

BIOENGINEERING FOR SOIL SLOPE STABILIZATION:

**Vegetation with potential for erosion
control on sloping lands in Trinidad**



Commonwealth Secretariat

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Cover photograph:

A Weeping Fig (*Ficus benjamina*) with extensive root system.

PREFACE

This publication follows two previous texts written by Dr. Gumbs and published by the Commonwealth Secretariat. In 1992 a report entitled *Integrating Soil Conservation into Farming Systems in the Commonwealth Caribbean*, was produced and in 1994 this was followed by a second document entitled *Farmers and Soil Conservation in the Caribbean*.

This present volume is the latest contribution on soil conservation from Frank Gumbs. The practical nature of the text and the carefully produced illustrations add an important dimension to soil conservation studies in the Region. The text should be of interest to both agriculturalists and civil engineers.

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Brian Kerr
Chief Project Officer
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F. A. Gumbs
Trinidad
1995

1 INTRODUCTION

Bio-engineering is defined as the use of plants or vegetation for engineering purposes. Bio-engineering for soil slope stabilization utilizes living plant materials, viz., stems, branches, and roots, to provide mechanical and hydrological support to the soil against erosion. Although the use of vegetation for soil slope stabilization and erosion control is well known in the Caribbean, there has not been a systematic approach nor a strong conscious effort to use vegetation in this way.

Soil erosion by water occurs in the following forms:

- raindrop impact or splash erosion;
- rill erosion where the runoff water concentrates in narrow channels or rills;
- sheet erosion which is the removal of soil particles from sloping land in thin sheets by water runoff;
- soil slippage or slumping which is the sliding of soil above a failure plane;
- gully erosion which is the removal of soil resulting in large channels;
- river and stream bank erosion;
- beach and coastal area erosion.

Most vegetation if it is close to the ground and covers the soil surface completely will prevent raindrop impact, rill erosion, and sheet erosion. However, vegetation which is not perennial, or dies back during the dry season, or is destroyed by dry season fires will not adequately protect the soil. If the ground under the trees is bare, splash, rill, and sheet erosion can occur from the raindrops falling within the drip circle of the trees. The height and architecture of the canopy are two plant factors which can influence the energy, spatial distribution, and erosivity of the falling raindrops.

The ability of plant roots to improve soil surface structure is an important factor in erosion control. Improved soil surface structure increases infiltration and reduces runoff and erosion. Therefore, prolific deep rooting systems, especially fibrous root systems are very desirable.

Land slippage can be shallow or deep depending on the structure of the soil profile and the depth to the slip plane. Grasses and shrubs may not be able to hold the soil against slippage if the slopes are steep, slip planes are deep, and rainfall is heavy. However, trees may be effective under these conditions especially if the tree roots are deep and well distributed.

Many rivers and streams in the Caribbean may run dry or at very low flow rates in the dry season but may overflow their banks in the wet season. Hence, river and stream bank erosion is prevalent in the wet season and is promoted by the velocity, turbulence, and sediment load of the water flow. Grasses, shrubs, and trees that can tolerate waterlogging can protect the banks against erosion.

Engineers have normally sought remedies for soil slope stabilization in traditional engineering structures to protect civil works. Many road building contracts however, require the contractors to vegetate the roadside embankments. In for example Trinidad, vetiver (*Vetivera zizanioides*) is the plant species that is recommended but it would appear that adherence to the recommendations are not enforced. Consequently, embankments are invaded by volunteer plant species which may not be the most appropriate species for stabilizing the slope, since they may possess a poor root system which cannot effectively stabilize the soil or they may not completely cover the ground.

In the Caribbean, only a few species are recommended or are used specifically for soil slope stabilization. Besides vetiver which is also recommended as contour grass barriers particularly on agricultural land, *Gliricidia*, *Leucaena*, and *Acacia* spp. are used for slope stabilization and gully control mainly because of their ease of establishment, rapid growth, and resistance to drought. Vegetation suitably selected for the environmental conditions and for engineering purposes can substitute for, or be supportive of, engineering structures. In these cases, bio-engineering can reduce the high cost of protection associated with engineering structures or provide a cost-effective level of protection.

There is no systematic information on the suitability of plant species for bio-engineering under prescribed environmental conditions in the Caribbean. If plant species are to survive and effectively perform their engineering function, they must be adapted to the soil, rainfall, temperature, humidity, wind, and other environmental conditions such as grazing, fires,

flooding, salinity, and seaspray. This study aims to identify and to recommend plant species which are suitable for soil slope stabilization under specific environmental conditions and engineering purposes. The study was undertaken exclusively in Trinidad but the findings would be applicable to other Caribbean islands under similar environmental conditions and, indeed, to other countries in the humid tropics.

It was not possible to scientifically test the response of the species to these conditions. Recommendations are based on careful observations and the knowledge of local experts. Where all the relevant information has not yet been verified the recommendations are tentative and should be adopted with caution. It is proposed that further knowledge gained from field tests would be used to update the recommendations.

1.1 *Scope of the Resource Book*

Since very few species are currently used for soil slope stabilization in the Caribbean this resource book is aimed at providing the engineer, agriculturalist, forester, and environmentalist faced with the problems of slope stability, with a wider selection of suitable species.

The book is intended as a guide to the selection of vegetation that is suitable or has potential for stabilizing slopes under a range of conditions. It also recommends species that can be used for specific types of erosion control. Based on the field observations there is a high level of confidence in the ability of the recommended species to stabilize slopes. However, the rate of spread and the potential to become a weed could not be assessed. Therefore, there is need to adopt the recommendations cautiously where this is indicated. Future field monitoring will contribute to the upgrading of the recommendations.

2 CLIMATE OF THE EASTERN CARIBBEAN

The eastern Caribbean is located in the humid tropics but the rainfall is strongly influenced by topography. The intertropical convergence zone and to a lesser extent easterly waves, wave disturbances, or upper level troughs are the main weather systems that cause rainfall in the wet season. Convictional showers are the main forms of precipitation in the dry season. The wet season lasts between five and seven months from May or June, to November or December depending on location in the eastern Caribbean and on topography of the islands.

The islands of the eastern Caribbean can be divided into two topographical classes: flatter islands with low relief e.g. Antigua and Barbados, and hilly or mountainous islands to which most of the other islands belong. Dominica is the most mountainous.

The moisture laden northeast trade winds blow onto the islands from the east. These winds are forced to rise when they reach the mountains or mountain ranges on the islands. These rising winds result in condensation and precipitation or orographic rainfall. Consequently, there is increasing rainfall with elevation on the windward or eastern sides of the islands and a rainshadow effect and low precipitation on the leeward or western side. Leeward coasts can have quite low annual precipitation. Annual rainfall on the windward sides of the islands can vary from 1500-3500 mm depending on the island and on elevation. The leeward coast can have rainfall as low as 800 mm per annum. The range of rainfall on the leeward side of the islands can be 800-1200 mm per annum. The highest rainfall occurs at high elevation on the windward coast on the island of Dominica where rainfall can be as high as 7000 mm per annum. Rain falls almost every day and there can be several showers on some days.

The flatter islands of Antigua and Barbados have the lowest rainfall. The annual rainfall can vary generally from 750-1750 mm and the dry season can be prolonged.

Rainstorms in the Caribbean can be intense. It is not unusual to have storms of 50-100 mm per hour and a duration of more than one hour. Storms of greater intensities also occur. In some years, 50-70% of the annual rainfall may occur in 10-15 rainfall events. These rainstorms are very erosive and significant soil loss takes place.

Temperature and humidity vary with elevation and on the windward and leeward sides of the islands. Temperature decreases with elevation and with shade and is higher on the leeward side which does not benefit from the cooling effect of the moist northeast trade winds and precipitation as the windward side. There is also radiative cooling which can be high on cloudless nights giving rise to relatively low temperatures. Temperatures can therefore vary from a night time minimum of 18 - 20°C to a day time maximum of 34 or 35°C depending on location and elevation. The mean monthly minimum and maximum temperatures are 24°C and 29°C respectively.

Humidity varies from about 50-100% depending on rainfall, elevation and location on the island. The mean annual humidity is about 80%. The northeast trade winds, shelter, and temperature are the other factors which influence humidity.

On every island there are variations of the local climate which may be influenced by factors such as local wind circulation, slope aspect, and shelter. This results in variations in the local environment and ecology.

3 **METHODOLOGY**

Field trips were undertaken to several areas throughout Trinidad which have different climatic and soil conditions. Careful observations were made and field notes prepared on the following:

Plants

name of the species, height, spread, rooting depth, root distribution, root strength, abundance, and health and luxuriance of growth in the dry season or after an environmental event like fire. Root characteristics were determined on plant samples (except trees) excavated from the soil. The root strength was assessed by the force required to uproot the plant and to rupture roots during the uprooting. Additional information on plant characteristics e.g. maximum plant height and canopy spread was obtained where possible from the literature.

Soil

soil type, elevation, slope, stoniness, and fertility status.

Climate

rainfall, sunlight (shade and full sunlight), humidity, and temperature.

Other environmental factors

plant response to fire, grazing, salinity, and flooding.

Retired technician Mr. M. Borai Kalloo who worked for several decades with the National Herbarium of The University of the West Indies and have had years of field experience collecting plants throughout Trinidad accompanied the field team on many of the field visits. His knowledge of the behaviour and responses of plant species to different environmental conditions informed the species selection and recommendations in this report.

4 PRINCIPLES OF SPECIES SELECTION FOR SLOPE STABILIZATION

This monograph considers vegetation that is suitable for stabilizing slopes against the seven types of erosion listed in the Introduction. These types of erosion can occur on both agricultural and non-agricultural land. On agricultural land erosion threatens the sustainable production of agricultural crops. On non-agricultural land, it can affect embankments that abut civil works e.g. bridges, buildings, and roads which can threaten public safety and well-being. The effectiveness of the vegetation in controlling erosion will depend on the

- type of erosion;
- physical and morphological properties of the vegetation;
- ability of the vegetation to survive and grow well under the specific environmental conditions.

4.1 *Principles of Species Selection for Protection against Splash, Rill, and Sheet Erosion*

There are two basic approaches to the use of vegetation to protect against splash, rill, and sheet erosion

- complete ground cover
- vegetative strip barriers

Species characteristics for complete ground cover

The species must

- be a perennial
- be short in height
- establish and grow readily under the environmental conditions
- not grow prolifically and ubiquitously
- not be a fierce competitor against other species
- not produce seeds in prolific quantities
- show a preference for particular environments

Species characteristics for vegetative strip barriers

The species must

- be a perennial

4 *Principles of Species Selection*

- be short in height
- not require frequent cutting
- establish readily but must grow slowly
- be sterile or produce non-viable seeds to limit spread from the barriers
- produce a root system that is dense at or close to the soil surface but must not be too shallow to cause ready desiccation

4.2 ***Principles of Species Selection for Protection against Soil Slippage/Slumping***

Soil slippage can be shallow or deep and massive. The extreme cases frequently cannot be protected by vegetation except perhaps by huge trees. To protect the soil against slippage the roots must be extensive, well distributed, must extend well below the slip planes, and must have high tensile strength.

Slippage forces increase with increase in depth to the slip plane, soil water content, and the angle of the slope. Therefore, vegetation with the most extensive root systems will be required to protect the soil on steep slopes with deep slip planes.

Soil slippage or slumping may occur gradually and progressively with time and eventually erode the soil sufficiently to threaten civil works. The vegetation must again be selected based on the above principles and the protective vegetation must be located at the critical point or zone of the land slippage i.e. where the slippage is currently occurring or likely to occur. It must extend over a sufficient distance above and below the critical zone to ensure protection and avoid a shift to or creation of a new critical zone.

4.3 ***Principles of Species Selection for Protection against Gully Erosion***

The vegetation is required to reduce the rate of flow of water in the gully and hence to prevent the erosion of the gully floor and walls. The vegetation is therefore planted at intervals across the gully floor. Since individual stems of the vegetation is not effective, the cuttings are planted close together or in a criss-cross manner. Recent findings by the author (unpublished data) that the stem of *Gliricidia* loses its apical dominance when ring barked at intervals and produces vertical shoots at intervals from

horizontal stems, mean that a row of plants can be developed across the gully from a single cutting. The eroding soil collects behind the vegetation to create check dams and prevent further erosion.

Grassing of small shallow gullies is frequently sufficient to arrest further erosion provided the grass species are appropriate. Shrubs are better suited to the medium sized and steeper gullies. However, vegetation is usually not effective in the large gullies. It is difficult for the young plants to resist uprooting by the erosive forces of the flowing water. Engineering structures or a combination of vegetation and engineering structures are more effective and are preferred.

Plant species which are suitable for shallow and medium sized gully control should have the following characteristics

- be a perennial
- establish and grow rapidly
- good rooting; grasses should have thick, strong dense roots which are well distributed in at least the top 30 cm of the soil profile; shrubs should have spreading, thick, deep branched roots
- withstand high soil moisture conditions and even temporary waterlogging
- grasses whether they reproduce by rhizomes, stolons, or tillers must be close growing to produce a dense growth and shrubs must be capable of growing closely together

4.4 *Principles of Species Selection for Protection against River and Stream Bank Erosion*

River and stream banks are eroded by the flowing water and erosion increases with increasing flow rates. Erosion is highest at river bends because of increased turbulence of water flow in these areas. Because the stage or level of water in rivers and streams varies enormously erosion can occur at different elevations or heights of the banks.

Vegetation that is suitable for protection against this form of erosion must

- be able to withstand the forces of flowing water
- have thick, deep, strong much branched root systems which extend below the depth of the lowest stage of the river or stream

4 *Principles of Species Selection*

- withstand high soil moisture, high water table, and waterlogging as well as low soil moisture conditions
- be a perennial and must not die back in the dry season

4.5 *Principles of Species Selection for Protection against Beach Edge and Coastal Areas*

Wave action can be damaging to both beaches and coastal areas. The sand on the upper reaches of the beach is less resistant to water erosion than the beach sand at the low tide levels. Consequently, beach erosion can be severe at high tide if the beach is unprotected. In addition, strong on-shore winds can cause wind erosion. Shrubs and small trees can significantly reduce beach erosion.

Similarly, wave action on other coastal areas which are not protected by rocks and boulders can also cause severe erosion. These areas cannot be readily protected by trees. However, many coastal regions are eroded by runoff water from elevated inland areas, and sandy areas are affected by wind erosion.

Vegetation that is suitable for protection against beach and coastal area erosion must be

- adapted to sand or sandy soils, in particular, must be drought tolerant and have a low nutrient requirement
- resistant to wind damage
- resistant to saline conditions

5 **BIOENGINEERING FOR EROSION CONTROL**

This section considers the plant species that are suitable for stabilizing soil slopes against the various types of erosion viz., splash, rill, sheet, land slippage/slumping, gully, river and stream bank, and beach edge and coastal areas on both agricultural and non-agricultural lands. The desired architecture of the vegetation for soil protection depends on both the type of erosion and on land use. Selection of the species must take into consideration physical or engineering properties of the vegetation together with aesthetics, and implications for the prevailing land use. For example, the maximum height of the vegetation on roadside embankments or as barriers on agricultural lands will determine the suitability of the species in these situations. The responses of the species to specified environmental conditions are provided so that species selection can be appropriate to the environment.

For simplicity and a logical framework, plant species are grouped firstly by the type of erosion likely e.g. rill, or sheet erosion and secondly by the type of slope or structure e.g. embankment or verge. The magnification of the drawings are given in Appendix A, and the relevant botanical and ecological characteristics of the species are given in Appendix B.

5.1 ***Plant Species for Protection against Splash, Rill and Sheet Erosion***

The vegetation must provide for:

- ground cover
 - vegetative barrier
- on the following types of roadside verges or slopes
- flat roadside verges
 - verge of the downward sloping roadside embankment
 - downward sloping roadside embankments
 - upward sloping roadside embankments
 - gently sloping hillsides
 - steeply sloping hillsides

5.1.1 *Flat Roadside Verges*

Ideally, the cross-section of a road built on the hillside should have the components shown in Figure 1. The road shoulder should be paved with a thinner layer of bitumen or asphalt and road verges should be vegetated. The roadside drain should be paved. Frequently in the Caribbean, however, the road shoulder may be unpaved or absent and there may be no roadside drain. If there is no road shoulder, the vegetation would abut the road. This is not ideal because the plant roots would invade the road edges with time. If a road shoulder or verge is not required for pedestrian traffic, or “pulling-over” of vehicles then the road can abut the roadside drain.

The vegetation for a roadside verge can be either:

- (1) a short drought tolerant perennial grass or sedge:
- (2) a short drought tolerant, perennial, decorative shrub which would also enhance the aesthetics of the roadside, or
- (3) a combination of (1) and (2)

Grasses for road verges

- *Cynodon dactylon*
- *Imperata brasiliensis*
- *Ischaemum timorense*
- *Panicum maximum*
- *Paspalum pulchellum*
- *Sporobolus indicus*
- *Sporobolus poiretti*
- *Zoysia matrella*

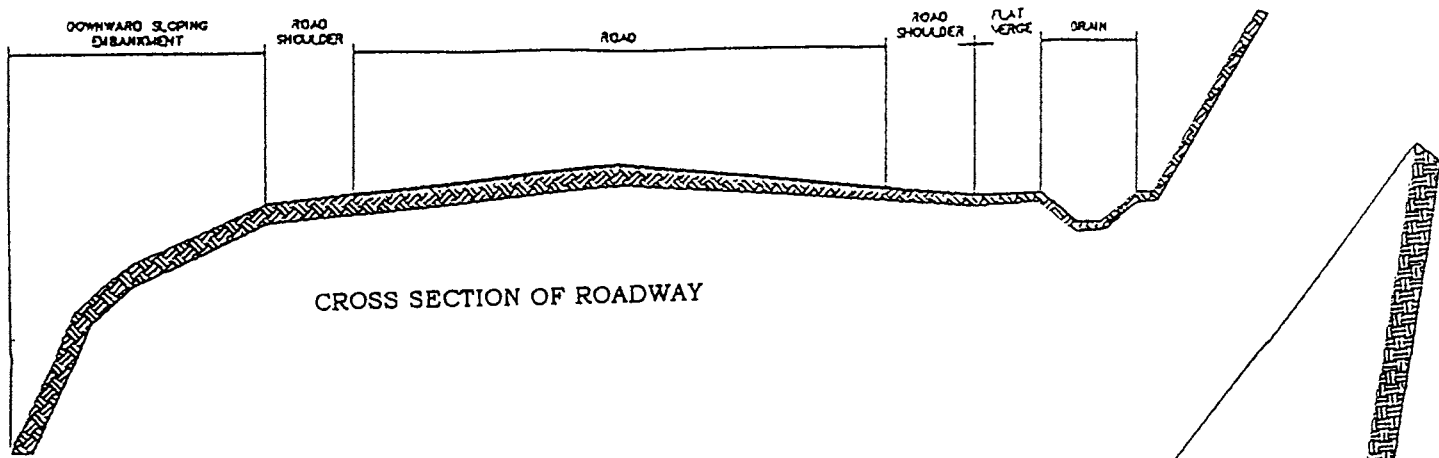
Sporobolus spp. produce an abundance of fertile seeds and therefore the invasion of cultivated pastures can be a problem.

Sedges for road verges

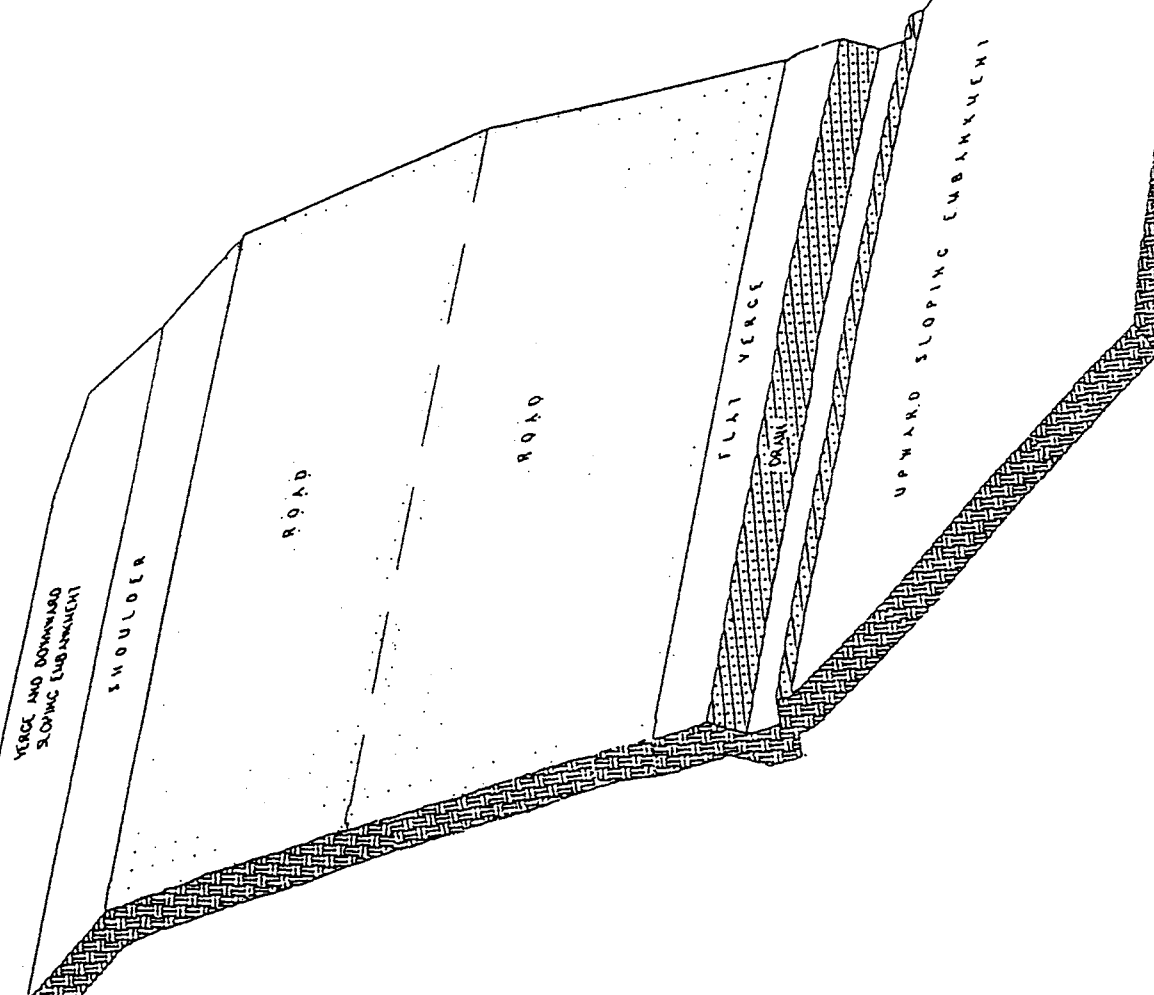
- *Lagenocarpus guianensis*
- *Rhyncospora cephalotes*

Shrubs for road verges

- *Heliconia psittacorum* (shrub)
- *Agave sisalana*



CROSS SECTION OF ROADWAY



3D CROSS SECTION OF ROADWAY

FIGURE 1 DIAGRAMS OF ROADWAY

5.1.2 *Protection of the Verge of the Downward Sloping Roadside*

Embankments

This roadside verge needs to be protected against land slippage as well as splash, rill, and sheet erosion. Therefore, larger species with deep roots are more suitable. The recommended species are:

- *Actinostus arborescens*
- *Arundinella confinis*
- *Cortaderia selloana*
- *Cymbopogon citratus*
- *Dicranopteris pectinata*
- *Nephrolepis multiflora*
- *Panicum maximum*
- *Vetivera zizanioides*

5.1.3 *Protection Of Upward Sloping Roadside Embankments*

To protect upward sloping roadside embankments against splash, rill, and sheet erosion the vegetation must be a ground cover or vegetative barrier planted on the contour. If the selected species have relatively shallow roots, they will not protect against deep landslippage. Trees can be used to protect against landslippage on steep embankments and the trees considered under the protection of steeply sloping hillsides (5.1.5) are suitable.

Ground cover

The plant species that are recommended above for road verges are also suitable for protecting roadside embankments against splash, rill, and sheet erosion. *Cynodon dactylon* is relatively slow growing and does not provide rapid ground cover. It, however, can be grown in conjunction with *Sporobolus indicus* and *S. poiretti* for improved ground cover of embankments.

In addition to those grasses and shrubs, a few ferns and grasses have been found to dominate some embankments and are recommended.

These are:

- *Arundinella confinis* (grass)
- *Dicranopteris pectinata* (fern)
- *Nephrolepis multiflora* (fern)

Vegetative barriers for roadside embankments

The barrier can be a grass or short shrub, preferably decorative, to enhance the aesthetics of the roadside, but the selected species should not spread or tiller rapidly and the barrier must retain its integrity.

Grass barriers

- *Cortaderia selloana*
- *Cymbopogon citratus*
- *Vetivera zizanioides*

The non-flowering feature of *V. zizanioides* (vetiver) makes it an ideal candidate for grass barriers. The other species produce flowers and viable seeds. They therefore have the capacity to spread by seed dispersal if they are not managed by cutting. They do not spread rapidly by tillering.

Shrub barriers

- *Agave sisalana*
- *Isertia parviflora*
- *Palicourea crocea*
- *Sansevieria guineensis*

5.1.4 *Gently sloping hillsides*

Species that are suitable for gently sloping open hillsides or sheltered hillsides (as vegetation on the forest floor or lower storied vegetation in the forest) are:

- *Acnistus arborescens* (open)
- *Andropogon bicornis* (open)
- *Bromelia plumeri* (sheltered)
- *Cnemideria spectabilis* (sheltered)
- *Cortaderia selloana* (open)
- *Cymbopogon citratus* (open or sheltered)
- *Dracaena fragrans* (open)
- *Heliconia psittacorum* (open or sheltered)
- *Miconia acinodendron* (sheltered)
- *Panicum maximum* (open)
- *Pisonia eggersiana* (sheltered)
- *Vetivera zizanioides* (open)

5.1.5 *Steeply sloping hillsides*

Species which occurred commonly on steep hillsides are:

- *Arundinella confinis*
- *Croton gossipofolius*
- *Dicranopteris pectinata*
- *Panicum maximum* (particularly recommended for high elevation)
- *Pitsairna integrifolia* (particularly rocky/stony outcrop areas)

Many tree species have deep root systems and can stabilize steep slopes against erosion. The following tree species are suitable:

- *Anacardium occidentale*
- *Andira inermis*
- *Calliandra* spp.
- *Cassia* spp.
- *Causaina equisetifolia*
- *Ficus benamina*
- *Gliricidia sepium*
- *Sesbania* spp.

The species must however, be selected in relation to the soil type and climate.

5.2 *Plant Species for Protecting against Landslippage/Slumping*

Many tree species with deep well distributed roots will protect against landslippage. Any hillside which is prone to slippage must therefore be protected by suitable tree species. Fruit tree orchards with standard spacing on hillsides, are also usually adequate to protect the soil against slippage.

To protect against soil slippage which would affect civil works e.g. roads, buildings, and bridges, selected tree species can be planted alone or in combination with engineering structures. The trees must be planted sufficiently close to each other to avoid landslippage occurring between the trees. The canopy or crown of the tree must not be too wide i.e. the architecture of the tree must allow close planting without affecting the growth and rooting depth of the plant. In addition to the tree species which have been recommended for protecting steeply sloping hillsides (5.1.5) the following species are also suitable for protecting against landslippage:

5 Bioengineering for Erosion Control

- *Byrsonima coriacea*
- *Pandanus odoratissimus*

5.3 **Plant Species for Protecting against Gully Erosion**

Erosion in small gullies can be controlled by planting shrubs at intervals across the gully. Plant species that are suitable should be planted in a criss-cross manner by themselves or in combination with a small earth dam on the upstream side of the shrub cuttings. The cuttings should be at least one metre above the ground after they are planted. The species that are suitable are:

- *Calliandra* spp.
- *Gliricidia sepium*
- *Leucaena leucocephala*
- *Sesbania* spp.

Grasses such as

- *Cortaderia selloana*
- *Cymbopogon citratus*
- *Imperata brasiliensis*
- *Vetivera zizanioides*

can be used for grassing the gully head, in addition to the planting of the shrubs, to provide extra protection. Large gullies often require engineering structures.

5.4 **Plant Species for River and Stream Bank Protection**

The species must be capable of withstanding high moisture or even flooding conditions and include:

- *Arundo donax*
- *Gynerium sagittatum*
- *Pandanus odoratissimus*
- *Spathiphyllum cannifolium*

5.5 **Plant Species for the Protection of Beach Edge and Coastal Areas**

The recommended species must be able to withstand saline and sandy soil conditions, e.g.

- *Chrysobalanus icaco* (beach edge and coastal areas)
- *Rhyncospora barbata* (beach edge)
- *Tridax decumbens* (beach edge)

Tridax decumbens provides very good ground cover on beach edges, but it is a pantropical weed and therefore the adoption of this species should be carefully considered.

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APPENDIX A

MAGNIFICATION OF DRAWINGS

Name of Species	Magnification compared to specimen		Magnification compared to mature plant	
	Vertical	Horizontal	Vertical	Horizontal
<i>Actinistus arborescens</i>	0.20	0.20	0.40	0.10
<i>Agave sisalana</i>	0.10	0.20	0.03	0.10
<i>Arundinella confinis</i>	0.20	0.80	0.20	0.80
<i>Arundo donax</i>	0.10	0.20	0.04	0.10
<i>Byrsonima coriacea</i>	0.20	0.20	0.05	0.10
<i>Chrysobalanus icaco</i>	0.10	0.10	0.03	0.06
<i>Cnemidaria spectabilis</i>	0.20	0.30	0.10	0.20
<i>Cortaderia selloana</i>	0.20	0.20	0.05	0.10
<i>Cymbopogon citratus</i>	0.20	0.40	0.20	0.20
<i>Cynodon dactylon</i>	0.60	0.60	0.50	0.50
<i>Dicranopteris pectinata</i>	0.20	0.30	0.20	0.20
<i>Dracaena fragrans</i>	0.10	0.10	0.03	0.06
<i>Gynerium sagittatum</i>	0.10	0.20	0.04	0.10
<i>Imperata brasiliensis</i>	0.20	0.20	0.10	0.20
<i>Ischaemum timorense</i>	0.50	0.20	0.30	0.10
<i>Isertia parviflora</i>	0.10	0.20	0.05	0.10
<i>Lagenocarpus guianensis</i>	0.30	0.30	0.30	0.30
<i>Miconia acinodendron</i>	0.10	0.20	0.04	0.10
<i>Pandanus odoratissimus</i>	0.10	0.20	0.04	0.10
<i>Panicum maximum</i>	0.10	0.30	0.05	0.20
<i>Paspalum pulchellum</i>	0.20	0.20	0.20	0.20
<i>Pitsairna integrifolia</i>	0.20	0.20	0.20	0.20
<i>Sporobolus indicus</i>	0.20	0.30	0.20	0.30
<i>Sporobolus poiretti</i>	0.30	0.30	0.30	0.30
<i>Zoysia matrella</i>	0.30	0.50	0.20	0.30

APPENDIX B

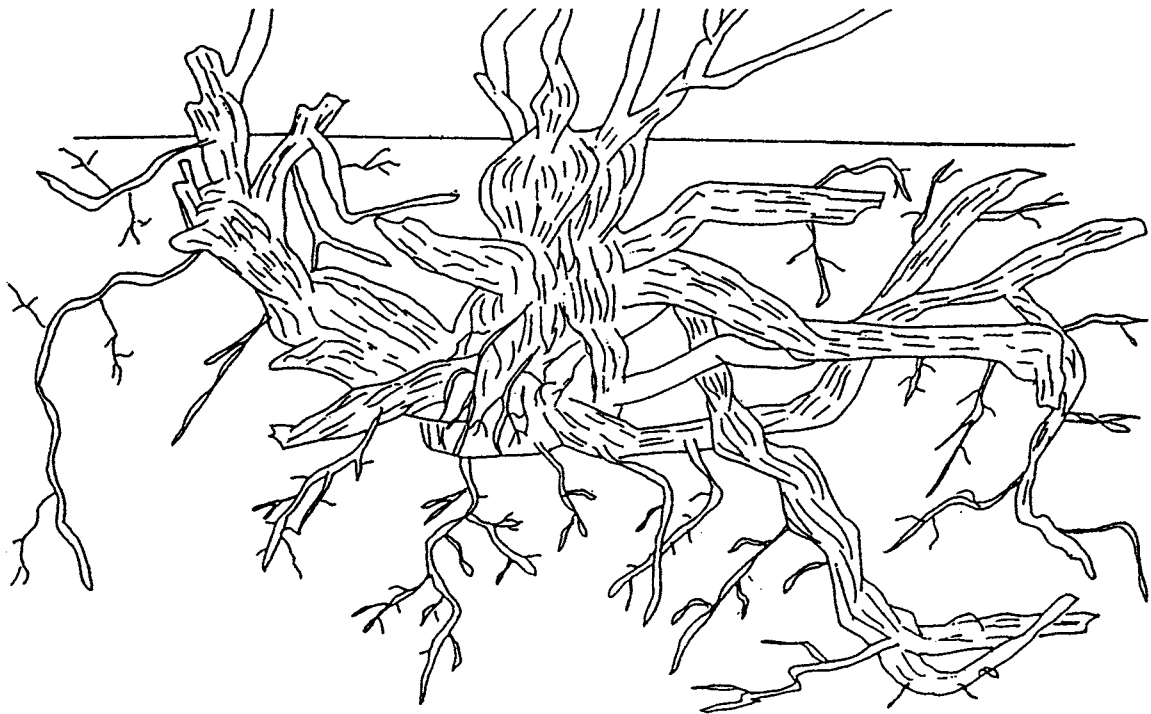
Botanical name:	<i>Actinistus arborescens</i>
Family:	Solanaceae
Common name:	
Classification:	shrub
Bio-engineering attributes	
Root form:	massive thickened underground stems that are strongly branched and bear mainly coarse branched roots; moderate to deep rooted (>100 cm).
Rooting depth:	1 - 2 m
Rooting strength:	extremely strong
Canopy height:	2.5 - 3 m
Canopy spread:	2 m
Bio-engineering use:	good potential for soil conservation purposes
Other uses:	unknown
Method of propagation:	seeds
Ecological and cultural factors	
Potential weediness:	moderate potential to become a weed
Resistance to fire:	unknown
Resistance to grazing:	unknown
Resistance to drought:	dries in the dry season and shoots profusely in the rainy season
Reaction to shade or full sunlight:	grows well in moderate sunlight
Flood tolerance:	unknown

<i>Erosion control:</i>	good potential for erosion control
<i>Natural habitat:</i>	unknown
<i>Rate of growth:</i>	rapid in the rainy season
<i>Ability to spread naturally:</i>	good spreading ability

Remarks

The shoot may die in the dry season but its underground stems send out shoots at the beginning of the rainy season which grow rapidly. Its massive, thickened, branched underground stems hold the soil together against land slippage. Its large leaves provide good ground cover in the rainy season but the drying of leaves in the dry season is a disadvantage. The species is therefore recommended for hillside locations with mild dry seasons.

Actinistius arborescens



Botanical name: *Agave sisalana* Perrine

Family: Agavaceae

Common name: sisal

Classification: shrub

Bio-engineering attributes

Root form: spreading fibrous system; shallow rooting but with some roots reaching moderate depths; good horizontal spread; limited branching; anchoring or bearer roots 2 -4 mm in diameter giving rise to feeder roots which are 1-2 mm in diameter

Rooting depth: extend horizontally 1.5 - 3 m and up to 5 m in the top 30-40 cm of soil

Rooting strength: very strong

Canopy height: 0.7 - 1 m

Canopy spread: 0.7 - 1 m per single plant

Bio-engineering use: useful for holding soil together on road verges, moderately steep embankments, and slopes

Other uses: manufacture of binder and baler twines, ropes in agriculture

Method of propagation: vegetatively by suckers or bulbils, but bulbils are preferred since they are produced in greater quantities (2000 per plant) and these plants are more robust with more leaves. Each bulbil can remain viable for several months after collection

Ecological and cultural factors

Potential weediness none

Resistance to fire: resistant

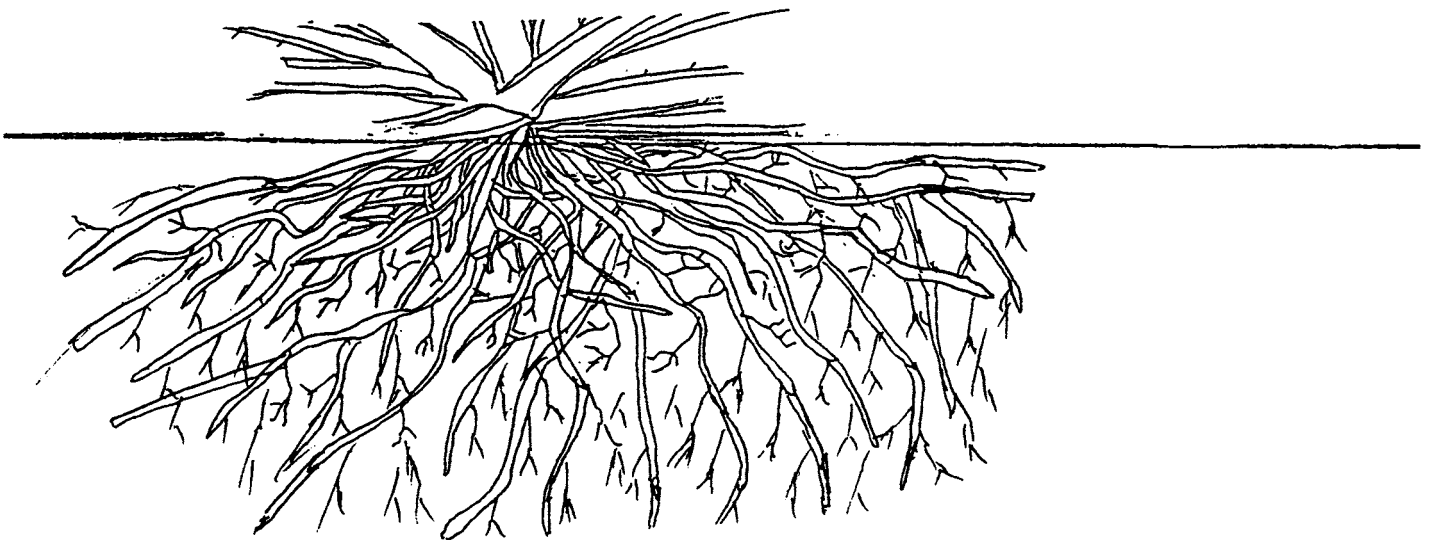
Resistance to grazing: resistant

<i>Resistance to drought:</i>	resistant
<i>Reaction to shade or full sunlight:</i>	requires full sunlight and moderate humidity
<i>Flood tolerance:</i>	cannot withstand water logging
<i>Erosion control:</i>	good erosion control
<i>Natural habitat:</i>	woodland, savannah and grassland areas; from hot and humid coastal belts to the cooler and drier regions and in areas with one or two rainy seasons per year.
<i>Rate of growth:</i>	slow
<i>Ability to spread naturally:</i>	good spreading ability; each plant may produce 5-10 rhizomes at one time and about 20 during its life span

Remarks

Can be grown on a wide range of soils provided they are well drained and rich in bases especially calcium, but thrives best on alluvial and colluvial soils, red earths derived from recent and tertiary coral limestone, non laterized red earths derived from gneiss and on volcanic soils; but can grow under a wide range of conditions. Can be grown as barriers on the contour on roadside embankments to protect the soil against erosion.

Agave sisalana Perrine



Botanical name: *Andropogon bicornis* (L.)

Family: Gramineae

Common name: ridging grass; foxtail

Classification: grass

Bio-engineering attributes

Root form: fibrous; dense rooting at the soil surface

Rooting depth: 20 - 25 cm; can be deeper on light pervious soils

Rooting strength: very strong

Canopy height: 1 m

Canopy spread: 0.7 m

Bio-engineering use: good potential for soil slope stabilization

Other uses: unknown

Method of propagation: root divisions

Ecological and cultural factors

Potential weediness: moderate weed potential but unlikely to become an obnoxious weed

Resistance to fire: resistant

Resistance to grazing: resistant

Resistance to drought: resistant

Reaction to shade or full sunlight: grows well in full sunlight

Flood tolerance: unknown

Erosion control: good potential for soil erosion control

Natural habitat: grassy hills and banks

Rate of growth: moderate

Ability to spread naturally: good spreading ability

Remarks

This species is suitable for hillsides where the soil is not very erodible. It can protect against sheet erosion but its relatively shallow rooting would not protect against land slippage where the failure plane is below 30-50 cm. In these situations it has to be planted with other deeper rooted species. It can provide grazing but it needs to be controlled to prevent overgrazing.

Botanical name: *Arundinella confinis* Schult

Family: Gramineae

Common name:

Classification: grass

Bio-engineering attributes

Root form: fibrous; shallow to moderately deep; long coarse primary roots with limited secondary roots

Rooting depth: 20 - 25 cm; extremely strong; cannot be uprooted by hand

Canopy height: 2 - 3 m

Canopy spread: effectiveness obtained by stolons running along the surface of the soil and forming clumps

Bio-engineering use: used to stabilize soils on steep surfaces

Other uses: unknown

Method of propagation: seeds, stolons

Ecological and cultural factors

Potential weediness: unknown

Resistance to fire: very resistant

Resistance to grazing: unknown

Resistance to drought: resistant, grows profusely in the dry season

Reaction to shade or full sunlight: very good tolerance to sunlight and shade

Erosion control: very good at controlling erosion on slopes
Rate of growth: slow to moderate

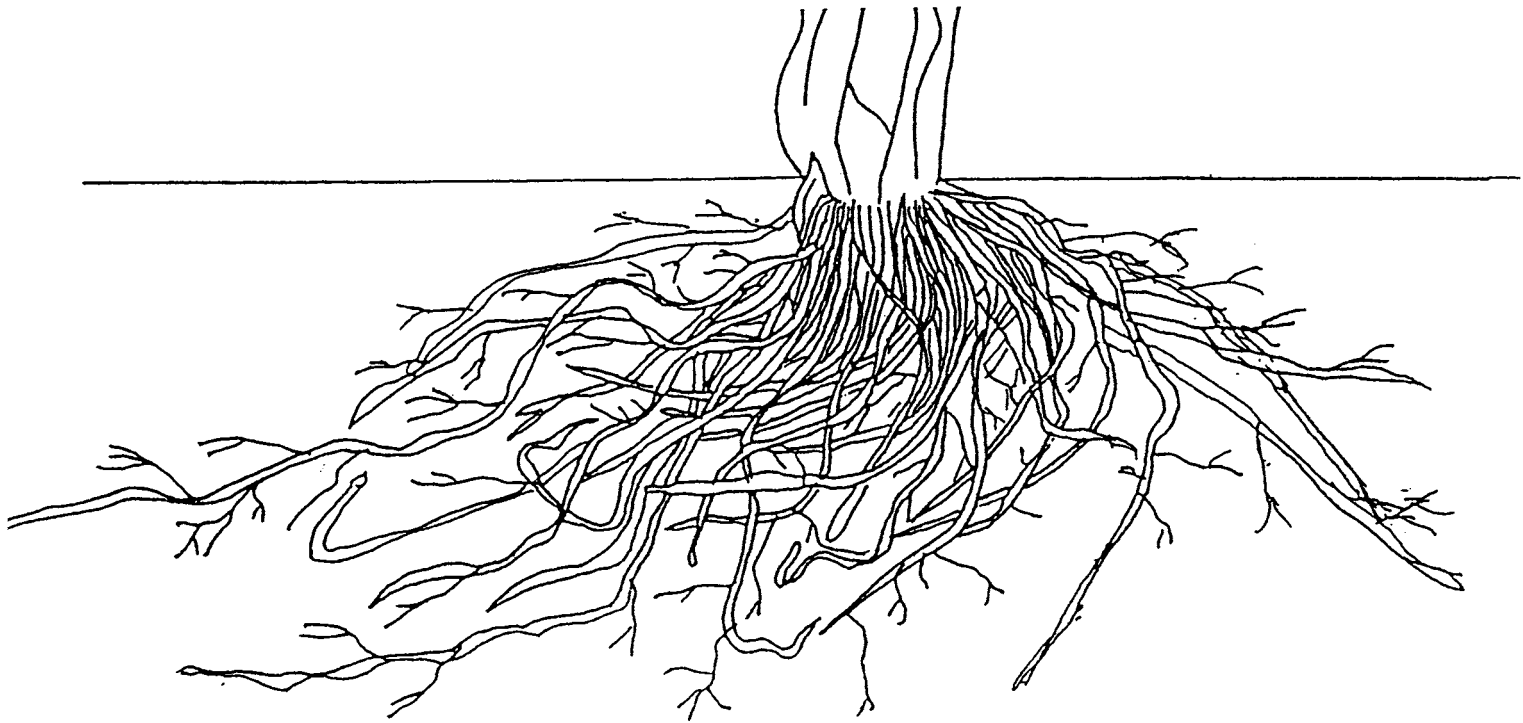
Ability to spread naturally:

good spreading ability

Remarks

Grows on both steep hillsides and on flat land. In both Maracas and Las Cuevas where it was found growing, it appeared to be the first species to regrow after fires and subsequent soil slippage. By virtue of its creeping growth habit it totally covered the top soil. It appeared to grow in conjunction with *Dicranopteris pectinata* only. *Dicranopteris pectinata* appeared after *Arundinella* had established itself and both provided excellent surface cover on the very steep hillsides. Once these two species had established themselves no other ground species were apparently able to grow. This species of *Arundinella* appeared to be a better soil stabilizer on slopes > 20° holding the soil very well since no signs of erosion could be detected when this species was present. It appeared however, that once *D. pectinata* had established itself first, *Arundinella* could not compete with it effectively and tended to be less predominant.

Arundinella confinis Schult



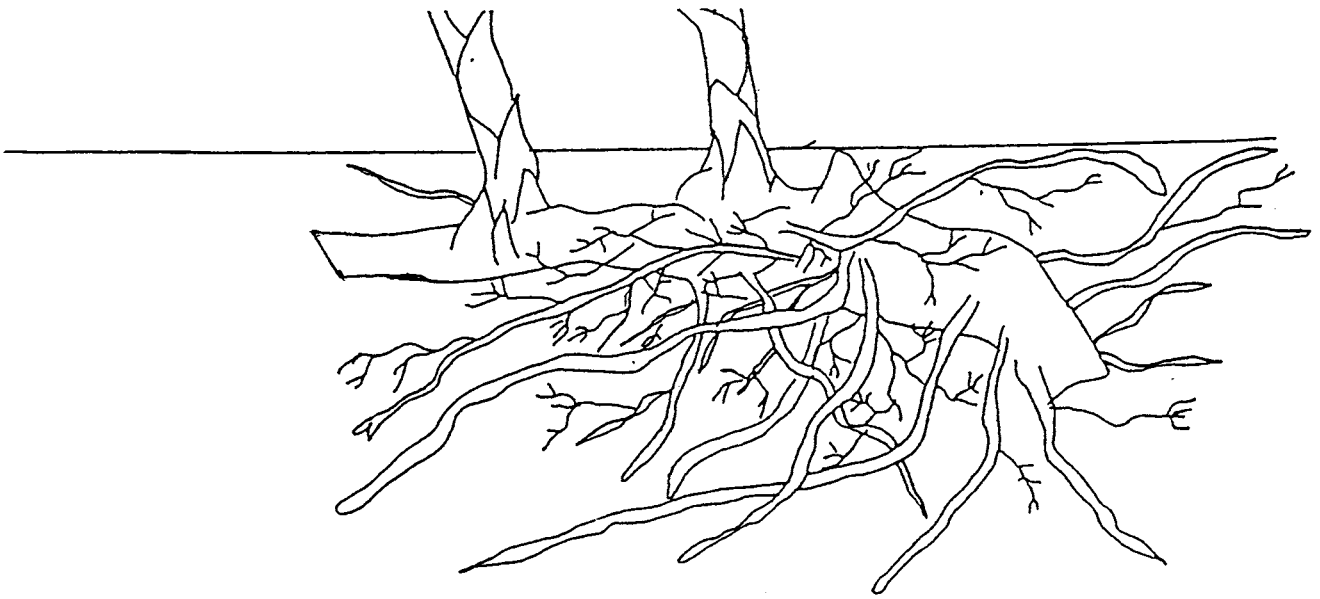
Botanical name:	<i>Arundo donax</i> (L.)
Family:	Gramineae
Common name:	spanish weed, spanish cane, giant reed, carrizo
Classification:	grass
Bio-engineering attributes	
Root form:	fibrous; shallow to moderately deep; large underground rhizomes; coarse primary roots with fine branched roots
Rooting depth:	1.7 m
Rooting strength:	extremely strong
Canopy height:	2 m
Canopy spread:	each plant is approximately 1 m in diameter
Bio-engineering use:	good erosion control potential
Other uses:	woody stems used for light construction work and lattices
Method of propagation:	tillers, cuttings
Ecological and cultural factors	
Potential weediness:	slight to moderate potential to become a weed
Resistance to fire:	resistant
Resistance to grazing:	resistant
Resistance to drought:	resistant
Reaction to shade or full sunlight:	grows well in full sunlight; shade tolerance unknown

<i>Flood tolerance:</i>	tolerant
<i>Erosion control:</i>	good potential for erosion control
<i>Natural habitat:</i>	river banks and moist ground
<i>Rate of growth:</i>	moderate
<i>Ability to spread naturally:</i>	good spreading ability

Remarks

A very hardy species that can withstand a range of environmental conditions; good for stabilizing stream banks against erosion but the production of rhizomes facilitates spread which can be a disadvantage.

Arundo donax (L.)



Botanical name:	<i>Bromelia plumerii</i> (E.Morr) L.B.Smith
Family:	Bromeliaceae
Common name:	ping wing
Classification:	shrub
Bio-engineering attributes	
Root form:	fibrous; horizontal spread to about 0.3 m in the top 50 - 70 cm of soil
Rooting depth:	0.7 m
Rooting strength:	very strong
Canopy height:	1.7 m
Canopy spread:	2 m
Bio-engineering use:	good potential for soil conservation purposes
Other uses:	edible fruit
Method of propagation:	seeds; vegetative side shoots
Ecological and cultural factors	
Potential weediness:	little or no weed potential
Resistance to fire:	resistant
Resistance to grazing:	resistant
Resistance to drought:	resistant
Reaction to shade or full sunlight:	requires shade
Flood tolerance:	unknown

Erosion control: good potential for controlling erosion

Natural habitat: under forested areas

Rate of growth: rapid

Ability to spread naturally: good spreading ability

Remarks

Good as a secondary species in the forest to provide cover to the forest floor. It is not a good species for bright open areas.

Botanical name: *Byrsonima coriacea* (Sw.)

Family: Malpighiaceae

Common name: serrette

Classification: shrub

Bio-engineering attributes

Root form: abundant tuberous roots with branches some of which may be enlarged; swollen underground stem with finer branched roots; moderate to deep rooting

Rooting depth: 1 - 2 m

Rooting strength: very strong

Canopy height: 5 m

Canopy spread: 5 m

Bio-engineering use: good potential for soil conservation purposes

Other uses: fruit is edible

Method of propagation: side shoots, tillers

Ecological and cultural factors

Potential weediness: because it dominated the roadside areas it appears to have the potential to become a weed

Resistance to fire: resistant ; its thick bark protects it from deleterious effects of fire

Resistance to grazing: unknown

Resistance to drought: very resistant

Reaction to shade or full sunlight: requires full sunlight

Flood tolerance: unknown

Erosion control: good potential to be a soil stabilizer

Natural habitat: common in secondary woodlands

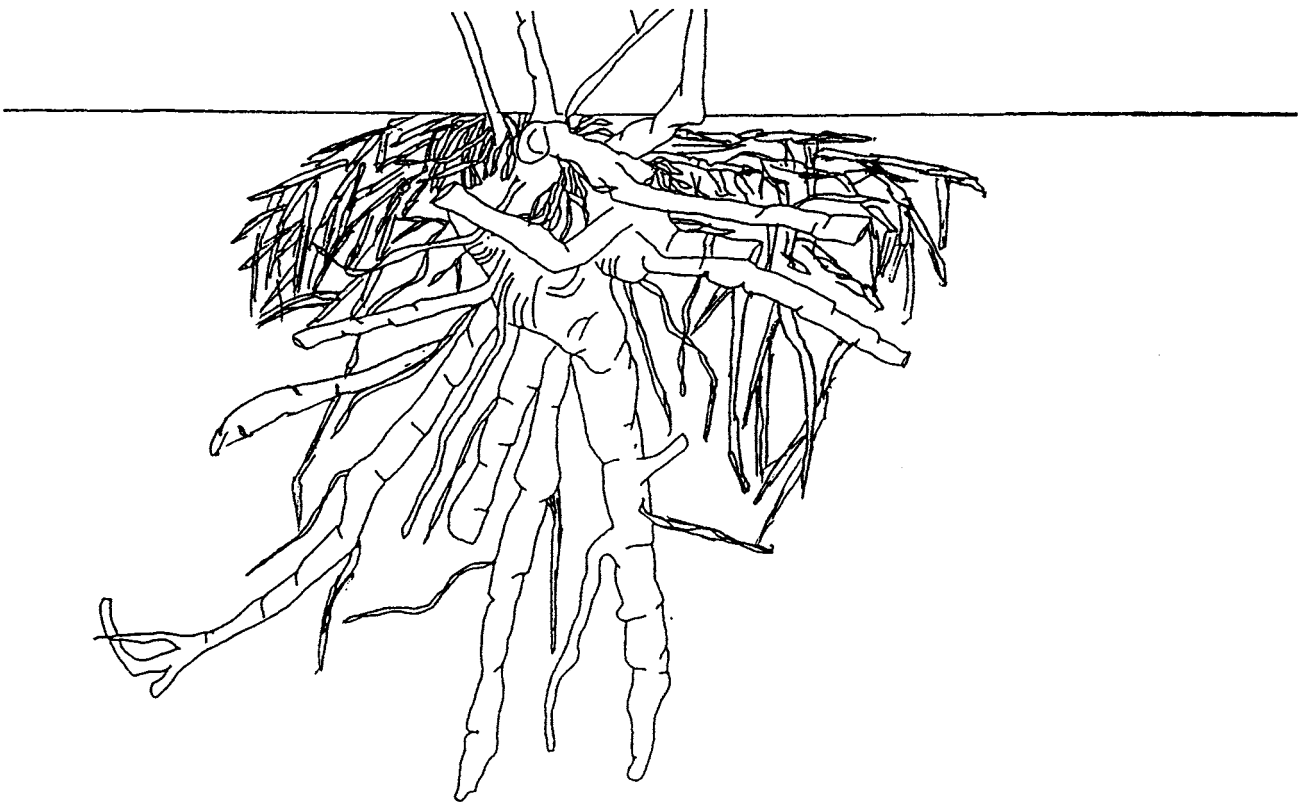
Rate of growth: moderate

Ability to spread naturally: good spreading ability

Remarks

Tolerant of poor soil conditions and harsh climatic conditions; this species can be grown on hillsides. Its resistance to fire and ability to resprout from the swollen underground stems make it a good species on hillsides subject to bush fires in the dry season.

Byrsonima coriacea (Sw.)



Botanical name: *Chrysobalanus icaco*

Family: Rosaceae

Common name: fat pork, cacao plum

Classification: shrub, tree

Bio-engineering attributes

Root form: strong thickened underground stems; buttress roots; coarse primary, tap, with fine branched secondary roots; deep and moderately spreading

Rooting depth: 2 m

Rooting strength: extremely strong

Canopy height: 4 m (tree) and 2 m (shrub)

Canopy spread: 2 - 4 m

Bio-engineering use: good potential for erosion control especially in sandy soils

Other uses: fruits eaten by both animals and humans

Method of propagation: seeds, cuttings

Ecological and cultural factors

Potential weediness: little

Resistance to fire: resistant

Resistance to grazing: can withstand grazing

Resistance to drought: resistant

Reaction to shade or full sunlight: grows extremely well in full sunlight and moderate in shade

Flood tolerance: limited tolerance

Erosion control: good potential on slopes 0°-10°

Natural habitat: sandy, saline areas

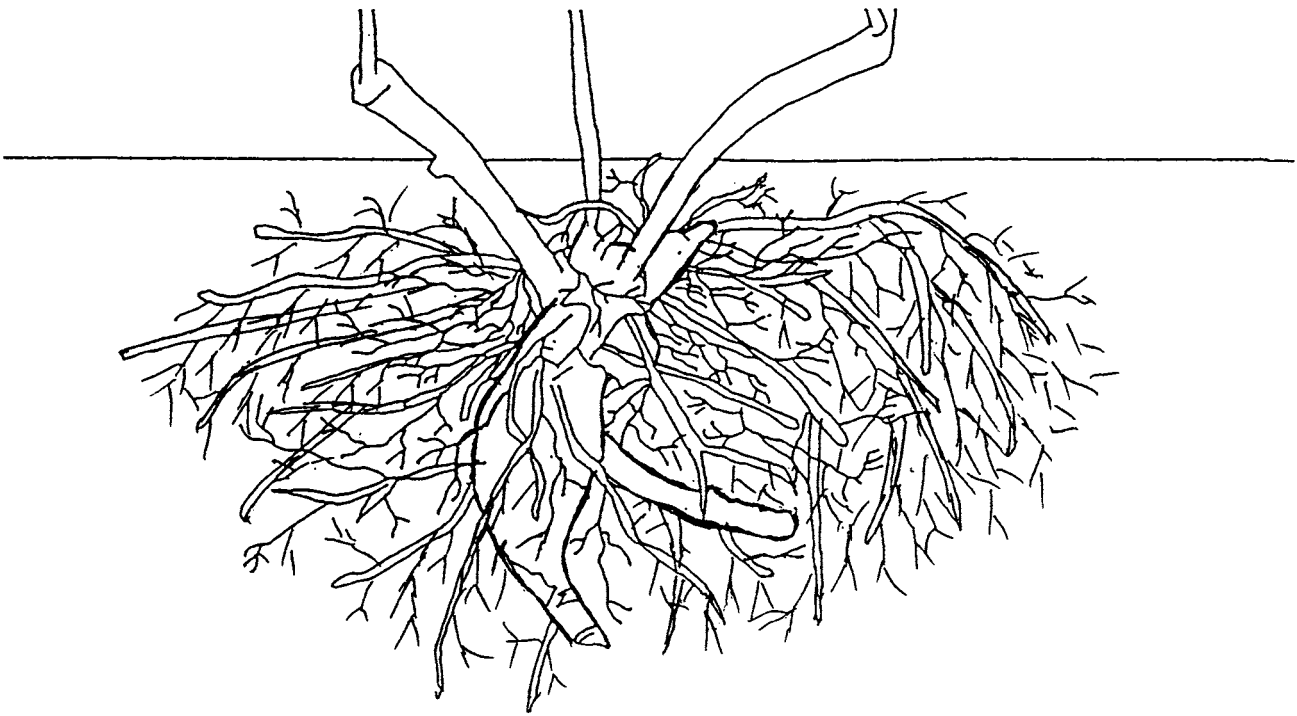
Rate of growth: slow

Ability to spread naturally: good spreading ability

Remarks

Its ability to grow well in sandy and saline soils and in dry windswept localities makes it very suitable for beach and coastal erosion control.

Chrysobalanus icaco



Botanical name: *Cnemideria spectabilis*

Family: Cyathaceae

Common name: tree fern

Classification: fern

Bio-engineering attributes

Root form: fibrous; moderate to deep rooting; roots branched and proliferate more in the lower than the upper part of the soil profile; very strong anchorage; difficult to pull from the soil

Rooting depth: 1 m

Rooting strength: extremely strong

Canopy height: 1.5 m

Canopy spread: 2 m

Bio-engineering use: good potential for soil conservation purposes

Other uses: stems used for growing orchids

Method of propagation: sori

Ecological and cultural factors

Potential weediness: little or no potential to become a weed

Resistance to fire: resistant

Resistance to grazing: resistant

Resistance to drought: resistant

Reaction to shade or full sunlight: grows poorly in full sunlight; grows well in shade

Flood tolerance: cannot withstand floods

Erosion control: good for slopes greater than 5° in forested areas

Natural habitat: forested areas and hills bordering roadsides in the Northern Range; never found on flat lands; requires acid soil and good drainage

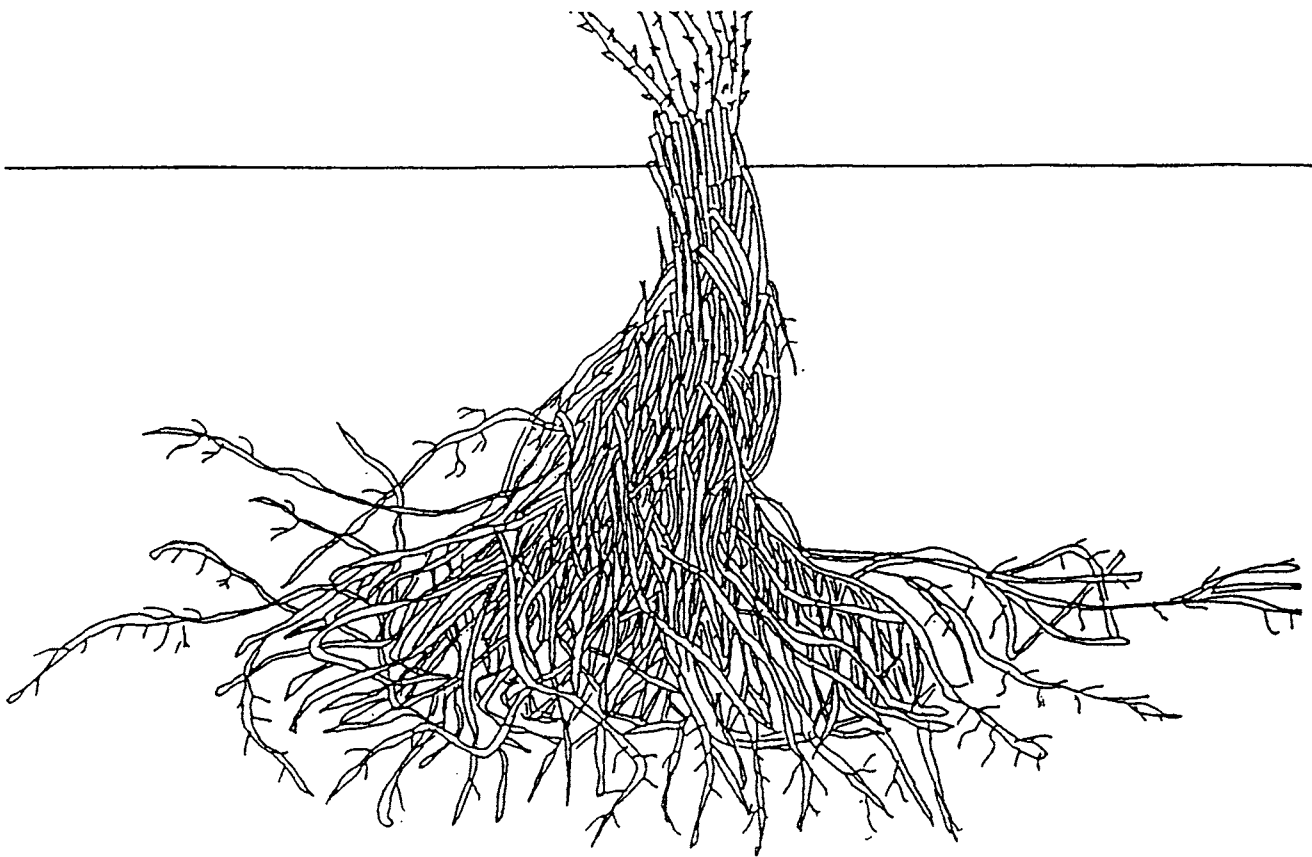
Rate of growth: moderate

Ability to spread naturally: good spreading ability

Remarks

Suitable as secondary vegetation on forest floors where temperatures are cool, humidity is high and conditions are shaded. The species requires high rainfall for good growth. It would prevent erosion by raindrops falling from forest tree canopy and would be suitable as soil protection during forest establishment.

Cnemidaria spectabilis



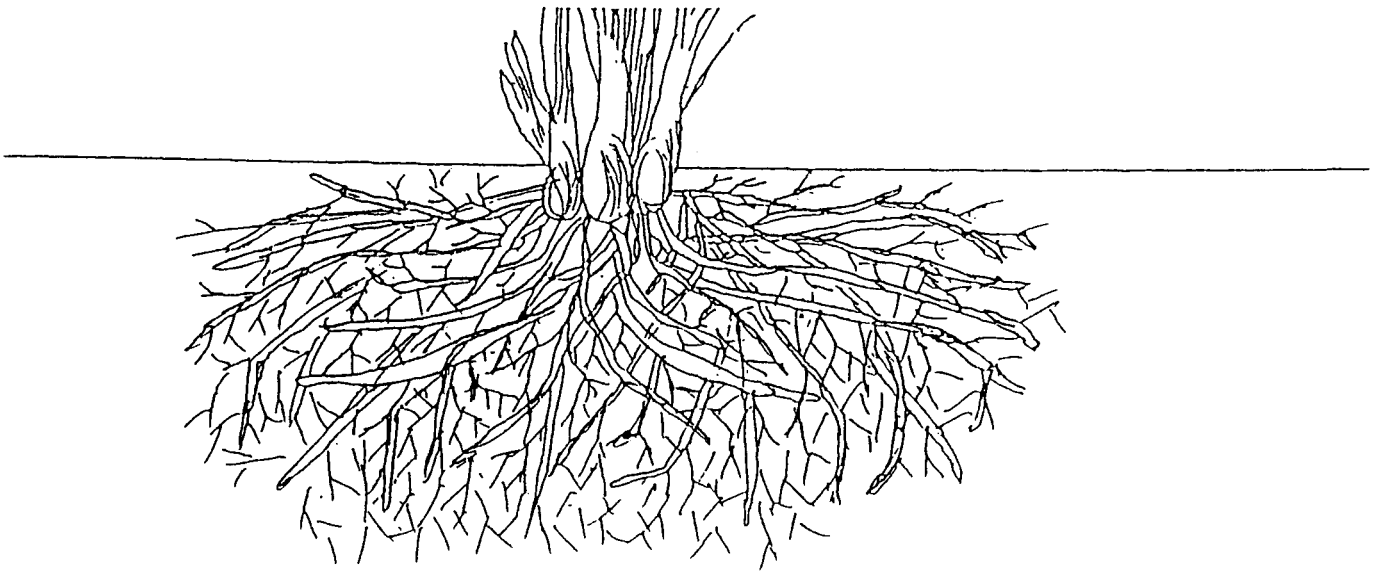
Botanical name:	<i>Cortaderia selloana</i> (Schult.) Aschers & Graebn.
Family:	Gramineae
Common name:	pampas grass
Classification:	grass
Bio-engineering attributes	
Root form:	fibrous; deep rooting; limited branching but close tillering results in moderately dense rooting
Rooting depth:	1 m
Rooting strength:	extremely strong
Canopy height:	2 m
Canopy spread:	spreads by tillering to provide ground cover
Bio-engineering use:	very good potential for erosion control; similar in habit to vetiver
Other uses:	inflorescence used in making carnival costumes
Method of propagation:	seeds, tillers
Ecological and cultural factors	
Potential weediness:	potential as a weed is limited due to slow rate of tillering
Resistance to fire:	resistant
Resistance to grazing:	resistant
Resistance to drought:	very resistant
Reaction to shade or full sunlight:	requires full sunlight for good growth rate
Flood tolerance:	unknown

Erosion control: very good potential for use in erosion control
Natural habitat: common to savannahs of Argentina and Brazil
Rate of growth: slow; does not tiller profusely
Ability to spread naturally: limited spreading ability

Remarks

This grass has been introduced into Trinidad from South America and is found in the Botanic Gardens. Its seeding ability will limit its utility in contour bunds. It can be effective as a ground cover.

Cortaderia selloana (Schult.)
Aschers & Graebn



Botanical name: *Croton gossipofolius* Vahl.
Family: Euphorbiaceae
Common name: blood wood croton; candle tree
Classification: shrub, tree

Bio-engineering attributes

Root form: strong tap root system spreading horizontally in the top 30 - 60 cm of the soil
Rooting depth: 1 - 2 m
Rooting strength: very strong
Canopy height: 3 - 5 m
Canopy spread: 3 - 5 m
Bio-engineering use: good soil stabilizer holds the soil very well on slopes
Other uses: unknown
Method of propagation: seeds; cuttings

Ecological and cultural factors

Potential weediness: none
Resistance to fire: very resistant; regrows rapidly after exposure to fire
Resistance to grazing: resistant
Resistance to drought: very resistant
Reaction to shade or full sunlight: grows both under shade and in full sunlight
Flood tolerance: unknown

Erosion control: very good at controlling erosion on hillsides
Natural habitat: dry hillsides
Rate of growth: moderate
Ability to spread naturally: good spreading ability

Remarks

Good for hillsides that become very dry in the dry season.

Botanical name: *Cymbopogon citratus* (DC) Stapf

Family: Gramineae

Common name: lemon grass, fever grass

Classification: grass

Bio-engineering attributes

Root form: thick underground jointed rhizomes with few coarse roots; profuse coarse roots emerge from the group of tillers comprising a plant; roots exhibit limited branching

Rooting depth: 20 - 25 cm

Rooting strength: very strong

Canopy height: 0.7 m

Canopy spread: tillers readily to give good ground cover

Bio-engineering use: used for planting on bunds for soil conservation and as a mulch

Other uses: leaves used as flavouring for food, drinks, medicinal properties, commercial oil

Method of propagation: root matt division; planted at a spacing of about 1 x 0.5 m; seldom produces flowers

Ecological and cultural factors

Potential weediness: minimal

Resistance to fire: very resistant

Resistance to grazing: resistant

Resistance to drought: very resistant

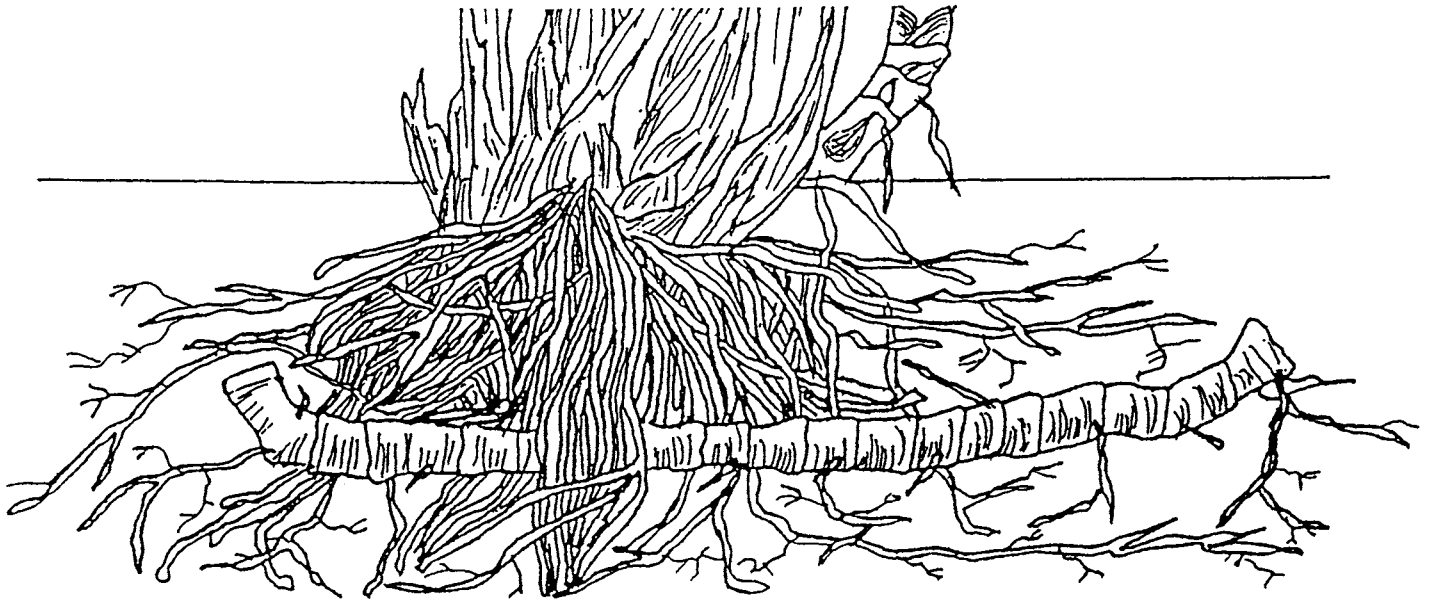
Reaction to shade or full sunlight: can withstand both full sunlight and shade

<i>Flood tolerance:</i>	moderate
<i>Erosion control:</i>	very good erosion control as a ground cover; good potential as a grass barrier or contour bunds
<i>Natural habitat:</i>	widely distributed throughout the tropics; requires warm climate with plenty of sunshine
<i>Rate of growth:</i>	very slow rate of growth
<i>Ability to spread naturally:</i>	slow spreading ability; moderate on the more fertile soils; stems/shoots are produced from the slow growing underground rhizomes

Remarks

Suitable for contour bunds but may need some cutting management to limit spread and ensure the integrity of the contour bunds. It does not grow well on poor infertile soils. Tufted stems arise from rhizomatous rootstocks. It seldom flowers in cultivation.

Cymbopogon citratus (DC) Stapf



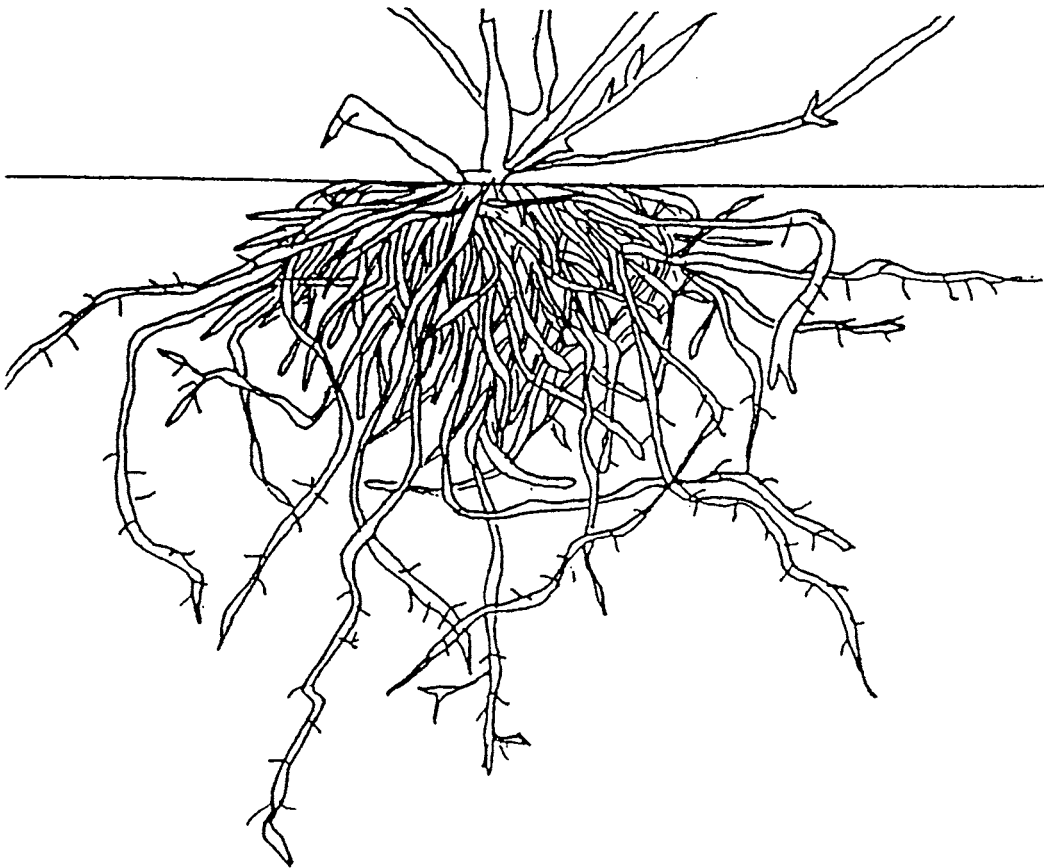
Botanical name:	<i>Cynodon dactylon</i> (L.) Pers.
Family:	Gramineae
Common name:	star grass, bermuda grass, bahama grass, doob
Classification:	grass
Bio-engineering attributes	
Root form:	fibrous; shallow dense rooting but with some primary roots elongated to moderate depths; limited branching; many fine rootlets
Rooting depth:	15 - 20 cm
Rooting strength:	strong; binds tightly to the soil; very difficult to uproot
Canopy height:	1 m
Canopy spread:	stoloniferous and rhizomatous growth habit provides good ground cover and effective soil stabilization
Bio-engineering use:	soil bunds on road embankments and road verges
Other uses:	ornamental purposes as lawn cover
Method of propagation:	rhizomes, seeds
Ecological and cultural factors	
Potential weediness:	could become a serious weed in cultivated land; once it becomes established it is very difficult to eradicate
Resistance to fire:	resistant
Resistance to grazing:	can withstand heavy grazing but not less than 5 cm height
Resistance to drought:	one of the most drought resistant grasses remaining greener longer than any other grass
Reaction to shade or full sunlight:	grows well in full sunlight but cannot tolerate shade

<i>Flood tolerance:</i>	unknown
<i>Erosion control:</i>	very good for control of sheet erosion due to shallow rooting
<i>Natural habitat:</i>	common in open rather dry ground in the tropical regions; prefers a high pH
<i>Rate of growth:</i>	variable depending on existing conditions
<i>Ability to spread naturally:</i>	good spreading ability

Remarks

It can grow on poor infertile soils but it responds to nitrogen and flourishes exceedingly well when the land has been manured. High yielding non-rhizomatous strains exist. It survives drought conditions very well. Good for roadside embankments and road verges.

Cynodon dactylon (L.) Pers



Botanical name: *Dicranopteris pectinata*

Family: Gleicheniaceae

Common name: scrambling fern

Classification: shrub

Bio-engineering attributes

Root form: shallow, limited branching but with good horizontal spread due to the many branched stems which join the many vertical above ground stems

Rooting depth: 30 cm

Rooting strength: very strong

Canopy height: 3 m in the field; maximum height 10 m

Canopy spread: effectiveness is due to distinctive forked pattern of leaf growth which completely covers soil surface

Bio-engineering use: very good potential for bio-engineering uses

Other uses: unknown

Method of propagation: sori, side shoots

Ecological and cultural factors

Potential weediness: slight potential; unlikely to be obnoxious

Resistance to fire: resistant

Resistance to grazing: resistant

Resistance to drought: resistant; growth remains profuse in the dry season

Reaction to shade or full sunlight: thrives extremely well under both conditions especially in full sunlight

Flood tolerance: unknown

Erosion control: extremely good erosion control

Natural habitat: banks, road embankments and steep hillsides in full sunlight and under shade

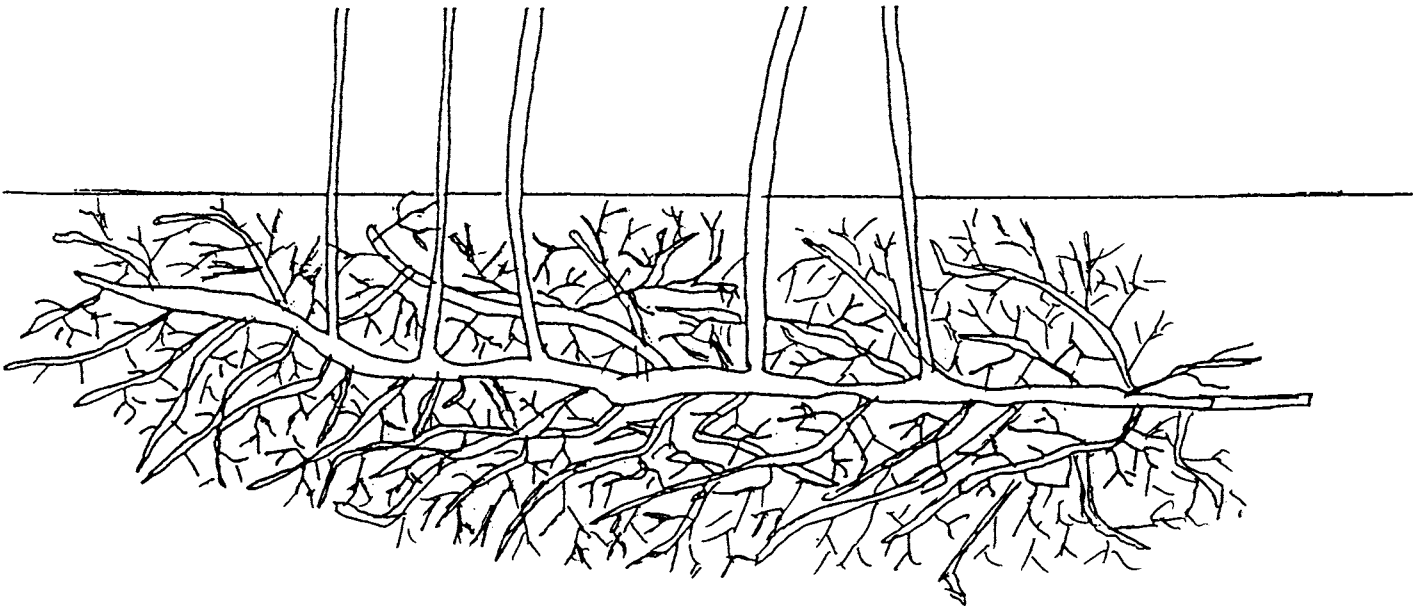
Rate of growth: very rapid

Ability to spread naturally: very good spreading ability

Remarks

The creeping habit of the fern results in complete ground cover, leaving a thick vegetative covering. The fern grows better on slopes less than 20° and in shaded, moist conditions.

Dicranopteris pectinata



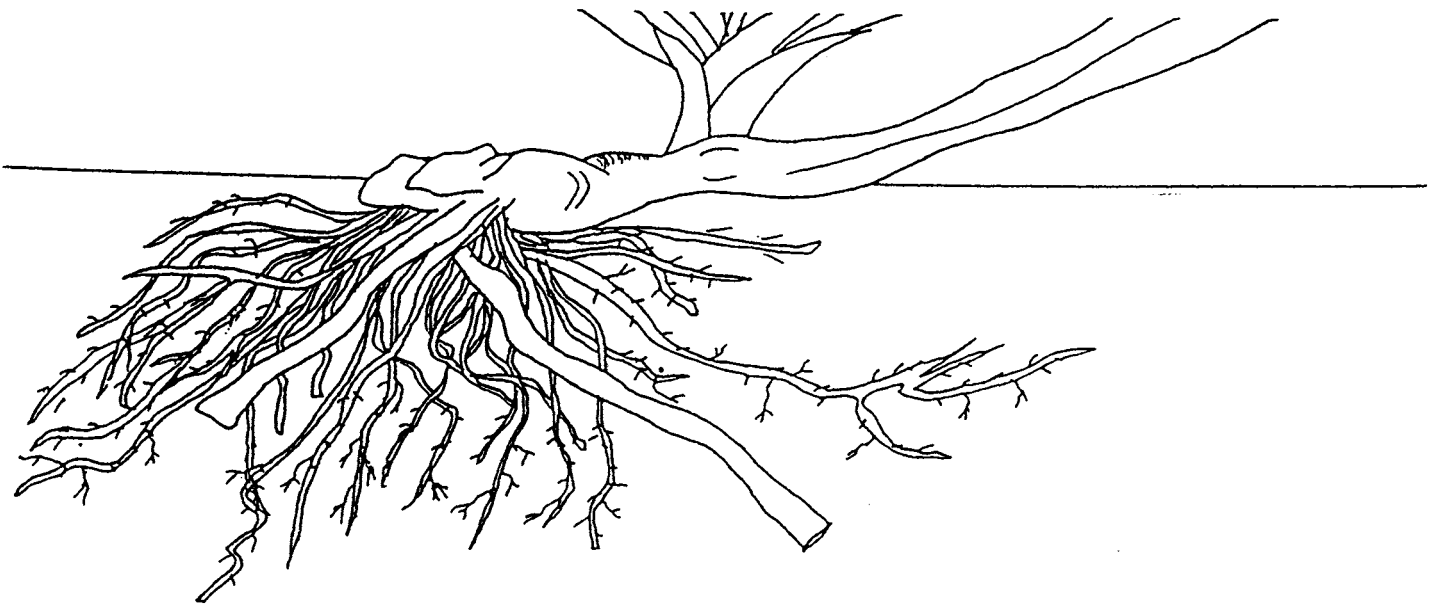
Botanical name:	<i>Dracaena fragrans</i> (L.) Ker-Gawl
Family:	Agavaceae
Common name:	rhyo
Classification:	shrub
Bio-engineering attributes	
Root form:	fibrous; thickened roots that are deep (>100 cm in the mature plant); moderate to high density of roots in the surface layers; moderate branching
Rooting depth:	1 - 2 m
Rooting strength:	extremely strong
Canopy height:	6 m
Canopy spread:	1.5 m per plant
Bio-engineering use:	good potential for soil conservation measures
Other uses:	used very effectively as windbreaks around cocoa and banana trees in Trinidad; fences
Method of propagation:	large cuttings
Ecological and cultural factors	
Potential weediness:	limited potential to become a weed
Resistance to fire:	extremely resistant
Resistance to grazing:	resistant
Resistance to drought:	very resistant
Reaction to shade or full sunlight:	grows well in both shade and full sunlight

<i>Flood tolerance:</i>	tolerant
<i>Erosion control:</i>	very good erosion control species; effectively holds the soil against sheet erosion and mild land slips
<i>Natural habitat:</i>	semi desert areas
<i>Rate of growth:</i>	rapid; rate of regrowth very rapid after fires
<i>Ability to spread naturally:</i>	good spreading ability

Remarks

Good for fences on hillsides where it can also protect against erosion; useful on road edges which slope downward to protect the road edges from erosion damage; needs to be trimmed if less than 6 m height is required; grows under a range of climatic conditions.

Dracaena fragrans (L.) Ker-Gawl



Botanical name: *Gynerium sagittatum* (Aubl.) Beauv.

Family: Gramineae

Common name: wild cane; uva grass; white roseau

Classification: grass

Bio-engineering attributes

Root form: thick suberised roots which penetrate deeply into the soil with profuse fine branched roots closer to the soil surface giving rise to tufted rooting habit

Rooting depth: 1 m

Rooting strength: extremely strong

Canopy height: 2m

Canopy spread: each plant is approximately 1 m in diameter

Bio-engineering use: very useful for holding the soils on the banks of rivers

Other uses: stems used for lattices and light construction work

Method of propagation: vegetative side shoots

Ecological and cultural factors

Potential weediness: very little, spreads slowly by tillering

Resistance to fire: resistant

Resistance to grazing: resistant

Resistance to drought: resistant

Reaction to shade or full sunlight: grows very well under full sunlight and in moderate shade

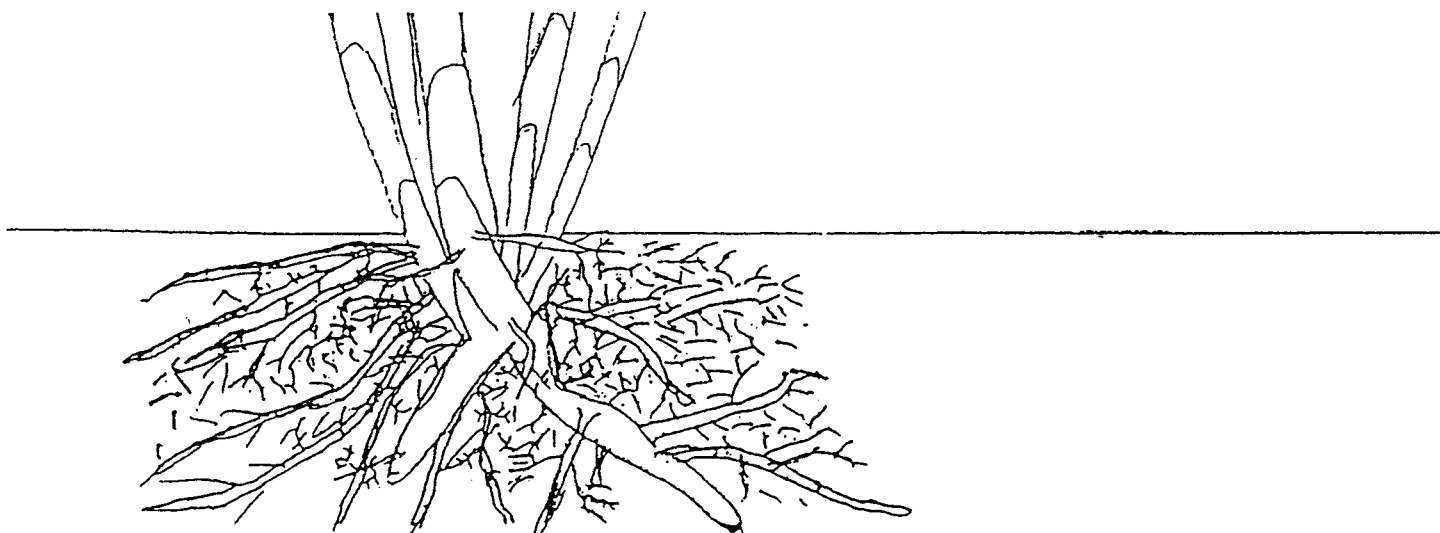
Flood tolerance: very tolerant

Erosion control: very good erosion control on river banks
Natural habitat: river banks and low ground forming dense colonies
Rate of growth: moderate
Ability to spread naturally: slow spreading ability

Remarks

Grows well under dry or wet conditions and can withstand saline conditions. It occurs on river banks and is not affected by periodic flooding or high river stage. It is suitable for stabilising river banks against stream bank erosion.

Gynerium sagittatum (Aubl.) Beauv.



Botanical name:	<i>Heliconia psittacorum</i>
Family:	Heliconiaceae
Common name:	wild ginger
Classification:	shrub
Bio-engineering attributes	
Root form:	spreading tube roots
Rooting depth:	20 - 30 cm
Rooting strength:	very strong
Canopy height:	0.5 m
Canopy spread:	varies with spread of plants by rhizomatous growth
Bio-engineering use:	useful for covering soil of arid regions
Other uses:	flowers could be used in the ornamental industry
Method of propagation:	division of the rootstock; rhizome
Ecological and cultural factors	
Potential weediness:	some potential to become a weed
Resistance to fire:	very resistant
Resistance to grazing:	very resistant
Resistance to drought:	very resistant
Reaction to shade or full sunlight:	grows well in full sunlight and shade
Flood tolerance:	tolerates flood

Erosion control: good potential for erosion control especially on lands that are liable to be razed by fires

Natural habitat: arid savannah regions

Rate of growth: very rapid

Ability to spread naturally: good spreading ability

Remarks

This species recovers rapidly after fires and can therefore protect the soil against erosion by rainfall which follow. It grows well in full sunlight and shade and therefore can be a secondary species on the forest floor or a protective species on exposed hillsides of gentle to moderate slopes. Because of its spreading ability it must not be introduced into agricultural lands or the perimeter of agricultural land.

Botanical name: *Imperata brasiliensis*

Family: Gramineae

Common name: house grass

Classification: grass

Bio-engineering attributes

Root form: fibrous sparse root system with limited branching;
shallow rooting

Rooting depth: 20 cm

Rooting strength: strong

Canopy height: 0.8 - 1 m

Canopy spread: 5 cm per plant but effectiveness for ground cover is
via its spreading habit due to rhizomatous growth

Bio-engineering use: good for covering soil especially after fires have
razed the vegetation

Other uses: unknown

Method of propagation: rhizomes, seeds

Ecological and cultural factors

Potential weediness: moderate since it grows rapidly and spreads

Resistance to fire: very resistant to fire; one of its features is that after
exposure to fires it immediately begins to flower and
hence young plants establish very rapidly

Resistance to grazing: unknown

Resistance to drought: resistant

Reaction to shade or full sunlight: very tolerant to full sunlight and to some shade

Flood tolerance: unknown

Erosion control: very good erosion control

Natural habitat: open dry ground at low altitudes

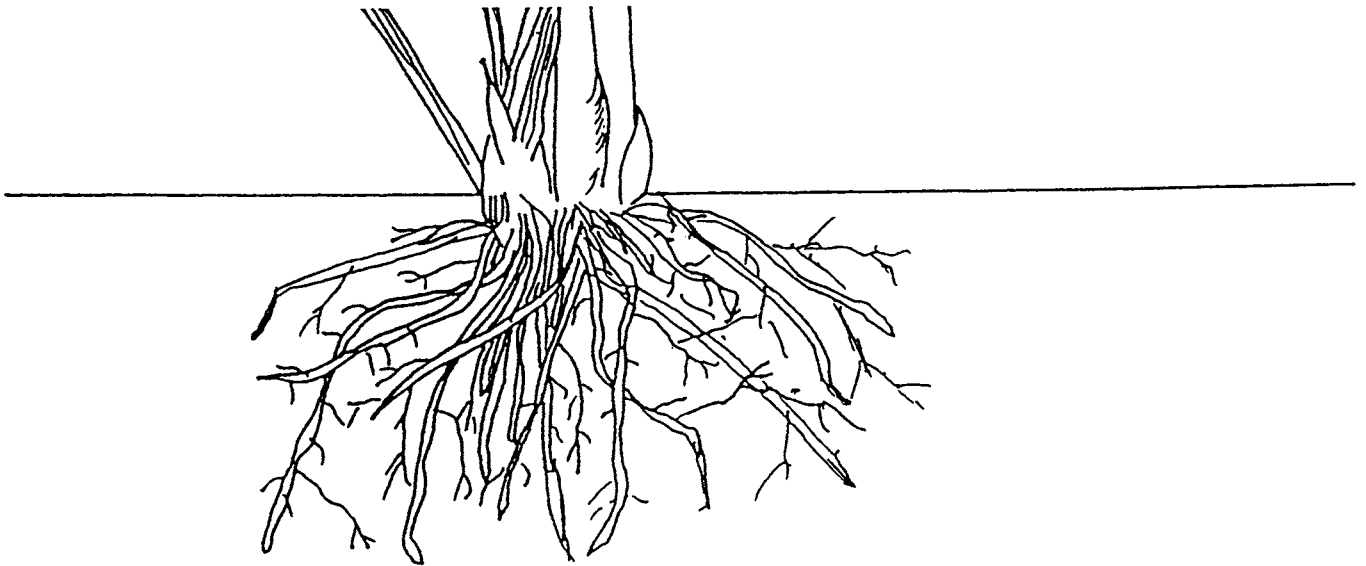
Rate of growth: appears to have very rapid rate of growth

Ability to spread naturally: very good spreading ability; if it were left unchecked, it would cover an area which it is invading within a few months

Remarks

Can tolerate both dry and some waterlogged conditions; good for roadside embankments and road verges.

Imperata brasiliensis



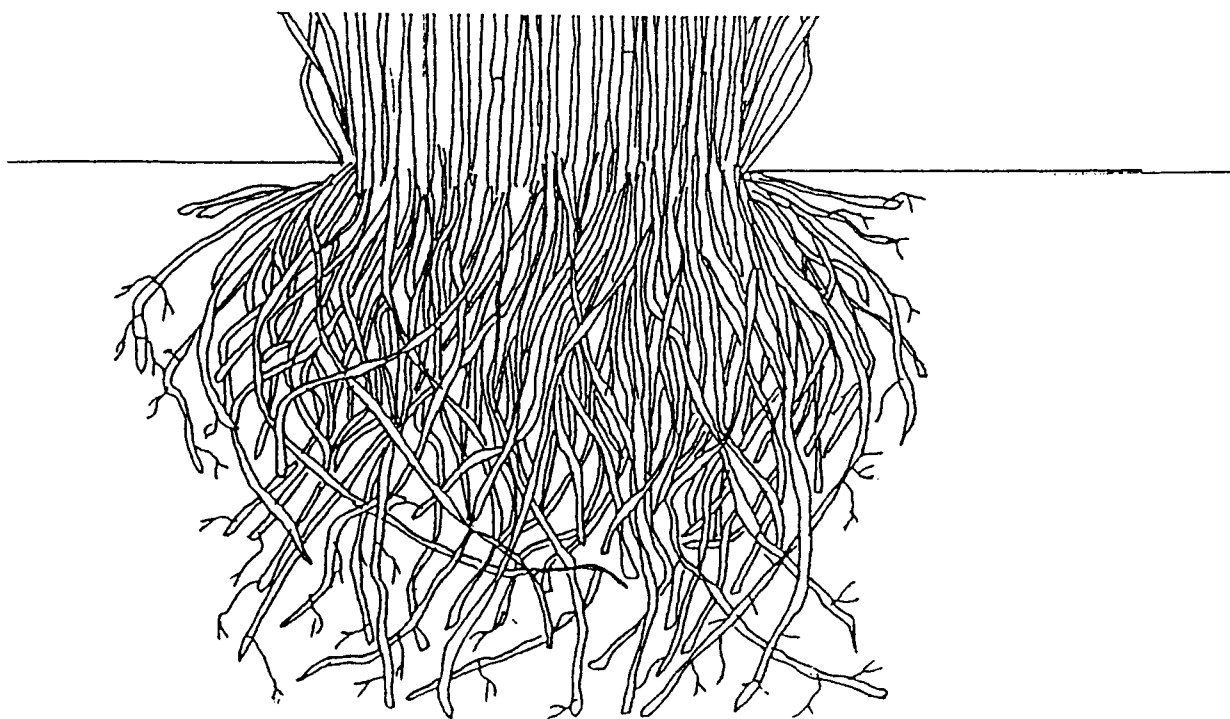
Botanical name:	<i>Ischaemum timorense</i> Schult
Family:	Gramineae
Common name:	lucuntu
Classification:	grass
Bio-engineering attributes	
<i>Root form:</i>	fibrous; moderately deep; long coarse primary roots with limited secondary branching
<i>Rooting depth:</i>	15 cm
<i>Rooting strength:</i>	very strong
<i>Canopy height:</i>	0.5 m
<i>Canopy spread:</i>	rhizomatous spread which promotes rapid ground cover
<i>Bio-engineering use:</i>	very good soil binding properties on road embankments and on road verges
Other uses:	fed as fodder to livestock
Method of propagation:	seeds, rhizomes
Ecological and cultural factors	
<i>Potential weediness:</i>	some potential to become a weed
<i>Resistance to fire:</i>	appears to be resistant
<i>Resistance to grazing:</i>	cannot withstand grazing below 5 cm
<i>Resistance to drought:</i>	resistant
<i>Reaction to shade or full sunlight:</i>	tolerates both shade and full sunlight
<i>Flood tolerance:</i>	unknown

<i>Erosion control:</i>	very good against erosion on road embankments and on road verges
<i>Natural habitat:</i>	unknown
<i>Rate of growth:</i>	rapid
<i>Ability to spread naturally:</i>	good spreading ability

Remarks

The ability of this grass to spread rapidly and to tolerate dry, wet and high temperature conditions and to grow on poor soils is an advantage for vegetating, bare or denuded soil slopes. However, its rapid spreading ability especially where the environmental conditions are favourable can encourage the species to become a weed and this needs careful assessment. Under dry conditions, the shoots die back annually leaving a tufted matt of dried leaves on the surface of the soil which remain adhered to the roots. At the start of the rainy season new shoots are produced from the tufted matt.

Ischaemum timorense Schult



Botanical name: *Ixertia parviflora* (Vahl.)

Family: Rubiaceae

Common name: wild ixora

Classification: shrub, small tree

Bio-engineering attributes

Root form: abundant, enlarged, tuberous roots, emanating from thickened stem base; thinner moderately branched roots; moderately deep rooting; good horizontal spread

Rooting depth: 1 - 2 m

Rooting strength: very strong

Canopy height: 2.5 m (shrub) or 6 - 8 m (tree)

Canopy spread: 1 - 2 m

Bio-engineering use: good soil stabilizing potential

Other uses: ornamental uses

Method of propagation: seeds, cuttings

Ecological and cultural factors

Potential weediness: very little potential to become a weed

Resistance to fire: resistant

Resistance to grazing: resistant

Resistance to drought: very resistant

Reaction to shade or full sunlight: responds very well to full sunlight; reaction to shade unknown

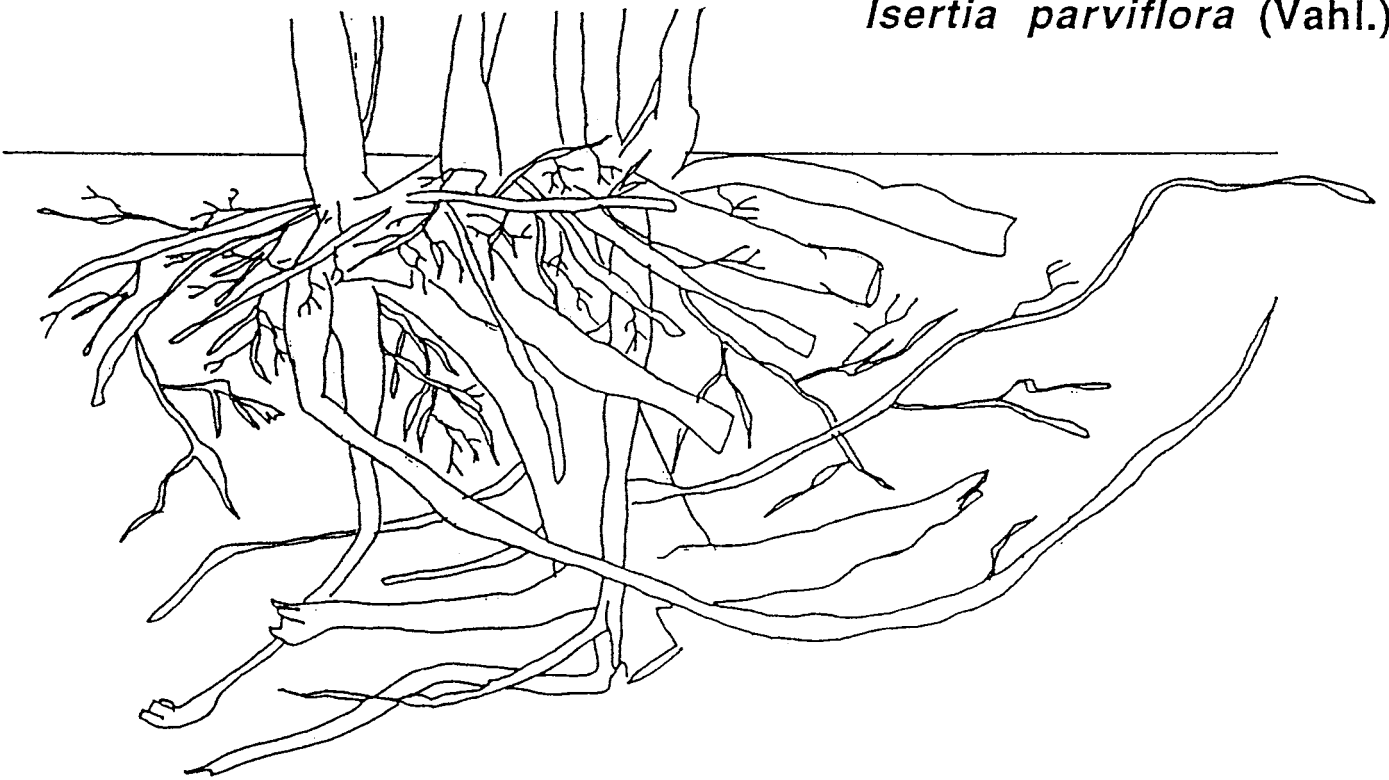
Flood tolerance: some tolerance

Erosion control: good potential for erosion control
Natural habitat: common in woodlands throughout Trinidad
Rate of growth: moderate
Ability to spread naturally: good spreading ability

Remarks

This species is very tolerant of high temperatures and dry soil conditions. It can grow on relatively poor soils. It is suitable for hillsides and can be used on leeward sides of mountains with strong wet and strong dry seasons.

Isertia parviflora (Vahl.)



Botanical name: *Lagenocarpus guianensis* Nees

Family: Cyperaceae

Common name:

Classification: sedge

Bio-engineering attributes

Root form: fibrous; shallow to moderately deep; dense roots with limited secondary branching

Rooting depth: 20 - 25 cm

Rooting strength: very strong

Canopy height: 1 m

Canopy spread: 0.3 m

Bio-engineering use: good erosion control potential for road embankments and road verges

Other uses: unknown

Method of propagation: side shoots, tillers

Ecological and cultural factors

Potential weediness: some potential to become a weed

Resistance to fire: resistant

Resistance to grazing: resistant

Resistance to drought: very resistant

Reaction to shade or full sunlight: requires full sunlight

Flood tolerance: tolerant

Erosion control: good for erosion control on road embankments and road verges

Natural habitat: Aripo savannah

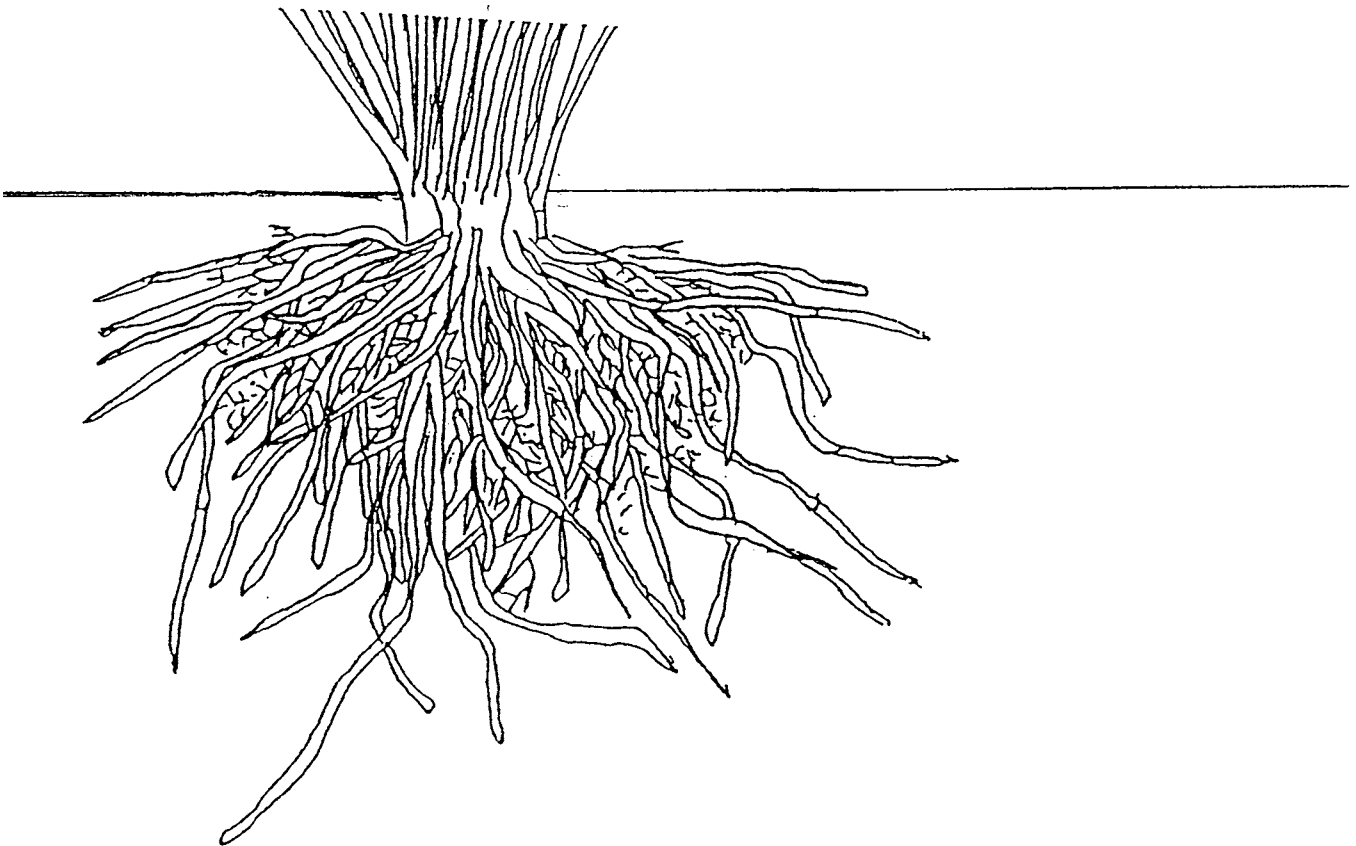
Rate of growth: very rapid

Ability to spread naturally: very good spreading ability

Remarks

This sedge is very tolerant to a range of soil and tropical climatic conditions. It is relatively shallow rooting but can protect the soil against raindrop impact and sheet erosion of the topsoil. Its ability to spread rapidly increases its potential to become a weed.

Lagenocarpus guianensis Nees



Botanical name: *Miconia acinodendron*

Family: Melastomaceae

Common name: monkey bone

Classification: shrub

Bio-engineering attributes

Root form: fibrous; well developed branched underground stem with thickened roots; abundant fine branched roots; good horizontal spread; good root distribution to moderate depths(80 - 90 cm)

Rooting depth: 1 m

Rooting strength: very strong

Canopy height: 1 - 3 m

Canopy spread: 1 - 3 m

Bio-engineering use: good soil stabilizing potential

Other uses: unknown

Method of propagation: seeds, cuttings

Ecological and cultural factors

Potential weediness: none

Resistance to fire: resistant

Resistance to grazing: unknown

Resistance to drought: unknown

Reaction to shade or full sunlight: grow wells in shade and limited sunlight

Flood tolerance: unknown

Erosion control: good erosion control potential

Natural habitat: thickets and forests in moist districts in Trinidad; only grows in forested areas and roadside undergrowth

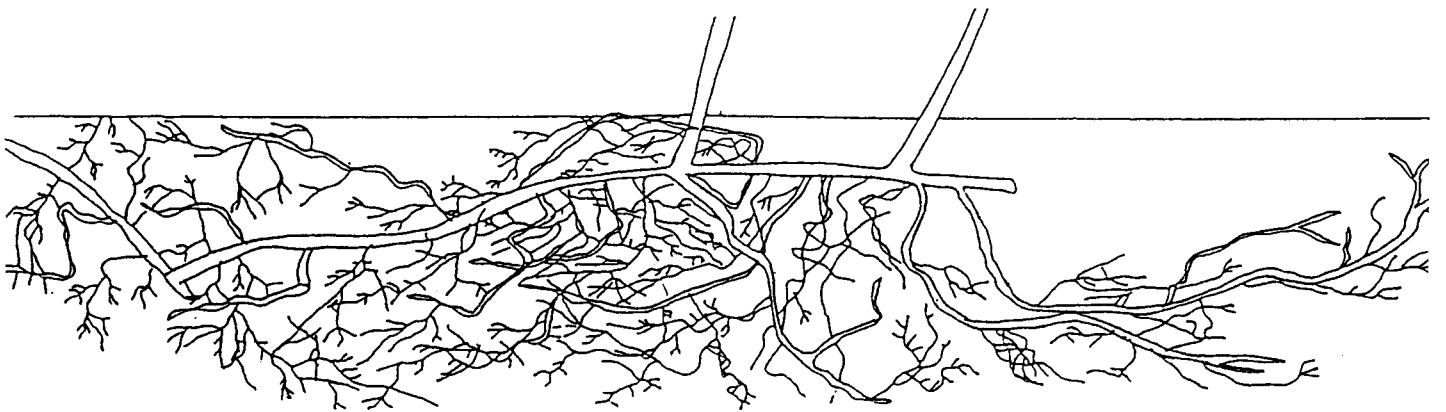
Rate of growth: rapid

Ability to spread naturally: good spreading ability

Remarks

Good as a secondary species in forested areas and roadside undergrowth where it provides additional protection against erosion.

Miconia acinodendron



Botanical name:	<i>Nephrolepis multiflora</i> (Roxb.) Jarret ex Morton
Family:	Davalliaceae
Common name:	hassar back fern, giant sword fern
Classification:	shrub
Bio-engineering attributes	
Root form:	fibrous, thick and extensive
Rooting depth:	15 - 20 cm
Rooting strength:	strong
Canopy height:	1-2 m
Canopy spread:	plants grow vertically and with a narrow spread; close growing plants establish complete ground cover
Bio-engineering use:	good soil stabilizing potential
Other uses:	cut foliage in the ornamental industry
Method of propagation:	sori, side shoots
Ecological and cultural factors	
Potential weediness:	none
Resistance to fire:	some resistance
Resistance to grazing:	resistant
Resistance to drought:	resistant
Reaction to shade or full sunlight:	grows well in both
Flood tolerance:	tolerant

Erosion control: good erosion control possibilities
Natural habitat: roadsides; on the trunks of palm trees
Rate of growth: very rapid
Ability to spread naturally: very good spreading ability

Remarks

A very common fern on roadside embankments and on the edges of forests. Although it grows better under shade, it does well under both conditions. It is suitable for roadside embankments and as a secondary species on the forest floor. It resprouts readily after it has been burnt by fire.

Botanical name: *Palicourea crocea* (Sw.) R&S

Family: Rubiaceae

Common name: palicourea

Classification: shrub

Bio-engineering attributes

Root form: tap root system; well developed branched underground stem with thickened roots; abundant fine branched roots; good horizontal spread; good root distribution to moderate depths

Rooting depth: 0.7-1 m

Rooting strength: very strong

Canopy height: 1 - 3 m

Canopy spread: 2 - 3 m

Bio-engineering use: holds edges of soil very well

Other uses: unknown

Method of propagation: seeds; cuttings

Ecological and cultural factors

Potential weediness: ubiquitous in Trinidad, but is not a potential weed

Resistance to fire: moderate resistance

Resistance to grazing: since it is a euphorbiaceae, it may be resistant

Resistance to drought : shows strong preference for shady habitat, but may not be drought resistant

Reaction to shade or full sunlight: grows very well under shade but growth is restricted in full sunlight

<i>Flood tolerance:</i>	some tolerance to flood
<i>Erosion control:</i>	very good at controlling erosion on both upward and downward sloping embankments
<i>Natural habitat:</i>	favours semi shady or moist situations; borders of forests
<i>Rate of growth:</i>	moderate
<i>Ability to spread naturally:</i>	good spreading ability

Remarks

This shrub is good for controlling erosion at the edges of roadsides and edges of forests. Its attractive colours enhance its aesthetic value as a roadside plant. It is not likely to become a weed.

Botanical name: *Pandanus odoratissimus* L.f.

Family: Pandanaceae

Common name: screw pine

Classification: shrub, tree

Bio-engineering attributes

Root form: conspicuous aerial stilt roots; elongated coarse roots which emerge from the base of the rosette of leaves; branching is limited and consists mainly of fine branched roots

Rooting depth: 2 - 4 m under ideal conditions

Rooting strength: extremely strong

Canopy height: 6 m

Canopy spread: 2 m

Bio-engineering use: very good as a soil binder and for use as fences

Other uses: ornamental purposes; handicraft; perfumes

Method of propagation: offsets; division of suckers or by cuttings

Ecological and cultural factors

Potential weediness: very little potential to become a weed

Resistance to fire: resistant

Resistance to grazing: resistant

Resistance to drought: resistant

Reaction to shade or full sunlight: grows very well in full sunlight and shade

Flood tolerance: very good tolerance

Erosion control: extremely good species for controlling erosion

Natural habitat: wild forms grow along coasts producing a belt of dense impenetrable vegetation above the high water mark. The cultivated plants are often grown along the banks of rivers, canals, ponds, and fields

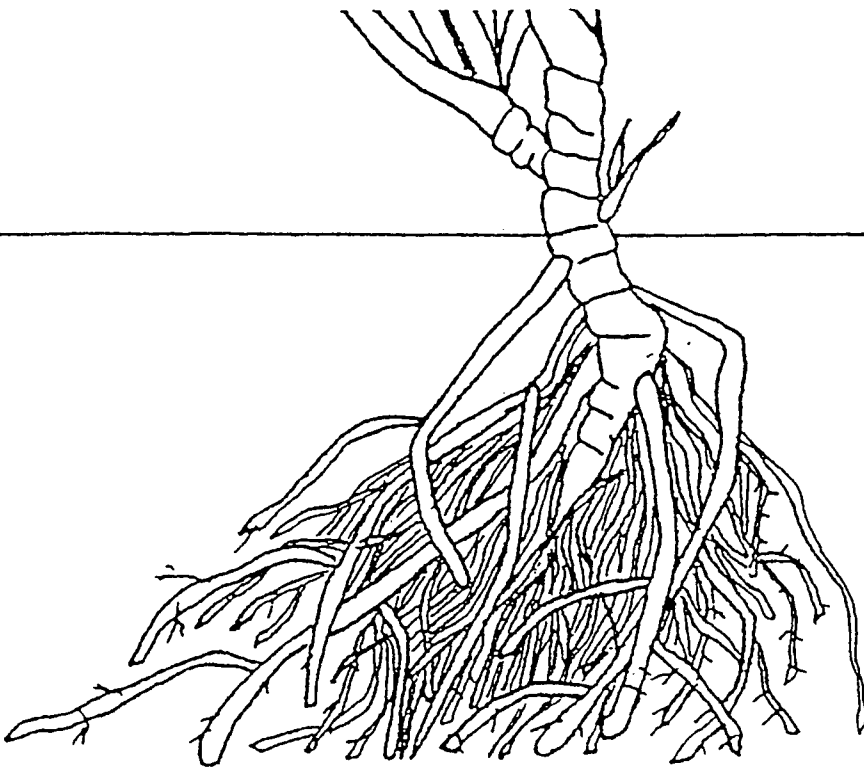
Rate of growth: moderate

Ability to spread naturally: moderate to good spreading ability

Remarks

A hardy species which tolerates a wide range of conditions including salinity. Can be used to protect against erosion and to protect the banks of water courses.

Pandanus odoratissimus L.f.



Botanical name: *Panicum maximum* Jacq.

Family: Gramineae

Common name: guinea grass

Classification: grass

Bio-engineering attributes

Root form: tufted matt of fibrous roots close to the surface with branched roots extending to moderate depths (30 - 60 cm); good horizontal spread; many fine rootlets throughout the root system

Rooting depth: 0.7 m

Rooting strength: very strong

Canopy height: 3 m

Canopy spread: grows in clumps which can be 2 m wide; spreads by stolons which run along the surface of the soil

Bio-engineering use: could be used to bind soil on road verges, roadside embankments, and gently sloping hillsides

Other uses: forage, brooms from inflorescence

Method of propagation: spreads slowly by seed; more rapidly by stolons which root at the nodes; tillers

Ecological and cultural factors

Potential weediness: moderate; not likely to become an obnoxious weed

Resistance to fire: very resistant

Resistance to grazing: some resistance; should not be grazed below 15 cm

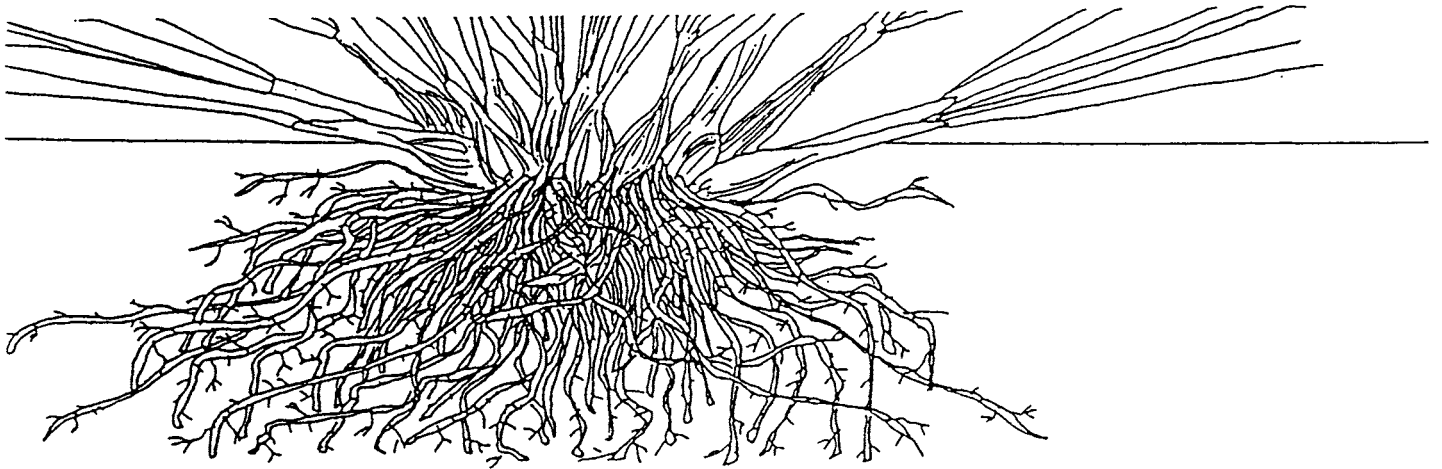
Resistance to drought: may largely desiccate in the dry season, but readily regenerates with rainfall

<i>Reaction to shade or full sunlight:</i>	grows well in full sunlight; fairly tolerant to shade
<i>Flood tolerance:</i>	cannot tolerate waterlogging
<i>Erosion control:</i>	its great bulk aids in erosion control, but its generally tussocky growth makes it less valuable than other species
<i>Natural habitat:</i>	grassland; open woodlands; shady places
<i>Rate of growth:</i>	easy establishment especially using root divisions; rapid growth in fertile soils
<i>Ability to spread naturally:</i>	spreads slowly by seed unless in fertile soil; spreads easier by tillers and stolons

Remarks

Will grow on a wide range of soils, but produces poor stands on infertile soils and shows little tolerance of saline conditions; well adapted to sloping, cleared land in rainforest areas where it will support heavy stocking; less suitable for droughty or seasonally-droughty conditions; can be a fire hazard in the dry season; will tolerate acid conditions if drainage is good.

Panicum maximum Jacq.



Botanical name: *Paspalum pulchellum* Kunth.

Family: Gramineae

Common name:

Classification: grass

Bio-engineering attributes

Root form: fibrous; shallow; dense rooting

Rooting depth: 15 cm

Rooting strength: very strong binding roots

Canopy height: 0.8 m

Canopy spread: 0.3 m

Bio-engineering use: very good soil binding properties on roadside embankments and on road verges

Other uses: unknown

Method of propagation: rhizomes

Ecological and cultural factors

Potential weediness: some potential to become a weed

Resistance to fire: resistant

Resistance to grazing: unknown, but if grazed cannot withstand grazing < 5 cm height

Resistance to drought: resistant

Reaction to shade or full sunlight: grows well in full sunlight; shade tolerance unknown

Flood tolerance: tolerant

Erosion control: very good potential to control erosion especially on road embankments and on road verges

Natural habitat: savannahs

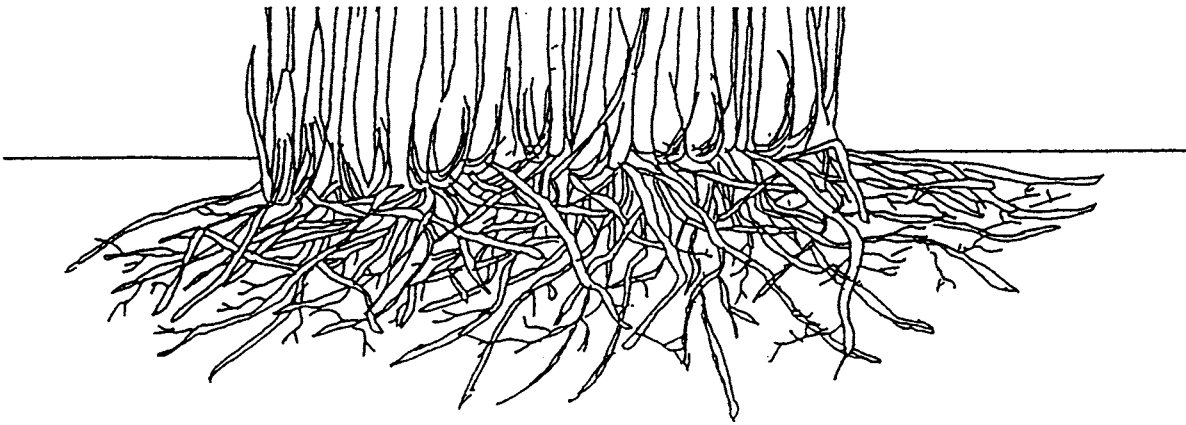
Rate of growth: appears to be very rapid

Ability to spread naturally: good spreading ability

Remarks

Dominant plant in the Aripo savannah (covered about 90% of the savannah; withstands the alternating flooding and drought conditions of the Aripo savannah; does not require cutting; its rhizomatous growth habit allows it to spread fairly rapidly but it can be a disadvantage; its weed potential needs to be assessed.

Paspalum pulchellum Kunth.



Botanical name:	<i>Pitsairna integrifolia</i> Ker - Gawl
Family:	Bromeliaceae
Common name:	
Classification:	shrub
Bio-engineering attributes	
Root form:	fibrous; shallow rooting but with some roots reaching moderate depths; moderate horizontal spread; limited branching
Rooting depth:	0.25 - 0.3 m
Rooting strength:	very strong
Canopy height:	1 m
Canopy spread:	1 m
Bio-engineering use:	very good soil stabilizing potential for steep slopes and rocky outcrops.
Other uses:	possible use in the ornamental industry for its flowers
Method of propagation:	seeds, side shoots
Ecological and cultural factors	
Potential weediness:	little or no possibility of becoming a weed in non rocky areas
Resistance to fire:	resistant
Resistance to grazing:	resistant
Resistance to drought:	resistant
Reaction to shade or full sunlight:	grows well in full sunlight and limited shade
Flood tolerance:	unknown

Erosion control: very good erosion control on rocky areas

Natural habitat: dry rocky places, roadsides, banks; often a conspicuous feature of the local flora; found in many locations in Trinidad

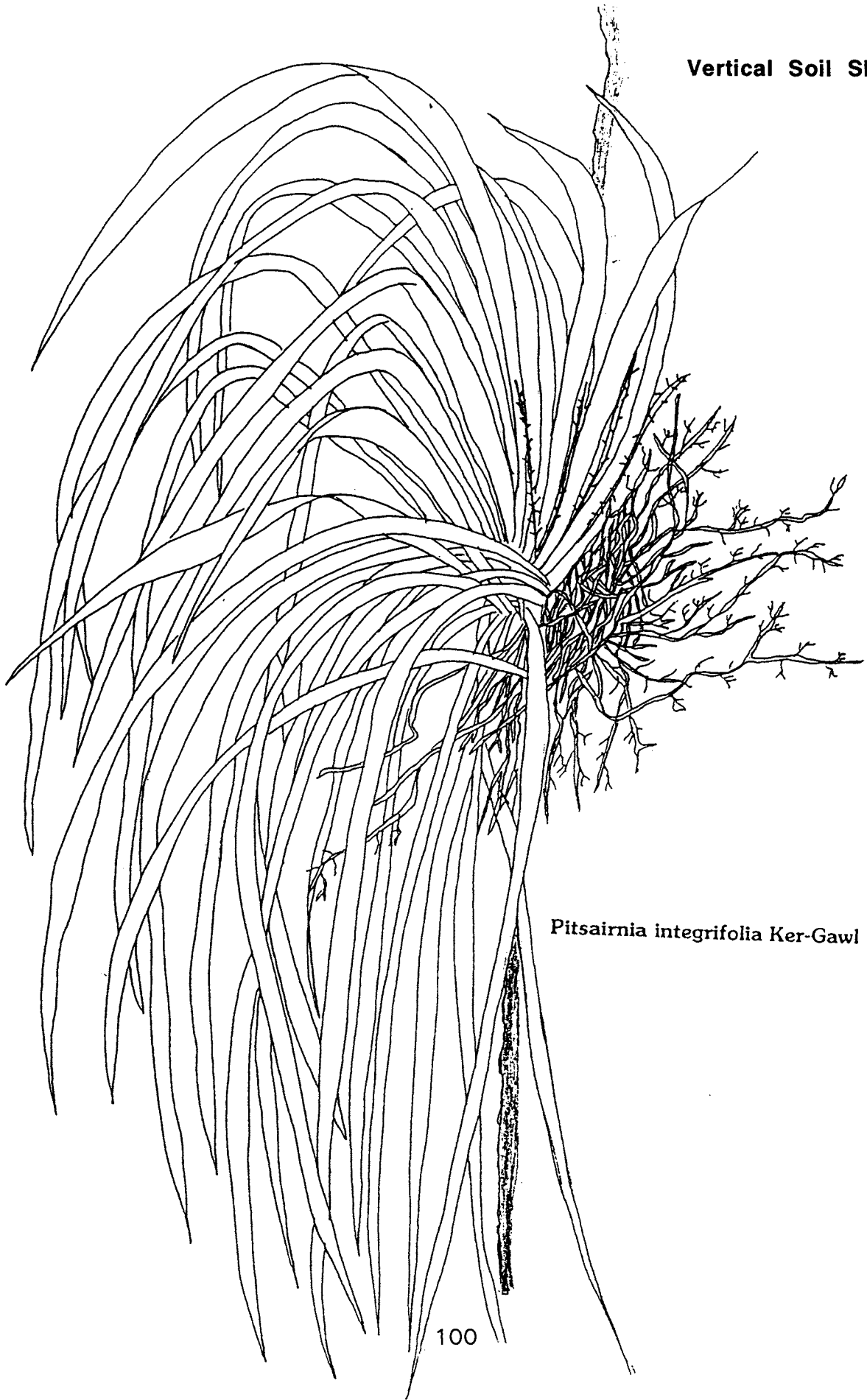
Rate of growth: rapid

Ability to spread naturally: very good spreading ability

Remarks

This species is particularly suited to dry soil conditions and locations that are seasonally very dry

Vertical Soil Slope



Pitsairnia integrifolia Ker-Gawl

Botanical name:	<i>Rhynchospora barbata</i> (Vahl) Kunth.
Family:	Cyperaceae
Common name:	
Classification:	sedge
Bio-engineering attributes	
Root form:	fibrous
Rooting depth:	10 - 20 cm
Rooting strength:	strong
Canopy height:	15 - 45 cm
Canopy spread:	20 cm
Bio-engineering use:	some usage in sandy soils where it grows well spreading easily and covering the soil surface
Other uses:	unknown
Method of propagation:	division of the rootstock
Ecological and cultural factors	
Potential weediness:	limited potential
Resistance to fire:	very resistant
Resistance to grazing:	very resistant
Resistance to drought:	very resistant
Reaction to shade or full sunlight:	requires full sunlight
Flood tolerance:	tolerates flood
Erosion control:	good erosion control potential

Natural habitat: sandy arid regions
Rate of growth: very rapid
Ability to spread naturally: very good spreading ability

Remarks

This sedge tolerates low soil fertility and a range of tropical climatic conditions. Its very shallow rooting habit reduces its potential for erosion control but its short height, ability to spread rapidly on sandy or pervious soils makes it a suitable candidate where these conditions exist or the plant characteristics are desired.

Botanical name:	<i>Rhynchospora cephalotes</i> (L.) Vahl
Family:	Cyperaceae
Common name:	
Classification:	sedge
Bio-engineering attributes	
Root form:	fibrous; shallow to moderately deep; dense roots with limited secondary branching
Rooting depth:	25 cm
Rooting strength:	strong
Canopy height:	0.7 m
Canopy spread:	effectiveness obtained by clumps which are contiguous
Bio-engineering use:	useful for protecting road verges and road embankments
Other uses:	unknown
Method of propagation:	seeds, side shoots
Ecological and cultural factors	
Potential weediness:	moderate potential to become a weed
Resistance to fire:	resistant
Resistance to grazing:	resistant
Resistance to drought:	resistant
Reaction to shade or full sunlight:	requires full sunlight for good growth
Flood tolerance:	can tolerate some waterlogging

Erosion control: good erosion control on road verges and road embankments

Natural habitat: roadsides

Rate of growth: rapid

Ability to spread naturally: very good spreading ability

Remarks

This sedge is very tolerant of low fertility soils and a wide range of soil moisture conditions. It is relatively shallow rooting but can protect the soil against raindrop impact and sheet erosion of the topsoil. Seed production encourages rapid spread which is good for vegetatively denuded slopes but its potential to become a weed has to be assessed.

Botanical name: *Spathiphyllum cannifolium* (Dryander) Schott.

Family: Araceae

Common name: wild anthurium

Classification: shrub

Bio-engineering attributes

Root form: tube roots which spread horizontally in the top 30 - 50 cm of soil

Rooting depth: 0.3 - 0.5 m

Rooting strength: very strong

Canopy height: 1 m

Canopy spread: 0.7 - 0.9 m

Bio-engineering use: holds the soils of the banks of rivers and streams very effectively

Other uses: ornamental industry for its flowers

Method of propagation: side shoots; propagates rapidly

Ecological and cultural factors

Potential weediness: can become a weed because of its tube roots which are difficult to eradicate once they become established

Resistance to fire: because of its tube roots this species could regenerate after fires

Resistance to grazing: unknown

Resistance to drought: some tolerance

Reaction to shade or full sunlight: tends to prefer cooler environments and hence may not grow well in full sunlight

Flood tolerance: tolerant

Erosion control: could be a good erosion control species on river banks
Natural habitat: river banks and related waterway areas
Rate of growth: rapid regrowth
Ability to spread naturally: very good spreading ability

Remarks

Flood tolerant; grows well in moist places and is suitable for erosion control on river and stream banks.

Botanical name:	<i>Sporobolus indicus</i> (L.)
Family:	Gramineae
Common name:	broom grass, tapia grass, wire grass, lizard grass, mulatto plant
Classification:	grass

Bio-engineering attributes

Root form:	fibrous, but with good horizontal spread and matting close to the surface as a result of abundant branching of fine roots.
Rooting depth:	15 - 20 cm
Rooting strength:	very strong
Canopy height:	0.3 - 0.5 m
Canopy spread:	spread per clump is about 0.3 m
Bio-engineering use:	excellent as a soil stabilizer on road embankments and road verges
Other uses:	used for fodder, for stuffing mattresses, principal fibre in tapia plastering for constructing native houses.
Method of propagation:	cuttings, seed

Ecological and cultural factors

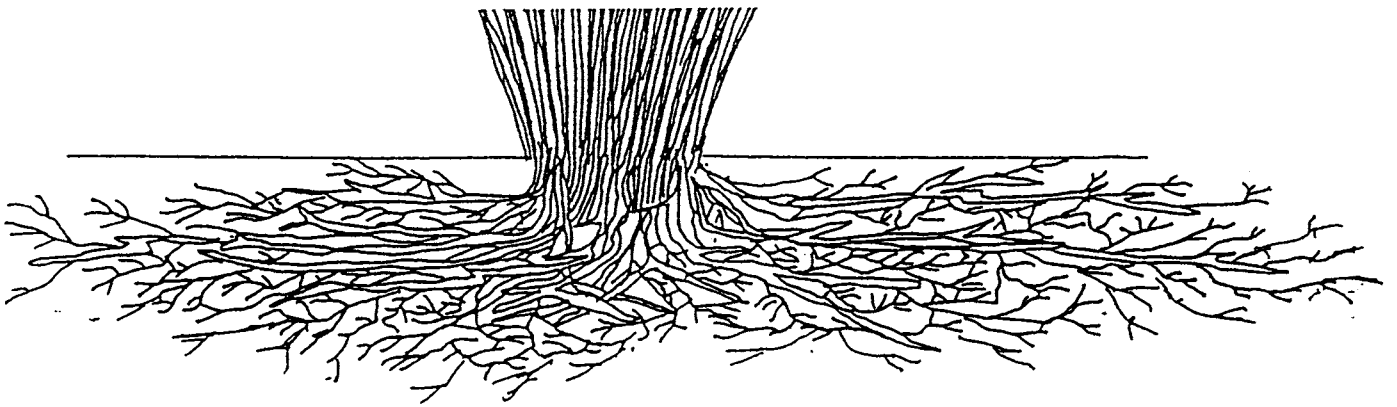
Potential weediness:	could become a weed if left unchecked
Resistance to fire:	resistant
Resistance to grazing:	resistant
Resistance to drought:	very resistant

<i>Reaction to shade or full sunlight:</i>	performs extremely well in full sunlight and well in shade
<i>Flood tolerance:</i>	tolerant
<i>Erosion control:</i>	very good erosion control on road verges and on road embankments
<i>Natural habitat:</i>	roadsides, grassy hills, and dry savannahs
<i>Rate of growth:</i>	rapid
<i>Ability to spread naturally:</i>	good spreading ability

Remarks

The height of the plant is manageable for roadside embankments so cutting is not required. However, a possible disadvantage of this species is its rapid growth and good spreading ability. It seeds fairly readily and is very tolerant of dry conditions. It should not be planted on roadside embankments which are adjacent to cultivated pastures.

Sporobolus indicus (L.)



Botanical name:	<i>Sporobolus poiretii</i> (Roem. and Schult)
Family:	Gramineae
Common name:	smutgrass
Classification:	grass
Bio-engineering attributes	
Root form:	dense fibrous root system; strong roots that exhibit good vertical penetration; limited fine root branches
Rooting depth:	15 - 20 cm
Rooting strength:	very strong
Canopy height:	0.5 - 1 m
Canopy spread:	spread per mat is about 0.5 m
Bio-engineering use:	good as a soil stabilizer on road embankments and on road verges
Other uses:	unknown
Method of propagation:	tillers, seed
Ecological and cultural factors	
Potential weediness:	fertile seed production contributes to spread; could become a weed if left unchecked
Resistance to fire:	resistant
Resistance to grazing:	resistant
Resistance to drought:	very resistant
Reaction to shade or full sunlight:	performs extremely well in full sunlight and well in shade
Flood tolerance:	tolerant

Erosion control: good erosion control on road verges and on roadside embankments

Natural habitat: open ground, grassland, and waste places

Rate of growth: rapid

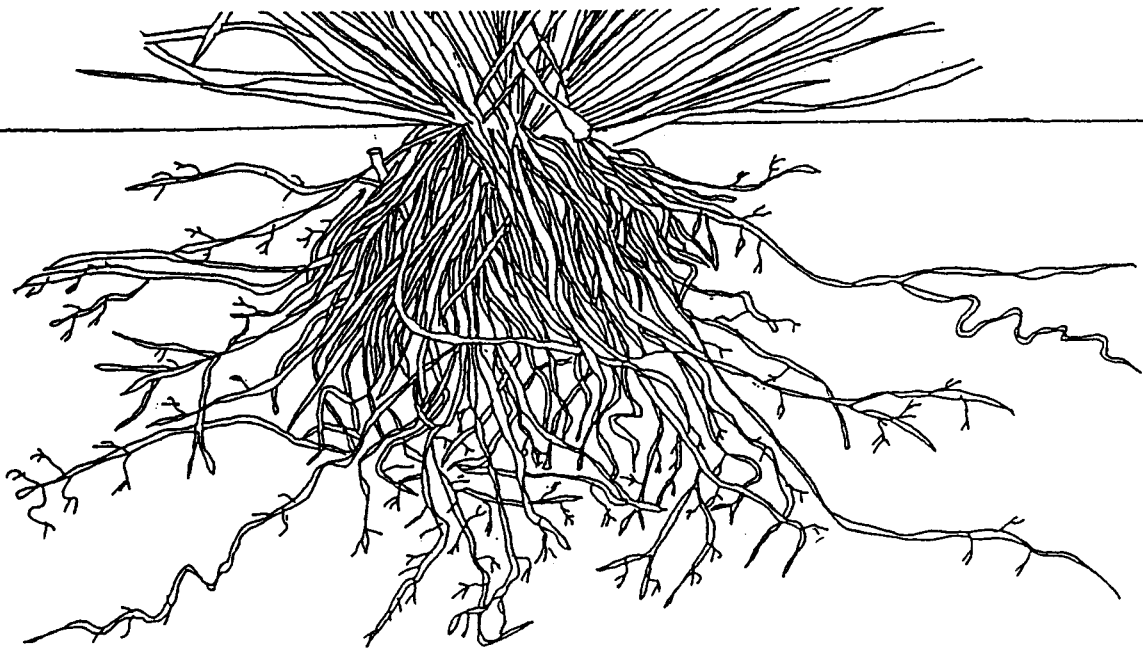
Ability to spread naturally: good spreading ability

Remarks

This grass readily colonizes droughty, poor fertility soils. It is a relatively short grass and no cutting is necessary.

Sporobolus poiretii

(Roem. & Schult)



Botanical name: *Tridax decumbens* L.

Family: Compositae

Common name: tridax

Classification: shrub

Bio-engineering attributes

Root form: fibrous; shallow rooting with horizontal spread in the top 15 - 20 cm of soil; limited secondary branching

Rooting depth: 15 - 20 cm

Rooting strength: strong

Canopy height: 25 cm

Canopy spread: stolons which creep along the ground

Bio-engineering use: useful as soil surface cover on sandy areas

Other uses: unknown

Method of propagation: stolons; cuttings

Ecological and cultural factors

Potential weediness: pantropical weed

Resistance to fire: resistant

Resistance to grazing: resistant

Resistance to drought: resistant

Reaction to shade or full sunlight: grows well under full sunlight and moderate shade

Flood tolerance: tolerant

Erosion control: good erosion control
Natural habitat: grassy places, waste or cultivated land
Rate of growth: rapid
Ability to spread naturally: spreads rapidly

Remarks

Useful as a soil cover on sandy saline soils.

Botanical name: *Zoysia matrella* (L.) Merr.

Family: Gramineae

Common name: manilla grass

Classification: grass

Bio-engineering attributes

Root form: fibrous; shallow to moderately deep rooting; thick strong underground rhizomes; fine roots with limited branching

Rooting depth: 25 cm

Rooting strength: very strong

Canopy height: 30 - 35 cm

Canopy spread: by rhizomatous growth

Bio-engineering use: very good soil binder on road embankments and road verges

Other uses: ornamental purposes for lawn cover

Method of propagation: seeds, but usually vegetatively by sprigs, setts

Ecological and cultural factors

Potential weediness: little potential

Resistance to fire: resistant

Resistance to grazing: resistant

Resistance to drought: very resistant

Reaction to shade or full sunlight: grows best in full sunlight

Flood tolerance: tolerant

Erosion control: good erosion control since it effectively covers the soil surface by forming a dense matt over it; its roots are very matted and thick effectively holding the top 5 - 10 cm of the soil.

Natural habitat: sandy areas

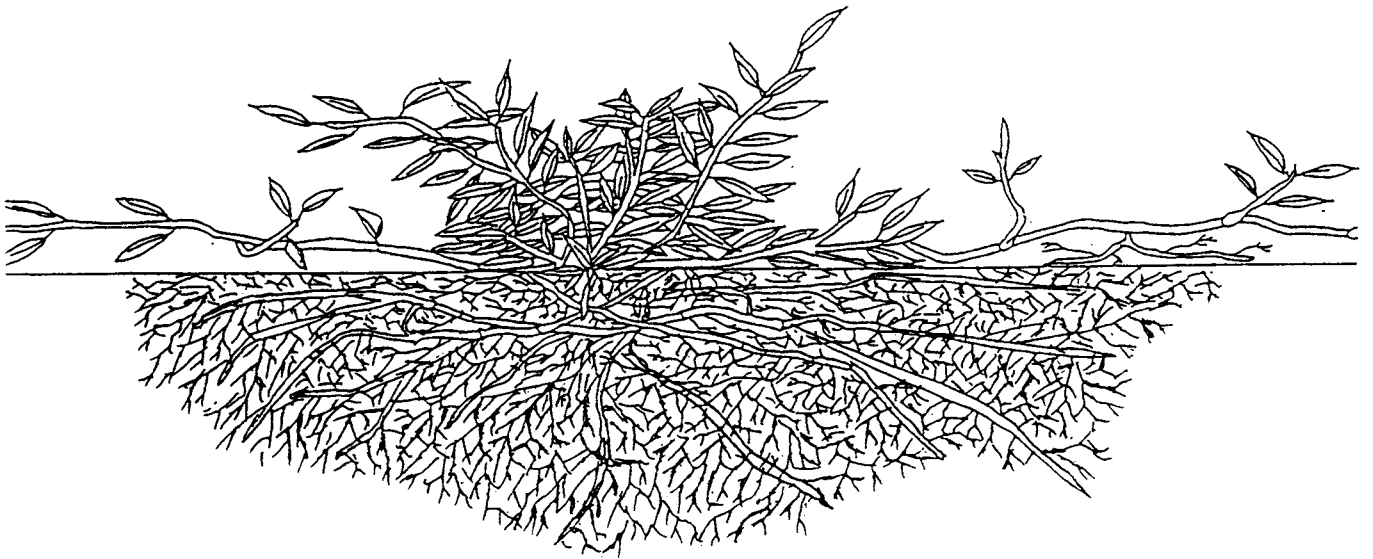
Rate of growth: slow

Ability to spread naturally: spreads slowly

Remarks

Not aggressive but persistent grower eventually pushing out other grasses or herbaceous species which die back in the dry season; no cutting or other management required once the grass has been established and has covered the ground; tolerant to a wide range of soil conditions.

Zoysia matrella (L.) Merr.





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