Country Pasture/Forage Resource Profiles

PAPUA NEW GUINEA

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1. INTRODUCTION

According to the last census in 2000 Papua New Guinea supported 5 190 786 people (although this was possibly an underestimate) on a land area of 462 243 km^2 stretching from 141^{o}E to 156^{o}E and 1^{o}S to 11^{o}S (see Figure 1). The mainland, eastward from the Iryan Jaya border to the Milne Bay area, is divided by the Owen Stanley Ranges with a peak elevation of 4 793 m at Mt Wilhelm. Latest SPC data (SPC, 2008) give a mid-2008 population estimate of 6 473 910 and a mid-2010 estimate of 6 761 669 (with a 2008–2010 growth rate of 2.2%). According to the World Factbook (July 2008 estimate) the population is 5 931 769 with a 2008 growth rate of 2.118%.

In 1996 agriculture, industry and the services sector contributed 26.4%, 41% and 32.6% respectively to GDP. Approximately 64% of the workforce is involved in agriculture. From 1980–1993 GDP grew at 7%, since then it has ranged between -6.5 and 5.2%. Growth in agriculture over the last 5 years has ranged from 6.1% in 1996 to –3.5% in 1997 due largely to a major drought (ADB, 1998). In 1996 agriculture contributed 26.4% of GDP, industry contributed 41% and the services sector 32.6%. Benjamin and Sivasupiramaniam (2001) indicate that livestock production has an estimated annual output value of US$ 70 million: all meat and eggs produced locally are consumed within PNG and almost 60% never enters the formal commercial trade but is consumed within the family or local community.

There are 550 000–570 000 rural households supporting 4 200 000 people – 60–65% of which keep grazing livestock – 345 000 raise pigs which graze or are fed forages, 155 000 raise poultry, 9 600 raise goats, 3 100 raise sheep and 8 700 raise cattle (Banguinan *et al*,, 1996) – about 570–620 smallholders keep cattle commercially. Household participation in livestock production varies between regions as shown in Table 1. In number and for food security pigs and chickens are by far the most important, followed by cattle, then goats and sheep. Based on 1994 data 77.6% of commercial cattle are in Mamose 18.7% in the Southern Region 3% in the Islands Region and 0.6% in the Highlands Region. Estimates of livestock numbers in 2000 (some

Table 1. Percentage of rural households owning pigs, chickens, cattle, sheep and goats by region

Type	% livestock-owning households by region			
	Mamose	Southern	Highlands	Islands
Pigs	44.1	48.6	77.5	47.1
Chickens	35.9	36.8	13.4	44.4
Cattle	2.5	2.1	1.1*	0.2
Goats	1.3	0.7	2.6	0.5
Sheep	0.5	0.4	0.8	0.1
Households	160 252	87 840	255 589	70 587
% by region	27.9	15.3	44.5	12.3

(The discrepancy between the 2 668 highland cattle owning households and 500 reported cattle in Banguinan* et al. *(1996) requires clarification)*

Figure 1. Map of Papua New Guinea

Table 2. Papua New Guinea statistics for livestock numbers, beef, veal, sheep, goat meat, pig meat, total meat production and milk production, cattle imports and meat and milk imports for the period 1997–2007

Item	1997	1998	1999	2000	2001*	2002	2003	2004	2005	2006	2007
Cattle nos. (,000)	87.0	86.0	87.0	87.0	88.0	89.0	90.0	91.0	92.0	93.0	94.0
Pigs nos.(,000,000)	1.5	1.55	1.55	1.55	1.7	1.8	1.8	1.8	1.8	1.8	1.8
Sheep nos. (,000)	6.0	6.2	6.2	6.3	6.3	7.0	7.0	7.0	7.0	7.0	7.0
Goat nos.(,000)	2.0	2.2	2.2	2.3	2.4	2.4	3.0	3.0	3.0	3.0	3.0
Beef & veal prod. (mt)	2 475	2 550	2 550	2 700	3 000	3 000	3 075	3 105	3 135	3 200	3 200
Pig meat prod. (mt) (,000)	56.0	58.0	58.0	58.0	64.0	68.0	68.0	68.0	68.0	68.0	68.0
Sheep meat prod. (mt)	22	24	24	25	25	30	30	30	30	30	30
Goat meat prod. (mt)	8	8	8	8	9	9	11	11	11	11	11
Total meat prod. (mt) (,000) ***	328.8	336.0	341.0	346.2	362.5	376.7	386.9	396.9	406.9	407.0	407.0
Cow milk prod. (mt)	135	130	130	150	150	150	155	160	160	160	160
Cattle imports nos.	560	40	-	-	2	-	-	-	-	-	n.r
Mutton and lamb imports (mt)	37 211	33 600	32 000	35 654	29 273	21 474	22 698	25 933	25 415	24 790	n.r
Cow milk fresh imports (mt)	3 300	4 000	3 300	2 950**	210	2 522	2 094	2 494	2 287	2 763	n.r
Beef & veal imports (mt)	4 506	4 700	3 400	19	8 046	5 601	4 397	4 043	3 898	4 264	n.r
Sheep meat imports (mt)	37 211	33 600	32 000	35 654	29 273	21 474	22 698	25 933	25 415	24 790 (+)	n.r

Source: FAO Database 2009
n.r. = no record
** Benjamin and Sivasupiramaniam (2001) estimate livestock numbers as: Beef cattle – 83 000; Sheep – 10 000; Goats – 25 000; Buffaloes – 2 000; Dairy cattle – 1 000; Pigs (village) – 1 900 000; Pigs (commercial) – 6 000*
*** In 2000 total Milk Equivalent imports were 25 897 mt. and in 2006 were 17 355 mt. and in 2005 imports of dried, cond. and evap. milk were 1 522 Mt.*
**** Total meat production includes: cattle, chicken, duck, game, goat, horse, pig, sheep and turkey meat.*
(+) in addition in 2006 some 874 Mt of pig meat and 986 Mt of chicken meat were imported
No data for 2008

of which are slightly different from FAO figures – see Table 2) were: 87 000–91 000 cattle, 2 000 horses, 6 000 goats and 6 000 sheep (down from 12 000). There were 1 000 buffalo, 500 of which are feral, and feral deer in Western province. Estimates of smallholder cattle range from 19 000 – 21 000 head (Enyi 1986, SPC 1998, FAO 1998). [Benjamin and Sivasupiramaniam (2001) give figures of 84 000 cattle, 10 000 sheep, 25 000 goats and 2 000 buffaloes.]

Keeping ruminants is not traditional, cattle were introduced in the 1880s and numbers were in excess of 21 000 in 1939, but were almost wiped out in World War II; redevelopment began in the 1960s, numbers rising to 153–156 000 at Independence in 1976. Sheep raising began in the 1970s. In 1995, 65 000, 19 000 and 7 000 head of cattle were owned by 31 large farms, 570–620 smallholders and 60 institutions respectively. There are no longer any commercial dairies. After 1976, cattle numbers fell to 75 000 re-building to 96 000 head in 1995 and slipping again to 87 000 in 1999 and although FAO data shows 88 000 in 2001 Benjamin and Sivasupiramaniam (2001) suggest a lower figure of 84 000. 71% of cattle are in Morobe and Madang Provinces; particularly in the Markham-Ramu valleys. An average small cattle farmer runs 34 head on 136 ha.

1.1 Livestock production and market demand

In 1994, 8 000 tonnes of canning beef and 3 106 tonnes of higher quality beef were imported. Production in 1996 was approximately 1 800 and 600 tonnes per year of boneless beef for the commercial trade and subsistence respectively. A refrigerated trade has developed between Lae and Port Moresby. Domestic meat purchase is: mutton 31%, canned meat 27%, poultry 21%, beef 18% and pork 3% (Enyi 1986). Beef consumption ranged between 6 500 and nearly 16 000 tonnes over the last six years. Retailers at Gusap and Madang report dramatically increased demand for beef by offering meat on the bone at 3–4 kina/kg. An import quota system for non-Melanesian Spearhead Group exporters ensures that potential importers buy locally if available. Pig and poultry production is protected so the industry has thriven and PNG is largely self-sufficient. In 1998 imports were 4 881 tonnes beef valued at US$6 286 000, 33 600 tonnes mutton (US$34 535 000), 1 885 tonnes pig meat (US$7 439 000), 966 tonnes poultry meat (US$1 254 000), 2 533 tonnes canned meats (US$6 495 000), 5 516 tonnes milk (US$3 472 000), 10 331 tonnes dairy products and eggs (US$15 543 000) and 48 744 tonnes total meat imports (US$50 976 000) (FAO 1998). From 1996 the effect of a devalued kina was reflected in reduced meat imports and especially beef and sheep meat.

1.2 Land use

Eighty per cent of the total land of 453 000 km^2 is under natural vegetation - primary, secondary, recently disturbed or replanted forest. Given 30 300 km^2 currently in food production (cropping and regrowth) or 6.6% of total land area (Saunders, 1993), a household farms 5.5 ha including fallow. From PNGRIS (Computerised Resource Information System) 2 880 km^2 of intensive plantation and smallholder tree crop, sugar and other cash crops has been defined (concentrated in New Britain, New Ireland, Morobe and Madang Provinces). There are 2 600 km^2 of coconuts (FAO, 1998), 90% of which are harvested. Intensive food crops cover a further 7 950 km^2 (86% of the intensive total in the Highlands). There is historical evidence of cultivated land use over 118 000 km^2 (Saunders, 1993). Estimates of open, under coconut and under forest tree grazed pastures are 191 000, 10 000 and 20 000 ha respectively, giving a grazing area of 203 000 ha; 260 000 ha of coconuts are not grazed (FAO, 1998). Benjamin and Sivasupiramaniam (2001) mention much larger areas, 600 000 ha of natural grassland, highly suitable for grazing and another 500 000 moderatly suitable for grazing from the 'land use point of view'.

2. SOILS AND TOPOGRAPHY

2.1 Major topographic features

There are three major classes: plains and valleys; low mountains and hills and high mountains.

2.2 Soils and soil fertility constraints

Seventy nine percent of soils, covering the three main topographical groups, have major limitations as follows: (percentage coverage) salinity (1.74% – Western and Gulf), inundation or tidal flooding (16.9% – significant in Western, Gulf and East Sepik), soil depth of <25 cm (9.5% – Gulf, Southern Highlands and Morobe), extreme stoniness (16.8% – Southern and Eastern Highlands and Enga), anion fixation problems (35.1% – mainly Western but also Northern, Southern Highlands and East and West Sepik) (PNGRIS).

The main existing and potential grazing areas are dominated by soils which are: in *valleys and plains;* undifferentiated, poorly drained soils (Fluvaquents, Tropofluvents, Pellusterts, various Histosols); undifferentiated soils with seasonal moisture stress (mainly Haplustolls, Ustorthents); strongly weathered, poorly drained, fine textured sub-soils (Plinthaquults, Plinthudults, Tropudults, Plinthaqualfs); *low mountains and hills* slightly to moderately weathered soils with altered B horizons (Eutropepts, Troporthents, Dystropepts, Tropudults, Tropoudalfs, Haplorthox). Low available soil N, P, sulphur and copper are the commonest limiting chemical attributes for grazing land soils. The major ruminant livestock areas of Morobe-Madang Provinces have 15 000 km^2 constrained by stoniness, 10 500 km^2 by anion fixation and 12 000 km^2 by soil depths of under 25 cm.

3. CLIMATE AND AGRO-ECOLOGICAL ZONES

3.1 General climate – effects of topography

As the Inter-Tropical Convergence Zone moves south over the equator in October–November and north in March–April it is associated with monsoonal activity from the north and north-west. From May to October it is influenced by the south-east trades. The interception of moisture-laden air by mountains creates areas of high rainfall and rain shadows. Rainfall, which does not necessarily increase with elevation as Figure 4 shows, ranges from 950 mm in Port Moresby to 1 000 mm at Leron Plains in the

Markham - Ramu to over 7 000 mm in the Western Highlands. Thirty four per cent of the country receives 2 000–3 000 mm rainfall/year, 45.9% receives 3 000–5 000 mm, 7.3% receives 5 000 mm or greater and 12.3% receives less than 2 000 mm rainfall/yr. Most grazing areas receive 2 500 mm rainfall or less.

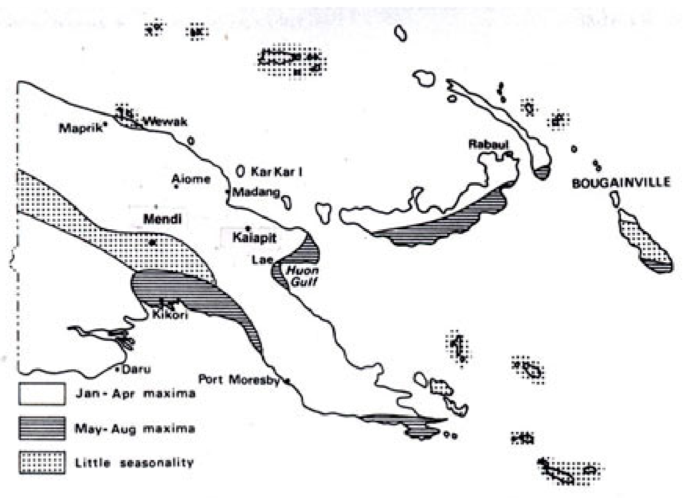

Figure 2. Time of occurrence of maximum monthly rainfall

Figure 2 shows that most of the country has a January–April maximum monthly rainfall, the Western Highlands show little seasonality of rainfall, whilst much of Gulf Province and the Southern Highlands, Milne Bay, Huon Peninsula and the southern portions of New Britain have May–August maxima. Seasonality and the quantity of rainfall produces highly variable soil moisture deficit situations. Mendi (5 000 mm) in the Highlands has no soil moisture deficit, Madang on the north coast (3 000 mm) is infrequently affected by deficit, Kaiapit in the Markham Valley (1 500 mm) experiences 20 weeks of 1/2–2/3 available soil water capacity and Port Moresby (950 mm) regularly experiences 25 weeks of the year with less than a third of available soil water capacity.

Temperatures are strongly affected by altitude. Lowlands below 600m (temp max 30–32 ^{o}C, mean min 19–23 ^{o}C) cover 66% of the area and support 54% of the population. Mid altitudes from 600–1 200 m (mean max 27–30 ^{o}C, mean min 16–19 ^{o}C) cover 14.2% of land and support 5.9% whilst the highlands from 1 200–2 400 m (mean max 19-27, mean min 9–16 ^{o}C) covering 16.1% of land support 38.2% of the population; montane regions above 2 400 m (mean max 16-19 ^{o}C, mean min <7–9 ^{o}C) and above the gardening limit cover 3.8% of land and support 1.9% of the population. Lowlands support 46.1% of significant land use and the highlands support 38.3%. Highlands are cloudier, receive less solar radiation and experience lower evaporation. The Highlands receive less than 170 Wh/cm^2 annual radiation, most of Momase Region receives 170–190 Wh/cm^2; radiation peaks around Port Moresby at 200 Wh/cm^2 or greater.

3.2 Agro-ecological zones based on climate and topography

Agro-ecological zonation is most simply reflected by various rainfall groups within altitude classes as shown in Figure 3. Rainfall class x altitude agro-ecological zonation is particularly important in explaining variation in land use in the lowlands.

Most grazing in Papua New Guinea is in lowlands with 1 000 mm to 2 500 mm rainfall per year, in mid-altitude areas with up to 3 000 mm and in scattered highland areas receiving over 3 000 mm. Two subsistence and commercial crops are grown in almost all zones – sweet potatoes and groundnuts. The genetic diversity of bananas and yams allows them to be cultivated over a range of altitude and temperature and rainfall and soil moisture deficit regimes.

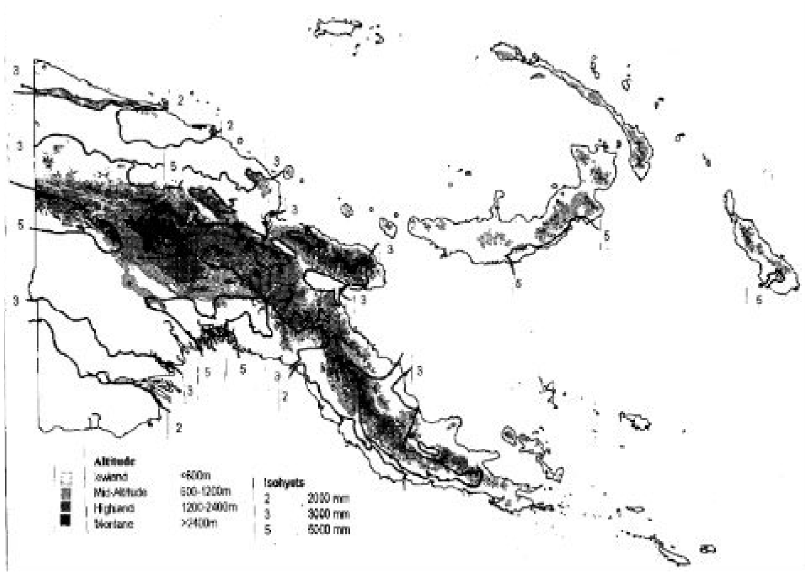

Figure 3. Agro-ecological zones based on rainfall classes within altitude classes

4. RUMINANT LIVESTOCK PRODUCTION SYSTEMS

4.1 Scale, type and potential of ruminant enterprises

The average small cattle farmer has 34 head on 136 ha. The average large farmer raises 2 100 head on 3 645 ha. Sixty one per cent of smallholder sheep-owning households are in the Highlands, they usually own between 2 and 6 sheep. Sixty nine per cent of goat-owning households are in the Highlands and average 1-2 goats. Some 570–620 smallholder cattle projects carry 19 000–21 000 head on 780 km^2 of predominantly native pastures. Gama *et al.* (1991) suggested 4 530 km^2 of grassland, carrying an additional 200 000 head could be developed for grazing, while Benjamin and Sivasupiramaniam (2001) estimate that at least 600 000 ha of natural grassland is highly suitable and another 500 000 ha moderately suitable for grazing, from a 'land use point of view'.

In the Markham and Ramu valleys smallholders working on estates gain livestock expertise, and income and or breeding stock to establish their own herds. In some cases they sell stores or finished cattle to estates who market their own and smallholder-finished cattle; some estates have leased grazing to smallholders but there has been damage through over-grazing.

Animal reproductive and growth performance could be greatly improved and pasture degradation minimized during long dry periods with readily available supplementary feed. Current annual production of palm kernel cake is 16 000 tonnes from 44% of the crop, the rest is exported. Interest is developing in combining copra and palm kernel cake and oil production in the same mills. Copra production averaged 132 000 tonnes from 1984 to 1993 with a potential cake yield of 33% or 43 500 tonnes; 20 000 tonnes of cake is produced; 90% is exported.

Holmes *et al.* (1980) noted the low liveweight gains from *Imperata* pastures. Galgal *et al.* (1990) demonstrated that Brahman cross steers on open *Imperata* pastures, or native pastures under coconuts, can achieve 0.93 kg/head/day when supplemented with 1 kg /head/day copra cake (30% of estimated DM intake). Without supplementary feed animals gain at most 0.3 kg/head/day. Galgal and Komolong (2000) further reported on the use of copra meal and palm kernal meal supplementation with and without molasses and urea for weaner steers on *Imperata cylindrica* pastures. Large farms have raised steer growth rates on predominantly Signal pastures from 0.4 to 0.6 kg/head/day by feeding palm kernel cake and molasses. Incorporation of Guinea into leucaena thickets (DAL Erap) and leucaena into Signal (*Brachiaria decumbens*) pastures (Ramu Beef Munnum Estate, lower Markham Valley) produced growth rates of 0.7 kg/head/day on pastures stocked at 1.06 ha/animal. Galgal *et al.* (2000) reported on the liveweight gain of cattle grazing various leucaena genotypes and Kamolong *et al.* (1998) reported on new leucaena germplasm evaluation. Lemerle and Holmes (1986) report steer growth rates from *Cenchrus ciliaris* (Buffel), *Calopogonium mucunoides* (Calopo) and Siratro (*Macroptilium atropurpureum*) of 0.73 kg/head/day at 1 animal/ha and 0.65 kg/head/day at 2 an/ha. The creeping native *Dicanthium annulatum* replaces overgrazed *Themeda triandra* on gravelly Markham Valley soils and Tupper (1986) reports that it sustained five-eighths Brahman crossbred yearlings at 0.48 kg/head/day at 0.75 an/ha and 0.3 kg/head/day at 1.82 an/ha.

4.2 Feeding systems

Feeding systems are based on grazing native and improved pastures. Some estates are interested in time controlled rotational grazing or cell grazing. Tethering is growing rapidly in mid-altitude areas 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. Two feedlots regularly finish cattle – one in West New Britain using palm kernel cake and the other in the Ramu valley feeding cane tops, molasses and copra meal.

Macfarlane (FAO, 1998) estimated the current pasture-based feeding system as shown in Table 3.

4.3 Current and potential integration of livestock into farming systems

Cattle rearing is integrated with approximately 100 km^2 of coconuts. FAO (1998) suggests that this could increase to 250 km^2; the potential is 600–700 km^2. There is immediate potential to expand cattle under coconuts in New Ireland to supply the Lihir gold mine, rising to 200 tonnes/year – a stable cattle herd of 5 000 is required for this market. Ramu Beef's feedlot bales green cane tops and helps Ramu Sugar

Table 3. Currest pasture-based feeding system

Smallholder native pastures	(<1 800 mm)	open	75 000 ha
Large farm native pastures	(<1 800 mm)	open	72 000 ha
Native pastures	(<1 800 mm)	open + legumes	2 000 ha
Native pastures	(<1 800 mm)	open	5 000 ha
Native pastures	(<1 800 mm)	open + legumes	2 000 ha
Improved grass			30 000 ha
Improved grass + legume			5 000 ha
Native pasture	(>1 800 mm)	under coconuts	9 000 ha
Improved grass and legume		under coconuts	1 000 ha
Pasture with crops and forestry			2 000 ha
Total			203 000 ha

by reducing the amount of crop residue during ploughing. The Forestry Department is interested in establishing evergreen legumes to smother grasses which are a major fire hazard, and in managed grazing to reduce fuel loads. Smallholders see tethered livestock as an income source which can reduce weeding in perennial crops. The potential to integrate leys with crops is under-utilized and could break weed, disease, insect and nematode cycles. Sulikon at Erap rotate some of their maize with native pastures. Low growing, legumes like *Arachis* could be introduced to maize and other cropping systems to reduce nitrogen input requirements.

4.4 Production limitations

4.4.1 Animal nutrition and grazing system management

The main constraints to ruminant production are low weaning, 45%, and low average growth rates of 0.25–0.3 kg/head/day; the causes of poor performance are mainly nutritional. The major native grass, *Imperata* is of inherently low quality. Holmes *et al* (1980) showed that 5 week old *Imperata* had a digestibility of 41.1% whereas Setaria, Buffel and Elephant grass had between 56.2–63% and this is reflected in daily weight gain (0.2–0.25 as against 0.35–0.41 kg/head/day) in grass dominant swards. From Figure 3 it is clear that native pastures in the Central Province and in much of the Markham-Ramu Valleys and in the East Sepik have up to 30 weeks per year of restricted or no growth. Well adapted introduced grasses and deep rooted shrub and tree legumes can improve the quality, quantity and reduce seasonality of forage but require a high level of management.

In order of decreasing importance deficiencies in nitrogen, phosphorus, sulphur, molybdenum, potassium, calcium and boron can restrict pasture productivity. Legumes on grassland soils respond to S; fertility-demanding legumes in Sepik are likely to respond to P, K, S, Mo and boron (Tupper, 1986). Haifa white clover (*Trifolium repens*) at Menifo in the Highlands responded to Ca, B, zinc and S (Sivasupiramanian *et al.,* 1986). Apart from seasonal or year round N and energy limitations to animal digestion, the low sodium content of most pastures restricts lactation and growth. Localized deficiencies in forage P, S, copper, iodine, cobalt and zinc restrict animal performance. Several large operations regularly using multi-mineral supplementary blocks report enhanced performance (e.g. Ramu Beef Management).

Farms do not match pasture species with specific fertility requirements, or low fertility tolerances, to their soils types. This should be a focal area for advisory, extension and farmer training. The principles of sustainable grazing management are not well understood - the most basic are allowable levels of pasture use and the minimum forage biomass required to sustain productivity and compete with weeds.

Overgrazing and the uncontrolled use of fire reduce production by causing weed invasion or species shifts to less palatable, lower quality grasses. Wide boundary strips of low growing, drought tolerant forages can restrict fires which are often lit for hunting. Regular burning contributes to N and S losses from grazing systems; planned, timely use of fire is an important tool in converting native to improved pastures and for controlling woody weeds.

Forages differ in nutritive value and freedom from anti-nutritive factors; this needs to be more widely understood. Some fodder shrubs have tannin types and contents which restrict rather than enhance protein availability to the ruminant. Also the establishment of psyllid resistant *leucaena* and other fodder trees needs further work. High sodium grasses such as *Brachiaria decumbens*, Para and Setaria can complement others sub-optimal in Na. In addition to mycotoxins in Signal grass which cause hepatic dysfunction, saponins, particularly in young leaf, contribute to depressing weight gains and even weight loss. Animals under 18 months are most susceptible and some localities are worse than others. Varied forage sources are necessary. High access to *Solanum torvum* has been implicated in the very localized incidence of enzootic calcinosis.

4.4.2 Animal husbandry and herd management

Management factors of critical importance in lifting the efficiency of beef production enterprises are:

- seasonal mating to concentrate calving at the onset of the wet season;
- cow culling for age (Max 10 years) and infertility;
- weaning at 4–5 months onto top quality pastures with supplementary feeding of weaners; achievement of calving intervals of 12 months including supplementary feeding if required to ensure adequate body condition for conception;
- ensuring post-weaning average growth rates of 0.45 kg/head/day or greater;
- first mating of heifers at 270–300 kg live weight, ideally by 18 months of age;
- replacement of herd bulls every 3–4 years, using adapted genotypes;
- calving in confined, carefully monitored areas, to treat for screw-worm fly attack of navel areas, facilitate management and the control of wild dogs;
- timely castration, dehorning and drenching if parasite burdens reach economic thresholds, particularly in calves during the wet season;
- ready availability of water, sodium and other deficient minerals;
- surveillance for and control of reproductive and other diseases and the avoidance of new exotic. e.g. Foot and Mouth disease is present in parts of Indonesia.

4.5 Socio-economic limitations

4.5.1 Selling prices and costs and competitiveness

Abattoir prices for prime steer carcasses are K2.50/kg or US$0.80/kg – the price in 1994–5 was K2.20/kg or US$1.50/kg. The devaluation of the kina made imports from Australia dearer. In 1995 a 40% tariff was imposed on imported beef which declined to 27% and is planned to drop to 25%. Vanuatu, a member of the Melanesian Spearhead Group, can export beef to PNG duty free. Devaluation of the kina has added to input costs. There is solid demand growth for beef but established farmers are not expanding. Profitable development of grazing must keep costs to internationally competitive levels.

4.5.2 Markets and market access

Commercial cattle production will continue to be concentrated in productive areas within economic freighting distances of markets. There is considerable opportunity to lower the total unit costs of beef production by raising production per hectare through cost-effective pasture improvement and targeted supplementary feeding. Applying nitrogen to grass pastures is not a pathway to profitability. Making beef more readily available and affordable in rural areas, often with bone in and using lower quality components, is one way to increase market share for meats. This approach also reduces the average freighting distance if closer district level outlets can be developed. A butcher collaborating with the Ramu Beef abattoir has reported dramatically increased turnover using this approach.

4.5.3 Variability in security of land tenure

Industry expansion will rely on existing large farms intensifying production and from new smallholders and joint ventures. There have been serious problems with developments on customary lands, where tenure was not clearly known. Cattle damaging gardens is a noteworthy and avoidable issue. Improved business training for new land-owner entrepreneurs is essential for viable new developments. Whilst future industry expansion has to be on a competitive commercial return basis, additional land, with high productivity potential and minimal requirements for nutrient addition, will need to be securely tenured to sustain target levels of productivity.

4.5.4 Extension/training/information systems

Livestock extension has declined, relative to support for the crops sector, over a 20 year period. Livestock extension has been less attractive, resources have been inadequate to service the needs of farmers effectively. In-service training of livestock officers has declined compared with the 1970s. The Cattleman's Association provides informal training to its members and there has been community impact from the grazing system improvement activities of a number of large farms in the last 5 years. SRPM, as a subsidiary of the Rural Development Bank has provided quality extension, training and marketing services to its clients, which has had dramatic effect on the financial performance of smallholder cattle operations.

An FAO Regional Pasture Improvement Project (1994–95) indicated that targeted training for community-active livestock farmers led to significant group activity given the provision of a minimal level of resource and organizational support. This led to a quantifiable level of pasture improvement.

5. EXISTING AND POTENTIAL PASTURE RESOURCES

5.1 Vegetation overview

Grasslands, eucalypt and melaleuca savannahs and herb-lands of 44 300 km^{2,} as defined in the Papua New Guinea Resource Inventory System (PNGRIS), cover 9.5% of the land area (McAlpine and Quigley, 1998). Native grasslands and savannahs that are regularly burnt, grazed or hunted upon comprise 14 300 km^2 (Saunders, 1993). Other coverage of vegetation and land use (by area) are: forests (71%), woodlands (5.8%), scrub (1.2%), mangroves (1.3%), urban, mining and other land use (10.2%) and bare areas, lakes etc (0.6%).

5.1.1 Natural grasslands and savannahs

Saunders (1993) describes 9 482 km^2 of dry-land, continuous grassland in upland and lowland areas, maintained in a stable disclimax by regular burning, an estimated 1 930 km^2 are used for managed grazing. These grasslands grow under various soil moisture regimes from permanently dry to periodically inundated terrain, from sea level to 2 600 m.

Tall grasslands (>1.5 m) of *Imperata cylindrica* (Kunai), *Themeda triandra, Saccharum edule* (pitpit) and *Pennisetum macrostachyum* occur on deep and fine textured soils of lowland plains subject to brief seasonal inundation and on foot-slopes, drainage lines and seepage areas of hilly and undulating terrain and alluvial fans. Tall *Miscanthus* grasslands cover recently abandoned garden land between 1 500 and 2 500 m particularly in the Western Highlands. Tussocky mid-height (0.5–1.5 m) grasslands comprising *(Heteropogon contortus, Themeda triandra, Dicanthium, Bothriochloa)* occur mainly on lowland hills with a marked dry season and on well drained slopes. Low grasslands occur on permanently shallow or seasonally inundated plains and swamp grasslands occur in lowland flood plains or in peat bogs in highland inter-montane basins.

Small areas of sub-alpine grasslands with tree fern savannahs (*Cyathea)* are found in inter-montane valleys and basins between 2 500–3 000 m, possibly subject to occasional burning (123 km^2). Alpine grasslands covering 103 km^2 are found above the tree line and above the limit of garden cropping (2 600 m).

Savannah woodlands with trees of three metres or higher, especially *Eucalyptus,* and a grass under-storey, cover 2 529 km^2 in Western, Central and Oro provinces.

Themedatriandra is dominant over a wide area. *Imperata* dominates on deeper, more fertile or recently disturbed soils. *Eriachne* and *Elionurus* displace *Themeda* to some extent in Papua while *Capillipedium* and *Arundinella* are prominent at higher altitudes (900–2 000 m). *T. triandra* does not stand hard grazing. *Coelorhachi* and *Ophiuros* are widespread as tall tussocks. In the *Eucalyptus*, *Melaleuca* and *Acacia* savannahs in south-central and south-west Papua *Themeda* is the main grass with sub-dominant *Heteropogon*, *Cymbopogon* and *Dicanthium*.

In the alpine zone Festucoid grasses prevail. Tussocky species of *Danthonia*, *Deschampsia*, *Hierochloë* and *Poa* are prominent in well drained areas and in bog areas *Poa* and *Monostachya* are dominant.

In swamp areas *Leersia hexandra, Echinochloa stagnina, Hymenachne amplexicaulis* usually dominate; *Oryza, Polytoca* and *Coix* are also present. *Saccharum robustum* occupies river banks and sandbanks and *Phragmites karka* swampy areas. *Miscanthus floridulus* colonizes disturbed land and old gardens, particularly above 1 800 m.

Coix lachrma-jobi, maize, *Setaria palmifolia*, *Saccharum edule* are grown as cereals or vegetables; *Saccharum officinarum* is grown in all regions for chewing.

5.1.2 Grazed natural and improved pastures

Grazed native grasslands, which occasionally include some naturalized legumes, cover 156 000 ha. An estimated 9 000 ha of native carpet (*Axonopus compressus)* and t-grass (*Paspalum conjugatum)* are grazed under coconuts, 36 000 ha of natural grazing have been sown with improved grasses, with or without adequate legumes, and there are about 2 000 ha of grazing under forest - a total current grazing resource of 203 000 ha (FAO, 1998). There are 60 000 ha coconuts in Madang Province.

5.1.3 Introduced grass/legume pastures

Lowland improved pastures based on Signal (*Brachiaria decumbens*), Biloela buffel (*Cenchrus ciliaris*), Guinea and Hamil (cultivars of *Panicum maximum*), Para (*Brachiaria mutica*) with *Brachiaria humidicola* (Koronivia) and Sabi grass (*Urochloa mosambicensis*) are being evaluated by several large farms. From the 1970s to the early 1990s often no legumes were sown; now they are usually sown with an improved grass. The commonest sown legumes include centro (*Centrosema pubescens),* siratro (*Macroptilium atropurpureum*),puero (*Pueraria phaseoloides),* Cook and Schofield stylo *(Stylosanthes guianensis),* Cooper glycine (*Neonotonia wightii)* and Verano stylo (*S. hamata*). In the 1990s farmers tried more legumes: Glenn and Lee joint vetch (*Aeschynomene americana),* Cavalcade centro (*C. pascuorum)*, Seca stylo (*S. scabra)* and leucaena (*Leucaena leucocephala* cvv. Cunningham, Tarramba). *Arachis pintoi* cv. Amarillo, *Arachis glabrata* and *Arachis repens* require more widespread evaluation. In the Markham Valley areas of giant leucaena e.g. K8, initially planted unwisely for cocoa shade, now have under-storey improved grasses such as Guinea, Buffel (*Cenchrus ciliaris)* and native species, producing high levels of animal growth.

Persistent upland improved pastures rely on Kikuyu (*Pennisetum clandestinum)*, Nandi and Narok setaria (*Setaria sphacelata*), paspalum (*Paspalum plicatulum).* Persisting legumes include Kenya white clover (*Trifolium semipilosum*), Haifa white clover (*Trifolium repens*), greenleaf desmodium (*Desmodium intortum)* and Shaw vigna (*Vigna parkeri).*

5.1.4 Other forages

Forage crops are rarely grown. Some farmers have planted the weakly perennial Silk sorghum, and sugar cane tops are used by Ramu Beef in their feedlot.

5.1.5 Limitations to the utilization of forage resources

The key limitations are: 1) extended periods of soil moisture deficit, 2) overgrazing leading to permanent weed ingress and loss of pasture productivity; 3) under-grazing in some areas; 4) specific areas of serious phosphorus deficiency and widespread nitrogen deficiency in soils reducing pasture quality and quantity; 5) widespread sodium deficiency and locally significant copper and sulphur deficiency reducing forage quality; 6) low digestibility of Imperata dominant pastures; 7) low legume content of most pastures; 8) lack of reliable access to locally produced seed and vegetative planting material; 9) uncontrolled fire dramatically reducing dry matter on offer to grazing animals in the dry season; and 10) significant localized reduction of animal performance associated with anti-nutritive compounds in Brachiaria decumbens.

6. OPPORTUNITIES FOR PASTURE IMPROVEMENT

Native pasture can be improved, cost effectively, by incorporating legumes. Sowing inoculated Seca, Siran (*S. scabra)*, Verano and Amiga (*S. hamata)* into ash of native grasslands is proven and successful. Oversowing into burnt *Imperata* has variable success due to rapid regrowth which competes severely with legume seedlings. The establishment of legumes (e.g. siratro, centro, puero) in *Imperata* is best done using disc strip or zero-till technology. Incorporating legumes into *Imperata* raises live weight gain potential from 0.2–0.25 to 0.4–0.5 kg/head/day at around one 400 kg animal per 2 ha. The legume should be complemented with the addition of an improved grass. Zero-till planting into *Imperata*, in strips, or broad-acre, should follow glyphosate spraying of regrowth. The replacement of *Imperata* by an improved grass with 20% of legumes increases carrying capacity from 0.3–0.5 to 1.2–2 animal units /ha depending on rainfall (1 000 mm – 2 000 mm) and soil moisture deficits.

Legume-deficient grasslands, much of the 360 km^2 currently sown, would see improved animal weight gains after establishment of legumes - increases from 0.35–0.4 to 0.5–0.6 kg/head/day are realistic expectations. Strategies for rehabilitating weedy pastures depend on the degree of infestation. For serious infestations the best technique in seasonally-dry areas is a hot burn, with a carefully planned pasture improvement programme. In any pasture improvement, other than for trees, a range of legumes should be sown to allow for variations within individual paddocks and seasonality in production patterns.

Encouraging proven small and large farms to grow selected legume seed would improve the reliability of seed supply. Support for establishing smallholder based legume and grass nurseries for planting material would assist farmers in their improvement programmes.

7. RESEARCH AND DEVELOPMENT ORGANIZATIONS AND PERSONNEL

National Agricultural Research Institute (NARI); University of Technology (UNITECH), Lae.
Masayan Moat, Regional Livestock Adviser, Department of Agriculture and Livestock, Lae.
Mr Miok Kumolong - *Investigation of tannins in leucaena* PhD thesis University of Queensland;
Mrs Sue Low - investigation of anti-quality factors in signal grass linked with saponins (1994-1998), PhD thesis University of New England, Armidale [Ms. Sue Low, Lecturer, UNITECH, Lae.];
Mr Ian Grant - leucaena forage for feeding rabbits for rural household food security (1996-1998);
Department of Agriculture and Livestock (DAL)
Erap Station - Mr Martin Raurela - rehabilitation of weed infested native and improved pastures [Mr. Martin Raurela, Officer-in-Charge, DAL Erap Station, Erap, Markham Valley].
Aiuyura - evaluation of productivity of lines of leucaena
Large farm evaluation of improved pasture species:
Ramu Beef (Munnum, Leron, Gusap) - Mr Tom Molok, Mr Joe Bruno, Mr Scott
Sulikon - Mr Steve Farhall, Manager, Sulikon Farms, Erap, Markham Valley.
Markham Farming - Mr Bruce Nixon
Smallholder Rural Projects Management Ltd (SRPM)
Mr Keith Galgal, Livestock Specialist, Smallholder Rural Projects Management Ltd, Lae - potential for enhanced animal production from various leucaena in Markham Valley, PhD thesis, University of Queensland.

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