

# FEEDS AND FORAGES IN PACIFIC ISLAND FARMING SYSTEMS

by

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## 1. Introduction

## 2. Livestock numbers and distribution in the Pacific Islands

## 3. Production systems

## 4. Some cattle production systems in six countries

Fiji

Samoa

*Village beef production*

*Large-farm production system*

Papua New Guinea

Tonga

Solomon Islands

*Smallholder sub-sector*

*Intermediate communal sub-sector*

*Large scale commercial sub-sector*

Vanuatu

*Smallholder sector*

*Estate plantation sector*

## 5. Feeding systems

Cut and carry

Grazing systems

*Rotational or paddock grazing*

*Strip grazing*

Cattle grazing open pastures

Integrated animal and tree cropping systems

*Crop/livestock systems*

*Cattle under coconuts*

Role of forage and feed in the systems

Crop residues and agro-industrial by-products

Legumes and trees

## 6. Descriptive and analytical data on some forages (grasses and browses)

### Some common grasses found in the Pacific Islands

Batiki grass (*Ischaemum aristatum*)

Guinea grass (*Panicum maximum*)

Signal grass (*Brachiaria decumbens*)

Para grass (*Brachiaria mutica*)

Nadi blue (*Dichanthium caricosum*)

Setaria grass (*Setaria sphacelata*)

## Some common browse plants of the region

Calliandra (*Calliandra calothyrsus*)

Erythrina spp.

Gliricidia (*Gliricidia sepium*)

Leucaena (*Leucaena leucocephala*)

Cassava leaves (*Manihot esculenta*)

Sweet Potato leaves (*Ipomoea batatas*)

Vi or Vie plant (*Spondias mombin*)

*Flemingia macrophylla*

*Moringa oleifera*

Mulberry (*Morus alba*)

*Sesbania grandiflora*

Legumes as feed

## 7. Descriptive and analytical data of some feed resources

Crop residues

Agro-industrial by-products

Cocoa by-products (*Theobroma cacao*)

Noni juice extract waste (*Morinda citrifolia*)

Coffee pulp meal (*Coffea arabica*)

Copra cake/meal (*Cocos nucifera*)

Brewers' grains

Palm kernel meal

Molasses

Cereal by-products

Rice bran, pollard and polishing

## 8. Impact of the use of the feeds/forages

Some economic data

*Country studies*

Feeds and forages likely to increase in use and why

## 9. Conclusion

## 10. References

Elephant or Napier grass (*Pennisetum purpureum*)  
 Guatemala grass (*Tripsacum laxum*)  
**Some common creeping legumes found in the Pacific Islands**  
 Centro (*Centrosema pubescens*)  
 Hetero (*Desmodium heterophyllum*)  
 Mimosa (*Mimosa pudica*)  
 Puero (*Pueraria phaseoloides*)  
 Siratro (*Macroptilium atropurpureum*)

## 1. Introduction

There are many grazing systems in the Pacific Island countries (PICs) – see map; for a target level of animal performance from forage, daily ingested young forage leaf and stem dry matter should possess specified levels of protein (nitrogen), metabolisable energy, phosphorus, calcium, potassium, magnesium, sulphur, sodium and trace elements. The quantity and quality of pasture available to different classes of ruminants in the region varies considerably. Besides environmental factors, others such as inherent nutritive (and sometimes anti-nutritive) characteristics of selected pasture plants, quality of management, weeds and grazing systems and animals contribute to affect pasture quantity and quality.



**Map of the Pacific Island countries**

Ruminant livestock can subsist on forage alone but, to achieve this, available forage for year round feeding should be of good quality to meet the nutritional requirements of grazing animals so as to attain their genetic potential. With good management quality forage could be available year-round, where this is lacking alternative feed should be provided.

Ruminant livestock rely mostly on native and some introduced grasses along with crop residues in the PICs (Macfarlane, 1998). Maximum animal production from

an environment or farming system is based on a mix of the best-adapted legumes and one or more grasses while the primary factors which maximize digestible nutrient intake and hence, animal performance (growth, lactation, reproduction and work) are: (i) the quantity of feed; (ii) its nutrient content, and (iii) digestibility.

Most pastures in the PICs are characterized by large fluctuations in quantity and quality of herbage available to free-ranging ruminants. Such fluctuations influence intake and production, thus animal performance in terms of reproduction, growth, traction, milk and meat in the region is generally less than half their genetic potential due to poor quality forage.

Details of the pasture and forage resources of fifteen (15) countries and territories in the Pacific have been summarized in a series of **Country Pasture Profiles** which should be consulted for more detailed information.

## 2. Livestock numbers and distribution in the Pacific Islands

The Pacific island countries have no long history of grazing livestock management and production. Despite this, there are now substantial numbers of ruminants (**Table 1**) in the region. Ruminant production is promoted by all governments for import substitution, self-sufficiency in meat and a source of income for farmers. Ruminant livestock form an integral part of the rural life of the PICs because, at village level, raising cattle, goats and sheep provide many benefits. They are assets that are readily saleable and relied on for income and for meeting large payments such as school fees. In countries which have suffered cyclone disasters, such as Samoa and Vanuatu, smallholders increasingly view cattle as more important than tree crops and relatively cyclone-proof. Smallholders are involved with several species (Macfarlane, 1998).

Ruminant livestock are numerically less significant than non-ruminants but they have the potential to increase smallholder incomes. The countries in the region currently graze 664,900 beef cattle, 30,100 dairy cattle, 24,900 sheep, 258,000 goats, 12,000 farmed deer and 110,000 feral deer (in New Caledonia) (Macfarlane, 1998). Beef cattle, the predominant ruminants, are raised mainly for meat and secondarily for draught, especially by the Indo-Fijians in Fiji. There are dairies in Fiji, Tonga and Papua New Guinea; sheep in Fiji and Papua New Guinea and an important goat industry in Fiji and Vanuatu (Macfarlane, 1998). Vanuatu has the highest number of cattle per person amongst countries in the Pacific Islands.

<b>Countries</b>	<b>Ruminant type (thousand head)</b>				
	<b>Beef cattle</b>	<b>Dairy cattle</b>	<b>Sheep</b>	<b>Goats</b>	<b>Deer</b>
<b>Major</b>					
Fiji	254	26	7.5	180	-
New Caledonia	125	1	4	17	12
Papua New Guinea	91	-	12	6	-
Samoa	20.5	0.5	-	1	-
Solomon Islands	9.5	-	-	1	-
Tonga	5.8	2.2	-	14	-
Vanuatu	151	0.4	1	12	-

<b>Sub-total</b>	<b>656.8</b>	<b>30.1</b>	<b>24.5</b>	<b>321</b>	<b>12</b>
<b>Minor</b>					
Cook Islands	0.4	-	-	7	-
French Polynesia	7	-	0.4	16	-
Micronesia	0.5	-	-	4	-
Niue	0.1	-	-	-	-
Wallis & Futuna	0.1	-	-	-	-
<b>Sub-total</b>	<b>8.1</b>	<b>0</b>	<b>0.4</b>	<b>27</b>	<b>0</b>
<b>Total</b>	<b>664.9</b>	<b>30.1</b>	<b>24.9</b>	<b>258</b>	<b>12</b>
Source: Macfarlane, D.A. (1998).					

### 3. Production systems

Land mass, pressure on land for other activities; culture and tradition, size and number of livestock and feed availability determine the type of production system (Aregheore, 2004a). Ruminant livestock in greater or lesser numbers are associated with production systems which differ from one country to another. The smallholder unit (tethering and free range) is common in all countries, always relying on pasture. Foliage of shrubs is used to supplement low quality forage to meet requirements for maintenance, fattening and other physiological processes. Livestock production systems can be classified as free range, tethering, fenced and penned.

**Free range** – The simplest system where animals roam freely finding their feed and are thought of having no production cost because they exist and reproduce without contribution or inputs from the owner. This system requires little or no skill and involves minimal labour (Ramsay, 1999). Animals are very hardy and are products of their own environment (Aregheore, 2002a).

**Tethering** – Animals are tied to a tree or stake but have to be moved often to ensure that they can reach feed. This system requires more input than free range but does not guarantee a greater output; it is very common among the Indo-Fijians and in the Cook Islands (Figure 1). It has advantages and disadvantages (Ramsey, 1999). The advantages are:

1. animals cannot damage gardens;
2. animals can be used to clean land after harvest and before planting;
3. animals can be moved to areas where feed is available; and
4. limited labour is required to collect manure.

The disadvantages are:

1. it requires some skill because an animal may not find enough feed in the small area where it is tethered and is dependent on the farmer for the provision of additional feed and water;
2. if the tether is too tight or not properly applied it can cause problems;
3. reproductive rates in tethered females may be low as detection of heat and the introduction of males at appropriate times may be difficult; and
4. it is difficult to control breeding because the possibilities of free range males mating with tethered animals cannot be ruled out.



**Figure 1: Goat tethered to a coconut tree in the Cook Islands**

**Fencing** - Fences such as permanent post, wire or electric are used to control stock. Fenced animals require a regular supply of clean, fresh water and sufficient feed of good quality. When animals are kept in paddocks, their entire feed requirement should be met by the development and maintenance of available pasture or through supplementation.

**Penning or confinement** - Animals are confined at all times so this system requires much higher levels of husbandry than the other systems, since all inputs must be provided; this increases production costs. This system is not very common in the PICs. Farmers prefer a semi-intensive system where animals graze during the day and are housed at night or during adverse weather.

**Figure 2** shows a make-shift housing or shelter for goats under semi-intensive system at Siusega, Samoa.



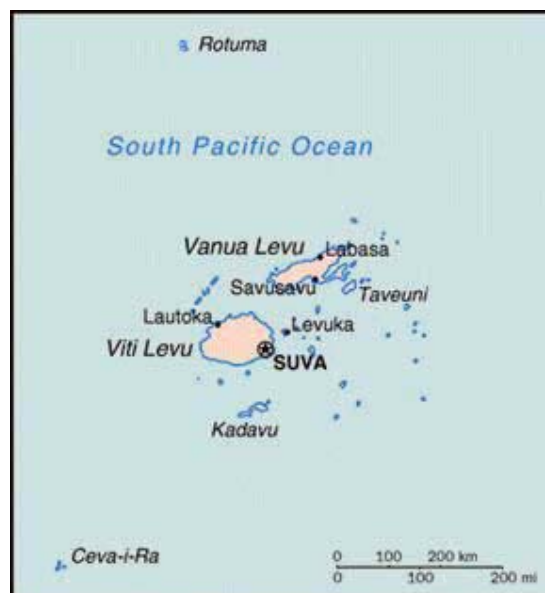
**Figure 2: Shelter used for semi-intensive production system at Mr. Paul Too Soon's farm (Siusega, Samoa).**

These are the general production systems, however countries have modified them to suit conditions peculiar to their environment.

#### **4. Some cattle production systems in six countries**

Production systems for cattle in some Pacific Island countries (Aregheore, 2004a) are described below.

##### **Fiji**



Beef production systems in Fiji can be classified as: -

- small arable subsistence farms of less than 10 ha;
- commercial farms of 10 – 50 ha;
- ranching operations of 50 – 2,000 ha; and
- cattle under coconuts or pines.

**Small arable farms - under 10 ha.** These own up to 75 % of the beef cattle. Beef is a sideline to sugar cane or rice production. Most cattle are in the sugar and rice areas of Viti Levu and Vanua Levu. Farmers tether animals along roadsides and field fringes. Bullocks are kept for draught. Fencing is not used and in some situations animals are allowed to roam and fend for themselves.

**Commercial farms of 10 – 50 ha.** This involves the breeding and/or fattening of animals under extensive grazing. Owners and family members manage the farms, but contract labour is hired from time to time for fencing and daily routine tasks.

**Ranching operations of 50 – 2000 ha or more.** These are based on intensive cattle systems for breeding and provision of stock to smallholders. Ranches in Fiji are found in Uluisaivou and Yaqara and also in Cakaudrove and Taveuni and are large estates with full time managers, stockmen and labourers. The Yaqara Pastoral Company, Fiji's largest single operation, covers over 4,000 hectares and maintains 7,000 head of cattle. This includes the recent acquisition of the famous French Limousin breed, purchased from New Caledonia.

**Cattle under coconuts.** This is concentrated in Northern and Eastern Fiji. Cattle are kept to control weeds and provide income. Grazing is continuous. This system requires large areas. Sixty percent of beef farmers in the northern division produce under coconuts and of these 40 % are indigenous Fijians. This system is also found in some bigger outer islands including Rotuma (Vulaono, 2004).

**Cattle under pines.** This system which is mainly used in the dry, western part of Fiji, involves a small herd maintained by the Fiji Pine Commission. Cattle graze under pine plantations and are used as weeders; grazing is continuous on an extensive area of land.

There are 1,825 beef producers with 30.5 animals per farm and three large properties with more than 1,000 cattle each. The commercial beef herd is distributed by region as 27 % Central, 56.9 % Western, 14.1 % Northern and 2 % Eastern Division. Commercial beef farmers have about 1,100 work oxen (Macfarlane, 2000a). Poor nutrition leads to low weaning percentages and daily liveweight gains. The Ministry of Agriculture, Fisheries and Forests assists farmers in access to beef cattle in Fiji through a breeding programme that aims at improving the genetic composition of local beef herds and involves the importation of high quality semen.

Fiji is well endowed with pasture resources. The potential role of pastures as cheap and available feed has been well documented by Macfarlane (1998) and Kumar *et al.*, (2001). Beef production systems rely on tethering and enclosed grazing with some cut-and-carry feeding. Natural and improved pastures are used. The national cattle herd grazes 125,000 hectares of unimproved Mission grass (*Pennisetum polystachyon*), 43,000 hectares of naturalized/native pastures including Nadi blue grass (*Dichanthium caricosum*); Batiki grass (*Ischaemum aristatum* var. *indicum*); carpet grass (*Axonopus compressus*) T-grass (*Paspalum conjugatum*) and an unquantified area of roadsides and harvested cane fields (Macfarlane, 2000a).

Mission grass (*Pennisetum polystachyon*) is extensive low cost feeding. But limitations to its use are low productivity, low digestibility and inadequate protein and mineral levels; its quality and quantity can be improved by adding legumes with appropriate fertilization. Improvement of Mission grass by sowing Siratro (*Macroptilium atropurpureum*) or Stylo (*Stylosanthes guianensis*) and broadcasting single-superphosphate at 440 kg/ha into burnt grassland resulted in a three-fold increase in dry matter from 6.0 tons/ha/yr to 18.0 tons/ha/yr. Maximum liveweight gain of 520 kg/ha was recorded from improved Mission grass leading to reduced gains in later years when Mission grass and legumes rapidly disappeared. There is a need for more stable grasses and legumes. Nadi blue (*Dichanthium caricosum*) and Hetero (*Desmodium heterophyllum*) have these attributes and were actively promoted.

## Samoa



In 1995 the cattle population of Samoa was split among sectors in the following proportions:- Government (3 %), Western Samoa Trust Estates Corporation (WSTEC) (12 %), NGOs (17 %), and private (68 %) (Lee, 1999a), thus breaking the early monopoly of WSTEC. At present beef cattle are raised in Samoa under two systems: village production, and large-farm production (Tevita (2001), personal communication).

(a) Village beef cattle production is divided into two types:

- subsistence or village
- smallholders sub-sector

(b) Large farm production is also further divided into two types:

- commercial or large private estates
- government/WSTEC estates

### Village beef production

**Subsistence/smallholder or village/district system.** Farmers have 1 - 20 cattle per household and there were approximately 2,000 households with 9,200 cattle in 1989. Now there are over 1,000 farmers under the village/district based beef cattle production system. Households with five or fewer cattle use tethering but many are increasingly opting for fenced grazing (Lee, 1999a). The advantages and disadvantages of tethering as a beef production system in the Pacific Island countries have been reported by Ramsay, (1999).

The subsistence system is a very significant in Samoa's beef industry and plays an important role in increasing the number of animals in the country. There are

46 registered cattle farmers' association or village groups. The formation of the Village Cattle Farmers' Association, a self-help group activity to improve and draw more farmers to develop interest in beef cattle production, has motivated farmers' interest in the keeping of cattle. Cattle ownership by small farmers is increasing and development of the beef industry has received government support through importation of cattle, development of breeding farms, distribution of cattle to farmers at subsidized prices and training in pasture development and maintenance (Ramsay, 1999).

**Smallholders cum commercial systems.** Farmers in this group usually have five – fifty cattle on properties where both subsistence and commercial production are carried out. A farmer will produce livestock, root crops, coconut and bananas for home use. Today, the strength and growth in the beef cattle industry is in the emerging commercial smallholders sector.

#### **Large-farm production system**

**Commercial or large private estates.** These are owned by wealthy individuals or business groups and churches such as Methodist and Congregational Christian Church of Samoa. This group owns approximately 4,500 or more cattle. Commercial or large private estates have been the springboards for the expansion of Samoa's cattle industry. Farmers only sell or donate cull animals for festival purposes and appear to have struck a comfortable balance between customary demands and commercial pressures. This group is responsible for 15 % of individual requests to the Livestock Division, MAFF for pasture and livestock development and is involved in about 35 – 40 % of pasture improvement activities.

**Government/WSTEC Estates.** Two government farms at Togitogiga, Le Mafa and Tanumalala were established under Asian Development Bank funding during 1972 – 1979 to provide demonstration and training, conduct research and provide improved breeding stock for distribution to WSTEC estates and to farmers. WSTEC estates is government owned and has about 3,000 cattle grazing 2,400 ha under coconuts at Mulifanua. WSTEC once controlled most of the cattle in Samoa, but the number of animals and the land area of WSTEC properties have fallen drastically. Government farms sell some of their breeding animals to the other sectors under the village level beef system. Samoa has identified cattle development as an important strategy for import substitution. Beef stock is based on Braham-Hereford mix which seems adapted to the environment. In 1989, Droughtmaster cattle were introduced from Australia with additional shipments in 1993 and 1995. The beef farms at Togitogiga, Lamefa and Tanumalala breed and distribute calves at subsidized rate. Bulls are imported periodically to prevent inbreeding. Droughtmaster cattle have adapted very well to Samoan conditions and have become a breed of choice (Tevita, 1995).

Samoa's climate favours the growth of forage all year round. Batiki grass (*Ischaemum aristatum* var. *indicum*) is the predominant pasture grass, either under coconuts or in open fields. Other grasses such as signal (*Brachiaria decumbens*), Guinea (*Panicum maximum*), carpet (*Axonopous compressus*) and elephant (*Pennisetum purpureum*) grasses contribute to the nutrition of ruminants. Signal, Guinea and elephant grasses are mostly used in cut-and-carry feeding. Browse plants including *Leucaena leucocephala*, *Gliricidia sepium*, *Erythrina* spp., *Spondias mombin*, *Calliandra calothyrsus*, *Morus alba* and *Sesbania grandiflora* are available to supplement batiki grass during the dry season (Aregheore, 2003).

Some agro-industrial by-products, especially brewer's grains, noni (*Morinda*

*citrifolia*) juice extract waste, desiccated coconut waste meal and copra cake are available year-round and are used to supplement grazing animals during adverse weather. The use of brewer's grains is widespread.

## Papua New Guinea



The cattle industry expanded rapidly from the early nineteen-sixties and numbers peaked in 1976 at around 153,000 head (although current estimates suggest a national herd of only 82,000 cattle). Numbers have declined sharply in both large and smallholder sectors.

Two production systems are identified (Benjamin, 2001) and these are:

- smallholder projects; and
- largeholder properties

**Smallholder projects.** Based on earlier data over 1,000 smallholder projects run a total of 50,000 cattle. The remainder is on 550 smallholder farms on 78,000 hectares of grazing land. Cattle graze native, semi-improved or fully improved pastures. Tethering is growing rapidly in mid-altitude zones and areas of high land pressure where smallholders use forage along roadsides and around tree crops. This system is associated with cut-and-carry (Macfarlane, 2000b). Improvements in smallholder projects are limited (Benjamin, 2001, Personal communication).

**Large properties/commercial/ranching.** Based on earlier data there were 30 ranches with 103,000 head. About 80% of the cattle are on large properties that occupy 113,000 hectares. This system is integrated with about 100 km<sup>2</sup> of coconuts. Ramu Beef's feedlot bales green cane tops and helps Ramu sugar by reducing the wastage of crop residues during ploughing. There are 203,000 ha of extensive natural grasslands in PNG most of which are maintained by regular burning. These grasslands have been recognized as an important resource (Falvey, 1981, Smith and Whiteman, 1985) and have been successfully improved, usually by over-sowing with *Stylosanthes* spp. following burning and application

of appropriate fertilizer (Partridge, 1977). Shelton et al., (2002) stressed the importance of pasture as a cheap feed in PNG. All beef production systems in PNG rely on natural or improved pasture.

The beef industry has developed the supplementary paddock feeding systems with locally-produced by-products. Copra meal, palm kernel meal and molasses are used to supplement pasture (Bubar, 2000). This is a major step through improved growth rates and animal handling. Smallholders can benefit from technologies developed and introduced by ranches. Besides the above mentioned, a number of crop residues such as sugar cane tops, rice straw and bran, cocoa husk, coffee hulls and pulp, palm fibre press and oil palm sludge are available as possible supplementary feed for grazing beef cattle (Moat, 2002).

## Tonga



Beef cattle in Tonga are held under two systems (Lee, 1999b); these are:- smallholders, and large commercial properties:

**Smallholders.** Beef animals are raised in small numbers. Crop production is the farmers' priority and livestock are integrated into this system. Their purpose is to supply animals for traditional and social obligations such as funerals, wedding and church functions. Animals are tethered and graze along roadsides, fallow land or under-utilized bushland. Forty percent of beef herds of 10 or fewer animals are under the smallholder system.

**Large commercial style properties.** Nobles, entrepreneurs who sub-lease land and the churches operate commercial properties involving beef cattle. These properties are now few, but they are very important because of their ability to produce surplus meat for local markets and breeding stock for the beef industry. They specialize in both milk and beef, often with separate herds. They have some developed, fenced long-term pastures and land is generally cropped only during pasture renewal (Lee, 1999b).

## Solomon Islands



In the Solomon Islands over 56 % of the cattle are in the Central district, 20 % in Western district, 16 % in Malaita and 8 % in the Eastern district, (Wahananiu *et al.*, 1993). However, the 1998-2000 civil war or disturbance in the Solomon Islands affected commercial beef production and it declined to less than 78 % of the previous level. Three beef production systems are recognized (Kama, 1994):- small holder; intermediate communal, and large-scale commercial-government.

### **Smallholder sub-sector**

This is oriented towards subsistence and cash and is aimed at utilizing land unsuitable for crops and making use of excess family labour. The number of cattle is usually 10 or fewer. The animals are tethered around backyards or around the villages. The system provides meat for the family, a source of income and to meet social obligations that may require a beast. The land holding comprises farms of 5 - 50 ha to 20 - > 200 ha in group/joint ventures. Grasses common in the sector are koronivia (*Brachiaria humidicola*), signal (*Brachiaria decumbens*), Para (*Brachiaria mutica*), batiki (*Ischaemum aristatum*) grasses, while pueru (*Pueraria phaseoloides*) and centro (*Centrosema pubescens*) are the legumes.

### **Intermediate communal sub-sector:**

These are commercial agricultural enterprises administered by established communal groups on alienated and customary land that is unsuitable for crops and makes use of available community or tribal labour. Herds often comprise 10 - 25 cattle. As in the smallholder sub-sector the beasts in this system are slaughtered at communal gatherings and ceremonial activities.

### **Large scale commercial sub-sector:**

This is made up of large commercial companies or government; e.g. Levers Solomon limited, missions and Livestock Development Authority (LDA), respectively. Levers Solomon Limited, Central Province, keep their cattle under coconuts on 3,000 - 4,000 ha on the Russell Islands with 2,000 ha on Yandina. Cattle are kept as "sweepers" to graze the native pasture. Highly skilled labour is used and herd numbers range from 75 upwards. Animals graze in open pastures that are improved and this system is largely used by the LDA for farms at

Lungga, Tenuvatu, Koli and Six Mile. Indigenous legumes in plantations are *Desmodium canum* and *D. heterophyllum*. Patches of Siratro, puero and centro occur in some areas.

A national cattle development plan was initiated some years ago for the rehabilitation of the beef cattle industry. The Solomon Islands government is keen to rebuild the cattle industry in commercially viable areas that have access to established markets. Government policy goals and objectives are to sustain self-sufficiency in all livestock sectors with exports where possible (Wate, 1995). The cattle development strategies of the Solomon Islands included the continued provision of breeding animals for smallholder expansion and restocking. In 1996 the impact of genetic improvement from imported bulls and semen came to fruition. There was a strong interest on Malita and Santa Cruz for breeding stock. The Mamara breeding unit set up by the Livestock Development Authority (LDA) provided vigorous replacement stock to farmers.

Beef cattle have access to both natural and improved pastures. Grazing areas range from open pastures under extensive grazing under plantations to those in the smallholder sector (Wahananiu *et al.*, 1993). The Livestock Development Authority (LDA) operated five farms on Guadalcanal and four in the Western Province and owned most of the large open pasture. It has been estimated that only 4,000 ha of pasture might be left for grazing. As a consequence of the different holding systems, land for pasture development was allocated in the sixth Development Plan (1970 – 1984) as follows; smallholder (6,441 hectares); LUD projects (3,943 hectares); holding grounds (442 hectares); LDA fattening (760 hectares) and Government (2,060 hectares). By 1991, it was estimated that 9,000 hectares would revert to bush while in some areas pastures will be undergrazed. There is still scope for targeted pasture development in Gizo, Kolombangara, North New Georgia, Rendova areas of western Province, Santa Isabel, Makira; and accessible and adequately fertile areas on Maliata and Guadalcanal (Wate, 1995).

Commercial pasture development in the Solomon Islands was based on the replacement of *Themeda australis/Pennisetum polystachyon* natural grassland with a minor contribution of *Gleichenia linearis* and *Cyperus* spp. by cultivation and planting of grasses such as Para (*Brachiaria mutica*); signal (*Brachiaria decumbens* cv. Basilisk); green panic (*Panicum maximum* var. *trichoglume* cv. Petrie); batiki grass (*Ischaemum aristatum*); koronivia (*Brachiaria humidicola*) and Nadi blue (Steel and Whiteman, 1980; Watson and Whiteman, 1981). The nutrient content and palatability of the grasses would be improved by legumes as mixtures. Legumes used in the Solomon Islands are *Centrosema pubescens* cv. Common (Centro); *Pueraria phaseoloides* (Puro), *Stylosanthes guianensis* cv. Endeavour (Stylo); *Vigna luteola* (Vigna); *Desmodium uncinatum* (Silverleaf); *D. heterophyllum* (Hetero); *Macroptilium atropurpureum* cv. Sirato (Sirato) and *Glycine wightii* cv. Tinaroo (Glycine). Macfarlane (1996) reported that the pasture resources for ruminant livestock production in the Solomon Islands could be categorized into open pastures, pastures under coconuts and pastures under trees.

## Vanuatu



The production systems in Vanuatu are:-

### **Smallholder sector**

The smallholder sector is subsistence and cash crop oriented; farmers keep fewer than 25 animals, mainly to meet immediate family commitments for finance and food. A few sell cattle to the small abattoirs. Over the past 20 years an increasing number of commercial smallholder grazers developed open improved pasture and the rapid increase in stockyard infrastructures over the past 10 years has improved management and production per hectare; the best smallholder farms are now equivalent to the best plantations (Mullen, 1999). Smallholder cattle numbers grew throughout the nineteen-sixties and nineteen-seventies but production did not become formally commercialised until 1975 when marketing of smallholder stock through abattoirs began. When the market in Japan for small beef animals opened in 1978, smallholder cattle became significantly commercialised (Loughmann, 2001).

### **Estate plantation sector**

This comprises the large commercial enterprises (private) or those run by the government. Most plantation beef production is based on open pastures on the Islands of Espiritu Santo and Efate. In well-managed operations, cattle are grazed at 1.5 – 3.0 AU/hectare depending on agro-ecological region (Mullen, 1999). It is estimated that the plantation sector has 85,000 cattle of which 35,000 are controlled by Ni-Vanuatu mission or government farms and 50,000 by expatriate plantations (Gunn Rural Management (GRM) International Pty Ltd report, 1992). It is estimated that Ni-Vanuatu control 63% of the national herd. Plantation sector beef cattle graze 58,000 ha, mainly under old coconuts or on improved grasses and partly on cleared bush with or without adequate legumes. The government plantation - Vanuatu Livestock Development (VLD) play a significant

role in assisting smallholders in production and marketing.

Other plantations owned by the private sectors are Mon-beef Tech on the Island of Santo which supply beef solely to the abattoir in Santo; Din van Tan which owns one of the biggest beef cattle holdings, supplies beef mainly to its own SAEF cannery. Michelle (a French lady) owns a plantation that also supplies beef to her small abattoir which, in turn supplies beef to wholesalers and retailers. Another worth mentioning is the French Plantation known as Roche and Madam Coshe. These plantations contribute to the export market through their abattoirs and they have assisted to improve the economy of Vanuatu (Otto, 2001).

## 5. Feeding systems

### Cut-and-carry

Cut-and-carry systems are where feed and crop residues are cut and carried to livestock which are confined close to the farm or tethered. Most of the feed is cut and carried from outside the farm. For part of the time the animal may still be tethered on communal areas. **Figure 3** presents a photo of a farmer carrying harvested forage. **Figure 4** shows harvested forage being processed manually using a bush knife, while **Figures 5** and **6** show a manual chaff cutter and processing of harvested forage, respectively. Cattle, goats, goats and sheep show the greatest potential for cut-and-carry systems. **Figures 7** and **8** are photographs of goats browsing the foliage of *Erythrina* spp. at Alafua, Samoa. Cut-and-carry is labour-intensive so is found in densely populated rural areas with a high potential for crops – land surrounding large residential areas and peri-urban sites where free grazing is not allowed by local laws or is restricted to prevent damage to crops or trees.

Cut-and-carry is an indicator of pressure on land for crops and the application of local laws to regulate the exploitation of communal and on-farm resources. The present trend of population growth and land ownership in the Pacific Islands has resulted in an increase in its use and competition for feed. This system gives lower production levels and even changes to lower production objectives (milk, traction, reproduction and growth) and in herd size and composition (fewer large ruminants and more small ruminants). The general rule in cut-and-carry is to give freshly cut forage equivalent to about 10 % of an animal's body weight daily. Ideally half of the cut forage should be given in the morning and the rest in the evening so that the animal can make more efficient use of it and reduce waste.

The quality and the year-round availability of feed are good because farmers look for the best forage to harvest. However, the constraints are mainly availability of forage especially during adverse conditions and household labour, distance of feed from the farm, means of transport and access rights to feed on private and or communal or public land. Cut-and-carry is very common in Fiji, Samoa, Tonga, the Cook Islands, Vanuatu, the Solomon Islands and Papua New Guinea; the farmers involved are those with small farms, cultivating as shareholders, farmer labourers and landless households. The land these farmers have access to is often intensively cultivated, the households are poor and a major share of their income is derived from casual labour and/or employment. The livestock they keep are their main assets and savings.

**Fiji** – Feeding systems rely on tethering and enclosed grazing, with some cut-and-carry. There are no feedlots. Dairy cattle receive a lot of supplementary feed (Macfarlane 2000a).

**PNG** – Feeding systems are based on grazing. Some estates are interested in

time controlled rotational grazing or cell grazing. Tethering is growing rapidly in mid-altitudes and areas of higher land use pressure where smallholders use forage along roadsides and around tree crops. It may be associated with cut and carry. Some estates feed copra meal, palm kernel cake and molasses with mineral supplementation (Macfarlane, 2000b).

**Tonga** – Cut and carry feeding of elephant grass, pasture, supplements such as copra meal, crop by-products for feeding, urea supplementation (Lee, 1999)

**Samoa** – Cut and carry is now practiced by farmers who tether their animals around Apia. Also Sunny Island Dairy farm at Lalom auga uses cut-and carry Napier and Guatemala grass (the latter on the wetter soils) to satisfy part of the feed requirements of the herd of 15 milking cows.

**Vanuatu** – Both smallholder and plantation graziers predominantly use free grazing. Tethering occurs occasionally but stall feeding is not practiced. The feeding system in both sectors is pasture based and no supplements or conserved feeds are used (Mullen, 1999).



**Figure 3. Harvested forage**



**Figure 4. Manual processing with a bush knife**



**Figure 5. Manual chaff-cutter**



**Figure 6. Using manual chaff cutter to process forage.**



**Figure 7. Goats browsing harvested foliage of *Erythrina***



**Figure 8. Goats browsing**

### Grazing systems

Ruminants digest cellulosic substances and convert them to produce milk, meat, wool, hides for leather and draught power. A well managed pasture is therefore critical to the survival of ruminants and the products they provide. To obtain maximum profits from grazing, farmers must manage the land for high production and manage the animals to minimize forage waste and ensure that they are growing sufficiently. Grazing systems employ the basics of rational management to help producers accomplish their goals. Depending on what

system farmers choose, they may improve pasture conditions, increase forage use, or enhance livestock production. Pasture-based livestock systems appeal to farmers seeking lower feed and labour costs and to consumers who want alternatives to grain-fed meat and dairy products. The choice of grazing system is the key to an economically viable pasture-based operation. Grazing systems vary widely in the degree of control which the farmer has in the management of grassland, but all are designed to help match the nutritional demands of animals to the forage supply. There are three main types of grazing system in the Pacific Island countries: (i) continuous grazing or set stocking, (ii) rotational or paddock grazing and (iii) strip grazing.

### **Continuous grazing or set stocking**

Continuous grazing, the commonest system in most Pacific island countries, usually results over time in a plant community of less desirable species. Animals graze a specific area freely and uninterrupted throughout the year or grazing season; continuous grazing allows animals to graze selectively so individual animal performance is usually maximal. When livestock graze without restriction, they eat the most palatable forage first; if these plants are repeatedly grazed without time to recover, they die. Plants not eaten mature and go to seed: undesirable plants increase, while preferred plants are eliminated, reducing the quality of the forage. Trampling and animals' avoidance of undesirable plants and soiled areas further reduce the amount of usable forage under continuous grazing. It is the simplest method of grazing and in some cases perhaps more economical than rotational grazing when:

- fencing is expensive, since it requires the least amount of fences;
- provision of drinking water is costly; it requires fewer water points than rotational grazing.

**Figures 9 – 13** show photographs of pasture for continuous grazing in some PICs. This results in selective grazing and under such grazing regime it is hard for nutritious and palatable legumes to survive.

This type of grazing frequently results in higher per-animal gains than other systems, so long as adequate forage is available to maintain high growth rates. Where continuous grazing is used the number of animals in the paddock must be adjusted from time to time to allow for seasonal pasture production. As animals grow, some animals have to be taken out of the grazing area to maintain a correct stocking rate. If pastures are overstocked, growth rates usually dwindle. Continuous grazing often results in poor forage utilization in the rainy season when re-growth is rapid. A high stocking rate should be used in the rainy season when forage production is high and decreased during the dry season. This system is of value on farms where pasture is plentiful and the farmer does not intend to increase stock numbers. In some countries such as Samoa and Vanuatu grazing cattle under coconut and on open pasture centre around continuous grazing.



**Figure 9. Open pasture for continuous grazing (Samoa)**



**Figure 10. Open pasture for continuous grazing (Cook Islands)**



**Figure 11. Fenced area for continuous grazing (Cook Islands)**



**Figure 12. Limousin cow under continuous grazing system (Vanuatu)**



**Figure 13. Pasture under coconut for continuous grazing (Vanuatu)**

### **Rotational or paddock grazing**

Animals are periodically moved to fresh paddocks to allow pastures to regrow. Rotational grazing requires skilful decisions and close monitoring of their consequences. Electric fencing and innovative water-delivery devices are important tools. Feed costs decline and animal health improves when animals harvest their own feed in well-managed rotational grazing. **Figures 14 - 18** contain photographs of paddocks, cattle and sheep on rotational grazing at Togitogiga, Samoa; Fiji and Vanuatu. Rotational or controlled grazing or management-intensive grazing increases weight of animal production per unit area. The way the system is managed influences the level of production. Grazing emphasizes the intensity of management rather than the intensity of grazing. The pasture is sub-divided into paddocks and animals are systematically moved from

has been suggested as a rule of thumb, although this depends to some extent on the pasture species being grazed and for some, for example guinea grass, the grazing height should be higher), they are moved to the next. The rotation depends on the number of paddocks, management goals and personal preferences. In a four paddock system a rotation of about 30 – 40 days is used. By the time the last paddock in the sequence has been grazed, the first should be ready for grazing. This system is very common among government and large commercial-private farms in Fiji, Samoa, Tonga, Solomon Islands, Vanuatu, Papua New Guinea and New Caledonia. It has some advantages and disadvantages.

#### **Advantages –**

- farmers using the system can achieve higher stocking rates at each grazing;
- well managed rotational grazing often doubles animal productivity per hectare compared to continuous grazing due to increased forage production and utilization;
- the farmer sees his animals more often and they become easier to manage;
- segregation of the herd becomes possible which facilitates weaning and controlled mating;
- regrowth of pasture is often all of high quality and palatable forage;
- weed control is easier as the pasture is quite short after grazing and animals are out of the paddocks;
- easy control of gastrointestinal worms by breaking their cycle;
- farmers have more control of the timing and intensity of forage harvest by the livestock which can allow improved pasture growth and utilization over the season;
- having a proper rest period interval between grazing allows the use of forages that are more productive than unimproved ones.



**Figure 14. Paddocks partitioned for rotational grazing (Samoa)**



**Figure 15. Paddocks partitioned for rotational grazing (Fiji)**



**Figure 16. Cattle under rotational grazing**



**Figure 17. The Fiji Fantastic sheep under rotational grazing (Fiji)**



**Figure 18. Cattle under rotational grazing system (Vanuatu)**

**Disadvantages –**

- rotational grazing requires more capital for fencing, water supply and for keeping mineral licks for animals;
- if the farmer neglects daily checking of the pasture height there is the risk of over grazing the pasture which allows sunlight to reach the soil surface so that weeds begin to germinate and may in this way increase weed problems (**Figures 19 – 24**).



**Figure 19. Cattle in an over-grazed batiki pasture at Togitogiga, Samoa**



**Figure 20. Weeds (Navua sedge) invasion as a result of overgrazing at Avele dairy farm**



**Figure 21. Fiji Fantastic sheep grazing a paddock overgrown with Navua sedge (Avele)**



**Figure 22. Weed invasion at Alafua goat unit**



**Figure 23. Manual weed control (Alafua goat unit)**

**Figure 24. Weeds manually removed piled under a tree (Alafua goat unit)**

### **Strip grazing**

Strip grazing with electric fencing involves giving animals a fresh allocation of pasture each day. It is usually organized within a paddock system or where there are no paddocks at all and the animals are controlled solely by the use of electric fences (Figures 25 -26). In the Pacific Island countries strip grazing systems are often employed where a farmer uses communal land with significant excess of forage when providing animals with access to a larger area would result in waste through trampling or spoiling by dung. The temporary fencing gives the farmer the versatility to strip graze. Generally the fence is moved daily and the distance it is moved is based upon the number of animals being grazed and the quality and quantity of pasture available. A back fence should be used to stop animals from returning to land already grazed. Sheep and goats require three wires instead of a single wire.

Strip grazing has a number of benefits, such as:

- it ensures maximum use of available pasture, particularly in times of feed shortage;
- enhanced pasture growth;
- more controlled and even grazing;
- areas which are not normally fenced such as open field or road embankments can be quickly and easily fenced and grazed;
- improved financial returns from increased production;
- electrical fences can be erected much more cheaply than conventional fences.

If properly managed, constructed and serviced electrical fences can increase the efficiency and profitability of cattle, sheep, or goat enterprises through better management of animals and forage resources.



**Figure 25. Battery powered energiser for electric fence strip grazing (Cook Islands)**



**Figure 26. Strip grazing of goats (Cook Islands) with electric fence.**

### **Cattle grazing open pastures**

The bulk of cattle production occurs on open pastures in the Pacific Island countries (**Figure 32**); in well managed operations cattle are grazed at 1.5-3.0 AU/ha, depending on agro-ecological region and turn off slaughter weight cattle (280-300 kg carcass) at 24-36 months. Over the past 20 years an increasing number of commercial smallholder graziers have developed open improved pastures. For example in Vanuatu, the rapid increase in stockyard infrastructures on smallholder farms over the past 10 years has improved stock management and production per hectare from the best smallholder farms so that it is now close to some commercial farms.

### **Integrated animal and tree cropping systems**

#### **Crop/livestock systems**

The interactions between plants and animals are complex compared to other systems of agricultural production and these are extremely dynamic and constantly changing. Integrating ruminants with tree crops is not yet fully exploited but haphazardly introduced. In most countries in the South Pacific cattle are integrated with coconuts (Reynolds, 1995). Alley farming and animal agroforestry are possible systems in crop/livestock integration in the region.

The potential for animal production is one of the advantages of grazing livestock under plantation crops; they can be integrated with coconuts, oil palm, rubber, cocoa, and noni (*Morinda citrifolia*). Coconut and oil palm are significant and grazing under them is becoming increasingly important. In Fiji, cattle graze 27,000 ha under coconuts while sheep grazed puero (*Pueraria phaseoloides*) based pasture under coconuts on Taveuni. With the population of goats relatively constant and the development of sheep farming in Fiji, integration with tree crops is likely to increase (Macfarlane, 2000a). In Papua New Guinea cattle are integrated with approximately 100 km<sup>2</sup> of coconuts (Macfarlane, 2000b), oil palm and rubber. In Vanuatu the preferred pasture plant under coconuts for cattle is buffel grass because it is extremely tolerant of high grazing pressure and the lower rainfall coastal environment where coconuts grow (Mullen and Shelton, 1996; Mullen, 1999). It is envisaged that in the Solomon Islands cattle will run under oil palm plantations as well as coconuts. In Samoa pasture-cattle-coconut systems are very common. **Figures 27 – 30** contain photographs to illustrate crop/livestock systems in the PICs.

The main objectives of integration of animals with coconut and oil palm are:

- to increase the production of meat economically without having to open new large areas of land for animal production;
- to reduce weeding costs through controlled grazing of palatable plants and/or treading and trampling of unpalatable ones;
- to reduce soil erosion through control grazing;
- to use the dung and urine to fertilize the coconut trees and inter-crop, and thus reduce the cost of inorganic fertilizer on one hand and thus improve soil fertility on the other;
- to provide additional income to coconut growers through increased productivity from a unit of land; and
- to open opportunities for diversification.



**Figure 27. Cattle grazing newly harvested sugar cane leaves in Fiji**



**Figure 28. Cattle grazing old coconut plantation (Vanuatu)**



**Figure 29. Cattle grazing under coconuts in Samoa (Upolu)**



**Figure 30. Goats grazing under coconuts in Cook Islands**

### **Cattle under coconuts**

The cattle industry in most of the Pacific Island countries is associated with coconut plantations. In Papua New Guinea cattle are integrated with 100 km<sup>2</sup> of coconuts (Macfarlane, 1999) which could increase to 250 km<sup>2</sup>; the potential is 600 – 700 km<sup>2</sup>. There is a potential to expand cattle under coconuts in New Ireland to supply the Lihir gold mine, rising to 200 tons/meat/year.

Today nearly all smallholder and plantation graziers have at least part of their herds under coconuts. As copra prices continue to decline in real terms, the importance of cattle in the cattle-coconut farming system has increased. Daily liveweight gain of steers grazing under coconuts is below that of animals on open pastures due to the reduced quality of shaded herbage (Macfarlane 1993). Reduction in liveweight gains are exacerbated by dense plantings of coconuts (>150 palms/ha) on some smallholder farms. However, high quality veal is produced by specialist graziers who graze cows and calves under coconuts (**Figures 28, 29 and 31**). A unique quality of coconuts compared to most other plantation crops is that they can be intercropped on a semi-permanent basis. Unlike rubber and oil palm, the light environment under coconut is relatively constant and bright over the life of the crop which can be as long as 60 – 80 years (Shelton *et al.*, 2002), although in the period 5-20 years light levels at ground level may be somewhat reduced (Reynolds, 1995).

### **Pasture under coconuts (Savai'i)**



### **Open pasture for grazing**





**Figure 31. Cattle grazing under coconut (Vanuatu)**



**Figure 32. Open pasture for grazing**

### **Role of forage and feed in the systems**

Tropical pasture technology aims to improve animal production through the judicious use of inputs according to prevailing economic and social conditions (t'Mannetje, 1993). Nutritional research has demonstrated that very large increases in ruminant production can be achieved by small alterations to the feed base (Leng, 1993). In most tropical countries, including those in the South Pacific region, ruminant production is based on grazing pasture. Most tropical pastures are low in nutritive value due to their rapid growth and early lignification. Feed availability is more critical during the dry season.

To improve the nutrition of ruminant livestock it is recommended that cheap sources of protein should be used as supplements. Aregheore (2000a) suggested the inclusion of foliage of browse plants and multipurpose trees; the use of urea/mineral lick blocks to supplement grazing animals for correcting protein, energy and mineral deficiencies is highly advocated. In Fiji, the production of urea molasses blocks is common (Manueli and Mohammed, 2002).

There are several possibilities for improving forage production, and several options are open to smallholders. They can improve forage production by establishing:

- grass pastures requiring fertilization with NPK;
- grass-legume mixtures;
- over-sowing legumes into pastures;
- pure stands of legumes (protein banks); and
- fodder crops.

Thus the reasons for improving forage production are to supplement the forage resources available with more and/or better quality feed for purposes such as:

- to reduce dry season mortalities with extra feed from improved pastures, protein banks or fodder crops, either for the whole herd to provide (near) maintenance rations or for a nucleus of animals to ensure survival of the herd;
- to increase conception and calving rates where an increasing plane of nutrition leading up to conception can increase fertility and reduce calving intervals;

- to keep the herd on a smaller area of land throughout the year, or part of the year (by over sowing part of the area) to reduce mustering costs; and
- to fatten younger stock on improved pasture, fodders or protein banks (Mannetje, 1993).

This system advocates the adoption of cheap forage improvement based on legumes with minimum fertilizer use and the supplementation of low quality forage with the leaves of browses, legumes and multipurpose trees.

### **Crop residues and agro-industrial by-products**

Animal production does not depend on pastures and forages alone. Crop residues and agro-industrial by-products make a substantial contribution in integrated crop-forage production systems. Aregheore (2000a) reported that they complement each other in ruminant nutrition and this is widely recognized by farmers. However, the feeding of livestock solely on poor quality forage, crop residues and agro-industrial by-products leads to low liveweight gains and low animal productivity. Inadequate nutrition of animals in the tropics is associated with delayed age at puberty or maturity; age at first conception and parturition; prolonged parturition interval, prolonged non-productive life and high mortality (Devendra and Li Pun, 1993). In the South Pacific region quantity and quality of forage, particularly in the dry season, are major constraints to livestock production from pastures. Therefore, there is the need to supplement fodder then. Strategic supplementation for energy, proteins, and minerals that might be deficient in low quality forage or crop residues offer an important means to ensure that animal performance is maintained during periods when feed shortage is imminent. Low quality forages can be improved in several ways. The use of foliage of browse plants and multipurpose trees is a cheap way of supplementing animals on poor pasture.

### **Legumes and trees**

The use of foliage of forage legumes and multipurpose trees is underestimated but these can improve the quality and utilization of roughages. Several browses and multipurpose trees are used in the South Pacific region including: *Leucaena leucocephala*, *Erythrina* spp. (dadap), *Calliandra calothyrsus*, *Sesbania grandiflora*, *Gliricidia sepium*, *Spondias mombin* (Vi or Vie) breadfruit, bananas/plantain and mango. Advantages of using these forages especially in mixed farms in the humid tropics are as follow:-

- availability on farms;
- accessibility;
- provision of variety in the diet;
- source of dietary nitrogen, energy, minerals and vitamins;
- laxative influence on alimentary system;
- reduction in the requirements for purchased concentrates, and
- to reduce cost of feeding. (Devendra, 1988)

Devendra (1990) reviewed the potential value of these forage and observed that, with ruminant livestock, the use of supplements consistently increased liveweight gain or milk production. In many instances the beneficial response was associated with reduced production costs of the forage supplements used. Legumes have been particularly advantageous and in a majority of situations stall-feeding or cut-and-carry systems are commoner than grazing. The leaves of these plants are cheap sources of protein, energy and sulphur for the rumen bacteria. They have great potential to be exploited for the benefit of ruminant livestock production.

## 6. Descriptive and analytical data on some forages (grasses and browses)

[Click on the name of the grasses to access the Grassland Index for more information]

### Some common grasses found in the Pacific Islands

#### Batiki grass (*Ischaemum aristatum*)

This is a creeping, stoloniferous, perennial with ascending culms and conspicuously red-coloured stolons rooting at hairy nodes (**Figure 33**). It is propagated by stem cuttings. Once established it spreads quickly. It is shade tolerant and therefore found in most coconut plantations in the Pacific Island countries. Batiki is very suitable for open pastures and performs well on acid soils at high altitudes. It is very competitive, therefore it is difficult to use in mixtures. Compared to most grasses it has low protein content (Aregheore, 2003).



**Figure 33. Batiki grass**

#### Guinea grass (*Panicum maximum*)

Guinea is an erect tufted, perennial which can grow up to two metres if not grazed; there are many cultivars. Examples are Tall Guinea (a tall, robust variety that is well accepted by cattle) (**Figure 34**); Creeping Guinea (very well adapted for coconut plantations) and Common Guinea (not as high as Tall Guinea, but tall enough to interfere with coconut harvest). Guinea grass may be propagated by seed or vegetatively using splits. Seed propagation can be unreliable due to poor seed viability. Creeping Guinea is exceptionally shade tolerant and therefore suitable under plantations. Guinea grass can be used in open pastures where it could be combined with legumes in such a way that the legume can grow in the open spaces between bunches to prevent weed growth as well as fix nitrogen. It is a grass that cannot stand waterlogging, therefore a well-drained soil is required for its growth.



**Figure 34. Guinea grass**

Photo by S. Reynolds

**Signal grass** (*Brachiaria decumbens*)

This is a coarse perennial with erect, ascending stems up to one metre high. The nodes are usually smooth but sometimes slightly hairy (**Figure 35**). It is propagated by stem cuttings or seeds. It is aggressive, smothers weeds easily and covers the ground rapidly. It could be used in grass/legume mixtures. It is shade tolerant, so can be recommended under coconuts and it produces good quality, palatable forage. It is well established on different soils but requires well-drained soil although it has been shown to be resistant to flooding.



**Figure 35. Signal grass**

**Para grass** (*Brachiaria mutica*)

Para is commonly used in rotational grazing and can be cut for green fodder or used for hay. It is a perennial that is widely distributed in the tropics and subtropics especially in areas with high rainfall. It is unproductive in the dry season because of its high water requirement. It is well suited to very wet, even waterlogged soils where it maintains a high dry matter content. It can be cut at

intervals of 4-6 weeks and compares well in quality with most tropical fodders. Para grass combines well with creeping legumes, but is easily grazed out unless well-managed.

**Nadi blue** (*Dichanthium caricosum*).

Nadi blue is a tall robust perennial grass and has broad leaves which can be up to 40 cm long and 8-20 mm wide (Reynolds, 1995). It originated in tropical East and South Africa and grows well in areas with rainfall between 900 – 1,825 mm. Nadi blue spreads by short rhizomes. It combines well with legumes such as Sirato, *Glycine* and Greenleaf desmodium. It has a high digestibility and palatability and is usually established by seed in a well-prepared seedbed. It can also be established from cuttings or divided rootstocks. Nadi blue has been very effective in competing with Navua Sedge (*Cyperus aromaticus*) in low-lying (wet) areas in Fiji.

**Setaria grass** (*Setaria sphacelata*)

Setaria is a long-lived, caespitose perennial which generally forms dense tussocks and spreads by short rhizomes. Leaves can be up to 40 cm long and 8 – 20 mm wide, but considerable variations in the leaf width and plant height occur. It has a well-developed root system. The leaf blade is widely lanceolate, long acuminate, dense scabrous, and may have a brightly coloured midrib; leaf edges serrate. Leaf sheaths longer than the nodes; collar indistinct, ligule, short and thick. Inflorescence has a main stalk with shortened branches bearing spikes and bristles. Flower has two spikelets and the upper is bisexual (Ranacou, 1985).

**Elephant or Napier grass** (*Pennisetum purpureum*)

It is a tall deep-rooted perennial (**Figure 36**), widely found the Pacific Island countries and is more suited to cutting for fodder than grazing, but under rotational grazing a satisfactory stand can be maintained for many years. Elephant grass is normally established from stem cuttings that are planted similarly to sugar cane in rows of 60 – 90 cm apart. The yield of green forage depends on soil fertility and on how much fertilizer is applied. Compared to other tropical pasture grasses it has a high yield (120 tons per acre are not uncommon). Young leafy grass has low dry matter content (10-15 %).



**Figure 36. Elephant grass**

**Guatemala grass** (*Tripsacum laxum* or *T. andersonii*)

An alternative grass for the dry season. It is a tall leafy perennial (**Figure 37**) and spreads by short stout rhizomes to form large clumps or stools (Whyte *et al.*, 1959, Reynolds, 1995). The leaves are hairy and large. The grass is propagated by stem cuttings or pieces of root-stock (Reynolds, 1995). It is used as a cut-and-carry fodder because it is shallow rooted and can easily be uprooted by grazing stock. It is persistent in both dry and rainy season. In the dry season it is chopped with a manual chaff-cutter to about 8-10 cm and mixed with other feeds for ruminant livestock. It has a reasonable content of nutrients, especially protein, in both dry and rainy seasons. It is more persistent than elephant grass, but less productive and lower in nutritive value. It tolerates acidity.



**Figure 37. Guatemala Grass**  
Photo by S. Reynolds

**Tables 2 – 3** present the proximate chemical composition and macro mineral contents of some common grasses found in the Pacific Island countries.

<b>Table 2. Dry matter content and chemical composition of some common grasses</b>								
Common Names	Scientific Names	Origin	Dry matter	Crude protein	Crude fibre	Ether extract	Ash	Organic matter
Batiki blue	<i>Ischaemum aristatum</i> var. <i>indicum</i>	Fiji (Nasouri)	46.8	9.6	38.4	-	9.4	90.6
Batiki blue	<i>Ischaemum aristatum</i> var. <i>indicum</i>	Samoa (Upolu)	49.9	8.3	38.5	-	7.5	92.5
Guinea grass	<i>Panicum maximum</i>	Samoa (Upolu)	34.5	11.5	10.8	-	10.5	89.5
Guinea grass	<i>Panicum maximum</i>	Samoa (Savai'i)	40.5	10.1	24.0	1.0	10.0	90.0
Guinea grass	<i>Panicum maximum</i>	Fiji	54.9	8.2	28.7	-	8.2	91.8

Guinea grass	<i>Panicum maximum</i>	Fiji	30.1	12.8	-	-	11.3	88.7
Guinea grass	<i>Panicum maximum</i>	Vanuatu	40.6	11.8	24.6	0.7	15.4	84.6
Guatemala	<i>Tripsacum laxum</i>	Samoa	41.5	7.0	48.0	17.5	6.5	93.5
Elephant grass	<i>Pennisetum purpureum</i>	Samoa (Upolu)	34.2	10.2	31.1	2.9	10.9	89.1
Elephant grass	<i>Pennisetum purpureum</i>	Vanuatu						
Palisade	<i>Brachiaria decumbens</i> var. <i>brizantha</i>	Samoa (Upolu)	59.5	6.4	32.0	-	9.5	90.5
Signal grass	<i>Brachiaria decumbens</i>	Fiji	42.0	12.0	33.3	-	11.9	88.1
Signal grass	<i>Brachiaria decumbens</i>	Samoa (Upolu)	32.4	15.5	31.6	-	9.4	90.6
Para grass	<i>Brachiaria mutica</i>	Fiji	36.4	11.1	30.1	-	8.3	91.7
Nadi blue	<i>Dichanthium caricosum</i>	Fiji	32.2	8.2	38.4	-	8.5	91.5
Mission	<i>Pennisetum polystachyon</i>	Fiji	25.0	6.50	28.7	-	12.6	87.4
Koronivia	<i>Brachiaria humidicola</i>	Fiji	32.8	10.4	31.0	-	8.3	91.7
Sugar Cane leaves	<i>Saccharum officinarum</i>	Fiji	89.5	7.7	14.8	4.0	6.5	93.5
Setaria	<i>Setaria sphacelata</i>	Vanuatu	46.9	9.6	15.0	0.4	23.4	76.6
Setaria	<i>Setaria sphacelata</i>	Fiji	15.8	11.1	-	2.7	12.2	86.8
- indicates no data available.								

**Table 3. Macro mineral concentration of some grasses (g/kg)**

Common Names	Scientific Names	Origin	P	K	Ca	Mg	Na
Batiki blue	<i>Ischaemum aristatum</i> var. <i>indicum</i>	Fiji (Nasouri)	0.19	2.76	0.44	0.25	0.24
Batiki blue	<i>Ischaemum aristatum</i> var. <i>indicum</i>	Samoa (Upolu)	0.28	1.65	2.53	-	-
Guinea grass	<i>Panicum maximum</i>	Samoa (Upolu)	0.29	3.90	0.45	-	-

Guinea grass	<i>Panicum maximum</i>	Samoa (Savai'i)	0.29	2.49	0.95	-	-
Guinea grass	<i>Panicum maximum</i>	Fiji	0.29	3.9	0.49	0.25	0.02
Guinea grass	<i>Panicum maximum</i>	Vanuatu	0.15	2.11	0.82	0.16	-
Guatemala	<i>Tripsacum laxum</i>	Samoa	0.18	1.69	0.50	-	-
Elephant grass	<i>Pennisetum purpureum</i>	Samoa (Upolu)	0.45	4.19	0.51	-	-
Elephant grass	<i>Pennisetum purpureum</i>	Vanuatu					
Palisade	<i>Brachiaria decumbens</i> var. <i>brizantha</i>	Samoa (Upolu)	0.36	0.31	0.51	-	-
Signal grass	<i>Brachiaria decumbens</i>	Fiji	0.25	3.18	0.23	0.45	0.02
Signal grass	<i>Brachiaria decumbens</i>	Samoa (Upolu)	0.22	2.18	0.47	-	-
Para	<i>Brachiaria mutica</i>	Fiji	0.39	3.07	0.72	0.25	0.37
Nadi blue	<i>Setaria sphacelata</i>	Fiji	0.21	-	0.42	-	-
Mission	<i>Pennisetum polystachyon</i>	Fiji	0.22	-	0.40	-	-
Koronivia	<i>Brachiaria humidicola</i>	Fiji	0.23	2.1	0.1	0.24	0.67
Setaria	<i>Setaria sphacelata</i>	Vanuatu	0.32	7.75	0.57	0.18	-

- indicates no data available; Source of data: Aregheore, E.M. (2004d)

### Some common creeping legumes found in the Pacific Islands

#### Centro (*Centrosema pubescens*)

This is a perennial twinning and climbing legume with long, smooth stems which often root at the nodes. The trifoliate leaves are slightly hairy. Although centro roots at the nodes it is propagated by seeds which need to be inoculated with the right Rhizobium strain. Centro is slow to establish, however, once established it tolerates higher stocking rates than most legumes (VPIP, 1990). Centro mixes well with both creeping and tufted grasses and is regarded as the most persistent of the introduced legumes to the Pacific (**Figure 38**). It is well adapted to a wide range of soil but does not grow well on coral soils. It can tolerate heavy grazing better than puero but less than hetero (Pottier, 1983).



**Figure 38. Centro**  
Photo by S. Reynolds

**Hetero** (*Desmodium heterophyllum*)

It is a small strongly stoloniferous plant with trifoliate leaves of which the central leaflet is the largest. This legume is usually propagated by cutting because the seeds are difficult to harvest. It spreads quickly with runners on a really wet soil which is the prerequisite for its successful establishment. It is adapted to a wide range of soils. It is a native legume in the Pacific (**Figure 39**) and it is well represented in open pasture and coconut areas. It may be shaded by tall grasses, however it mixes well with stoloniferous grasses and is very persistent under heavy grazing situations (Pottier, 1983).



**Figure 39.Hetero**  
Photo by S. Reynolds

**Mimosa** (*Mimosa pudica*)

Commonly called small mimosa or sensitive grass is a creeping plant with thorny stems (**Figure 40**) and many lobed leaves. It is very common in the Pacific. The leaves are sensitive and fold-up quickly when touched. Although it has proven to be able to produce liveweight gains, it is however, considered a weed and a volunteer pasture legume. It tolerates heavy grazing and does well with low growing stoloniferous grasses. It is not recommended for planting, but should be

accepted where it grows. Small mimosa should be grazed back by continuous grazing rather than rotational grazing as cattle will eat the young tender shoots, but not the older woody thorny material (Pottier, 1983; Reynolds, 1995).



**Figure 40. Mimosa**  
Photo by S. Reynolds

**Puero** (*Pueraria phaseoloides*)

Commonly called Puero or tropical kudzu

It is a perennial creeping legume, vigorously climbing or twining legume with large hairy leaves and hairy stem. The leaves are made up of three round large leaflets. Puero is cylindrical shaped but sometimes somewhat flattened, hairy and turns black in maturity. It can be established from cuttings or seed. It is a legume that is adapted to high rainfall tropical areas and is moderately drought tolerant because of its deep root system. It is fairly tolerant of waterlogging and shading. It also tolerates acid conditions and prefers heavy soils (Vanuatu Pasture Improvement Project (VIP, 1990). It is commonly found on a wide range of soils. It shows seasonal variation in its palatability to cattle, being more palatable after flowering. It cannot tolerate heavy grazing, therefore it is advisable that farmers should be more cautious with early grazing as this may cause it to disappear from the pastures. Puero is the most important cover crop (**Figure 41**) for plantation crops such as coconuts, cocoa, rubber, citrus, oil palm and mango. It is best used in open pastures and it mixes well with improved grasses. It may be sown with a persistent legume such as centro (Pottier, 1983).



**Figure 41. Puero**  
Photo by S. Reynolds

**Siratro** (*Macrotium atropurpureum*)

Is a pioneer legume that is under-rated in the Pacific. Siratro along with leucaena and glycine is the best adapted to coastal soil fertility conditions. It is a deep rooted, creeping and twinning perennial with stems that root readily at the nodes (**Figure 42**). Leaves are trifoliate, dark green and slightly hairy with a characteristic lobe on one side of the leaf. It is not persistent at stocking rates in excess of 1.8 Animal unit (AU)/ha. It has proven more productive than legumes such as centro or verano stylo (VIP, 1990). However, it is more susceptible to leaf and stem damage from fungus *Rhizoctonia solani* than other legumes and can be devastated during extended periods of high humidity. It combine well with a range of grasses and is more drought tolerant than glycine.



**Figure 42. Siratro**  
Photo by H.M. Shelton

For details of other creeping and non-creeping legumes such as: *Alysicarpus vaginalis*, *Calopogonium mucunoides*, *Desmodium heterophyllum*, *Desmodium canum*, *Desmodium intortum*, *Desmodium ovalifolium*, *Neonotonia wightii*, *Stylosanthes guianensis* etc. refer to Reynolds (1995).

**Some common browse plants of the region**

### **Calliandra** (*Calliandra calothyrsus*)

Calliandra (**Figure 43**) has been introduced in Pacific Island countries but has acclimatized and is found growing luxuriantly wild or semi-cultivated in most countries where it is used as a hedge. It is a woody, perennial legume that is well adapted, productive and has some degree of resistance to pests and diseases. The high production potential and high protein content of *Calliandra* make it promising as a supplementary feed. However, owing to its high tannin content, its palatability is less than that of *Leucaena* and *Gliricidia*. Like most tree legumes it remains green throughout the year and produces a lot of leaf biomass. The leaves are used to supplement low quality roughage diets because of its potential as a high protein source (Aregheore, 2005a). The constraint to the feeding of *Calliandra* is its low digestibility in the rumen when it is dried or wilted. It has a high content of phenolic compounds that are responsible for the protection of the protein against degradation in the rumen by microflora. For highly productive dairy cows that need some by-pass prote in, *Calliandra* is a good dietary ingredient (Paterson *et al.*, 1999).



**Figure 43. Calliandra calothyrsus**

### **Erythrina spp.**

The genus *Erythrina* (**Figure 44**) contains several species widely distributed throughout the tropics and subtropics. In the Pacific Island countries two are known, *Erythrina indica* and *Erythrina variegata* var. *orientale* which occur throughout the sub-region and are generally called 'dadap'. They are widely distributed in a wild or semi-cultivated state, especially as fencing and as hedges in compounds. It is a potentially valuable feed supplement (Aregheore, 2004a). *Erythrina* is high in crude protein (20.6 %), comparable with *Leucaena* and *Gliricidia* (Aregheore, 2004a). The season of the year and varietal differences affects its protein content. Aregheore, (2004b) reported a crude protein content of 32.6 %. Despite the high protein content, anti-nutritive factors in the form of soluble phenolic and condensed tannin compounds in the leaves may affect its full utilization in livestock nutrition. Another important anti-nutritional substance in foliage is the alkaloid betaerythroidine but some metabolism occurs in the rumen (*Erythrina* Production and Use, 1993). *Erythrina* spp. however, have high forage quality and could effectively serve as cheap protein supplements for low-quality diets during the dry season (Aregheore, 2004b, Aregheore and Pereira, 2004).



**Figure 44. *Erythrina* spp.**

**Gliricidia (*Gliricidia sepium*)**

*Gliricidia sepium* (**Figure 45**) is a deep rooted, fast growing, medium sized leguminous tree, common in many tropical countries. It was introduced into Pacific Island country animal agro- forestry systems some years ago. The tree has no thorns and a smooth whitish-grey bark. *Gliricidia* is generally deciduous and grows in a wide range of climates and soil types. As it matures, crude protein levels decrease slightly while crude fibre increases. Palatability or acceptability of *Gliricidia* forage can be a problem. The presence of inhibiting substances such as coumarin and flavanol has been suggested to cause low palatability. *Gliricidia* also contains high tannins and total phenols. With ruminants an adjustment period is needed if they have not been fed *Gliricidia* from birth. Animals will lose weight for the first 4-6 weeks after the introduction of *Gliricidia* to their diets. Once animals are adjusted its feed value is well utilized for maintenance and production. However, farmers have developed various means to improve the intake of *Gliricidia*. Wilting, drying or sprinkling of salt or diluted molasses on leaves apparently hastens acceptance (Aregheore and Yahaya, 2002; and Aregheore and Pereira, 2004). Drying and wilting may influence chemical composition, digestibility and voluntary dry matter intake. However, palatability is increased when mixed with grass, straw or other roughages.



**Figure 45. *Gliricidia sepium***

### **Leucaena** (*Leucaena leucocephala*)

*Leucaena leucocephala* (**Figure 46**) is a shrub or tree which can grow up to 20 metres. The leaves are bipinnate, 15 – 20 cm long, with 4-10 pairs of pinnae, each with 5-20 but mostly 10-15 pairs of leaflets; leaflets 7-15 mm long and 2-4 mm wide. The plant is valued for its ability to withstand repeated defoliation, high yields of foliage and tolerance to low soil fertility and relatively low rainfall (Bogdan, 1977). It is remarkably tolerant to adverse moisture conditions, apparently because of its deep roots, and can grow at annual rainfalls of 500 to 5,000 mm; at low rainfall it responds well to irrigation. It is more tolerant of low soil phosphorus status than many other tropical legumes which may be due to the presence of endotrophic mycorrhizae in the roots (Possingham, *et al.* 1971). *Leucaena* is highly productive and palatable (Morris and Du Toit, 1998). It is one of the most widely used forage trees in agro-pastoral enterprises as it provides a number of other products apart from protein rich forage (Brewbaker *et al.*, 1985) and serves as a source of energy and sulphur for rumen bacteria. Like *Gliricidia* it was introduced to Pacific Island country animal agro-forestry systems some years ago. *Leucaena* is one of the most productive fodders and is very popular among livestock farmers. *Leucaena* intake results in a notable improvement in the body condition of animals. Increased levels of *Leucaena* in the diets of both large and small ruminants have positive effect on forage intake and live weight gain. However, one problem with this tree is the defoliation caused by the psyllid (*Heteropsylla cubana*), although this was not as severe in the Pacific as in other areas such as S.E. Asia and psyllid-resistant varieties are now available (such as the cross between *L. leucocephala* and *L. pallida* - known as KX2 F1 hybrid).

The major problem in the utilization of leucaena by livestock is the presence of the non-toxic amino acid mimosine in the forage. Ingestion of large quantities of mimosine can lead to acute and chronic toxicosis, weight loss and death (Morris and Du Toit, 1998). The presence of DHP (3-hydroxyl-4(IH)-pyridone) a degradation product of mimosine, tends to depress rumen cellulolytic activity and cause rumen stasis (Jones 1994). Mimosine toxicity in leucaena diets can be limited by the introduction of mimosine degrading organisms into the rumen. Specialized rumen bacteria may degrade DHP further to harmless compounds. Where leucaena is fed to unadapted stock at rates of more than 30 % of diet, DHP may act as a potent goitrogen and result in hyperthyroidism and death. However, it is possible to inoculate ruminants with DHP degrading organisms and thus overcome the toxic effects (Norton *et al.*, 1994). Estimates indicate that cattle and goats fed with high levels of leucaena leaves plus fresh grasses have improved liveweight gains (Morris and Du Toit, 1998; Aregheore, 2004e).



**Figure 46. *Leucaena leucocephala***  
Photo by S. Reynolds

#### **Cassava leaves (*Manihot esculenta*)**

Cassava leaves (**Figure 47**) are relished as a vegetable in human and livestock nutrition; leaf meal could be successfully used as a protein and minerals source ruminant nutrition. Available ingredients determine the level of cassava leaf meal inclusion in ruminant diets. Cassava leaf meal has an appreciable amount of metabolisable energy with a range of 6.65 - 7.95 MJ kg<sup>-1</sup> (Hutagahung *et al.*, 1974). At high dietary levels the meal has an unfavourable effect due to bulkiness, reduced energy intake and methionine deficiency. Although, cassava leaves have a great potential in human, monogastric and ruminant nutrition, their high fibre and cyanide content limits their use as a major protein source. Cassava leaves contain condensed tannins which may present some grounds for concern in ruminant nutrition. Tannin content in cassava leaves increases with maturity of the plant and varies between cultivars. Tannins have the ability to lower protein digestibility and amino acid availability by forming indigestible complexes with dietary proteins or by inactivation of proteolytic enzymes. Their high fibre content affects their digestibility. Processing is a key element in reducing cyanide (HCN) concentrations in leaves. The anti-nutritional and toxic components present in the leaves of cassava such as HCN and tannins can be removed or reduced to a tolerable level by wilting the fresh leaves and simple sun drying removes these components.



**Figure 47. Leaves of *Manihot esculenta***

#### **Sweet Potato leaves (*Ipomoea batatas*)**

Traditionally sweet potato was grown for tubers and the foliage was considered as a waste and therefore under-utilised (Moat and Dryden, 1993). However, nowadays sweet potato is grown by smallholders as a dual-purpose crop. The vines are fed to livestock and the tubers used for human food. Dry matter production potential per hectare of some cultivars of sweet potato vines (**Figure 48**) can be as high as 4.3 to 6.0 tons/crop (Dominquez, 1992) and the forage (leaf, petiole and stem) accounts for approximately 64 % of fresh biomass. The forage contains 11 – 17 % crude protein and its digestibility is greater than 62 % (Aregheore, 2004c). It has been reported that as a supplement to low quality roughage, sweet potato vines increases intake and rate of liveweight gain of animals (Aregheore, 2004c). Sweet potato forage could be an important resource as an animal feed in the Pacific Island countries. The value of sweet potato is attributed to high yield, palatability and crude protein content. These characteristics coupled with high moisture content (Orodho *et al.*, 1993) make it a suitable protein supplement for animals receiving low quality forage in the dry season.



**Figure 48. Sweet potato vines**

**Vi or Vie plant (*Spondias mombin*)**

This is a native browse plant (**Figure 49**), not yet used in ruminant diets. However, its leaves have medicinal value at the traditional level. Its green fruits are well appreciated by local people. In the Pacific Islands it grows to a full tree whereas, in other tropical countries especially in Africa, its size is small to medium. Its sticks are used as a staking material in yam barns. The leaves have long been recognized to be of nutritional value to small ruminants – goats and sheep hence smallholders harvest them and feed them to their animals as supplements to low quality roughages. The fresh leaves have an astringent taste which indicates the presence of saponins and tannins (Aregheore, 2004d).



**Figure 49. *Spondias mombin***

***Flemingia macrophylla***

*Flemingia macrophylla* (**Figure 50**) is a shrub of 0.6-2.4 m high; branches 3-

angled; leaflets lanceolate to narrowly elliptical, acuminate, up to 30 cm long and 9 cm broad; racemes axillary, 5-15 cm long; bracts linear to lanceolate, 15-20 mm long; calyx-segments unequal, 9 mm long overall; corolla rosy-purple, the standard petal 9 mm long; pod 13 mm long (Adams, 1972). Leaves are stipulate; blades exstipulate, digitately 3-foliolate or 1-foliolate; leaflet blades gland-dotted below. Inflorescences are densely spicate-racemose or paniculate, bracts foliaceous or dry, persistent or deciduous, bracteoles absent; calyx lobes sub equal or lowest longer; vexillary stamen free, remainder connate, anthers uniform; style glabrous. Pods are turgid, dehiscent, continuous within; and about 1.2 cm long. In the South Pacific it is found in American Samoa, Cook Islands, Fiji, Palau, Papua New Guinea, Samoa and Tonga. *Flemingia* appears to have some value as a dry season browse (Skerman 1977), although its digestibility is less than 40 %. Palatability of immature herbage is considerably better than that of older material. Crude protein values range between 14.5 to 18.3% (Asare, 1985). *Flemingia* has lower leaf nutrient levels than *Leucaena* and *Gliricidia*. *Flemingia* with *Centrosema* could be promising for mixing with grasses for temporary pastures on arable land also it could be used to support creeping legumes.



**Figure 50. *Flemingia macrophylla***

### ***Moringa oleifera***

*Moringa oleifera* Lam (synonym: *Moringa pterygosperma*, Gaertner), (**Figure 51**) commonly referred to as 'drumstick tree' or 'horseradish tree' (the taste of the roots), is a member of the Moringaceae that grows throughout most of the tropics including many parts of Africa, Madagascar, India, Pakistan, Bangladesh and Afghanistan and in some Pacific Island countries such as Samoa, Fiji and the Solomon Islands. It is a multipurpose tree of significant economic importance with several industrial and medicinal uses. *Moringa* is a small tree (7-12 m high) with thick grey bark, fragrant white flowers and long green pods. The fruits, seeds, leaves and flowers are eaten as vegetables in some countries. The leaves are rich in carotene, iron and ascorbic acid and the pods in free leucine. The leaves are rich in protein and can be used as supplement to low quality forage (Aregheore, 2002b).



**Figure 51. *Moringa oleifera***  
Photo by Gerald D. Carr

**Mulberry (*Morus alba*)**

Mulberry trees are found in most of the Pacific Islands and from time immemorial have played an active role in the traditional festivity of the inhabitants. Mulberry bark is used for the production of the popular Tapa cloth in the Pacific Islands. In some parts of the world the main use of the mulberry is as feed for the silkworm. Its wood is valuable and, depending on location, it is also appreciated for its fruit, eaten fresh, as juice or as preserves. The young leaves and stems are a delicious vegetable and infusions such as mulberry leaf tea have medicinal properties (Sanchez, 1999). Mulberries can be incorporated in intensive farming systems and used to feed sheep and goats in cut-and-carry systems. Mulberry has high quality forage which is palatable to both monogastric and ruminant livestock (Sanchez, 1999). Small ruminants eat fresh leaves and the young stems avidly, even if they have not been exposed to it before. Cattle consume the whole biomass if it is finely chopped. The nutrient composition of mulberry shows that it would be a formidable forage for monogastric and ruminant livestock in the Pacific Islands where it is found almost everywhere because of the "tapa" cloth production (Aregheore, 2004d).



**Figure 52. *Morus alba***  
Photo by S. Reynolds

### ***Sesbania grandiflora***

It is a fast growing, shrub or short-lived tree that regenerates rapidly after lopping which grows to 4.5 - 6 m high (**Figure 53**) and is copiously branched, with pinnate leaves, pale yellow flowers, and slender, slightly twisted pods up to 25 cm long containing many seeds. The leaves and young branches are cut for fodder for cattle, goats and sheep. *Sesbania* contains the toxic constituent canavanine. Wilting leaves before they are fed to livestock could reduce this.



**Figure 53. *Sesbania grandiflora***

### **Legumes as feed**

A better understanding of legumes and their nutritional composition is necessary so that feeding methods can be modified to avoid some debilitating effects associated with them. Most tree legumes contain anti-nutritive factors (ANFs) such as condensed and hydrolysable tannins, saponins, toxic amino acids (canavanine and mimosine), coumarin, flavanol, and total phenols; their presence causes low palatability and unacceptability to farm animals (Aregheore, 1999). Where such feeds are eaten ANFs interfere with nutrient bio-availability and consequently, utilization. However, over the years, precautions have been taken to reduce these potential limitations and improve the use of legumes in ruminant

livestock feeding. There is now an wealth of information on ways of detoxification of such substances so as to reduce the incidence of toxicity in livestock. Some examples presently adopted at farm level are drying, wilting, soaking, spraying of leaves with chemicals e.g. polyethylene glycol (PEG) 4000 and the inclusion of highly fermentable carbohydrates in diets using the leaves of tree legumes. Plants that are tannin-rich should be fed at less than 25% of the diet dry matter to avoid detrimental effects such as reducing digestibility of fibre by inhibiting the activity of bacteria and fungi.

The proximate chemical composition and macro and micro mineral contents of foliage of some browse plants found in the Pacific Island countries is presented in Tables 4-6.

Local Name	Scientific Name	Origin	DM	CP	CF	EE	Ash	NFE	OM	GE
Calliandra	<i>Calliandra calothyrsus</i>	Samoa (Upolu)	20.8	15.8	21.4	2.0	6.7	54.1	93.3	20.6
Calliandra	<i>Calliandra calothyrsus</i>	Fiji (Suva)	23.2	14.4	28.7	1.3	7.8	47.8	92.2	18.6
Calliandra	<i>Calliandra calothyrsus</i>	Vanuatu	29.0	17.8	12.0	1.1	8.0	61.1	92.0	18.3
Gliricidia	<i>Gliricidia sepium</i>	Samoa (Upolu)	20.2	21.7	15.8	1.0	6.7	54.8	93.3	15.3
Gliricidia	<i>Gliricidia sepium</i>	Samoa (Savai'i)	17.6	13.7	23.8	2.5	14.1	45.9	85.9	14.7
Gliricidia	<i>Gliricidia sepium</i>	Vanuatu	18.0	21.4	12.0	1.6	10.0	55.0	90.0	14.3
Dadap	<i>Erythrina spp.</i>	Samoa (Upolu)	22.7	24.4	25.0	0.5	11.1	39.0	88.0	14.3
Dadap	<i>Erythrina spp.</i>	Samoa (Savai'i)	23.8	35.0	12.8	2.0	11.0	39.2	89.0	14.7
Dadap	<i>Erythrina spp.</i>	Vanuatu	28.0	23.9	18.0	2.4	12	43.7	88.0	13.8
Leucaena	<i>Leucaena leucocephala</i>	Samoa (Upolu)	21.5	24.1	20.0	2.1	6.0	47.8	94.0	17.6
Leucaena	<i>Leucaena leucocephala</i>	Samoa (Savai'i)	25.7	38.8	19.1	2.5	6.5	33.1	93.5	19.6
Leucaena	<i>Leucaena leucocephala</i>	Vanuatu	19.0	23.9	12.0	2.6	7.0	54.5	93.0	18.2
Leucaena	<i>Leucaena leucocephala</i>	Tonga	22.6	22.1	13.7	1.2	7.4	56.8	92.6	18.1
Sesbania	<i>Sesbania</i>	Samoa	20.2	16.	9.6	3.	6.1	63.	93.	16.



Leucaena	<i>Leucaena leucocephala</i>	Samoa (Savai'i)	0.46	4.90	0.94	0.23
Leucaena	<i>Leucaena leucocephala</i>	Vanuatu	0.24	1.31	1.19	0.28
Leucaena	<i>Leucaena leucocephala</i>	Tonga	0.20	1.23	1.66	0.12
Sesbania	<i>Sesbania grandiflora</i>	Samoa	0.20	0.09	1.61	0.23
Mulberry	<i>Morus alba</i>	Samoa	0.31	0.11	2.11	0.32
Vie or Vee	<i>Spondias mombin</i>	Samoa (Upolu)	0.25	1.18	1.39	0.26
Vie or Vee	<i>Spondias mombin</i>	Samoa (Savai'i)	0.32	1.64	1.69	0.34
Vie or Vee	<i>Spondias mombin</i>	Vanuatu	0.33	1.29	1.23	0.36
Cassava	<i>Manihot esculenta</i>	Samoa (Upolu)	0.22	1.88	0.18	0.37
Cassava	<i>Manihot esculenta</i>	Samoa (Savai'i)	0.24	3.35	1.15	0.45
Cassava	<i>Manihot esculenta</i>	Fiji	0.10	0.73	1.55	0.65
Cassava	<i>Manihot esculenta</i>	Micronesia	0.31	0.58	1.61	0.12
Cassava	<i>Manihot esculenta</i>	Vanuatu	0.15	1.47	0.50	0.11
Cassava	<i>Manihot esculenta</i>	Tonga	0.30	0.54	2.93	0.67

**Table 6. Micro mineral composition of leaves of the browse plants**

Names	Scientific Names	Origin	Na - mg/kg	Fe- mg/kg	Mn- mg/kg	Cu- mg/kg	Zn- mg/kg
Calliandra	<i>Calliandra calothyrsus</i>	Samoa (Upolu)	0.06	86	12.7	4.6	28.0
Calliandra	<i>Calliandra calothyrsus</i>	Fiji (Suva)	0.11	92	16.2	3.8	32.0
Calliandra	<i>Calliandra calothyrsus</i>	Vanuatu	0.13	92	15.2	2.8	22.0
Gliricidia	<i>Gliricidia sepium</i>	Samoa (Upolu)	0.05	365	48.5	7.0	22.0
Gliricidia	<i>Gliricidia sepium</i>	Samoa (Savai'i)	0.16	150	50.2	5.5	16.0
Dadap	<i>Erythrina</i> spp.	Samoa (Upolu)	0.03	362	45	10.5	48.0
Dadap	<i>Erythrina</i> spp.	Samoa (Savai'i)	0.08	132	2.5	16.5	61.0
Dadap	<i>Erythrina</i> spp.	Vanuatu	0.18	232	22.5	18.5	51.0
Leucaena	<i>Leucaena leucocephala</i>	Samoa (Upolu)	0.04	129	21.8	3.5	38.0

Leucaena	<i>Leucaena leucocephala</i>	Samoa (Savai'i)	0.05	130	25.8	11.0	28.0
Leucaena	<i>Leucaena leucocephala</i>	Vanuatu	0.05	148	35.8	16.0	38.0
Leucaena	<i>Leucaena leucocephala</i>	Tonga	-	176.8	58.9	3.9	61.4
Sesbania	<i>Sesbania grandiflora</i>	Samoa	-	62.7	11.9	4.3	37.1
Mulberry	<i>Morus alba</i>	Samoa	-	132.3	16.6	5.4	26.4
Vie or Vee	<i>Spondias mombin</i>	Samoa (Upolu)	0.04	93	1.5	6.5	14.0
Vie or Vee	<i>Spondias mombin</i>	Samoa (Savai'i)	0.08	96	1.8	5.4	16.0
Vie or Vee	<i>Spondias mombin</i>	Vanuatu	0.06	106	1.6	6.4	14.0
Cassava	<i>Manihot esculenta</i>	Samoa (Upolu)	0.06	138	3.7	15.0	96
Cassava	<i>Manihot esculenta</i>	Samoa (Savai'i)	0.02	154	4.5	18	104
Cassava	<i>Manihot esculenta</i>	Fiji	0.01	164	429.5	4	145
Cassava	<i>Manihot esculenta</i>	Micronesia	0.05	113	99.5	3	147
Cassava	<i>Manihot esculenta</i>	Vanuatu	0.05	143	129.5	8	132
Cassava	<i>Manihot esculenta</i>	Tonga	0.03	147	243	13	18

Leucaena generally has low levels of tannins which allow efficient utilization of the protein by assisting amino acids to bypass complete degradation in the rumen (Middleton *et al.* 1994). Ruminants need a special anaerobic bacteria, (*Synergistes jonesii*) to detoxify mimosine. Animals without the bacteria can only tolerate 30 % leucaena in their diet before growth is reduced, hair loss and thyroid enlargement occurs. This is the level that has given optimum growth rates in goats (Pacific Agroforestry, 1999). Animals without the bacteria can be infected with it by taking some rumen fluid from an animal with the bacteria and drenching them or adding the rumen fluid to their drinking water.

## 7. Descriptive and analytical data of some feed resources

### Crop residues

Crop residues are wastes from harvest and processing and in most cases constitute an environmental nuisance, but they could be a good source of nutrients for livestock when properly harvested, processed and stored. They are invariably fibrous, low in protein, minerals and vitamins; and some have low digestibility. **Table 7** presents the dry matter content and chemical composition of some common crop residues found in the region. Crop residues are produced on-farm and therefore widely scattered in farming communities. In most developing countries they form the major feed for ruminant livestock, especially

during adverse weather such as dry season and drought. Their nutritive value varies greatly according to kind (how rich in fibre, energy or protein); harvest conditions and methods can alter their food value. Certain indigestible compounds or anti-nutritive substances could also limit their use at least for certain types of animals especially monogastrics. Various physical, biological or chemical treatments can be used to improve the food value of the fibrous ones like straw, stover and bagasse, (Aregheore, 2000a). Some crops such as sugarcane or bananas could produce fodder units per hectare in quantities superior to most conventional fodders.

**Table 7. Dry matter content and chemical composition of some common crop residues**

By-product	Origin	Dry matter	Crude protein	Crude fibre	Ether extract	Ash	Organic matter	Gross energy (MJ/kg DM)
Breadfruit peel	Samoa	91.9	7.4	11.5	1.0	16.5	83.5	14.9
Breadfruit peel	Tonga	85.6	6.8	8.5	4.0	5.9	94.1	14.5
Breadfruit peel	FSM	91.7	6.6	6.4	1.0	6.5	93.5	14.9
Breadfruit peel	Fiji	90.1	9.1	8.1	5.0	7.8	92.2	15.0
Banana peel	FSM	88.4	6.4	13.0	1.8	9.6	90.4	13.5
Banana peel (short)	Fiji	88.4	6.4	7.2	11.0	9.6	90.4	13.5
Banana peel (short-ripe)	Fiji	85.7	6.2	5.3	7.5	12.1	87.9	15.9
Banana peel (long)	Samoa	92.6	5.3	6.4	4.0	9.0	91.0	15.3
Banana peel (long - ripe)	Samoa	87.1	5.0	5.5	9.0	13.8	86.2	15.9
Banana peel	Samoa	93.2	4.5	7.3	3.5	3.8	96.2	15.4
Banana peel	Tonga	85.5	6.0	9.2	8.0	6.8	93.2	15.5
Banana peel	Tonga	87.1	5.3	8.1	9.0	13.8	86.2	15.9
Banana pseudo stems	Samoa	94.0	7.0	63.2	3.5	18.5	81.5	13.5
Cassava	Vanuatu	93.2	4.5	18.3	2.5	3.8	96.2	15.4

peel								
Cassava peel	FSM	91.1	8.9	12.5	7.5	9.7	90.3	15.6
Cassava peel	Cook Islands	92.9	6.6	13.4	2.5	8.9	12.5	15.3
Cassava peel	Vanuatu	86.7	3.5	11.8	3.5	4.3	95.7	14.4
Cassava peel	Fiji	91.9	4.1		6.0	6.8	93.2	14.5
Cocoyam peel	Fiji	86.7	4.4	9.4	0.5	7.2	92.8	16.3
Cocoyam peel	Cook Islands	89.6	3.1	8.3	5.0	10.6	89.4	15.2
Potato peel	Fiji	87.2	5.5	19.5	1.5	5.1	94.9	14.1
Potato peel	Samoa	92.5	5.8	-	1.0	6.4	93.6	14.8
Potato peel		91.0	5.3	-	5.5	3.7	96.3	15.5
Rice straw	Fiji	92.4	4.6	36.4	0.3	15.8	84.2	13.4
Maize stover (sweet maize)	Samoa	90.0	6.0	45.3	0.2	8.3	91.7	12.2
Maize stover (white maize)	Samoa	89.6	7.4	29.4	1.7	8.1	91.9	18.6
Pineapple peel	Samoa	84.5	2.4	14.0	8.5	3.0	97.0	-
- indicate no data available. FSM – Federated States of Micronesia								

### Agro-industrial by-products

These are the material which remains after the main product has been removed or extracted in an industry and are confined to factory sites. They result from the processing of crops such as sugar cane, oilseeds, rice, sorghum, maize, malt, citrus, pineapple, cocoa, coffee, bananas, breadfruit or the slaughter and processing of livestock and fish. Some could be marketed and exported for foreign exchange. **Table 8** presents dry matter content and chemical composition of some agro-industrial by-products. Some are rich in protein (especially the oilseeds) or sugar (molasses, citrus and pineapple pulp/peel) and occasionally in starch (e.g. bananas, cassava peel) and are usually low in fibre. They are divided into four categories:-

- those that are high in fibre and low in protein;
- those that are high in fibre and in protein;
- those low in fibre and low in protein; and
- those that are low in fibre and high in protein.

Most by-products are cheap, low energy feed ingredients and locally available. Below is a description of some agro-industrial by-products which are available in the PICs.

### **Cocoa by-products** (*Theobroma cacao*)

Cocoa is grown in Samoa, the Solomon Islands, Vanuatu and Papua New Guinea. Cocoa beans are the commercial products. Several by-products of value to livestock are generated during processing. Shells and dust are waste but the value of these fractions as a possible livestock feed has received very little attention in tropical countries; they are a good source of feed for ruminants. When fed to cows they increase the butterfat and vitamin D content of the milk. Cocoa beans and shells are high in the alkaloid, theobromine, the presence of which reduces their use in large quantities in compound rations. Theobromine has an unpleasant taste; palatability and toxicity problems usually occur when large quantities of the beans or shells are used in stock rations. Absolute drying removes to a large extent the theobromine and other alkaloids that are present in the shells and the beans. Cocoa pod, husk and cocoa seed shell (**Figure 54**) when dried and milled are suitable to meet the maintenance and perhaps part of the production rations of sheep, goats and cattle (Aregheore, 2002c). The husk is free of theobromine but high in fibre and this makes it a suitable source of bulk in ruminant diets.



**Figure 54. Cocoa Shell**

### **Noni juice extract waste** (*Morinda citrifolia*)

*Morinda citrifolia*, also called noni, nonu or kura, great morinda or Indian mulberry is a member of the Rubiaceae and grows extensively throughout the South Pacific region as an important medicinal plant. Noni is a genus of about 80 species, mostly of tropical origin. Its traditional uses vary from one country to the other in the South Pacific. The juice from the fruit is regarded as having medicinal properties and most people in the Pacific Island countries drink it. The juice is high in vitamin C and there is a high demand for it as an alternative medicine for a host of illnesses. Its fruit is shaped like a potato with pineapple-like spots and turns from green to white as it ripens. It is the most used part of the plant but the seeds, roots, flowers, bark and leaves can be used medicinally. During extraction of juice from ripe noni fruits, large amounts of waste are generated which is discarded (Aregheore, 2005b). In both wet and dry state when noni juice extract waste (**Figure 54**) is offered on a cafeteria basis to livestock, they often reject it (Ken Newton, personal communication, 2002). The waste is the pericarp,

pulp and seeds.



**Figure 55. Noni juice extract waste (milled)**

#### **Coffee pulp meal (*Coffea arabica*)**

Coffee is grown in the South Pacific; its pulp represents a major agricultural waste which might be incorporated into animal feed. Pulp from wet processing forms 40 % of the weight of the fruit (Carlos *et al.*, 1982). Attempts have been made to use coffee pulp as a feed for cattle, pigs and poultry, but with little success (Clifford and Ramirez-Martinez, 1991). Coffee pulp as an animal feed has a number of problems; it has a good amino acids profile (Morgan and Trinder, 1980). Fresh pulp has a crude protein content between 2.1 - 3.2 %, while dehydrated pulp has 11.2 - 12 % crude protein. If coffee pulp is used in excess of 20 % of rations, feed utilization and growth rates are impaired due to the presence of ill-defined anti-quality and toxic components. Various components, including caffeine, low molecular mass phenols and tannins have been blamed for the undesirable effects. Caffeine level and its effects depend on variety. In ruminants coffee pulp has a diuretic effect due to the caffeine and unavailable lignified protein so ruminant rations which contain more than 20 % coffee pulp result in low feed intake due to poor palatability and the toxic effects of caffeine, chlorogenic acids, tannins and high fibre. Tannins interfere with protein and dry matter digestibilities by inhibiting protease and other enzymes or by forming indigestible complexes with dietary protein. Ensiling improves the digestibility of the pulp for ruminants.

#### **Copra cake/meal (*Cocos nucifera*)**

Copra cake remains (**Figure 56**) after the extraction of oil from the dried meat of coconut and is the most abundant and perhaps the cheapest protein and energy source in the South Pacific region (Ochetim, 1987; Aregheore, 2005c). Depending on the method of oil extraction the cake contains between 20 - 30 % protein, 1 - 7 % oil and about 7 - 10 % crude fibre (Creswell and Brooks, 1971). In the South Pacific, crude protein content ranges from 15.6 - 22 %. Dietary fibre and rancidity are major problems associated with the cake. Dietary fibres interfere with the absorption of other nutrients and in the macro-molecular form are anti-nutritional due to gel formation (hydrated polysaccharides). Residual oil in the cake has a tendency to become rancid, reducing appetite for feeds prepared with it. As a

feed ingredient, it should not be more than 15 % in the diet (Thomas and Scott, 1962). Efficient drying is the only means by which rancidity (free fatty acids) can be overcome.



**Figure 56. Copra cake/meal**

**Desiccated coconut waste meal.** Desiccated waste meal (DCWM) is obtained when fresh coconut flesh is crushed to extract coconut cream which is used for the production of oil for cooking, body cream and other products. It is readily available but is often discarded in both urban and rural areas. It is ideal for ruminants either wet or dry. In the wet form it does not keep long because of the development of rancidity and a foul smell. It is imperative to use it as soon as possible after processing or to dry it in the sun or by other cheap means (Aregheore and Tunabuna, 2000). If drying is not properly done an unpleasant flavour and odour result which affect intake and in some cases a total rejection of a concentrate diet compounded with it. There is need to dry it to minimize the development of free fatty acids that may develop due to residual oil. The protein is low in lysine and histidine. The meal is also high in fibre. These factors limit its use in the diets of monogastrics. In ruminants neither protein nor fibre content are limiting factors and DCWM provides an acceptable and very useful protein and energy supplement.

#### **Brewers' grains**

Brewers' grains, (**Figure 57**) are the extracted residue of malt (generally barley). They contain the insoluble material remaining after the process of mashing and cooking with water which include the fibre fractions, fats, proteins, together with residues of starch and dextrans. Brewers' grains are available in most countries of the region that have a brewery. The major use of this material is feed for livestock (Bovolenta *et al.*, 1999) especially ruminants. After drying to allow storage and improve nutrient concentration the product is known as dried brewers' grains (Bovolenta *et al.*, 1998). Concentration of fibre fractions and low protein degradability means that brewers' grains are preferentially used for feeding ruminants. They are available and wasted in some Pacific Island countries (Aregheore, 2000a). Brewers' grains are less bulky, less palatable and less laxative than wheat bran; their acceptance and value can be improved by adding molasses. They could be fed wet or dry but should not be included in high quantities in the diets of monogastrics. Their chemical composition is influenced by the type and cultivar of cereal in the fermentation process and the efficiency by which starch is converted to alcohol.



**Figure 57. Brewers' grains (Wet)**

### **Palm kernel meal**

Solomon Islands and Papua New Guinea have oil palm, the major source of palm kernel meal. Kernel meal after the extraction of oil is dry, gritty and not readily accepted by livestock, however, it is widely used in ruminant diets (Aregheore, 1992; 1993). Palm kernel meal has a low biological value and poor nutritive value compared to other oil-seed meals. Oyenuga (1968) implicated the fibrous and gritty nature of palm kernel meal as factors that militate against its use in the diets of monogastrics. Its crude protein content ranges from 15.8 - 20.4 % (Babatunde *et al.*, 1975; Gohl, 1981; Aregheore, 1992). Palm kernel meal is a wholesome material, readily eaten by ruminants if mixed with palatable or well-liked feeds such as molasses. Research in other countries, in particular Malaysia has confirmed that other parts of the oil palm such as fronds and by-products such as mill effluents can be used in feeding programmes.

**Oil Palm Fronds (OPF)** - Oil palm fronds are abundant waste fibrous material from oil palm plantations derived from the harvesting of oil palm fruit bunches and the pruning management; they are a source of forage in livestock-crop production systems (Dahlan, 1992a). OPF have been extensively evaluated in livestock feedings trials in Malaysia (Dahlan, 1992a, b), and although the use of oil palm fronds as ruminant feed is limited because of their low nitrogen content, fresh OPF could provide sufficient amounts of both metabolisable energy (ME) and protein for maintenance of pre-slaughter goats (Dahlan *et al.*, 2000). Oil palm fronds contain high fibre and low protein, but moderate dry matter digestibility. Different techniques of processing and supplementation of the fronds to make them suitable for ruminants have been advocated. The addition of non-protein nitrogenous source and soluble carbohydrate can improve the nutrient quality, nutrient intake and digestibility. It has been observed that preserved oil palm fronds with urea or molasses increased the nutrient content of OPF. Ensiling and pelleting could also increase the digestion characteristics of OPF.

**Palm Oil mill Effluents (POME)** - Sludge and condensate effluents from palm oil mill could also be effectively prepared and used in the diets of lactating and animals for fattening.

### **Molasses**

Molasses is the by-product after the maximum sugar has been extracted. There are many kinds of molasses but the description here is for cane sugar. Molasses

has considerable value in ruminant feeding. It has a very high moisture content, serves as a carrier for urea in liquid supplements for ruminants and is highly used in urea-molasses blocks, improving their palatability as well as increasing palatability, it settles dust and serves as a binder. It can be used to improve the intake of low quality feedstuffs. Molasses is a highly concentrated plant extract, and contains a wide range of trace minerals, vitamins, sugars and is particularly rich in potassium and sulphur. In silage making it ferments quickly and this is an advantage during the ensiling (Gohl, 1981). Molasses is abundant in Fiji and Papua New Guinea.

### Cereal by-products

They are by-products of flour mills; wheat bran or mill mix has wide acceptance in the diets of livestock. These are commercially available and extensively used in ruminant nutrition. Important by-products include maize bran, wheat bran and rice bran. They can be low or high in fibre depending on processing methods. These are usually cheap, low energy materials are used feed-millers to make cheap feeds or formulate low energy diets.

By-products	Origin	Dry matter	Crude protein	Crude fibre	Ether extract	Ash	Organic matter	Gross energy (MJ/kg DM)
Rice bran	Fiji	89.0	10.6	18.2	0.3	15.8	84.2	13.4
Wheatings	Fiji	86.3	19.5	10.3	4.8	5.7	94.3	10.4
Bagasse	Fiji	93.1	4.1	47.0	1.3	3.9	96.1	14.5
Fresh brewers' grains	Samoa	27.6	23.8	17.5	8.0	3.0	97.0	13.6
Brewers' dried grains	Samoa	92.0	23.5	38.3	8.5	5.6	94.4	18.5
Brewers' dried grains	Tonga	93.4	18.4	27.3	2.9	4.4	95.6	19.6
Brewers' dried grains	Vanuatu	85.5	18.7	11.8	6.2	7.2	92.8	-
DCWM*	Samoa	89.6	18.8	31.2	16.8	4.8	95.2	21.3
Cocoa pod husk	Samoa	91.8	6.7	45.8	1.4	11.1	85.7	21.3
Cocoa shell	Samoa	97.5	16.0	58.0	19.0	7.5	92.5	23.4
Cocoa dust	Samoa	94.5	13.8	61.0	22.0	3.5	96.5	22.6
Molasses	Fiji	8.6	7.8	0.8	0.4	18.4	81.6	-
Molasses	Fiji	77.4	3.5	0	0	8.9	91.1	12.9
Noni juice extract waste	Samoa	90.4	12.6	54.7	1.1	8.8	91.2	15.4
Copra cake	Fiji	83.1	18.6	31.0	22.0	1.2	98.8	15.6

Copra cake	Fiji	90.0	18.0	9.0	7.5	5.3	94.7	15.4
Copra cake	Fiji	90.0	20.4	9.0	11.7	-	-	18.0
Coconut flesh (fresh)	Fiji	83.1	6.0	-	22.0	1.2	98.8	15.8
Copra cake	Samoa	90.0	18.8	30.2	17.5	4.0	96.0	21.2
Copra cake	Samoa	97.8	24.2	10.0	9.6	7.9	92.1	14.9
Copra cake	FSM	96.6	18.4	29.3	8.5	4.1	95.9	30.2
Copra cake	Vanuatu	85.4	16.9	12.6	13.6	9.1	90.9	-
Meat/bone meal	Vanuatu	91.1	44.9	1.0	10.1	27.6	72.4	-
indicate no data available.								
*DCWM - Desiccated coconut waste meal								

### **Rice bran, pollard and polishing**

These are by-products of rice milling, and consist of the testa and embryo of the grain. Their composition varies depending on the processing procedure. The material may be separated as bran and pollard. Bran is higher in fibre, whereas pollard is higher in protein and fat. Rice bran is the ungraded by-product obtained in processing rice for human consumption. It is a good concentrate ingredient for ruminant livestock with a moderate concentration of fibre and is used as a filler in most formulated concentrates for ruminants (Gohl, 1981). Rice bran, pollard and polishings are found in Fiji, Solomon Islands and Papua New Guinea.

### **8. Impact of the use of the feeds/forages**

Agriculture in the South Pacific region is subsistence and crop-oriented, livestock are kept as a sideline against crop failure, consequently, the ruminant livestock industry is not as developed as it should be. With the increase in the demand for animal products, livestock production is now being embraced by farmers. There are many reasons for the relatively underdeveloped status of livestock in the region such as feed, social attitudes, lack of appropriate technologies, disease control, marketing, and poor extension services. The potential to increase and improve ruminant production requires the introduction of practical technologies in feeds for smallholders as the only means through which sustainability could be achieved, because smallholders hold much of the ruminant livestock.

Livestock are an integral component of the mixed farming systems that predominate in the Pacific island countries, therefore any introduced technologies should aim at achieving a balance to increase productivity, enhance wealth, while resource degradation is minimized. Grazing will avoid harvesting feed manually or mechanically, processing, storing it, and transporting it to animals. The livestock are moved to the forage during its peak production period. Farmers will manage the pasture as an important crop in itself and the animals provide a way to market it.

Grasses such as batiki, Guinea, signal and buffel are drought tolerant and could be used for pasture to provide biomass for an all-year round feeding. Legumes such as *Centrosema*, *Stylosanthes* and Siratro that are well established in the region could be in inter-cropping. Food-feed inter-cropping or mixed farming systems will make very efficient use of natural resources and use the synergies

that exist between livestock and crops. Crop residues feed animals and manure fertilizes the soil. Since mixed farming systems generally have a negative nutrient balance, the transfer of nutrients from grazing land to cropland through animal manure is important. Crop rotations involving a grazed pasture phase can be highly efficient in generating nitrogen, whilst helping control crop diseases. This is practiced in Fiji and Vanuatu. Food-feed inter-cropping or mixed farming can add to soil biodiversity and animals are often the justification for agro-forestry inputs such as fodder trees (Vizard, 2000), and according to Vizard (2000) with the growth of human population and greater need for both crop and livestock production, the need for integrated systems will increase. Animal husbandry in this context must utilize crop, animal and urban by-products and residues efficiently, combined with weeds, grasses and any crop surplus that may be available (Vizard, 2000).

### **Some economic data**

The role of livestock in human development is great; animal products are needed for physical and intellectual development and for developing immunity against disease. Livestock therefore are an important instrument for socio-economic change to improve income and quality of life. Reddy (2001) reported that livestock make an important contribution to most economies in the Pacific islands. They produce food, provide security, enhance crop production, generate cash for rural and urban populations, provide fuel and transport, and produce value added goods which can have multiplier effects and create a need for services. Furthermore, livestock diversify production and income, provide year-round employment, and spread risk; they also form a major capital reserve in farm households.

Feed is important for livestock production so the livestock sector is an integral part of agriculture. Questions that arise are, can domestic production be increased without consideration of feed and what are the implications of using local feeds for ruminants (Reddy and Sharma, 2002)? Information on the economic benefits of forages, crop residues and agro-industrial by-products as animal feeds are scant in the region. Reddy and Sharma (2002) looked at two types of livestock production in the Pacific: traditional and commercial. The traditional, small-scale, semi-subsistence production system, is cost-free because cattle, sheep and goats graze unmanaged pastures, while commercial, large-scale production systems use commercial feed (**Table 9**). If PICs were to increase domestic production of meat, more pasture will be needed but, in view of the contracting pastureland due to conversion to more profitable uses, there is a need for a substitute from either imports or an alternative domestic source.

Intensified livestock production requires high expenditure on feed and may be a potential cause of loss of foreign exchange for small Pacific Island nations. Substituting domestically available for imported feed can reduce this problem and help stimulate the whole economy. Reddy and Sharma (2002) suggested that there is a need for more work and research on how this could be achieved, bearing in mind the dietary requirements of livestock and cost-benefit factors related to domestic production vis-à-vis importation of feed.

### **Country studies**

In Samoa beef is now the major income earner on land planted with coconuts. On a well managed smallholder, integrated cattle-coconut unit a farmer can expect a gross margin of around US\$ 267 per hectare compared with US\$138 from coconuts alone. Both examples exclude the cost of labour (Lee, 1996). In Papua New Guinea cattle under coconuts reduces upkeep costs. With coconuts in monoculture it costs about US\$ 96.00 for upkeep but with cattle it costs only US\$

27.00, a reduction of about 70 percent.

In the Solomon Islands the economic advantage of cattle under coconut plantations is reduced weeding costs, increased copra production and income from beef sales. Jonah (2004), in a study to analyse the costs and returns from beef cattle production and using 30 beef cattle farmers in Efate Island Vanuatu, reported that 40, 50 and 70 % of household income came from beef cattle on small, medium and large farms respectively. Signal grass and glycine dominate the pastures used by farmers. Average per farm annual returns from livestock were US\$ 2,230 (small farms), US\$ 4,877 (medium farms), and US\$ 22,000 (large farms). Large farmers sell full grown mature cattle directly to butchers and abattoirs, whereas small and medium farmers sell young cattle to traders in the village, so they receive relatively low prices.

<b>Livestock</b>	<b>Traditional/Small Scale/Semi-Subsistence Production System</b>	<b>Commercial/Large Scale Production System</b>
<b>Cattle</b>	Tethered near crop farms, grazed along road side, etc.	Managed Pasture
<b>Sheep</b>	Tethered near crop farms, grazed along road side, etc.	Managed Pasture
<b>Goats</b>	Tethered near crop farms, grazed along road side, etc.	Managed Pasture

Source: Reddy and Sharma, P. (2002) Economic Benefit of Utilizing Local Resources for Livestock Feed

Aregheore and Tunabuna (2001), in a feeding trial used desiccated coconut waste meal (DCWM) at varying levels of 0, 38.5, 48.5 and 58.5 % with other feedstuffs in concentrate diets that were fed to goats for 56 days, reported that DCWM mixed well with other feedstuffs and goats accepted the diets without deleterious effects. The 38.5 % DCWM inclusion level was the best for the growing goats however the inclusion of DCWM at high levels did not significantly reduce cost/kg of the concentrate diet and liveweight gain (**Table 10**).

<b>Parameters</b>	<b>Diets</b>			
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
Weight gain, 56 days	6.5b	9.0 a	5.1 bc	3.7d
Average daily gain, kg/day	0.116 b	0.160 a	0.90 b	0.66 d
Concentrate intake, g/day	368 ab	358b	258c	188 b
Forage intake, g/day	309c	309c	385 a	406 b

Average daily feed intake, g/day (concentrate + forage)	677 a	667 ab	643 bc	594d
Feed efficiency [FE], feed/gain	5.8ab	4.2 ab	7.1 b	9.0c
Total cost of concentrate diet, WS\$	17.83	24.05	24.54	28.00
Cost/kg of concentrate consumed, WS\$	0.42	0.57	0.58	0.67
Cost/live-weight gain, WS\$	0.21	0.28	1.55	0.98
a, b, c, Means within row with different superscript differ (P<0.05) 1, 2, 3 & 4 = 0, 38.5, 48.5 and 58.5 % desiccated coconut waste meal (DCWM)				

Rokomatu and Aregheore (2005) studying voluntary dry matter intake, growth and nutrient digestibility by Fiji Fantastic sheep fed a basal diet of Guinea grass alone or supplemented with either a concentrate mixture or crushed wheat grain observed that:- a cost comparison indicated that total supplement (kg) offered to sheep in groups B and C for 92 days was 319.1 and 129.7 kg, respectively, while the total cost and cost /kg of supplement for sheep in groups B and C were US\$658.4 and US\$185.5; US\$2.0 and US\$0.86, respectively. Cost analysis of the supplementation demonstrated that the concentrate mixture was expensive compared to wheat grain. However, the significant differences observed in the daily liveweight gain of group B sheep above other groups seems to justify the supplementation when sheep are fed a basal diet of native Guinea grass (**Table 11**).

**Table 11. Performance characteristics of sheep on forage, concentrate mix and wheat**

Parameters	Diets*			sem ±	Isd	Sign.
	A	B	C			
Forage intake (g)	536	289	287	2.69	4.14	***
Concentrate intake (g)	-	578	-	-	-	
Crushed Wheat intake (g)	-	-	235	-	-	
Proportion of forage in total DMI	100	33	55	-	-	
Total dry matter intake (g)	536	867	522	22.11	11.90	***
Feed efficiency (kg DMI/kg live-weight gain)	17.87	11.56	12.43	-	-	-
Total supplement for 92 d (kg)	-	319.1	129.7			
Cost of total supplement (US\$)	-	658.4	185.5			
Cost/kg of supplement (US\$)	-	2.0	0.80			
*A - Guinea grass ( <i>Panicum maximum</i> ); B - Guinea grass plus concentrate mixture; C - Guinea grass plus crushed wheat grain. US\$ – United States Dollar sem-Standard error of mean; Isd-Least significant difference. Sign.-Significant; *** (P<0.001) at 0.001 % level of significance						

Tamani (2004) investigated the effect of inclusion of molasses in concentrate supplements on milk yield and the effects of supplementary feeding on voluntary

digestibility coefficients of cows grazing setaria pasture in Fiji. He reported that lactating dairy cows would require a source of readily fermented energy such as molasses in their diets. Economic data on production parameters - milk yield, fat corrected milk, body condition score and apparent nutrient digestibility coefficients, indicated that molasses levels in the range of 5 - 10 % are ideal, however 10 % was best and recommended for concentrate diets of lactating dairy cows on a basal diet of *Setaria*.

Supplementation of goats with 33% *Leucaena* and 66% *Sesbania* showed optimal digestible dry matter intakes (17.8 and 20.3 g/h/d respectively) and liveweight changes were 71 and 63 g/d respectively (Pacific Agroforestry, 1999). The digestibility of most tree legumes ranges from 40 – 65% with a crude protein percentage of 16 - 30% with leucaena identified as one of the highest quality giving the highest long-term growth rates in cattle.

Benefits and considerations of domestic production; a number of economic and social benefits could accrue to PICs with increased domestic production of livestock feed, including:

1. improved foreign reserves, through reduced imports, export of surplus production with competitive prices;
2. stimulation of domestic industries, increased employment opportunities, increased income (household and national)

There are important issues to be addressed before endeavouring to significantly increase domestic production and a need to:

1. identify all possible domestic sources of livestock feed;
2. examine the nutrient contents of these feeds;
3. develop feed formulation and carry out experiments on digestibility; and
4. conduct cost-benefit analysis to determine the total direct and indirect and net costs and benefits of domestic production vis-à-vis importation of feed.

### **Feeds and forages likely to increase in use and why**

A number of local feed resources are available in the Pacific Islands whose potentials as animal feed are partially untapped (Aregheore, 2000a). Some are used at various capacities in intensive production systems while smallholders use them as supplementation to their animals. Some available and potential feedstuffs in the region that can be used in ruminant livestock have been highlighted (Naidu 1989; Aregheore, 2001a, b). Where large quantities are produced, transport cost often limits their potential users while farmers nearby fail to use them due to lack of knowledge (Moat, 2002).

Crops such as cassava, cocoyams, breadfruits, bananas/plantains, potatoes and yams are major traditional staple foods, with rice and maize in Fiji, Vanuatu and the Solomon Islands. When these crops are harvested and processed, residues and by-products remain. Crop residues are produced on-farm and therefore widely spread in farming communities. Examples of crop residues are peel and leaves from cassava, breadfruit, taro, bananas/plantain and yams; vines from sweet potatoes, banana pseudostems; straw and stovers from rice and maize; sugar cane tops. These residues are characteristically low in metabolisable energy and nitrogen which leads to low intake, but they are a key element in ruminant nutrition and can meet nutritional requirements of animals if properly processed. When residues from roots and tubers including bananas are properly processed

they substitute in part for cereals and other carbohydrate sources in ruminant rations.

Generally, the cheapest and most available feed in the region for smallholders is pasture, so they rely heavily on it. Sustainable ruminant production depends on correct management of pasture and animals to provide profitable returns on investment in forage production. Farmers need adequate quantity and quality forage supply throughout the year for the least possible cost. Consequently, animal production in terms of growth, lactation and reproduction could only be achieved when the forage consumed is in excess of that required for maintenance; lactation needs are greater than for growth. The amount of forage eaten, therefore, depends on availability, physical and chemical composition and the nutrient requirements of the animal.

Intake is highly correlated with digestibility, but other factors are involved. A major physical factor that affects intake is the rate at which the material is broken down to a particle size small enough to pass out of the rumen. Legumes break down more easily than grasses and their intake is higher, even at the same digestibility. Differences also exist between parts of the same plant so leafiness is important. Most of our natural pastures, particularly in the dry season, are of poor quality and have a high content of less degradable materials such as cellulose, hemicellulose and lignin as well as a lower quantity of easily digested carbohydrates, sugars, pectin and fructosans (Singh, 2001). When tropical pastures are spelled for dry season grazing most of the material becomes too fibrous and lignified; it further loses quality when there are brief showers since most of the soluble sugars in the leaf blades are dissolved. Animals will tend to lose weight even when enough forage is on the ground in the dry season. This calls for supplementation with crop residues and agro-industrial by-products or with browse.

In the dry season when animals have only low quality native grasses for grazing, the foliage of tree legumes and shrubs complements low quality forage/roughage and crop residues (Aregheore, 2000b). Examples of common tree legumes fed to ruminants in the region are *Leucaena leucocephala*, *Gliricidia sepium*, *Sesbania grandiflora*, *Erythrina* spp. and *Calliandra calothyrsus*. Such legumes have advantages during drought:

- their protein quality of remains high at maturity;
- they have a deep root system and can exploit underground moisture that is not accessible to grasses and low growing legumes which normally die out;
- they can grow on soils of low fertility or barren terrain due to symbiosis with rhizobia;
- species that are suitable for both acidic and alkaline soils have been identified;
- tree and shrubs in grazing systems to provide browse to increases the carrying capacity;
- during drought or when tropical grasses flower and become stemmy they are a source of protein, vitamins and minerals;
- fruits and pods are sources of protein and carbohydrates;
- they are useful in cut and carry system and as shade trees for cash crops;
- trees provide shade and help stock dissipate their "heat load";
- they increase the digestible dry matter intake;
- legumes that have higher rates of degradability result in low rumen "load" by stimulating rumen function.

Pasture is the cheapest feed and will continue to play a significant role in ruminant nutrition in the Pacific Islands. The present trend is to match ruminant production with available feed, because resources within the region such as foliage of trees, grasses, crop residues and agro-industrial by-products can be used to counter the cost of imported feed. In the dry season, legumes have a proven record as palatable nutritious forage and can be used as supplements to poor quality feeds. Ruminants can utilize proteins from plants that have high fibre content. **Figures 58– 63** contain photographs to illustrate their role and why pasture will continue to be used in ruminant nutrition in the PICs.

Forage legumes are abundant in the region; *Gliricidia* grows well and is used as live fence posts; fodder may be cut and dropped in the paddocks a day before animals are to graze. Wilting increases intake although there is some initial aversion to the consumption of *Gliricidia* but animals usually accept it after an adaptation period (*Gliricidia* Production and Use, 1989).



**Figure 58. Farmers field-day visit at Tisman Malekula, Malampa Province, Vanuatu (Role of pastures in livestock nutrition)**



**Figure 59. Farmers' field - day at PRV Plantation Norsup, Malekula, Malampa Province, Vanuatu.**



**Figure 60. Fodder bank of *Gliricidia sepium* and batiki grass at Togitogiga**



**Figure 61. David Nawa with his cattle at Eratap Efate, Vanuatu**



**Figure 62. Open pasture for continuous grazing at Rentapao Efate, Vanuatu**



**Figure 63. Reliance on pasture as cheap feed (Vanuatu)**

*Calliandra* is mostly fed green since drying reduces its quality to maintenance levels. During dry spells *Calliandra* accumulates tannins which lowers its quality. Best results are when *Calliandra* forms 20% of an animal's diet and more than 30% can cause weight loss (Pacific Agroforestry, 1999). Legumes such as *Erythrina* (dadap or drala) have more than 40% of the crude protein soluble and 75% of the soluble nitrogen fraction is not true protein, which results in a fast release of nitrogen in the rumen. To efficiently use this nitrogen *Erythrina* fodder must be supplemented with a readily fermentable carbohydrate such as molasses.

## 9. Conclusion

For ruminant livestock, forages (grasses and legumes) are the cheapest source of feed. However, forage and other feed resources (crop residues and agro-industrial by-products) are often scarce and sometimes unavailable to the smallholder. Livestock production is essentially a process of converting feed into product (Barnard, 1969), and the provision of the required balance of nutrients plays an important role in livestock growth and performance. Cost is an important factor influencing feed availability and performance of livestock. The leaves of most tree legumes are high in protein and are used to supplement livestock during the dry season period, but feeding of legumes is not without problems. Legumes can be grown as fodder banks (**Figure 60**) to be fed on a cut and carry system or animals allowed to browse them every alternate day for a limited period of 15-45 minutes (crash grazing). The limited period prevents damage to the plants and excessive defoliation. They serve as a source of fermentable N and of bypass protein.

During the dry season the role of the legume is to increase the efficiency of utilization of the basal diets of poor quality. They supply fermentable and bypass protein and have additional benefits because they contain carbohydrates, minerals and vitamins. They enhance the rumen ecosystem by increasing microbial growth, rate of fibre digestion and propionate production. The efficiency of utilization of metabolisable energy is higher for a legume than grass because legumes provide a better balance of nutrients for productive purposes. When legumes provide highly digestible carbohydrate it increases the digestibility of the basal diet.

The potentials of the available feed resources in the PICs (see photos below), if properly harnessed, can sustain the present ruminant livestock population.

Ruminant physiological adaptation to the use of fibrous plant materials should be explored by nutritionists and appropriate diets formulated to meet requirements of grazing animals in year-round feeding systems.



**Dairy cows in Fiji supplemented with molasses**



**Cattle grazing batiki-hetero pastures in Samoa**



**Signal-sown legume (foreground) out producing signal only pasture at Elbee Ranch, Efate, Vanuatu**



**Indo-Fijian dairy farmer and his son in their splendida setaria and legumes at Tailevu - Fiji**



**Koronivia and legumes invading mission grass at Nawaicoba - Fiji**



**Native mission grass pastures on Guadalcanal plains, Solomon Islands**

Source: Macfarlane, D.A. (1998). Grazing Livestock in the Southwest pacific. The

benefits of improved production. FAO (Food and Agriculture Organization of the United Nations) Sub-regional Office for the Pacific. SAPA Publication 1998/1.

## 10. References

Adams, C.D. (1972). Flowering plants of Jamaica. University of the West Indies. Mona, Jamaica. P. 355.

Aregheore, E. M. and Pereira, D. (2004). Effects of *Erythrina variegata*, *Gliricidia sepium* and *Leucaena leucocephala* on dry matter intake and nutrient digestibility of maize stover, before and after spraying with molasses. *Animal Feed Science and Technology*, 111:191-201.

Aregheore, E. M. (1992). Effects of protein source on cassava peel utilization by growing sheep. *Tropical Science*, 32:313-317.

Aregheore, E. M. (1993). Comparative studies on urea, groundnut cake and palm kernel meal as protein source in the diets of the West African Dwarf sheep. *African Journal of Agricultural Science*, 20(2):167-174.

Aregheore, E. M. (1999). Nutritive and anti-nutritive value of some tree legumes used in ruminant livestock nutrition in Pacific Island countries. *Journal of South Pacific Agriculture*, 6(2):50-61

Aregheore, E. M. (2000a). Crop residues and agro-industrial by products in four Pacific Island countries: availability, utilization and potential value in ruminant nutrition. *Asian-Australasian Journal of Animal Sciences*, 13 Supplement 2000 B: 266- 269.

Aregheore, E. M. (2000b). The in vitro estimation of energy value and organic matter digestibility of some tropical crop residues and browses used in intensive ruminant livestock production in the dry season. *Scientia Agriculturae Bohemica*, 31(2):111-121.

Aregheore, E. M. (2001a). Availability and utilization of local feed resources in sustainable ruminant livestock production in the South Pacific region. In: Aregheore, E. M., Umar, M and Adams, E (eds). *Sustainable Ruminant Livestock production in the South Pacific Region. Proceedings of the regional Workshop held on June 25 – July 2, 2001 at Hotel Peninsula, Suva, Fiji Islands*. Pp 11-20.

Aregheore, E. M. (2001b). The contribution of pastures to sustainable ruminant livestock production in the South Pacific region. In: Aregheore, E. M., Umar, M and Adams, E (eds). *Sustainable Ruminant Livestock production in the South Pacific Region. Proceedings of the regional Workshop held on June 25 – July 2, 2001 at Hotel Peninsula, Suva, Fiji Islands*. Pp. 29-43.

Aregheore, E. M. (2002a). *Livestock Production 2 (Ruminant Livestock Production) AG 373 Coursebook*. The University of the South Pacific, University Extension, 292 pp (First published 1999).

- Aregheore, E. M. (2002b). Intake and digestibility of Moringa oleifera-batiki grass mixtures by growing goats. Small Ruminant Research, 46:23-28.
- Aregheore, E. M. (2002c). Chemical evaluation and digestibility of cocoa (Theobroma cacao) by-products fed to goats. Tropical Animal Health and Production, 34:339-348.
- Aregheore, E. M. (2003). Nutritional characterization and evaluation of batiki grass (Ischaemum aristatum var. indicum) and batiki grass-forage mixtures with steer calves. Journal of Animal and Veterinary Advances, 2(7):404-412.
- Aregheore, E. M. (2004a). A Review of Beef Cattle Production Systems Used in Seven Major Ruminant Livestock Producing Countries in the South Pacific Region. A mimeo, 32 pp.
- Aregheore, E. M. (2004b). Intake and digestibility of mixtures of batiki grass (*Ischaemum aristatum* var. *indicum*) and dadap (*Erythrina variegata* var. *orientale*) by crossbred Anglo-Nubian goats in Samoa. Scientia Agriculturae Bohemica, 35(2):69-73.
- Aregheore, E. M. (2004c). Nutritive value of sweet potato (*Ipomoea batatas* (L.) Lam) forage as goat feed: voluntary intake, growth and digestibility of mixed rations of sweet potato and batiki grass (*Ischaemum aristatum* var. *indicum*). Small Ruminant Research, 51:235-241.
- Aregheore, E. M. (2004d). Traditional staple foods and some feedstuffs of the Pacific Islands: their chemistry, biochemistry and nutrient composition. IRETA/CTA publication. IRETA Printery, USP, Alafua Campus, Samoa. 66 pp.
- Aregheore, E.M. (2004e). Nutritional characterization and evaluation of Batiki grass (*Ischaemum aristatum* var. *indicum*) and batiki grass-forage legume mixtures for steer calves. Journal of Animal and veterinary Advances, 2(7); 404-412.
- Aregheore, E. M. (2005a) Effect of Yucca schidigera saponin on the nutritive value of urea-ammoniated maize stover and its feeding value when supplemented with forage legume (*Calliandra calothyrsus*) for goats. Small Ruminant Research, 56:95-102.
- Aregheore, E. M. (2005b). Evaluation and utilization of Noni (*Morinda citrifolia*) juice extract waste in complete diets for goats. Livestock Research for Rural Development, Vol. 17, No. 4. <http://www.utaoundation.org/Irrd1704/areg17039.htm>
- Aregheore, E. M. (2005c). Utilization of concentrate supplements containing increasing levels of copra cake (*Cocos nucifera*) by growing goats fed a basal diet of Napier grass (*Pennisetum purpureum*). Small Ruminant Research, (In press – RUMIN 2767).
- Aregheore, E. M. and Yahaya, M.S. (2002). Effect of fresh *Leucaena* (*Leucaena leucocephala*) leaf supplementation on the growth of

young Anglo-Nubian goats feeding either batiki grass (*Ischaemum aristatum* var. *indicum*) or guinea grass (*Panicum maximum*). Papua New Guinea Journal of agriculture, Forestry and Fisheries, 45(1&2):13-18.

Aregheore, E. M., and T. Tunabuna (2000). The utilization of diets containing increasing levels of dried desiccated coconut waste meal by growing Anglo-Nubian goats in Samoa. Asian-Australasian Journal of Animal Sciences, 14(3):316-320.

Asare, E. O. (1985). Effects of frequency and height of defoliation on forage yield and crude protein content of *Flemingia macrophylla*. In Proceedings of the XV International Grassland Congress, August 24 – 31, 1985, Kyoto, Japan.

Babatunde, G.M., Fetuga, B.L., Odumosu, O. and Oyenuga, V.A. (1975). Palm kernel meal as a major protein concentrate in the diets of pigs in the tropics. Journal of Science of food and Agriculture, 26:1279

Barnard, C. S. (1969). Economic Analysis and Livestock Feeding. Journal of Agricultural Economics, 10(3): 323-330.

Benjamin, A. K. and Sivasupiramaniam, S. (2001). Availability and utilization of pasture for sustainable ruminant livestock production: Papua New Guinea perspective. In: Aregheore, E. M., Umar, M and Adams, E (eds). Sustainable Ruminant Livestock production in the South Pacific Region. Proceedings of the regional Workshop held on June 25 – July 2, 2001 at Hotel Peninsula, Suva, Fiji Islands. pp. 99-103.

Bogdan, A. V. (1977). Tropical pasture and fodder plants. Longman, London. 475 pp.

Bovolenta, S., Priasentier, E. Peresson, C. and Malossini, F. (1998). The utilization of diets containing increasing levels of dried brewers' grains by growing lambs. Animal Science, 66:689-695.

Brewbaker, J. L., Hegde, N., Hutton, E. M., John, R. J., Lowry, J. B., Moog, F. and Van Den Beldt, R. (1985). Leucaena – forage production and use. Nitrogen Fixing Tree Association, Hawaii.

Bubar, G. (2000). Prospects for a Papua New Guinea Livestock industry (Cattle). Papua New Guinea Journal of Agriculture, Forestry and Fisheries, 43(1):120-122.

Carlos, R., Menchu, J. F. and De Leon, R. (1962). Biotechnology in washed coffee processing. UNEP industry and environment. April/May/June pp 3-6.

Clifford, M. N. and Ramirez-Martinez, J. R. (1991). Tannins in wet processed coffee beans and coffee pulp. Food Chemistry, 40:191-200.

Creswell, D. C. and Brooks, RN. (1971). Effects of coconut meal

and coconut oil on performance, carcass measurements and fat composition in swine. *Journal Animal Science*, 33:370-375.

Dahlan, I. (1992a). The nutritive values and utilisation of oil palm leaves as a fibrous feed for goats and sheep. In: *Proceedings of the Sixth Asian-Australasian Association of Animal Production*. (Ed. C. Roedecha and P. Bunvaveichewin) *Animal Science Congress*, Vol. III. AHAT, Bangkok, pp. 271.

Dahlan, I. (1992b). Model of oil palm leaves dry matter yields for fibrous feed production. In: *Proceedings of the Sixth Asian-Australasian Association of Animal Production*. (Ed. C. Roedecha and P. Bunvaveichewin) *Animal Science Congress*, Vol. III. AHAT, Bangkok, pp. 272.

Dahlan, I., M. Islams and Rajion, M.A. (2000). Nutrient intake and digestibility of fresh, ensiled and pelleted oil palm (*Elaeis guineensis*) frond by goats. *Asian-Australasian Journal of Animal Sciences*, 13(10):1407-1413.

Devendra, C. (1988). Forage supplements: nutritional significance and utilization for draught, meat and milk production in buffaloes. *Proceedings of second World Buffalo Congress*, Indian Council of Agricultural Research, New Delhi, Vol. 2: pp 409-423.

Devendra, C. (1990). The use of shrubs and tree fodders for ruminants. In: *Shrubs and tree fodders for farm animals*. (Ed. C. Devendra). IDRC-277e. International Development Research Centre, Ottawa, Canada. Pp. 42-60.

Devendra, C. and Li Pun, H. (1993). Practical technologies for mixed small farm systems in developing countries. In: *Strategies for sustainable animal agriculture in the developing countries*. (Ed. Simon Mack). FAO. *Animal Production and health Paper 107*. *Proceedings of the FAO Expert Consultation held in Rome, Italy*. 10 – 14 December 1990. pp. 135-156.

Dominiquez, P.L. (1992). Feeding sweet potato to monogastric. In: Machin, D., Nyvold, S. (Eds.), *Roots, Tubers, Plantains and Bananas in Animal Feeding*. FAO *Anim. Prod. Health Paper*, 95, 217-233.

*Erythrina Production and Use* (1993). A field manual (Powell, M. H. and Westley, S.B. Eds.) Nitrogen Fixing Tree Association, Hawaii, USA.

Falvey, J.L. (1981). *Imperata cylindrical* and animal production in South East Asia: A Review. *Tropical Grasslands*, 15:52-56.

*Gliricidia Production and Use* (1989). (Glover, N. ed.). Nitrogen Fixing tree Association, Hawaii, USA.

Gohl, B. (1981). *Tropical feeds: Feed information summaries and nutritive values*. FAO *Animal Production and Health series*, No. 12. FAO, Rome.

- Hammond, A. C. (1995). Leucaena toxicosis and its control in ruminants. *Journal of Animal Science*, 73:1487-1492.
- Hutagahung, R. T., Jalaludin, S. and Chang, C.C. (1974). Evaluation of agricultural products and by-products as animal feeds. 11. Effects of levels of dietary cassava leaf and root on performance, digestibility and body composition of broiler chicks. *Malaysian Agricultural Research*, 3:49-59.
- Jonah, L. B. (2004). Economics of production and marketing of beef cattle in Efate, Vanuatu. Bachelor of Agriculture Project, The University of the South Pacific, School of Agriculture, Alafua Campus, Apia, Samoa. 40 p.
- Jones, R.J. (1994). Management of anti-nutritive factors - with special reference to leucaena. In: Gutteridge, R.C. and Shelton, H.M., eds. *Forage tree legumes in tropical agriculture*. CAB International, Wallingford, Oxford, UK, 216-231.
- Kama, A. U. (1994) Beef cattle production in the South Pacific. An Instructional Manual for Secondary School Agricultural Science Teachers. IRETA/CTA Publication. IRETA print Media Unit, Alafua Campus, Apia, Samoa. 375 pp.
- Kumar, A., Hussain, M. T. and Rufai, E. (2001). The contribution of pastures in the wet and dry lands to sustainable beef, dairy, sheep and goat production in Fiji. In: Aregheore, E. M., Umar, M and Adams, E (eds). *Sustainable Ruminant Livestock production in the South Pacific Region*. Proceedings of the regional Workshop held on June 25 – July 2, 2001 at Hotel Peninsula, Suva, Fiji Islands. Pp. 96-98.
- Lee, S (1999a). Samoa. Country Pasture/Forage Resource profiles. *Grassland and Pasture Crops*. 13 pp.  
[<http://www.fao.org/ag/AGP/AGPC/doc/Counprof/southpacific/Samoa.htm>.]  
]
- Lee, S (1999b). Tonga. Country Pasture/Forage Resource profiles. *Grassland and Pasture Crops*. 11 pp.  
[<http://www.fao.org/ag/AGP/AGPC/doc/Counprof/southpacific/Tonga.htm>]
- Leng, R. A. (1993). Practical technologies to optimise feed resource utilization in reference to animal agriculture in developing countries. In: *Strategies for sustainable animal agriculture in the developing countries*. (Ed. Simon Mack). FAO. Animal Production and health Paper 107. Proceedings of the FAO Expert Consultation held in Rome, Italy. 10 – 14 December 1990. pp. 107 – 120.
- Loughmann, J.P. (2001). The contributions of pasture to sustainable beef production systems in Vanuatu. In: Aregheore, E. M., Umar, M and Adams, E (eds). *Sustainable Ruminant Livestock production in the South Pacific Region*. Proceedings of the Regional Workshop held on June 25 – July 2, 2001 at Hotel Peninsula, Suva, Fiji Islands. Pp 110-113.

Macfarlane, D.A. (1993). Sustainable animal production from various tropical pasture systems. In; Evans, T. R., Macfarlane, D. A. and Mullen, B. F. (Ed.) Sustainable beef production in smallholder and plantation farming systems in the South Pacific. Proceedings of a workshop. Port Vila and Luganville, Vanuatu, August 2-22 1993.

Macfarlane, D.A. (1996). Regional project design document: sustainable commercial animal production from pastures in South Pacific farming systems (SCAPP)/Government cooperative Programme. Rome, FAO.

Macfarlane, D.A. (1998). Grazing Livestock in the Southwest Pacific. The benefits of improved production. FAO, SAPA Publication 1998/1 (Editor, Barbara Henson).

Macfarlane, D.A. (2000a). Fiji. Country Pasture/Forage Resource Profile. Grassland and Pasture Crops. 13 pp.  
[<http://www.fao.org/ag/AGP/AGPC/doc/Counprof/southpacific/fiji.htm>]

Macfarlane, D.A. (2000b). Papua New Guinea. Country Pasture/Forage Resource Profile. Grassland and Pasture Crops. 17 pp.  
[<http://www.fao.org/ag/AGP/AGPC/doc/Counprof/southpacific/png.htm>.]

Mannetje, L. (1993). Practical technologies for the optimal use of tropical pastures and rangelands in traditional and improved livestock production systems. In: Strategies for sustainable animal agriculture in the developing countries. (Ed. Simon Mack). FAO. Animal Production and health Paper 107. Proceedings of the FAO Expert Consultation held in Rome, Italy. 10 – 14 December 1990. pp. 121-133..

Manueli, P. and Mohammed, F. (2002). Urea molasses block – Preparation and implications in livestock nutrition. In: Aregheore, E. M. and Umar, M (eds). Formulation and utilization of feeds for livestock production using locally available feed resources in the South Pacific region. Proceedings of the Regional Workshop held on June 24 - 28, 2002 at Hotel Peninsula, Suva, Fiji Islands. Pp. 27-37.

Middleton, C. H., Jones, R.J., Shelton, H. M, Petty, S. R. and Wildin, J. H. (1994). Leucaena – Opportunities and Limitations. ACIAR Proceedings No. 57:214-219.

Moat, M. (2002). Local feed resources and utilization in livestock production in Papua New Guinea. In: Aregheore, E. M. and Umar, M (eds). Formulation and utilization of feeds for livestock production using locally available feed resources in the South Pacific region. Proceedings of the regional Workshop held on June 24 - 28, 2002 at Hotel Peninsula, Suva, Fiji Islands. Pp. 57-60.

Moat, M. and Mc L Dryden, G. (1993). Nutritive value of sweet potato forage (*Ipomoea batatas* (L). Lam) as ruminant animal feed. Papua new Guinea Journal of Agriculture, Forestry and Fisheries,

36(1):79-85.

Morgan, D. E. and Trinder, H. (1980). The composition and nutritional value of some tropical and subtropical by-products. Occasional Publication No. 3. British Society of Animal Production.

Morris, C.D. and Du Toit, L. P. (1998). The performance of Boer goats browsing *leucaena leucocephala* in KwaZulu Natal, South Africa. *Tropical Grasslands*, 32:188-194.

Mullen, B.F. (1999). Vanuatu. Country Pasture/Forage Resource Profile. Grassland and Pasture Crops.  
<http://www.fao.org/ag/AGP/AGPC/doc/Counprof/southpacific/vanuatu.htm>. 10 pp.

Mullen, B.F. and Shelton, H.M. (1996). *Stenotaphrum secundatum* – a valuable forage species for shaded environments. *Tropical Grasslands*, 30:289-297.

Naidu, R. K. (1989). Status of the livestock feed industry in the South Pacific. *Alafua Agricultural Bulletin*, 14(3):9-12.

Norton, B.W., Lowry, B. and McSweeney, C. (1994). The nutritive value of *Leucaena* species. *Leucaena - Opportunities and Limitations*. ACIAR proceedings No. 57, pp. 103-112.

Ochetim, S. (1987). Copra cake in diets for broiler chickens. 1. Effects of level of cake on nutritional and economic performance. *Alafua Agricultural Bulletin*, 12(1):19-24.

Otto, L. (2001). Beef cattle production in Vanuatu. Paper presented in AG 372 – Livestock Production 2 (Ruminant Production and Management) Seminar, Semester 1, 2001. 7 pp.

Pacific Agroforestry (1999). An Information Kit. (Rogers, S. and Thorpe, P. (eds.)). Pacific Regional Agricultural Programme, Suva, Fiji.

Partridge, I. J. (1977). Results of beef pasture research in Fiji. Proceedings, Regional Seminar on Pasture Research. Mini. Agric. and Lands, Honiara, Solomon Islands.

Paterson, R.T., Kiruiro, E. and Arimi, H.K. (1999). *Calliandra calothyrsus* as supplement for milk production in the Kenya Highlands. *Tropical Animal Health and Production*, 31:115-126.

Possingham, J.V., Groot Obbink, J. and Jones, R. K. (1971). Tropical legumes and vascular arbuscular mycorrhiza. *Journal Australian Institute of Agricultural Science*, 37(2):160-161.

Pottier, D (1983). A Pasture Handbook for Samoa. The Institute for Research, Extension and Training in Agriculture (IRETA), USP, School of Agriculture, Alafua Campus, Apia, Western Samoa. 99 pp.

Ramsay, G. (1999). Integration of livestock in traditional farming systems in the Pacific Islands. In: Improvement and Development of Traditional Farming Systems for the South Pacific. Proceedings of an IRETA workshop 18-22 October, 1999. IRETA, USP Alafua Campus, Apia, Samoa. Pp. 37-48.

Ranacou, E. (1985). Technical Bulletin on farming information. Information Unit, MAFF, Fiji.

Reddy, M. (2001). Contribution of livestock sector to economic welfare of Pacific Island population. A case study of Fiji. In: Aregheore, E. M., Umar, M and Adams, E (eds). Sustainable Ruminant Livestock production in The South Pacific Region. Proceedings of the Regional Workshop held on June 25 – July 2, 2001 at Hotel Peninsula, Suva, Fiji Islands. Pp. 44-51.

Reddy, M. and Sharma, P. (2002) Economic benefit of utilizing local feed resources for livestock feed. In: Aregheore, E. M. and Umar, M (eds). Formulation and utilization of feeds for livestock production using locally available feed resources in the South Pacific region. Proceedings of the Regional Workshop held on June 24 - 28, 2002 at Hotel Peninsula, Suva, Fiji Islands. pp. 70-73

Reynolds, S. G. (1995). Pasture-cattle-coconut systems. Food and Agriculture Organization of the United Nations. RAPA Publication, 1995/7. Bangkok, Thailand.

Rokomatu, I. and Aregheore, E. M (2005) Effects of supplementation on voluntary dry matter intake, growth and nutrient digestibility of the Fiji Fantastic Sheep on a basal diet of Guinea grass (*Panicum maximum*). (In Press)

Sanchez, M.D. (1999). Mulberry: an exceptional forage available almost worldwide. World Animal Review, 93:36-46.

Shelton, H. M., Stur W.W. and Gutteridge, R. (2002). Future directions for pasture improvement in Papua New Guinea. In: Dunbar, G., M. Moat, A. Quartermaine and S Low, (eds). Collected papers from meeting of the Papua New Guinea Society of Animal Production. Volume 1, 77-87.

Singh, R. (2001). Better understanding of the importance of legumes (fodder trees and shrub-browse plants) in the nutrition of ruminants especially in the dry season. In: Aregheore, E. M., Umar, M and Adams, E (eds). Sustainable Ruminant Livestock production in the South Pacific Region. Proceedings of the regional Workshop held on June 25 – July 2, 2001 at Hotel Peninsula, Suva, Fiji Islands. Pp. 21-24.

Smith, M.A. and Whiteman, P.C. (1985). Animal Production from rotationally-grazed natural pasture and sown pastures under coconuts at three stocking rates in the Solomon Islands. Jour. Agric. Sci. (Cambridge), 104:173-180.

Steel, R.J. and P.C. Whiteman (1980). Pasture species evaluation,

pasture fertilizer requirements and weed control in the Solomon Islands. Solomon Islands Pasture Research Project; Technical Report, Ministry of Agriculture and Lands, Honiara, Solomon Islands, January 1980. 95 pp.

Tamani, V. E. (2004). Effect of molasses at different levels in the concentrate supplement on the milk yield of dairy cows grazing *Setaria grass (Setaria sphacelata)* pasture in the Central Division, Fiji. M.Sc. Thesis. The University of the South Pacific, School of Agriculture, Alafua Campus, Apia, Samoa. 97 pp.

Tevita, F. (1995) Country Paper: Western Samoa. In: Lee, S. D and Macfarlane, D.C. (eds). The State of forage based ruminant livestock production in the South Pacific. Proceedings of a workshop on held in the Islands of Upolu and Savii, Western Samoa. 8-11 December 1995. pp. 45 - 49.

Tevita, F. (2001) Contribution of dairy and beef farmers' associations to sustainable ruminant Livestock Production in the South Pacific Region - the Samoa Experience. In: Aregheore, E. M., Umar, M and Adams, E (eds). Sustainable Ruminant Livestock production in the South Pacific Region. Proceedings of the Regional Workshop held on June 25 – July 2, 2001 at Hotel Peninsula, Suva, Fiji Islands. pp. 104-106.

Thomas, O.A. and Scott, M.L. (1962). Coconut meal as a protein supplement in practical broiler diets. *Poultry Science*, 41:477-485.

Vizard, A.L. (2000). Animal contributions to human health and well-being. *Asian-Australasia Journal of Animal Science*, 13 Supplement July, 2000A:1-9.

VPIP (1990). Vanuatu Pasture Improvement Programme. Technical Bulletin No. 1. Pasture Species identification and potential adaptation. (Evans, T.R. and Macfarlane, D. eds.).

Vulaono, S.W. (2004). Beef production in Fiji. Paper presented in AG 372 – Livestock Production 2 (Ruminant Production and Management) Seminar. Semester 1, 2004. 8 pp

Wahananiu, J., P. Sakuman, B. Keqa, D. Wate and Kiriau, G. (1993) Current pasture status/animal production in the Solomon Islands. In: Sustainable beef production from Smallholder and plantation farming systems in the South Pacific. (Tony Evans, David Macfarlane and Brendan Mullen, Eds). Proceedings of a workshop held at the Islands of Efate, Santo and Malokula, Vanuatu. 2-12 August 1993. ABC Printing, Milton, Brisbane, Australia, pp. 28-34.

Wate, D. (1995). Solomon Islands: Country paper. In: The status of forage based ruminant livestock production in the South Pacific (S. Lee and D. Macfarlane, Eds). Proceedings of a workshop held on the Islands of Upolu and Savai'i, Western Samoa. 8-11 December 1995. pp 22-228.

Watson, S.E. and Whiteman, P.C. (1981) Grazing studies on the

Guadalcanal Plains, Solomon Islands. 2. Effect of pasture mixtures and stocking rate on animal production and pasture components. *Jour. Agric. Sci. (Cambridge)*, 97:353-364.

Whyte, R. O., Moir, T. R. and Cooper, J. P. (1959). *Grasses in Agriculture*. FAO Agric. Studies No. 42. Rome, Italy.

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