REPORT ON THE POTENTIAL WEED PROBLEM OF VETIVER GRASS AND ITS EFFECTIVENESS IN SOIL EROSION CONTROL IN FIJI

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Report on a study tour of Fiji
between 4 and 11 June 1994

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SUMMARY

BACKGROUND

A study tour to Fiji was carried out by Mr Colin Creighton, Land Use and Fisheries Regional Manager (North) and Dr Paul Truong, Principal Soil Conservationist, between 4 and 11 June 1994. The aim was to look at the effectiveness of Vetiver grass as a soil erosion control measure and particularly its weed potential in the sugar industry where Vetiver grass has been used for over 40 years. Subsidiary activities were to gain information on Fiji's sugar industry, assess the appropriateness of catchment management and Landcare concepts to the management of Fiji's natural resources and evaluate progress with the ACIAR funded Underwater Visual Census Fish Stock Assessment project.

FINDINGS

1. ***Vetiver grass is not a weed.*** Following its introduction late in the 1800's and extensive planting for soil erosion control since 1950, Vetiver has not become a weed either in agricultural lands or other environments including wetland habitat.

People interviewed, including farmers, research and extension officers of the Fijian Sugar Corporation, agricultural advisers and executives of sugar mills were surprised when being asked whether Vetiver had become a weed in Fiji. They all emphasised that Vetiver remains where planted. Most sites visited are between 25 and 40 years old and Vetiver has only spread around its base through tillering. The seed situation is somewhat akin to sugar cane - while racemes form, no viable seed occurs and no seedlings become established. The only possibility where Vetiver could establish on sites where it was not intentionally planted, was when a living clump of Vetiver was dislodged from its original site accidentally, such as land slips and by road building machinery as observed in the field. On such occasions Vetiver clumps only moved a short distance down the slope and remained there. Clumps in locations such as creeks did not rapidly expand in size and would appear to be, as with Vetiver on dry land, very slow growing beyond the initial clump size. When it is not wanted, Vetiver can be eliminated by ploughing or repeated burning or applications of herbicide such as roundup.

2. ***Vetiver hedge system is a simple, practical and very effective soil erosion control method.*** When planted on contour lines Vetiver hedges are very effective in controlling soil erosion in sloping canelands by trapping eroded soil moving down slopes and ensuring water is slowed and dispersed across the contour. The hedges system is very simple and can be easily established by farmers. Numerous sites were observed where Vetiver had resulted in the retention of soil, forming a terrace effect on sloping lands. An example is a site with 12% slope with a terrace of at least 1.4m formed over a 25 year period. In a simple demonstration trial, the Vetiver hedge system improved yield by 55% (from 31 to 48 t/ha) on a steep slope near Rakiraki, through its retention of soil on this otherwise stony profile.

All people interviewed - farmers, research and extension officers from the Fiji Sugar Corporation and soil conservation officers from the Fijian Department of Primary Industries considered Vetiver hedges system a simple and effective method of soil conservation.

3. ***Other applications of Vetiver hedges.*** In addition to its main use in soil erosion control in canelands, Vetiver was also used widely to stabilise embankments, terraces, to delineate farm boundaries and recently for soil erosion control for cash crops on slashed and burnt plots on steep hill sides. Application within Queensland on disturbed lands such as quarries, road embankments and subdivisions are substantial and will enhance overall catchment management.

4. ***Proper maintenance is needed.*** Although farmers agree that the Vetiver hedge system is very effective in soil erosion control, they are reluctant to establish new hedges. The reasons given are the hedges take up too much land, they hinder farm machinery operation and sometimes harbour rats. However, extension staff pointed out that all these can be overcome by providing simple and regular maintenance to the hedge. Most farmers do not look after their hedges, so after 20-25 years a single 0.3m row has spread to between 2.5 to 3m wide row and terraces built up by trapped soil reached up to 2m high.

Fijian experience has found that if the hedges were trimmed every 3-4 years to keep them at approximately 0.5m wide, and trapped soil spread uphill, the hedge system did not take up too much land, farm machinery could be driven across and it did not harbour pests such as rats. In Australia, this maintenance could be achieved by deep ripping the upper edges of the Vetiver contour, with respreading of soils upslope as might be required from time to time.

CONCLUSION AND RECOMMENDATION

Mr V Seru, the Officer in Charge of Land Use and Soil Conservation of the Fijian Department of Primary Industries made the following summary:

> "*There is no doubt in my mind that Vetiver grass provides a very effective means of soil erosion control on steeplands. It is not a weed, it is very simple and practical for farmers to use, it does not compete with crops but it is a living barrier and it needs proper maintenance to provide the maximum benefit*".

We are confident that the sterile Vetiver cultivar Monto, will very unlikely be a weed under all Queensland dryland and wetland conditions. Its effectiveness in soil conservation has been proven both in Queensland and overseas hence its release will only benefit Queensland primary industries and catchment management generally. **It is recommended that:**

* **work on existing field trials in the Johnstone and Atherton Tablelands be intensified,**

* **further demonstration sites established in North Queensland's cropping lands; and**

* **activities to develop and promote a Vetiver management system appropriate to various Queensland industries and environments be enhanced**.

REPORT ON THE POTENTIAL WEED PROBLEM OF VETIVER GRASS AND ITS EFFECTIVENESS IN SOIL EROSION CONTROL IN FIJI

Paul Truong and Colin Creighton

1. BACKGROUND

Vetiver grass (Vetiveria zizanioides, L) is a grass native to South and South East Asia. It has several attributes such as drought, frost and water logging tolerance, it can be established on soils with extreme levels of pH, Al, Mn, salt and Na and it is very deep rooted. When planting on the contour Vetiver forms a thick hedge acting as a living barrier to spread and slow down surface runoff.

Recognising its potential in soil erosion control, the World Bank has promoted its use as a soil conservation measure worldwide in the last 10 years. Dr Paul Truong, Principal Soil Conservationist, Natural Resource Management Unit, Division of Land Management has been working with Vetiver grass in the last 6 years. Field trials have shown that Vetiver is very effective in the stabilisation of gullies, embankments, waterways and steep slopes. Vetiver is also very successful in the reclamation of grossly disturbed lands such as quarries and salt affected lands. It acts as an effective filter strip in trapping sand, gravel and silt. Most importantly Vetiver has not set any seed in any of the Queensland plantings over the past 6 years from Cairns to Ipswich.

Although the sterile cultivar of Vetiver grass has been registered (as Monto Vetiver) and approved for release by the Queensland Herbage Plant Liaison Committee since August 1993, the Department has not released Monto Vetiver for public use due to the concern expressed by the Department of Environment and Heritage and the North Region's Regional Assessment Panel on its potential weed problem, particularly in the wet tropical coast of Queensland. Recently an international Land Use Consultant, in a letter to the Minister and the Senate Standing Committee on Landcare, urged the Department to release Monto Vetiver for public use as he has found it is

a very effective soil conservation measure and widely used in Africa and Asia.

With the above background a study tour to Fiji was carried out between 4 and 11 June 1994 with the following objectives:

1. To observe and assess the potential weed problem of Vetiver grass in the wet tropics, with particular reference to the sugar industry.

2. To assess Vetiver grass effectiveness as a soil erosion control measure and document those management practices required to maintain its effectiveness.

2. VETIVER GRASS IN FIJI

Vetiver grass was first introduced to Fiji from India probably late in the 1800's to provide thatching material for houses and it is still being used for roofing and walls. Although it was commonly used to stabilise embankments, terraces and to delineate farm boundaries, its application as a soil conservation measure, was not realised until early in the 1950's. An Australian company, Colonial Sugar Refinery (CSR), at that time had complete control of the Fijian sugar industry, from sugar cane growing to milling. As the sugar industry expanded, CSR was faced with a very severe soil erosion problem on sloping lands, particularly on the northern area of the main island around Rakiraki, where the land is very steep and rainfall is often of very high intensity.

Recognising Vetiver potential in soil erosion control, John Greenfield developed a soil conservation system for CSR, based mainly on the use of Vetiver grass. Greenfield with soil conservation experience in New Zealand and Australia, recommended the planting of Vetiver hedges in contour lines instead of the use of graded banks and waterways. This system was very practical from an implementation perspective (Fijian agricultural systems being labour intensive rather than mechanised) and very effective as a soil conservation measure. Vetiver also

conserved water increasing subsurface recharge as runoff water slowly seeped through the hedge instead of being diverted off the field. This greater accession to subsurface and groundwater has probably led to productivity improvements and an improved overall water management system with greater stream persistence in the dry.

CSR rigorously enforced this soil conservation technique on all sloping lands until the company left Fiji in the 1960's. Since then this system has not been enforced under the land use policy of the Government, despite steeper lands (up to 96% slope) being used for sugar cane production.

Records show that the first Vetiver contour hedge was established in 1952 in the Penang Mill area, near Rakiraki, and hedges over 40 years old are quite common in the area.

Fiji provides an ideal location to assess the potential weed problem of Vetiver grass, due to the following reasons:

1. Fiji has a tropical climate similar to the Queensland wet tropical coast: same latitude as Ingham, high intensity summer rainfall (1,800-2,000mm on the west coast and 3,800-4,200 on the east coast).

2. Vetiver was introduced into a new environment with no threats from native diseases or pests.

3. Vetiver has been in the country for more than 100 years.

4. Vetiver has been widely used as a soil erosion control measure for more than 40 years over a wide range of land uses, soil types and habitats.

3. VETIVER GRASS IS NOT A WEED IN FIJI

Extensive field inspections and interviews were carried out with farmers, extension officers, agricultural advisers, research officers and sugar mill executives on sugar cane growing area (west and north coast) and horticultural crops on the east coast. They all stated that Vetiver is not a weed in their cropping lands or in other natural environments including wetland habitats.

In fact they were all surprised when being asked whether Vetiver had become a weed in Fiji. They all emphasised that Vetiver remains where planted. Most sites visited are between 25 and 40 years old and Vetiver had only spread around its base through tillering. The seed situation is somewhat akin to sugar cane - while racemes form, no viable seed occurs and no seedlings become established. The only possibility where Vetiver could establish on site where it was not intentionally planted, was when a living clump of Vetiver was dislodged from its original site accidentally, such as with land slips and by road building machinery, as observed in the field. On such occasions Vetiver clumps only moved a short distance down the slope and remained there. Clumps lodged in locations such as creeks did not rapidly expand in size and would appear to be, as with Vetiver on dry land, very slow growing beyond the initial clump size. When it is not wanted, Vetiver can be eliminated by ploughing, repeated burning, or applications of glyphosate (Roundup) herbicide.

4. VETIVER HEDGE SYSTEM IS A SIMPLE, PRACTICAL AND VERY EFFECTIVE SOIL EROSION CONTROL METHOD

Vetiver grass is widely used in Fiji from simple road embankment and stream bank stabilisation, to contour hedges in sugar cane lands, and, slashed and burnt plots. It is a common sight on all the farms visited that farmers planted Vetiver to stabilise farm roads, across a depression to spread and slow down the runoff water and most often on contour lines to protect their vegetable crops from rill erosion.

According to the local extension advisers, Vetiver grass systems provide a very simple and practical solution to the soil erosion problem on small farms where both educational and

technological knowledge is minimal and labour intensive activities dominate.

Due to its very deep and extensive root system, Vetiver is very effective in stabilising both cut or filled embankments. Vetiver is also highly salt tolerant, and was observed growing on tidal flats next to mangrove and marine couch.

When established on contour lines at regular intervals, Vetiver forms a thick hedge which slows runoff water and traps eroded soil moving down the slope. The hedge also collects and spreads water across the slope resulting in considerable water conservation/recharge.

In all sugar cane growing areas, from the low slope fields around Lautoka to very steep hillsides around Rakiraki, terraces formed by Vetiver hedges up to 2m high are quite common. These terraces were formed by soil erosion upslope and subsequent trapping by Vetiver hedges downslope over a 25-40 year period. The spacings between hedges are relatively close (averaging 30-40m apart). The quantity of soil eroded and then trapped by the Vetiver hedge to form these terraces clearly demonstrates the effectiveness of the Vetiver hedge systems and the huge soil losses that otherwise would have occurred off those steeply sloping lands.

With limited knowledge of soil conservation practice, farmers sometimes took out old established hedges on very steep slope resulting in massive soil erosion within a few years. In general, fields protected by Vetiver hedges often have higher yield than those unprotected by the hedge. The protection of Vetiver hedges was often demonstrated in paddocks where the hedges had been removed. Within a few years sugar cane yield from these unprotected fields was drastically reduced, covered with weeds and the ground surface was littered with stones.

In a simple demonstration trial, sugar cane yield of 48 t/ha from a field protected by vetiver hedges was reduced to 31 t/ha from unprotected fields. This represents a 55% loss in production.

On the average, under the practice used on steep canelands in the Rakiraki region, good yields can be expected for up to 7 to 8 ratoon crops if the field was protected by Vetiver hedges. The

number of ratoon crops from unprotected fields was much reduced due to lower yield. Farm advisers attributed the loss of production to both soil and water losses on unprotected fields.

The recommended hedge spacing for the Rakiraki region varies with land slopes, from 20-25m for 44% slope to 75-100m for 11% slope.

In the high rainfall area on the east coast near Suva (3,800 - 4,200mm/year), under slashed and burnt practices, hedge spacing of 5m on a 67% slope has produced very positive results.

5. PROPER MAINTENANCE PROGRAMS ARE NEEDED

Although the effectiveness of the Vetiver hedge systems in Fiji are obvious, farmers are often very reluctant to establish new hedges and occasionally have taken out well established hedges. The main reasons given by farmers are that:

* Vetiver hedges take up too much land;
* terraces formed by the hedges hinder farm machinery operation; and
* the hedges sometimes harbour rats

Most of the hedges visited were between 25-40 years old. Where no maintenance was practised, the single row of Vetiver had spread from about 30-40cm width to 2.5-3m width, trapping eroded soil and forming terraces up to 2m high. Rat colonies sometimes established under this thick and lush vegetation, particularly where weeds, vines etc became established within the Vetiver hedgerow.

Local extension officers pointed out that under a proper maintenance program all these problems can be adequately overcome. On farms where the hedges were topped once or twice a year and their widths were trimmed to 0.3 to 0.5m every 3 or 4 years, the hedge system remains small and it does not encourage rat infestation.

On the question of terracing, farmers can rip the trapped soil every 3-4 years and spread uphill.

Alternatively soil levelling and Vetiver replanting could be carried out after two plantings (10-14 years). This operation should be done in alternate hedges leaving every second hedge to protect the lands while the new hedges are being established.

6. APPLICATIONS UNDER QUEENSLAND CONDITIONS

After more than 40 years of application the effectiveness of the Vetiver hedge system in soil conservation and land stabilisation in Fiji was clearly observed during this study tour.

(b) Research Results: In Queensland, research conducted over the last five years has established that:

- Monto Vetiver can be established under extremely adverse soil conditions. It can tolerate soil pH between 3.3 and 9.5, soil Al saturation more than 68%, soil exchangeable Mn higher than 578 ppm, soil salinity at EC_e = 17.5 dSm^{-1} (50% yield reduction) and it has survived soil salinity up to EC_e = 47.5 dSm^{-1} and soil sodicity at more than 12 meq%.

- Monto Vetiver has not produced any seeds over the last six years from plantings from Cairns to Ipswich and the Darling Downs. It also has not produced any seeds under wetland conditions near Cloncurry last year.

- Monto Vetiver can be established under a wide range of climatic conditions although it is extremely drought tolerant, it also flourishes under wetland conditions. It can be established in areas with annual rainfall higher than 450mm. It has survived ground temperature of -10^{o}C and heatwave conditions at more than 45^{o}C in north west Queensland.

- Monto Vetiver needs N and P fertiliser (DAP) at planting and during first year growth. No fertiliser is needed later if adequate soil moisture is available.

- Monto Vetiver is palatable to cattle, sheep, horses and wallabies. These animals graze Vetiver even when rhodes grass and other native grasses are available. The grazing pressure is extremely severe during the dry period as it is the only green feed around. Monto Vetiver is moderately digestible (52% IVD), with 1.36% nitrogen and 2.5% Potassium.

- Field trials have also demonstrated that Monto Vetiver is highly effective in stabilising gullies, steep embankments, dam wall stabilisation, quarry reclamation and in filtering silt debris in drainage lines.

(b) General Application: From the above results and experience, the following guidelines can be applied:

- *Soil types:* Monto Vetiver can be established on practically any soil type in Queensland from extremely acidic to highly alkaline and sodic soils. Its tolerance to Mn, Al and salt make it highly suitable for the rehabilitation of severely eroded lands especially salt affected lands.

- *Nutritional requirements:* Monto Vetiver requires moderate rates of N and P early in the establishment phase (1 to 2 years, depending on growing conditions). With very active micorhyzal activity in fully grown plants further fertiliser applications are not needed.

- *Climate:* Under Queensland conditions, rainfall is the only limitation to Vetiver establishment and growth. Overseas experience indicates that it can be grown in semi arid environment with annual rainfall between 300-400mm. Monto Vetiver has been successfully established in area with approximately 450mm in the last few years.

  Monto Vetiver is extremely drought tolerant, this is due to its massive and very deep root system which can reach down to 3.4m during its first year. Therefore

once established Vetiver can survive extremely dry and harsh conditions.

Severe frost browns off most of the top growth and provided soil moisture is available lower growth, including young shoots are not badly affected and sometimes continue to grow even under very cold conditions. Overseas work indicates that most growth ceased when soil temperature was lower than 15^{o}C.

- *Palatability:* Monto Vetiver is quite palatable to both domestic and wild animals, so protection during establishment phase is essential to encourage hedge formation during the first two years.

- *Establishment requirement:* In north and central Queensland planting can be done any time of the year provided either soil moisture is adequate on supplementary watering is carried out.

  In southern Queensland and the Darling Downs, planting is recommended between November and April. Where planting material can be harvested and planted within 48 hours, direct planting is recommended when the soil is wet or watering is available. Otherwise tubing is needed before planting.

  As Vetiver is very intolerant to shading, especially in its first year, weed control, particularly broad leave weeds, may be required. All pre-emergent and 2, 4D type weedicide can be used.

(c) Applications in Agricultural Lands: Works to date on agricultural lands have been concentrated on gully reclamation and waterways/drainage line stabilisation. Guidelines for these works will be presented in the Land Stabilisation section. The following table shows guidelines resulted from overseas work on cropping and grazing lands.

RAINFALL EROSIVITY	SOIL ERODABILITY	VERTICAL INTERVAL BETWEEN HEDGES (m)

		CROPPING INTENSITY		
		HIGH	**MEDIUM**	**LOW**
Low	Low	4	5	6
	Medium	3	4	5
	High	2	3	4
Medium	Low	3	4	5
	Medium	2	3	4
	High	1	2	3
High	Low	2	3	4
	Medium	1	2	3
	High	0.5	1	2

HIGH CROP INTENSITY

Annual crops with low or any residue cover.

MEDIUM CROP INTENSITY

Annual crops with moderate to high residue cover levels.
Semi permanent crops with moderate residue cover levels.
Permanent crops with moderate residue cover levels.

LOW INTENSITY CROPS

Annual crops with high residue cover levels.
Semi permanent crops with high levels of residue cover.
Permanent crops with high levels of residue cover.

Two major projects, one evaluates the effectiveness/suitability of Vetiver hedges on steep canelands in Queensland and the other on the flood/soil erosion/water conservation on the flood plain of the Darling Downs, are now in their second year. It is too early at this stage to draw any conclusion, preliminary results has demonstrated very favourable results especially in the canelands where Vetiver hedges were established as a substitute for contour banks on steep slopes (12-18%). On these steeplands conventional soil conservation measures such as contour banks and waterways are not readily accepted by cane growers as these structures often hinder their farm machinery operations. South African works have demonstrated that Vetiver hedge systems of soil conservation on steep canelands can be effectively incorporated into their cane farming systems. We are confident that a similar system can be developed for the Queensland cane industry not only for north Queensland but also for central and southern Queensland.

(d) Applications in Land Stabilisation and Reclamation: The followings are guidelines for the application of the Vetiver system in both agricultural and disturbed lands in Queensland.

- *Gully heads stabilisation:* One or two rows of Vetiver planted on contour line above gully head. The hedges should be established 3 to 5m above the head to allow for further erosion during establishment phase. On complex gully system where continuous rows are not practical, overlapping short rows can be planted instead. When the hedges are fully formed, runoff water will be spread out reducing flow velocity and time of concentration.

- *Fully floor stabilisation:* To stabilise and build up gully Vetiver hedges should be established across the gully at regular intervals. For large and fast flowing gullies, hedges should be established 10-20m apart. For smaller gullies larger spacings can be used and planting should be concentrated on badly eroded sections.

- *Embankment stabilisation:* These guidelines are also applicable to high drainage

line, waterways and creek banks. One Vetiver hedge should be established 1.0m from the top edge of the embankment and one hedge on the top of the bank. When slope length exceeds 1.0m, another row should be established in middle of the slope.

For long and steep embankment, Vetiver hedges should be established as follows:

SLOPE	VI (VERTICAL INTERVAL)
1:1 to 1.5:1	0.5 - 0.80m
>1.5:1 to 3:1	1.0m
>3:1 - 5:1	1.4 to 2.0m

Grassing by hand sown or hydroseeding methods should be used in conjunction with the Vetiver hedge system.

- *Filtering strip:* Vetiver hedge can provide a very effective filtering system to trap debris, coarse sediment (stone, gravel, sand) and also silt on water course and drainage lines. Vetiver row spacing varies with slope gradient, flow volume and sediment load. This filtering system has been very effective in trapping sand and gravel on a drainage line of a working quarry near Brisbane.

- *Other potential applications:* With its tolerance to extreme levels of soil pH, Al, Mn, Na and moderately tolerant to salinity Vetiver hedge system would provide a very effective means of rehabilitation of mine spoils and tailings. Other applications would be in the trapping of manure from runoff water from feedlots, piggeries and dairies.

(c) Maintenance Strategies: As observed in Fiji, unless a comprehensive maintenance was developed for the Vetiver system for each industry, their effectiveness and acceptance by farmers would be limited.

Weed control, fertilisation and supplementary watering are required during the establishment phase.

On grazing lands, grazing should be allowed only in well established hedges.

On cropping land hedges should be trimmed occasionally to keep hedge width to approximately 0.5m. To avoid the terracing effect caused by the accretion of eroded soil, methods used to maintain contour banks can also be used for Vetiver hedges, where excessive build up of silt is moved and spread upslope with a grader every 3-4 years.

Further Research, Development and Extension R&D to date has demonstrated the effectiveness of the Vetiver systems on a wide range of applications under very difficult growing conditions, further investigations into other applications are needed such as its water conservation potential in cropping lands, the reclamation of salt affected lands and revegetation of scalded alluvial flats along the major river systems of western Queensland. But most importantly, the suitability of the Vetiver hedge system for soil erosion control in the sugary industry, not only the wet tropical coast, but also in central and southern Queensland should be investigated. Appropriate hedge management practices need also to be worked out for each industry.

7. CONCLUSION AND RECOMMENDATIONS

Mr V. Seru, the Officer in Charge of Land Use and Soil Conservation of the Fijian Department of Primary Industries made the following summary:

> "*There is no doubt in my mind that Vetiver grass provides a very effective means of soil erosion control on steeplands. It is not a weed, it is very simple and practical for farmers to use, it does not invade the crops but it is a living barrier and it needs proper maintenance to provide the maximum benefit*".

We are confident that Monto Vetiver, the sterile cultivar, will not beome a weed under all Queensland dryland and wetland conditions. Its effectiveness in soil conservation has been proven both in Queensland and overseas. Its release will benefit Queensland primary industries and catchment management generally.

It is recommended that:

- **Work on existing field trials in the Johnstone and Atherton Tablelands be intensified**

- **Further demonstration sites established in North Queensland's cropping lands and**

- **Activities to develop and promote a Vetiver management system appropriate to various Queensland industries and environments be enhanced**.

FIJIAN SUGAR INDUSTRY, CATCHMENT AND FISHERIES MANAGEMENT

As noted in the introduction, the opportunity was taken to examine the Fijian sugar industry, assess the applicability of catchment management and Landcare concepts and evaluate progress with the ACIAR funded fish stock assessment project. Attachments on each of these aspects are shown on Appendix IV.

BRIEFLY

(i) Catchment management in the Queensland model of community involvement is seen as inappropriate to Fiji at this time. However Landcare type activities on a local farmer group basis and Natural Resource Management focus on an Agency/Administrative division basis may be appropriate. This could be facilitated through continued close cooperation with mutual benefit to both Fiji and QDPI.

(ii) The Fijian cane industry is facing challenges from both natural resource sustainability and productivity improvement contexts. Training of Fijian staff through work experience in QDPI/BSES is recommended, with follow up initiatives in Fiji possible and of mutual benefit.

(iii) The ACIAR funded Fish Stock Assessment project is proceeding well, given the bounds of logistical constraints when working in itinerant fisheries. However the long term application and usefulness of this data in terms of fisheries management, regulation and enforcement is unclear, given the limited management/enforcement opportunities available to the Fijian Government.

APPENDIX I

Photographs illustrating various points discussed in the report.

APPENDIX II

The followings are summaries of the discussions/interviews with Fijian officials.

1. Mr Jai Gawander, Senior Research Agronomist, Sugarcane Research Centre, Fijian Sugar Corporation (FSR), Lautoka.

- Vetiver grass is not a weed in any sugar cane growing areas of Fiji. Jai has never heard farmers complaining about Vetiver as a weed in contrast to their complaints about guinea grass, sensitive weed and climbing plants as weeds in their crop.

- However farmers are reluctant to plant new hedges as they cannot drive/use equipment across the hedges. This was due to the lack of hedge maintenance and soil spreading. Vetiver hedges need trimming every 4-5 years to check its spread which can be as wide as 2.5-3m after 30-40 years. Hedges form terraces up to 1.5m high and require soil respreading at intervals as a function of soil accretion behind hedges.

- The only occasion that Jai observed Vetiver becoming established where it was not planted was when it was moved as a clump by landslides on steep slope or dislodged by machinery.

2. Mr Jonathan Subarmaniam, Chief Extension Officer, Sugarcane Research Centre, FSC, Lautoka.

- He has used Vetiver for 35 years for soil erosion control, gully and steep slope stabilisation, road embankments, marking of farm boundaries.

- If not properly maintained Vetiver will form benches after 20-30 years of soil accretion.

- Soil levelling and Vetiver replanting should be carried out after two plantings (10-14 years). This operation should be carried out on alternate hedges, leaving every second established hedges to protect the lands while the new hedges are being established.

- Vetiver is not a weed and only spread by new plantings.

- No die back had been observed in old clumps, up to 35 years after planting.

3. Mr Asish Sharma, Field Officer and Mr Kishne Kumar, Extension Officer, FSC Office, Mota District, Ba mill area.

- Vetiver is not a weed after more than 25 years application as soil erosion control measure in the region.
- Vetiver only spread from planted single row to 2.5-3m width after 35 years.
- Vetiver did not spread by itself to swamps or other habitat.
- Vetiver only moved down slope when a big clump was dislodged and washed down slope.
- Vetiver's main uses are for contour planting, stream bank and road cutting stabilisation.
- Vetiver hedges need topping every year and trimming every 3-4 years to reduce row width.

4. Mr Uday Singh, large land owner, ex Member of Parliament and Community leader.

- He has used Vetiver for soil erosion control for more than 40 years.
- Vetiver presents no weed problem on his farm - only vegetative spread laterally from the original clumps.
- Vetiver is effective in controlling rill and gully erosion and steep bank stabilisation.
- Vetiver needs maintenance and with appropriate maintenance there will be no problem with rats and other pests.
- Uday wants to encourage the local community to plant more Vetiver hedges. Farmers are reluctant due to lack of knowledge of soil conservation, limited extension effort and most particularly, the land ownership system of Fiji which does not encourage land stewardship.

5. Mr Vinay Hand, Farm Adviser, Malau Sector, Penang Mill, Rakiraki.

- Sugar cane is grown on very steep land in the Rakiraki region. Most of the crop is grown on slopes between 20-60% and on one site up to 96% (43^{o}). Rainfall intensity is also characteristically high (Table 1), producing massive soil erosion on steep slopes. The Vetiver hedge system was first introduced into this region by CSR with records of first contour hedge planting in 1952. Since the departure of CSR, soil conservation measures have not been enforced and farmers have often removed established Vetiver hedges, resulting in disastrous soil erosion and declined sugar production.

- Farmers are reluctant to establish new hedges. Reasons given are: old hedges harbour rats and high terraces (formed from soil accumulated by Vetiver hedges) hinder farm machinery operation. Effectively a lack of maintenance of the hedge was the real problem.

- Rats are found only on very old and unmaintained hedges. With good maintenance rats are not a problem.

- Land slips are more common in areas where no Vetiver was planted.

- Land with Vetiver hedge systems often produce more ratoon crops of high productivity than where Vetiver was not planted.

- Vetiver has not become a weed in the area.

- One year old Vetiver hedges are quite effective. However the hedge system provides maximum effectiveness after 2-3 years.

- On one farm, where the farmer has taken out 3-4 rows of well established, 20 year old contour hedges on a 45% slope, massive soil erosion occurred within two years, removing most topsoil and exposing a thick cover of stone and rock. This farmer will replant Vetiver hedges next year.

- On another farm, two paddocks of the same slope and soil type were trialled. One with Vetiver and one without. A very good third ratoon crop was harvested in the paddock where the Vetiver hedge system had been kept. On the paddock where the hedges were removed, weeds predominated and sugar cane production was low.

- In a simple demonstration trial, sugar cane yield was improved by 55% (48 t/ha) as compared with a control plot (no Vetiver) where only 31 t/ha were harvested.

- In general, under the Vetiver system good yield can be expected for up to 7-8 ratoons, while yield from unprotected fields reduces with each ratoon crop.

- Recommended hedgerow spacings for the Rakiraki region are as follows:

SLOPES		SPACINGS BETWEEN ROWS (m)
DEGREE	PERCENT	
20	44	20 - 25
15	33	30 - 35
10	22	50 - 60
5	11	75 - 100

TABLE 1: RAINFALL - RAKIRAKI

MONTH	1988	1989	1990	1991	1992	1993	AVERAGE
January	205.2	300	216	476	265	372	305
February	460.4	868	184	154	194	376	373
March	251	177	739	421	264	518	395
April	365	40	69	160	262	197	243
May	320	289	16	9.6	85	260	163
June	66	60	188	14	92	2.6	70
July	94	65	89	10.8	92	18.6	61
August	10.8	46	96	71.4	20	151	66
September	19.5	12	52	163	17	10	46
October	98.2	234	39	35	25	10	75
November	49.6	42	290	87	111	189	128
December	817.1	99	206	102	593	167	331
TOTAL	**2759**	**2681**	**2189**	**1706**	**2024**	**2275**	**2272**

6. Mr Osborne, General Manager, Penang Sugar Mill, Rakiraki.

- CSR had complete control of the sugar industry as landlord and also as mill owner. CSR has promoted strict soil conservation guidelines for sloping land. Either land was taken back or crop was not accepted by the mill if farmers did not comply to soil conservation guidelines.

- Native Land Board via the local tribe is now the landlord. The Board only administers the lease and has not developed a comprehensive land use policy. The mill has only a commercial link with farmers - receiving and milling product.

- Soil conservation ethics has not been enforced since CSR left.

- Although the mill's policy is to encourage more Vetiver planting, it can only be done through persuasion not enforcement.

- The extension method only has had high success rate with new farmers, not old established farmers.

- 75-80% of sugar cane crop in Penang Mill area is grown on slope higher than 11% (5^{o}).

- Vetiver is not a weed in the region and it is a very simple and effective means of soil erosion control.

- Like sugar cane, Vetiver flowers but it produces no seeds.

- When established on contour lines, Vetiver hedges also provide a good water conservation method.

7. Mr Vili Seru, Senior Land Use Officer, OIC Land Use Planning and Soil Conservation, Department of Primary Industries, Koronivia Research Station, Suva.

- Mr Seru was a Soil Conservation Adviser with CSR in the 1950's and he has extensive knowledge on the Vetiver hedge system developed by John Greenfield of CSR.

- Since CSR left, the Native Land Board has no policy on land use. Therefore strong soil conservation ethics employed by CSR have been neglected.

- CSR limit on slopes without protective soil conservation measures was 12%, beyond which contour Vetiver hedges were needed.

- Under CSR, no contract for milling of product was provided if Vetiver contour hedges were not planted on steep slopes. This was enforced by very well trained extension officers.

- Vetiver is very effective in soil and water conservation.

- Vetiver grass has not become a weed even in the high rainfall region of the east coast (3,800-4,200mm per annum).

- Vetiver has not spread to swampy lands.

- To obtain its maximum effectiveness the Vetiver hedge system needs to be maintained properly. Only simple topping and trimming are needed.

- When slashed, the clippings provides very good mulch for horticultural crops.

- Vili is now investigating the application of the hedge system under slashed and burnt conditions on slopes averaging 67% (30^{o}).

- When planted 5m apart, first year results showed significant reduction in soil loss.

- With effective soil erosion control Mr Seru expected farmers can significantly prolong their slashed and burnt cycle, leading to higher productivity, reduced disturbance to natural systems and reduced soil erosion and subsequent impacts.

- Mr Seru summarised the use of Vetiver grass in Fiji as follows:

  "*There is no doubt in my mind that Vetiver grass provides a very effective means of soil erosion control on steeplands. It is not a weed, it is very simple and practical for farmers to use, it does not invade the crops but it is a living barrier and it needs proper maintenance to provide the maximum benefit*".

APPENDIX III

Extension pamphlet prepared by the Sugarcane Research Centre for the Fiji Sugar Corporation Extension Services.

APPENDIX IV

A. CANE PRODUCTION & PROGNOSIS FOR THE FUTURE.

1. BACKGROUND

Fiji's Sugar Industry has proceeded through a series of changes including the withdrawal of the Colonial Sugar Refinery (CSR), the implementation of key recommendations of the Landell Mills Report, the development and consolidation of the Fiji Sugar Corporation and the implementation of the Native Titles Act.

Perhaps the two greatest challenges currently facing the Fijian Sugar Industry are:-

* the achievement of sustainable natural resource systems on farms of very small acreages and under generally leased arrangements from native owners; and

* the attainment of increased farm production and milling efficiencies to meet the foreshadowed dismantling of guaranteed price [with estimates of up to 300% increases in production suggested as being required].

Brief comments on both of these issues follow.

2. CURRENT STATUS OF FARM ACTIVITY

Farm size generally ranges from 4 to 10 ha with about 80% of a farm under cane. In the Raki Raki area Extension Officers recommend ratios as follows :-

20% plant
20% 1st return
20% 2nd return
20% 3rd return
20% fallow and/or small crops for cash market

Nevertheless, many farmers return for longer periods, with up to 18 returns recorded. Production techniques and general farm management vary. As an example in one sector of the Raki Raki area, 71% of the growers by area are Fijian and 29% Indian whereas about 70% of the production is off the 29% Indian farms. Production figures vary from about 210 tonnes/ha to less then 30 times/ha. In total there are about 23,800 farmers, with less than one third of these producing 2M of the 3M tonnes total production. CCS seasonal average for 1993-94 was 12.9 for the Ba Mill and apparently similar for other Mills.

Much of the farming is undertaken using oxen. Hire of tractors is limited and costs about $30.00/acre for ploughing and $15.00/acre for harvesting. In average, costs of production are estimated at $20.00/tonne, which, off a 4 to 6 ha farm implies an annual profit of about $9,000. Small crops (cash economy, local markets) supplement many farmers incomes.

Overall, it was suggested that cane farmers owe an estimated $200M. Payments for product are by instalment 3 times over the year. FSC assists with the provision of fertiliser and the staple of rice. Levies are taken off the top of FSC profits for the Growers Council (about $0.27/tonne), research (about $0.5M/annum) and for ancillaries such as marketing.

Land Conservation Boards, previously an important component of the farmer - mill extension program appear to be inactive and as yet, not replaced by a suitable land management system for the Native Land Trust. Integrated drainage/waterway management is now the responsibility of the Ministry of Primary Industries, activities of which are funded by a small annual levy. However, the scale of the problem is such that integrated water management/soil erosion control, as in Queensland, has rarely been implemented.

FSC employ Extension & Farm Advisory Officers based at each Mill. These Officers noted that adoption rates were often low and they were looking to new extension techniques by which production and sustainability messages could be got across to farmers and adoption rates increased accordingly.

Comment: While the above summary of the Cane Industry suggests that various production, natural resource management and organisational challenges remain to be met, it should be remembered that the Fijian Cane Industry has gone a long way from the days circa 1960's when CSR apparently often reported to the farmers that particular crops were only good for molasses and that the farmers owed the Mill for milling costs!

RECOMMENDATIONS

For DPI/BSES to assist the Fijian Sugar Industry in meeting the challenges facing the industry, as listed previously, two areas of joint action appear appropriate. These are:-

A1 **assistance in training of FSC and Ministry of Primary Industries staff through on-the job exposure to QDPI/BSES activities.**

[Activities nominated to be of interest to FSC staff included soil assessment, land use mapping, breeding techniques, integrated water management systems, extension techniques, property management planning, fertiliser - plant relationships, financial management and general soil erosion control/sustainability concepts such as Landcare/Catchment Management].

A2 **design and implementation of a joint QDPI/BSES and Ministry of Primary Industry/FSC pilot demonstration project.**

[Possibly ACIAR funded, which capitalised on the outcomes of the training program, as outlined in (i) and demonstrated to farmers the value of an integrated/property management planning approach on a sub-catchment scale.]

It is recommended that Action (i) be pursued with FSC in the first instance, with Action (ii) being a possible outcome of the training activities and undertaken in the context of the .. recommendations provided in Attachment 2.

B. CATCHMENT MANAGEMENT/LANDCARE IN FIJI

1.BACKGROUND

As part of the 1 week vetiver grass appraisal and subsequent 3 days (weekend and leave), the concepts of catchment management/landcare were discussed with key Fijian authorities and

contacts. Following is a brief summary of the results of these discussions:-

2. CATCHMENTS INSPECTED

During both the Vetiver field component and subsequent 3 days, wherever opportunities were presented, major river catchments were inspected. These include:-

* Ba River Catchment
* Wainia River Catchment
* Navua River Catchment
* Sigatoka River Catchment; and
* Maro River Catchment

Time precluded inspection of the other major catchment on the main island - Nadi River Catchment.

3. ISSUES & PROBLEMS

Tenure & Land Administration: At the outset it should be noted that tenure places particular constraints on the application of a Queensland style ICM system to Fiji. Canefarms are generally very small, between 4ha and 10ha total area (with about 80%-90% under cane cultivation). Title is in three major components:-

* Freehold - eg: some residential areas, some (few) canefarms in excess of 100ha;
* Native Title - leased by Fijians and Indians off the local Fijian village, with various lease terms, but virtually all up for reassessment in about 3 years time.
* Crown title - leased off the Crown and of various terms up to 75 years.

Native title predominates and comprises in excess of 70% of the main island.

Two constraints to a Queensland style ICM approach are immediately apparent. Firstly, the farm size, communication networks and social aggregations implies locally based groupings under the Landcare model are likely to be more appropriate. Secondly, with much of the land leased, the "tyranny of the commons" is well evident, with many not only lacking in motivation to maintain leased lands but also faced with uncertainty as to their future on these leased lands.

Recommendation B1: That subject to discussions with the Native Land Trust a Landcare - type approach be trialled in a pilot area, involving both landholders and leaseholders as well as key decision makers within the local community.

Soil Erosion On Farms: Detail on vetiver grass and soil erosion control is provided separately. In summary, while the majority of land is cultivated on the contour, management of vetiver grass has lapsed in recent years. Overall however, while excessively high slopes are cultivated, it is suggested that soil erosion off caneland may not be the major contribution to sediment budgets. This relates to the cultivation practices, using oxen rather than tractors, the green cane manual harvesting system and the general maintenance of cover on canelands during wetter months. Nevertheless, soil erosion control on canelands could be improved. Aspects for improvement include:-

* maintenance/re-establishment of vetiver practices;
* control (restriction?) over cultivation of high slope lands (often in excess of 30°);
* provision of catchment integrated grassed waterways and runoff systems;
* vetiver based sediment control traps at strategic points on waterways, such as exits to creeks/rivers; and
* extension of techniques / general stewardship ethic through application of the Landcare model.

Soil erosion on lands under small crops (eg. ginger, taro, cassava, cabbage, tomatoes, melons etc) varied. In many of the upper catchments, crops were grown in small plots with native vegetation surrounding them. In mid catchments, small alluvial fans were intensively cropped and presumably are subject to soil erosion during major rain/flood events. Lower slope floodplains in the Wainia Valley, used extensively for dairying exhibited signs of massive riverbank erosion, presumably a major source of sediment in the river downstream of Nausori.

Recommendation B2: That improvements in caneland management as outlined above be continued and pursued through the on farm extension activities of FSC Officers with assistance from Ministry staff as might be appropriate and with assistance from QDPI/BSES as might be requested from time to time.

Recommendation B3: That subject to further discussions with the relevant Fijian authorities, QDPI/BSES in consort with FSC and Ministry of Primary Industries consider approaching ACIAR with an on-farm targeted soil erosion assessment and control caneland productivity demonstration pilot project for a selected sub catchment in the Raki Raki or Lautoka area. [The Steering Committee for such a project could be a pilot Divisional National Resource Management Team as discussed in subsequent recommendations].

Soil Erosion - Infrastructural and Residential Development: Several infrastructual and residential developments were observed during field work. Soil erosion control techniques were generally lacking and equate to Australian conditions some 5-10 years ago, albeit in some cases, still occurring in Australia.

Examples of these developments included the road and bridge works on the Kings Road near Nanukuloa, tourist resort development on the coast from Nananu-i-Ra, and residential development in Suva. Soil erosion from such sites is likely to be substantial and given the coastal location of much of the Kings Road, is likely to directly impact marine resources.

During discussions reference was made to various QDPI and NSW Soil Conservation publications. Copies of these will be forwarded to key contacts.

Recommendation B4: That ongoing liaison be established to provide technical data on aspects such as road works stabilisation as it becomes available in Queensland.

River Management: The key areas of concern appear to be river bank erosion and sedimentation / navigability / flooding. Dredging is underway in the Wainia and Ba Rivers. Unfortunately due to logistic problems, a field trip to the lower Wainia River for Saturday 11 June 1994, had to be cancelled.

From discussions with Fijian authorities, it would appear that an integrated catchment perspective to river management has yet to be implemented and parallels somewhat the position and approach of bodies such as Queensland River Trusts prior to their current development of River Management Plans.

Recommendation B5: That the mid / lower slope components of the Waimia valley be targeted as a high priority for any riverbank erosion and control projects that the Fijian authorities might wish to pursue using Queensland techniques and expertise (Queensland information and techniques being provided to Fijian authorities).

Recommendation B6: That aspects such as river management be key areas for discussion between agencies within proposed interdepartmental forums as referred to under the following heading of Natural Resource Management.

Nearshore Reef Management & Nutrient Management: Overall, loss of fertilisers from canelands may not be an issue, fertiliser application rates being generally low. No data on this source of nutrients or of nutrients ex: sewage treatment etc, was readily available.

Management of fishing activities on reef areas is discussed separately. In terms of tourist impact, as in Australia, much could be done to minimise damage (eg. marked paths for reef walking, major resorts, Coral Coast; eg: increased extension activity/code of practice;)

Recommendation B7: Selected tourist/reef management documents be forwarded in cooperation with GBRMPA.

Weedicide & Pesticide Management: Due to the expense of these products, and the comparative cheapness of labour, limited application occurs in Fiji. The only application observed was backsprays in vegetable crops of the Sigatoka Valley. FSC commented that use in sugar cane is minimal to nil.

Natural Resource Management Ethic: Overall, there appears to be a gaining awareness amongst agencies for integrated natural resource management. This awareness is not shared by the community. [The lack of television and exposure to "environmental
issues" may be part of this lack of awareness amongst the community]. It is suggested that major gains might be achieved through cooperative interagency activity, possibly convened under the auspices of the Native Land Trust for key regions/catchments or possibly the 4 Administrative Divisions. Such forums might be able to replace some of the functions of the previous Land Conservation Boards and cover the range of issues across agencies as briefly listed in this report.

Recommendation B8: That NRM related information such as the Discussion Paper for the proposed Act and Catchment Strategies be provided to Fijian agencies.

Recommendation B9: That subject to further discussions with Fijian authorities, it might be appropriate to approach ACIAR with a pilot Natural Resource Management Forum/ integrated Land/ Water Management proposal.

CONTACTS

Key contacts included:-

* Fijian Sugar Corporation	-	Jone R Sovasova, General Manager, Field Services
	-	Jai S Gawander, Acting Manager, Research
	-	Jagdish C Raj, Chief Accountant, FSC
	-	John Osborne, General Manager, Penang Mill
* Ministry of Primary Industry	-	Peniasi Kunatuba, Director, Fisheries
	-	Krishna Swamy, Senior Fisheries Officer, Resource
	-	Suresh Chand, Senior Fisheries Officer, Western Division
	-	Ram, Manager, Western Division
* Private Landholders & Leaseholders	-	Sugar Cane farmers, varying from leaseholders (-~6ha) to a freehold grower (>100ha).

C. FIJIAN FISHERIES AND REVIEW OF THE ACIAR PROJECT

BACKGROUND

An ACIAR funded project titled "Application of Underwater Visual Census to Assessing Reef Fish Stocks in the Tropical Pacific" is underway in Fiji and the Solomon Islands with participation from other centres in Tropical Pacific. Hector Fuentes the QDPI lead operator in the project was in Fiji for part of the visit by Creighton and Truong so the opportunity was taken to assess progress in this project.

ACTIVITIES UNDERTAKEN AND ISSUES FOR FIJIAN FISHERY MANAGEMENT

Discussions were held with a range of divisional and Fijian Fisheries staff. One half day's field work involving interviews of fisherman and collection of data on daily catches was also undertaken in the Lautoka - Ba area.

Key problems facing the Fijian nearshore fisheries include:

- continual (and illegal) use of dynamite;
- fish kills in rivers and nearshore areas - suggested to be associated with sugar mills effluent and other sources of deoxygenated water;
- loss of habitat (riverine, estuarine and nearshore coral) through excessive sedimentation;
- some limited loss of mangroves associated with tourist/infrastructual developments and dredge spoil disposal;
- very limited data on fish stocks, effort and catch;
- a lack of a stewardship ethic amongst fishermen, the community generally, Fijian land/water holders and tourist operators;
- an apparent decline in tuna stocks (eg skipjack), of particular importance given the tuna fishery is the 3rd largest foreign exchange income earner; and
- very limited enforcement capability, and probably, given the itinerant nature of the fishery, very limited likelihood for enforcement activities to be cost-effective.

EVALUATION OF THE ACIAR PROJECT

Within the bounds of logistics when working in itinerant fisheries, the ACIAR project will give some broad indications of stocks on particular coral reefs. Probably equally important, the project provides an opportunity to train Fijian personnel in fisheries assessment activities.

However, the application of this stock assessment data to fisheries management in unclear. There is limited potential for enforcement to be funded and then to be cost-effective. It would seem the emphasis of fisheries management must be on extension - developing a stewardship ethic amongst the fishermen (difficult given their somewhat hand-to-mouth existence) and amongst the Fijian land/water holders, who to some degree regulate entry into their particular water area. Working with these Fijian land/water holders via the Fijian Chief system would seem to be the most appropriate strategy.

RECOMMENDATIONS

C1. The during the forthcoming meeting of all participants in Cairns a half day of the agenda be given over to discussions on Fisheries Management and Applications of the results of the ACIAR project - all participating nations.

C2. That subject to negotiations with Fijian authorities, Krishna Swamy stay in Australia for about 2 weeks after the Cairns workshop to receive training and be involved in discussion in the following issues:

- Water quality management
- Nutrient/catchment management
- Fish kills and regulation
- Fisheries Management approaches (including proposed Qld legislation)
- Fisheries enforcement - role in reef environments; and
- Fish disease - detection and control.