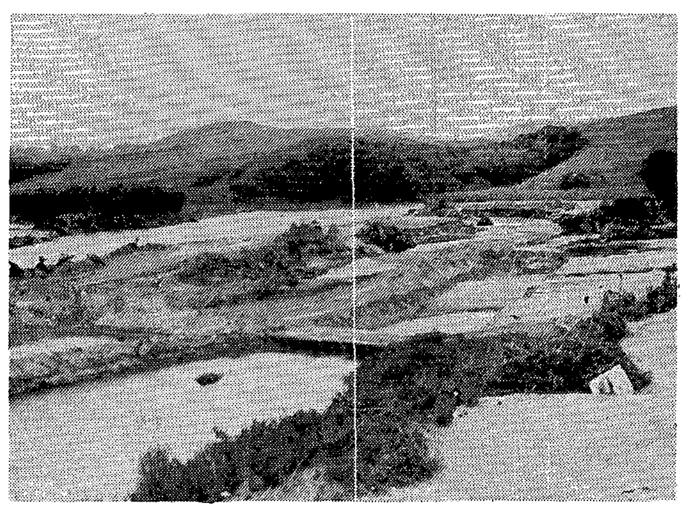

**FIGURE 6** Deposits of sand in the floodplain of the Umdloti river.

*Protection measures*

In order to establish a policy for adequate protection against flood damage it is necessary to evaluate the extent of each component of a catchment area and the hazards that need to be faced. For example, an analysis of the Nonoti catchment shows that the biggest area of the region is the infield area. This would generally apply in the sugar belt. On most farms the hilltop, hillside, and valley bottom areas are very large compared with the riverbanks and streamlines. The total catchment size is close to 30 000 ha. Approximately 24 000 ha of sugarcane are grown by 105 quota-holders. The soils in the area are diverse in nature but generally erodible (Figure 7).

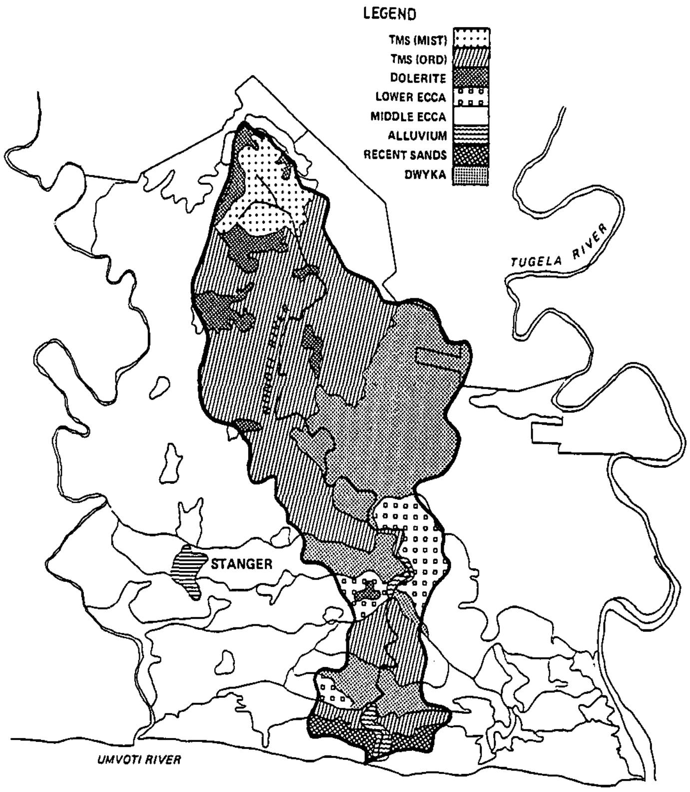


**FIGURE 7** The large variability of soils in the Nonoti river catchment area.

**FIGURE 8** A well-protected stream in the Nonoti catchment.

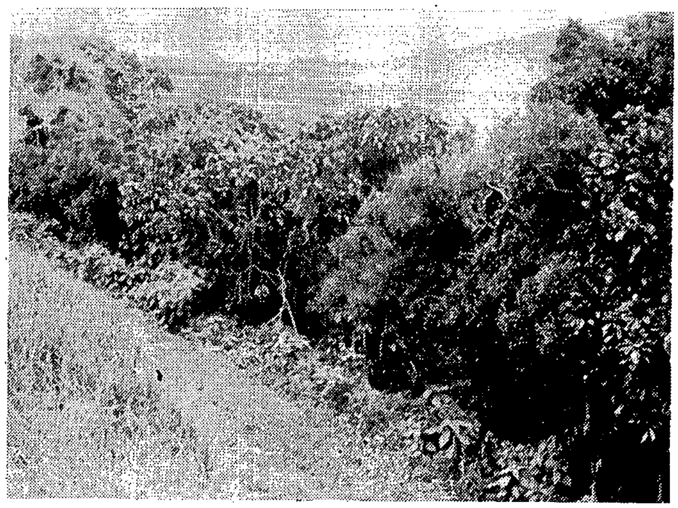

**FIGURE 9** Indigenous trees used for protection along a stream.

The slopes are mostly steep and consequently the protection of the hillside area is of the utmost priority. On average a quota-holder has 70 to 80% of the farm under cane, 5 to 10% under roads and loading zones, 5 to 10% under natural bush, planted trees or non-cane areas, and about 5 to 10% under waterways, drains and riverbanks.

Storms of the duration and intensity of those in 1987 inevitably cause some damage. Where minimum tillage and strip planting were practised at re-establishment, minimal soil loss occurred. Even in steep areas on the south coast where these management practices had been applied, few gullies or rills were evident.

**Protection of field areas:** the recommendations provided by the SASA Experiment Station for the hillside areas are based on the use of a nomograph (Platford[4]) to determine panel widths for any particular set of field and management conditions. Crop management practices are important criteria when a system of erosion control is being designed. The basic information required is slope and erodibility of the soil. Above certain limits applying to slope (12% for erodible soils, 15% for moderately erodible soils, and 20% for soil resistant to erosion) minimum tillage must be employed when replanting takes place. Strip planting is essential except when minimum tillage and water-carrying structures are used. In general, a policy of dividing slopes and fields into horizontal bands should be followed and the widths of the individual panels can be determined from the nomograph. All the recommended practices conform with the requirements of The Conservation of Agricultural Resources Act of 1983.

**Protection of drainage lines:** depressions in the fields which are used as waterways and the minor drainage lines which contain a perennial flow of water must be protected by vegetative cover (Figures 8 & 9).

Sugarcane should be removed from the banks to a distance of at least 4 m. Any collapsed banks along drains or minor streams should be shaped with a blade or other suitable equipment to have a 1:1 slope. Work in vulnerable areas must only be undertaken during the winter months. Cane must not be planted within 3 m of the top shoulder of the shaped or stable channel side. If the channel base is V-shaped it should be flattened if possible. Various species of grasses, sedges and trees are suitable for planting along the sides and tops of the channels (Table 2).

The first stage in most protective systems, if the ground is not eroded, is the planting of a grass species to give a quick cover. Couch (*Cynodon dactylon*), Coastal buffalo grass (*Stenotaphrum secundatum*), or Kikuyu (*Pennisetum clandestinum*) are the preferred grass species. Thereafter 'pioneer' plants such as Mitseeri (*Bridelia micrentha*), Kosi (raffia) palm (*Raphia australis*), Umdoni (*Syzygium cordatum*) or Wild frangipani (*Voacango thangarsii*) should be established. There are mostly soft-wooded trees and shrubs which produce berries and seeds which attract birds. The birds feed on the fruit and import the seeds of many other varieties, which germinate and stabilise the habitat. Where gullies or damage have occurred in a drainage line, a decision must be made whether to stabilize and shape the newly formed gully or to initiate a complete reclamation programme.

**Table 2**

**Grasses and trees suitable for planting for soil protection**

| Botanical name | Common name |
|---|---|
| Grasses | |
| *Stenotaphrum secundatum* | Coastal buffalo grass |
| *Cynodon dactylon* | Couch grass |
| *Pennisetum clandestinum* | Kikuyu grass |
| Trees | |
| *Bridelia micrantha* | Mitseeri |
| *Ficus trichopoda* | Hippopotamus fig |
| *Harperphyllum caffrum* | Wild plum |
| *Phoenix reclinata* | Wild date palm |
| *Podocarpus falcatus* | Common yellowwood |
| *Raphia australis* | Kosi palm (Rafia palm) |
| *Rauvolfia caffra* | Quinine tree |
| *Syzygium cordatum* | Umdoni waterberry |
| *Syzygium quineise* | Woodland waterberry |
| *Taberaemontana venticosi* | Forest toad tree |
| *Voacargo thouarsii* | Wild frangipani |

**Reclamation** entails restoring the area to its original state (as it was before any damage took place). This is normally possible only in the case of small gullies. Carefully designed grade stablisation structuring is necessary to form the solid base and infrastructure over which silt and recovered material accumulates. Structures such as gabion weirs, Reno mattress chutes or other available materials should be used to form the framework. Natural grasses and trees are then used to complete the cover once the gully has been filled.

**Stabilisation** consists of first shaping the sides of any gullies to a slope which, once protected with natural vegetation, will be able to withstand water flowing over the surface. The inlets or gully heads must also be stablised by shaping and providing a protective chute down which any runoff water can flow. Protection weirs with suitable filter materials must be built at the outlet of the gully where it rejoins the non-eroded streambed. These weirs safely spread any flood waters over the streambed in such a way that further erosion is avoided.

**Protection of major riverbanks:** where the riverbank is vertical or in danger of collapsing, limited shaping may be the only measure which can be undertaken. The shaped banks need to be planted to appropriate tree species. If the bank is well-defined, sugarcane should be removed for at least 10 m from the 10-year flood level, which must be defined in terms of the Act of 1983.

## Conclusion

Some lessons that have been learned from the floods are:

- the methods of analysis used previously underestimate the frequency of occurrence of very heavy storms. These occur in the coastal region more often than has generally been predicted.
- the volume of water when flooding occurs is presently underestimated.
- where recommendations for re-establishment, which include minimum tillage and strip planting are carried out, very little damage to fields will occur even during severe floods.
- where a good trash blanket exists run-off and erosion are considerably reduced.
- drainage lines and streambanks need to be shaped and protected with vegetation and sugarcane must be removed for a suitable distance.
- many indigenous plants are currently available for use in the protection of drainage lines.
- major rivers need bank protection such as shaping and vegetative cover.
- sugarcane grown in the floodplain areas of major rivers is always at risk.
- the definition of the 10-year flood level along major rivers is urgently required.

The Conservation of Agricultural Resources Act of 1983 states that protection must be provided against runoff from a flood that is likely to occur once in ten years. The recent storms in September 1987 which appear to have about a once in a 100-year return period, proved that where all recommended practices had been followed visible damage to agricultural land was minimal. The methods necessary to provide control are known, but are often not implemented.

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