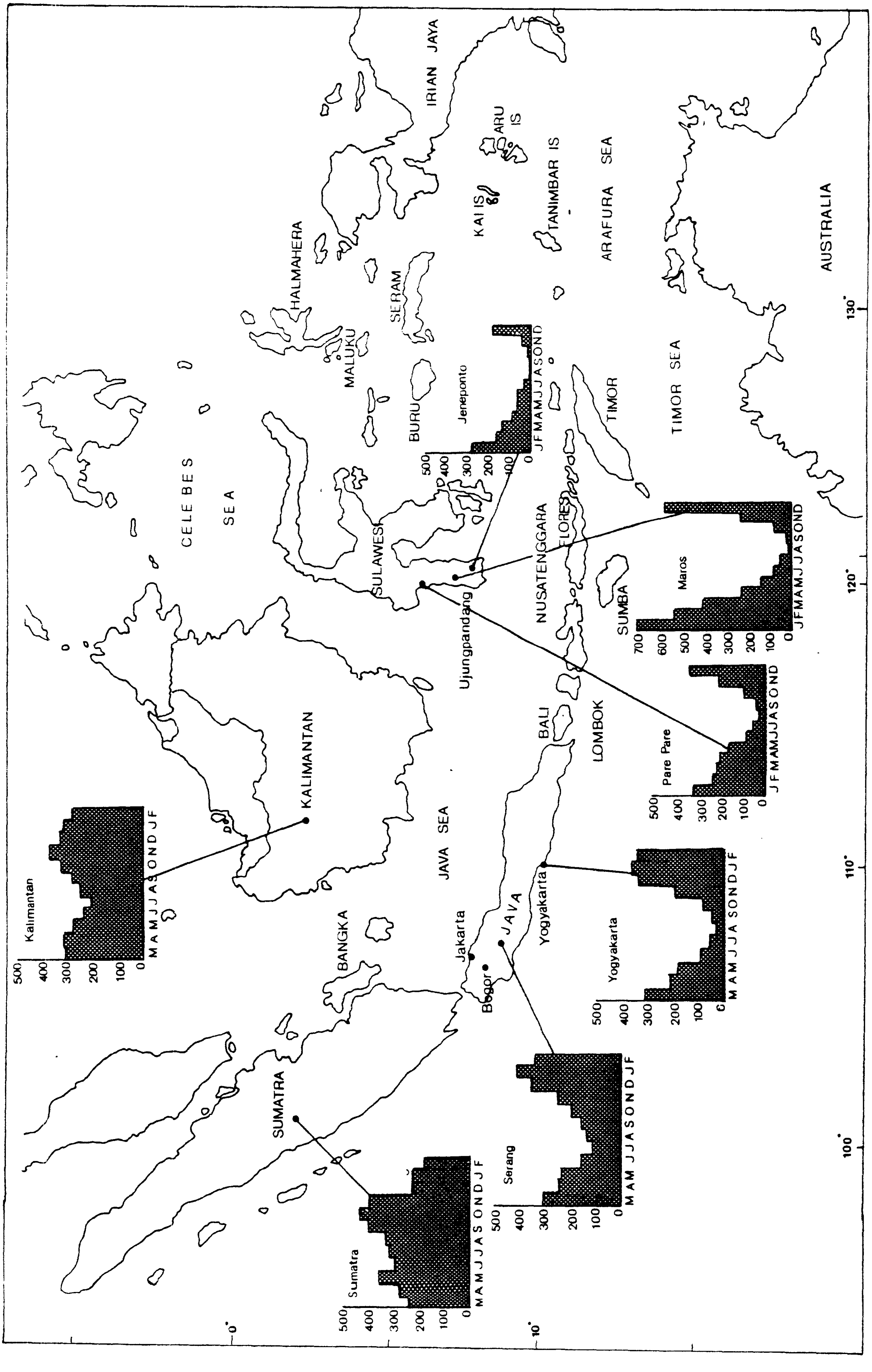
Chapter 1

INTRODUCTION

Indonesia is an island chain located in the tropics between latitudes 6°N and 11°S and extends from longitude 90°E to 141°E (Fig. 1.1). Although the country consists of over 13,000 islands, 90% of the land mass is made of Kalimantan, Sumatra, Irian Jaya, Sulawesi, Java, Madura and Bali.

The islands may be divided geologically into three areas. The first of these comprises Eastern Sumatra, Northern Java and Kalimantan and belongs to the chief core of Southeast Asia known as the Sunda platform. The second area overlies a similar mass, the Sahul Shelf, and includes the southern parts of Irian Jaya, Aru and other islands of the Arafura Sea. Between these two lies an unstable volcanic area encompassing Western Sumatra, most of Java, Madura, Bali, Sulawesi and Nusa Tenggara. The most productive soils of Indonesia are in this volcanic zone. In particular, extensive parts of Java, where there has been continuing eruption of neutral or basic lava which have subsequently been broken down and redistributed by river and wind action, have soils of high fertility. In contrast, large areas in Eastern Sumatra, Sulawesi, Kalimantan and Irian Jaya which are devoid of volcanoes have poor, infertile soils, especially where these have been formed from limestone or former coral reefs.

The topography of the islands varies considerably from flat plains to rugged mountains. All the larger islands, except Kalimantan, have a mountain spine for the most part surrounded by coastal plains.


IRIAN JAYA
ARU IS
KAI IS
TANIMBAR IS
ARAFURA SEA
AUSTRALIA
HALMAHERA
SERAM
MALUKU
BURU
TIMOR
TIMOR SEA
CELEBES SEA
SULAWESI
NUSATENGGARA
FLORES
SUMBA
Ujungpandang
BALI
LOMBOK
KALIMANTAN
JAVA SEA
BANGKA
Jakarta
Bogor
JAVA
Yogyakarta
SUMATRA
Jeneponto
J F M A M J J A S O N D
Maros
J F M A M J J A S O N D
Pare Pare
J F M A M J J A S O N D
Kalimantan
M A M J J A S O N D J F
Yogyakarta
M A M J J A S O N D J F
Serang
M A M J J A S O N D J F
Sumatra
M A M J J A S O N D J F
0°
10°
100°
110°
120°
130°

Kalimantan also has a pronounced spine but is hilly rather than mountainous. The alluvial coastal plains vary in extent between islands; in many instances they are well-drained and fertile, in others they are flat with impenetrable swamp and tidal mangrove areas. The Directorate of Topography in Indonesia has classified the land area of the country into three types of terrain, viz. Type 1 - mountainous land at least 200 m above sea level; Type 2 - land that is almost level to undulating and hilly, but less than 200 m above sea level (but not lowland); and Type 3 - lowland (including swamps). The various areas of these terrain types suitable for agricultural purposes are listed in Table 1. It can be seen that large areas of Type 2 and 3 land exists within the outer islands (those islands excluding Java, Madura and Bali).

TABLE 1.1 Estimates of area suitable for agricultural purposes ('000 ha).

Region	Terrain Type			
	1	2	3	Total
Java, Madura, Bali	1.1	3.2	3.7	8.0
Sumatra	3.3	14.2	1.8	19.3
Kalimantan	2.2	11.2	3.7	17.1
Sulawesi	1.6	4.3	1.1	7.0
Nusa Tenggara & Maluku	0.6	7.1	0.2	7.9
Indonesia*	8.8	40.0	10.5	59.3

* Excluding Irian Jaya
Source: International Bank for Reconstruction and Development (The World Bank) (BRD), Agricultural Sector Survey, Annex 1.

The climate of Indonesia is largely tropical, with two distinct seasons, wet (November to April) and dry (May to October). Generally, most of Indonesia receives adequate rainfall although quite marked variations in the amount and seasonal distribution of rainfall occur (Fig. 1.1) as a result of the complex interpenetration of land and water and differences in elevation and exposure.

Historically, agricultural production has been concentrated on the highly fertile soils of Java, Madura and Bali. At present approximately 60% of Indonesia's cattle and 47% of the buffalo can be found on these islands (which also support 66% of the population of 150 million people) and this is related to their primary function as draft animals in crop production. Little or no beef production occurs despite an increase in demand in recent years and cattle numbers remain low and stable. There is, however, considerable potential for livestock development in the outer islands where extensive areas of grassland exist. Such grasslands are largely dominated by *Imperata cylindrica* and hence have low carrying capacities and poor fattening abilities. While some improvement can be made through controlled pasture management, there is a need to introduce higher quality grasses, improve soil fertility and use suitably adapted legumes to supplement nitrogen deficient tropical grasses.

This thesis is devoted to a study of the nutritional value of native and oversown pastures over a three year period at Sulawesi. The literature review revealed that fertilizer, stocking rate and grazing system were the major factors influencing animal productivity in the wet/dry tropics. In the following study the first two of these factors were investigated.

Chapter 2

LITERATURE REVIEW

2.1 PASTURE IN THE WET TROPICS

2.1.1 Definition and classification of pastures

The term pasture is used to refer to all plant communities which support domestic livestock except for annually sown crops (Hodgson, 1979). Pastures may therefore range from communities consisting primarily of native species to highly improved pastures, consisting entirely of sown exotic species (Whalley, 1980).

Classification takes account of differences in the problems of management and improvement; pasture or grazing land are commonly divided into five classes (Semple, 1951; McIlroy, 1964). These are:

(1) Natural or native grassland or native pasture, consisting of indigenous species, ordinarily maintained without artificial seeding. This type of pasture according to Semple (1951) and Humphreys (1978) is commonly classified according to the climate, soil and management under which they develop. They can be divided into four subtypes;

(a) Tall grassland; usually higher than 90 cm, called prairies (USA), pampas (Argentina) and llanos (Venezuela and Colombia);

(b) Short grassland; usually less than 45 cm, that may be dominated by perennial species, in which vegetative buds survive the whole year, or by annual species which complete their life cycle during one growing season and have a seed resting period during the dry season;

(c) The high grassland; above the timber-line of mountains such as the Alps, Andes and Himalayas; and

(d) the mixed grassland; mostly of tall grass with islands of shrubs or small trees, which are known as savanna in the tropics. The savannas commonly have a dry season which varies from three to eight months.

(2) Permanent or perennial pastures, consisting chiefly of perennial grasses and legumes in humid and sub-humid regions which are grazed year after year. In most cases such pastures are artificially established. Permanent pastures may also consist in part of reseeded annual forage plants.

(3) Short-term pastures or leys, consisting of grasses and legumes used for grazing in succession with cultivated and harvested crops. Usually the periods of grazing extend from two to five years, alternating with similar periods of cropping. A customary rotation consists of maize, one year; small grain, one year; perennial grasses and legumes, three years. The forages are commonly used for both hay and grazing.

(4) Temporary or annual pasture, consisting of annual forage plants grazed during their period of growth and maturity. Livestock may be grazed on a succession of temporary pastures throughout the year.

(5) Supplemental pasture, used for short periods, perhaps one to three months of the year, to augment permanent pasture or native pasture.

2.1.2 Perennial Pasture for the Wet/humid Tropics

The essence of pasture management is the manipulation of the species composition of pasture to obtain and maintain a desirable species composition consistent with the overall management objectives for the particular pasture in question. Therefore, it is important to clearly define the management objectives and to identify desirable species compositions before any particular pasture can be managed (Whalley, 1980). Limitations to pasture production are imposed by many factors which operate in combination. Some of these factors cannot be modified with our present knowledge, e.g. temperature and day length fluctuations, radiation and rainfall (except for the use of irrigation) (Jones and Jones, 1971).

The wet/humid tropics region is characterised by natural evergreen forest vegetation with mean rainfall above 1500 mm per annum, with two seasonal peaks although some rain can be expected in every month. Humidity and temperature are commonly high and short periods of water stress can be expected between rains.

Pastures in this region are generally unsown and receive little attention. Tropical rain forest contains few grasses likely to be useful as pasture plants, and often consist of _Axonopus compressus_, _Imperata cylindrica_, Paniceae and Andropogoneae (Davies and Skidmore, 1966).

The importance of improving pasture quality has been generally accepted. Vilela _et al_. (1977) have shown that animal performance based on liveweight gains is greater on improved pastures than native highland pastures in Thailand (Table 2.1). Such results indicate that

Table 2.1 Seasonal liveweight changes (kg head^{-1}) of cattle grazing improved or native pastures in Thailand. (Vilela et al. 1977.

Pasture	Early Dry Season (9/12/76-2/3/77)	Late Dry Season (2/3/77-26/5/77)	Wet season (26/5/77-10/11/77)	Dry season (10/11/77-26/4/78)	Wet season (26/4/78-27/8/78)
			(kg head^{-1})		
Improved	11.2	2.6	73.6	1.1	33.6
Native	9.6	-3.6	11.8	-6.6	22.7

replacing native pastures with improved pastures is one potential means of increasing animal productivity. Suitable species for a range of tropical environments characterized by differences in length of humid and dry seasons, altitude and mean annual rainfall have been determined by Reid (1973) (Table 2.2). The legumes such as Stylosanthes guianensis, Centrosema pubescens and such grass as Digitaria decumbens and Melinis minutiflora were listed as being adapted to the tropical extended rainfall region.

Harding (1972) working in the wet tropics of Queensland found that native pastures have very low carrying capacity and usually only fatten over the four wettest months of the year. He suggested that grasses which give higher yields of digestible nutrients and animal products per hectare and high fertilizer efficiency should be sought. With legumes, the ability to produce well under grazing with good survival and greater competitiveness with grasses is required.

Table 2.2 Characteristics of species composition and environmental descriptions of the groups (after Reid, 1973)

Group	Environmental Means		Species
Tropical extended rainfall	Length humid season	6.4 mths	Digitaria decumbens
	Length dry season	1.9 mths	Stylosanthes guianensis
	Altitude	655 mtrs	Centrosema pubescens
	Mean ann. rainfall	1596 mm	Melinis minutiflora
Tropical seasonal rainfall	Length humid season	5.8 mths	Andropogon gayanus
	Length dry season	3.8 mths	Stylosanthes guianensis
			Centrosema pubescens
	Altitude	616 mtrs	Leucaena leucocephala
	Mean ann. rainfall	1350 mm	Brachiaria brizantha
Equatorial extended rainfall	Length humid season	8.4 mths	Pennisetum purpureum
	Length dry season	1.1 mths	Panicum maximum
	Altitude	271 mtrs	
	Mean ann. rainfall	2212 mm	
Wet tropical	Length humid season	7.1 mths	Setaria sphacelata
	Length dry season	1 mth	Desmodium cincinatum
	Altitude	1441 mtrs	Desmodium intortum
	Mean ann. rainfall	1387 mm	Glycine wightii

Keya et al. (1971) found that fertilizer alone did not appreciably increase the quality and productivity of native pasture. Oversown legume on native pastures together with superphosphate application gave a marked increase of both dry matter yield and crude protein content. These studies also identified a significant interaction between legumes and superphosphate application (Table 2.3), and indicate that grass/legume pasture mixtures with suitable fertilizer application are capable of improving the quality of the pasture and hence carrying capacity and animal productivity.

Table 2.3 Total dry matter production (kg ha^{-1}) and crude protein (kg ha^{-1}) 16 months after oversowing native pasture with legumes in the presence or absence of superphosphate in Western Kenya (After Keya et al., 1971)

	DM (kg ha^{-1})		Crude Protein (kg ha^{-1})	
Superphosphate (kg ha^{-1})	0	500	0	500
Legume				
No legume	3671	4477	266	325
Stylosanthes guianensis	4303	5805	274	423
Trifolium semipilosum	4781	7555	316	695
Desmodium cincinatum	4150	8230	306	749
Desmodium intortum	4763	7673	270	840

In general, adequate rainfall is received in the wet/humid tropical regions to allow for the management of perennial pastures used in the region. The use of perennial pasture is preferred for long term pastures as they give a long sequence of feed production to supply animal requirements (Humphreys, 1978). Introduced legumes are an important element of these pastures in terms of overall pasture growth. The nitrogen resulting from the legume symbiosis with rhizobium can have a profound effect on the vigour and nature of the companion grasses and of the potential invasion of weeds.

A stable grass-legume pasture is very important to assure consistency of feed supplies to livestock. Suitable pasture management techniques need to be developed to encourage such stable pastures.

2.1.3 PASTURE ESTABLISHMENT

Pasture establishment can be defined as the sequence of events that occur from the time the seed is sown until such time that the species are in a position to contribute substantially and permanently to pasture production (Cook and Lowe, 1977). The rate of establishment depends on the number of plants per unit area and on the growth rate per plant. These, in turn, are dependent on the process of seed germination and the growth and persistence of the seedlings.

Cook (1980) divided pasture establishment into two phases, viz. germination/emergence and seedling growth and survival. The first phase is primarily dependent on microenvironmental factors affecting the seed water balance and on the length of time the soil surface remains wet relative to the germination rates of the species sown, while the second phase is limited by competition between resident vegetation and the establishing seedlings for nutrients and moisture. The potential failure points in establishment were suggested by Humphreys (1978) as being (a) physical loss of seed due to harvesting ants or movement to inaccessible depths on cracking soils, (b) loss of viability of seed, often associated with seed weathering, (c) the failure of germinated seed to emerge from the soil due to environmental stress or soil mechanical impedance and (d) the mortality of emerged seedlings, due to environmental stress, plant competition and pathogen, or pest attack. It is evident that the relative importance of the above factors will vary markedly with location, time of year, soil type, species and management practices in the pre- and post-sowing period. For example, in Papua New Guinea, Chadhokar (1977) found discing before or ring-rolling afterwards improved the establishment of Stylo broadcast into burnt Imperata cylindrica. Similarly, Tudsri and Whiteman (1977) found in Queensland that cultivation (two passes with a rotary hoe at 7.5 cm depth) resulted in a marked improvement in the establishment of Siratro oversown into Setaria anceps. Treatments such as burning, cutting to 5 cm or spraying with paraquat were unsuccessful without cultivation.

Fertilizer type, placement and level of application can affect pasture establishment. Some fertilizers (particularly nitrogenous types) reduce pasture establishment if the seed remains in contact. In addition, rhizobium will be killed by acid single superphosphate. Humphreys (1978) found that the competitive strength of the sown species compared to weeds was increased by placing a band below and preferably to one side of the seed. Kalpage (1977) found that the best results in establishing pasture were obtained by placing phosphatic fertilizer in a band five to ten cm below and somewhat to the side of the seed. Broadcasting fertilizer encouraged weed growth and greater phosphate reversion in acid soils with high levels of iron and aluminium.

2.1.4 Fertilizer Management

Principles of pasture fertilization

Fertilizer programs depend on the system of pasture utilization, whether for fodder as fresh herbage, hay, dried grass and silage or for grazing. Pasture used for cut fodder is generally fertilized in the same way as arable crops in that adequate nutrients should be supplied to correct soil deficiencies and to make up for those removed in the herbage and by other losses. Fertilizer application on grazed pasture depends on the methods of management employed. The nature and extent of the legume component will determine the amount of nitrogen used. In legume based pastures on newly cleared forest soils, nitrogen may not be necessary for establishment or maintenance. Considerable savings in fertilizer costs are possible by using legumes to provide the nitrogen component (Kalpage, 1977). More nutrients are needed when animal products such as milk are sold off the farm. Grazing animals return some nutrients in form of dung and urine, for example beef cattle return most of the phosphorus and potassium in their excreta, whereas with dairy cows appreciable removal losses of these elements can occur. (Kalpage, 1977).

In rate of nutrient application experiments it is necessary for the researcher to decide what his objectives are, e.g. dry matter, recoverable nutrient, protein or animal products in their various forms (Andrew and Bruce, 1975) and to fertilize accordingly.

Effect of fertilizer application on pasture and animal productivity.

Chadhokar (1977) examined the effect of nitrogen application on dry matter yield and protein content of Imperata cylindrica in the Markham Valley of Papua New Guinea. His results showed that nitrogen application increased the yield of total dry matter but had little effect on the protein content of Imperata cylindrica. Dry matter production of the pasture in the presence of Stylo was equivalent to that of about 240 kg N ha^{-1} $year^{-1}$ applied to the grass alone and the high proportion of stylo (30-45%) in the mixed pasture would be expected to improve the overall protein content and acceptability of the available feed. A greater liveweight gain per head per day was obtained on grass/legume pasture than on those nitrogen fertilized in experiments conducted by Jones (1974) as shown in Table 2.4.

Table 2.4 Effect of nitrogen fertilized and legume based pasture on animal liveweight gain (after Jones, 1974).

Treatments	kg $hd^{-1}yr^{-1}$	kg hd^{-1} day^{-1}
Setaria + greenleaf desmodium	121.9	0.334
Setaria + siratro	106.6	0.292
Setaria + 336 kg N ya yr	87.7	0.240

Conversely, Bryan and Evans (1971) showed that animal productivity on pangola grass pasture with nitrogen fertilizer was higher than from pangola grass-legume pasture (Table 2.5). This apparent conflict may have been due to low legume percentage establishment in these pastures.

Table 2.5 Effect of N fertilizer on animal productivity of pangola grass pasture at Beerwah, Queensland (after Bryan and Evans, 1971).

Treatments	Liveweight gain	
	kg hd^{-1} yr^{-1}	kg $ha^{-1}yr^{-1}$
448 kg N ha yr	197.5	1106
168 kg N ha yr	162.6	699
+ Legumes	140.8	507

In the experiments of Ng (1972) significant dry matter yield responses to applications of 112 and 224 kg N ha^{-1} $year^{-1}$ were obtained in Digitaria decumbens and Brachiaria decumbens respectively, beyond which the efficiency of N utilization decreased markedly. Marked yield increases in Paspalum conjugatum and Ischaemum aristatum occurred only at 448 kg N ha^{-1} $year^{-1}$. These indigenous species were comparatively less efficient at recovering N and utilizing it for forage and crude protein than the introduced species. Nitrogen fertilization generally resulted in higher forage crude protein content, lower dry matter content but increased removal of other macro-nutrients in all species. The crude protein present decreased drastically when the regrowth interval exceeded 6 weeks. Hendy (1972) also examined the response of a pangola grass (Digitaria decumbens) pasture near Darwin to the wet season application of nitrogen. The results showed that there was a response in dry matter production up to the highest nitrogen level, but the differences in response occurred mainly during the early showers and not during the monsoonal rains of the wet season. Crude protein content and dry matter production per hectare increased and the nitrogen recovery decreased with increasing levels of N fertilizer when examined over the whole growing season.

Total dry matter yields were increased by superphosphate at each harvest of Stylosanthes guianensis pasture in the experiments of Bruce (1972). The initial response was by the legume but at later harvest the grasses also responded, possibly due to an increase in N fixation by the legumes, leading to a grass dominant mixture or to approximately equal proportions of grass and legume. Guinea grass (Panicum maximum) was more responsive than molasses grass (Melinis minutiflora).

Keya et al. (1971) also found that the interaction between legume content and superphosphate was significant. Application of superphosphate doubled the total dry matter and almost trebled the total crude protein yields of Desmodium intortum and Desmodium cincinatum oversown into native pastures in western Kenya. Applied phosphorus increased the phosphorus concentration in Siratro only at the responsive sites but increased grass phosphorus concentrations at almost all sites (Rayment et al., 1977). Under the experimental conditions Siratro took up very little of the applied phosphorus. Only where dry matter yields increased were there measurable increases in phosphorus uptake. On the other hand, grass phosphorus concentrations increased with applied phosphorus even in the absence of yield changes and were well above, sometimes double, those of the legume. This indicated that the companion grasses, apparently irrespective of species, compete strongly for the available phosphorus from the applied fertilizer even when nitrogen supply probably limits their ability to produce dry matter yield responses.

Fertilizer experiments with Stylosanthes guianensis were conducted on two deep granitic sandy soils of humid tropical lowland in North Queensland (Bruce and Teitzel, 1978). The results showed that maximum dry matter yields were achieved at 25 kg ha^{-1} P but yields were reduced by 100 and 200 kg ha^{-1} P. Yields were also increased by potassium and lime, whereas monosodium orthophosphate gave higher yields than superphosphate. Dry matter yield of Stylo was maximum at a rate of 50 kg ha^{-1} P and 56 kg ha^{-1} K on a beach sand from the same area, and higher rates of phosphorus and potassium reduced yields. Shaw and Andrew (1979) found that maximum dry matter yield was achieved at a rate of 125 kg ha^{1} $year^{-1}$ superphosphate from Heteropogon contortus - Stylosanthes humilis mixed pasture in central coastal Queensland.

Bruce and Teitzel (1978) also noted that three annual applications of 31 kg K ha^{-1} increased exchangeable soil potassium significantly and results indicate that a slightly lower rate would satisfy pasture requirements when combined with 125 kg ha^{-1} superphosphate. In this region fertilizer responses in Townsville Stylo (*Stylosanthes humilis*) may be expected if phosphorus in whole plant tops is below 0.14%, or if potassium is below 0.4%, while responses are unlikely when these values are 0.17 and 0.7% respectively.

Wickham *et al*. (1977) examined seed production of Townsville Stylo in north-eastern Thailand. They found that seed yield responded significantly to phosphorus and sulfur fertilizer application as shown in Table 2.6. Sulfur alone significantly increased seed yields, particularly in the second year. The response to added sulfur decreased with increasing phosphorus levels, probably due to the small amounts of sulfur in the double superphosphate used.

Table 2.6 Townsville Stylo seed production (kg ha^{-1}) on a red latosol soil at different levels of phosphorus and sulfur fertilizer applications in north-eastern Thailand (after Wickham et al. (1977).

Phosphorus Level (kg ha^{-1})	1974 Sulfur level (kg ha^{-1})		1975 Sulfur level (kg ha^{-1})	
	0	50	0	50
0	1150	1550	840	1420
18	1300	1660	910	1400
54	1290	1710	1020	1440
162	1850	1570	1230	1400

Large responses in legume yield to fertilizer have been obtained on alang-alang (Imperata cylindrica) grasslands in South Sulawesi, Indonesia (Blair et al., 1978). Sulfur application at 13 kg ha^{-1} together with 100 kg ha^{-1} triple superphosphate increased the yield of Centrosema pubescens markedly compared with application of 100 kg ha^{-1} triple superphosphate alone or no fertilizer treatment (Table 2.7). The proportion of sward as Imperata (%) was highest in the non-sulfur treatments at each harvest. After 1 year, Imperata content ranged from 73.8% of total production in this treatment down to a mean of 32.8% where sulfur fertilizer had been applied. Treatments with high Centro yields had low yields of Imperata. These results indicated that the high response of Centro to S application increased its competitive ability and suppressed Imperata. Recently, fertilizers containing 100% elemental sulfur have provided a cheaper alternative in areas where sulfur is the only nutrient limiting pasture growth (McLaughlin, 1980).

Table 2.7 Effect of fertilizer on Centrosema pubescens yield of Centrosema pubescens-Imperata mixed pasture at South Sulawesi, Indonesia (after Blair et al., 1978).

Treatment	Centrosema pubescens yield kg green ha^{-1}
0	8217
100 kg ha^{-1} triple superphosphate (TSP)	9023
100 kg ha^{-1} TSP + 13 kg elemental S ha^{-1}	22562

Gutteridge (1981a) examined the phosphorus and sulfur fertilizer requirements of oversown Townsville Stylo and Stylosanthes hamata over two years on a typical upland soil in north-east Thailand. The results showed that there was no effect of fertilizer on the initial establishment of both legume species but there was a significant response in yield to 30 kg S ha^{-1} in both species in both years. Although there was no significant effect of phosphorus on legume yields, there was a trend towards higher yields with increasing rates of P. Glasshouse trials indicated a critical phosphorus concentration in Townsville Stylo plant material of 0.15% P, while the critical sulfur concentration was 0.12%.

Potassium is one of the major nutrients limiting pasture productivity in a number of soil types in the Solomon Islands. Good responses to applied potassium have been demonstrated in grass/legume mixed pastures grown on soils of Dala Island system, Malaita (Gutteridge and Whiteman, 1978). Gutteridge (1981b) further examined the difference in response of 5 grasses and 5 legume species to applied potassium on two soils known to be deficient in potassium. The ratio of the total yield with no added potassium (K_0) to the yield with adequate applied potassium (K_{150}) was used as a measure of the ability of each species to utilize the natural potassium levels in the soil. Generally, the ratio K_0/K_{150} was higher for the grasses than for the legumes. Ischaemum aristatum and Desmodium heterophyllum gave the highest K_0/K_{150} value for the grasses and legumes respectively, indicating that these species are less responsive to applied potassium and appear to grow reasonably well in potassium deficient soils.

Differences in the nature of the response to lime can be explained in terms of soil pH, exchangeable calcium and the particular legume species involved (Tiver, 1960). On mildly acid soils (pH 5.5-6.5) which are low in exchangeable calcium, lime can correct defective nodulation by supplying calcium to the host plant for nodule development. Lime can affect plant nutrition by overcoming a calcium deficiency, by increasing the availability of molybdenum and by decreasing the availability of copper, zinc and manganese.

Teitzel and Bruce (1972) found that calcium carbonate applied at the rate of 560 kg ha^{-1} significantly increased the plant growth of Centrosema pubescens, Stylosanthes guianensis and Phaseolus lathyroides in the basaltic soils in the wet tropical coast of Queensland. The experiments also showed that calcium application increased molybdenum availability and immoblized zinc. The calcium and molybdenum treatment increased the nitrogen content of the legume to approximately the same level and that there was no further increase when both elements were applied together, indicating that both treatments increased the rhizobial symbiosis of legumes.

Manganese toxicity has been shown by Simon et al. (1971) to be a problem on basaltic soils on the north coast of New South Wales. Addition of lime resulted in an increased plant yield, a higher soil pH, and a marked reduction in available soil and plant manganese. Application of 5 tonnes or more of lime per hectare corrected manganese toxicity. Ammonium sulphate applications acidified the soil, increased manganese levels in both soil and plant tissue, and increased the frequency of manganese toxicity symptoms at less than 5 tons lime per hectare. Toxic levels of manganese in soil and leaves varied seasonally and yearly and symptoms were more closely related to high level of plant manganese than to soil manganese.

2.1.5. Pasture Stability

Definition

In practical terms a stable pasture implies a continued productive presence of the sown legume and acceptable associated species, almost always grasses, though not necessarily sown grasses, and a minor weed component (Tothill and Jones, 1977). In ecological terms pasture stability implies the maintenance of a long-term equilibrium state in the vegetation by means of managed inputs such as grazing, fertilizers and plant genetic resources against a background of the natural environment. Mostly the equilibrium stage is not natural but maintained by management, so that the concept of a stable pasture being a managed successional stage of vegetation is important in pasture management.

The main management factors affecting pasture stability are defoliation caused by grazing or cutting, and the level of fertilizer input.

Grazing animals accelerate the rate of circulation of nutrients, encouraging plants which can take advantage of a better nutrient supply and withstand defoliation, but grazing pressure should be controlled to maintain a satisfactory level of the desired plants in the pasture, the density and yield.

Effect of grazing management and level of fertilizer application on stability of pasture

Jones (1972) has shown that stocking rate is the most important factor controlling persistence of Siratro in coastal pastures at Samford. At the highest stocking rate the more rapid death of plants was initially offset by better survival of seedlings which resulted from seed set in the establishment and early years. Survival of these seedlings was satisfactory, competition for light being negligible, but the life span of such plants was subsequently reduced by heavy grazing. Jones and Jones (1971) pointed out that continued overgrazing of Siratro can lead to elimination of the legume as overgrazing reduced the legumes yield which reduced nitrogen fixation and subsequently grass growth. Reduced grass growth then led to additional grazing pressure on the legume and the decline continued.

Grazing management during the establishment phase is critical. In this phase there are generally three pasture components (grasses, legumes and weeds) each with different establishment growth rates and relative palatabilities. The growth rate of the grasses is usually much higher than that of the legumes. Early grazing (at 6-10 weeks after planting) is aimed at reducing the grass canopy and allowing light into the legumes. The best practice for about the first three months is generally to graze frequently, lightly and quickly, and the grazing pressure should be built up gradually over the first two years (Middleton and Teitzel, 1978).

Jones (1974) has shown that if Siratro and a suitable grass are grazed reasonably then the pastures are stable in the sense that sown species remain dominant and weed invasion is minimal. However, if the pastures are grazed to the crash point, or to the point where the stability of the plant community is affected, then the productivity of the pasture may be further reduced. Under such a situation efficiency of utilization at the animal level would be impaired (Alder, 1969).

That stocking rate has a great effect on pasture yield is widely accepted. Walker (1977) showed that the continuing input and build-up of nitrogen by Siratro at light stocking rates and the decline in nitrogen input at heavy stocking rates brought about differences in herbage yields and quality which were reflected in cattle performance.

Further, Partridge (1979) pointed out that at increased stocking pressure, the percentage contribution and presentation yields of Siratro declined but the naturalized legumes such as Desmodium heterophyllum, Desmodium triflorum, Alysicarpus vaginalis and Mimosa pudica increased especially with superphosphate application.

Dry matter percentage yield of Townsville Stylo was strongly increased by fertilizer and also by high stocking in the presence of superphosphate fertilizer in central coastal Queensland (Shaw 1978(a)). Different abilities between species of Stylo to persist under such conditions were recorded by Bishop et al. (1980) on the Mackay wet coast of central Queensland. These experiments were conducted at Kuttabul (well drained friable earth) and Roumala (poorly drained solodic duplex soil). The results showed that Stylosanthes hamata cv. Verano was the most persistent Stylo having the highest population of perennial plants and seedlings at Kuttabul and being similar to Stylosanthes guianensis cv. Graham at Koumala in a continuously grazed pasture.

Another experiment conducted by Robertson et al. (1976) examined the influence of cutting interval on the production of Townsville Stylo and bamboo grass (Arandinaria pusilla) at Khon Kaen, north-east Thailand. Townsville Stylo was dominant over bamboo grass in all treatments, and especially under 2 weeks cutting interval as shown on Table 2.8.

Table 2.8 Summary of the dry matter percentage yield of Townsville Stylo (TS) and Bamboo Grass (BG) at different cutting intervals at Manchakiri, Khon Kaen, Thailand, in 1974 (after Robertson et al., 1976).

Cutting Interval (weeks)	BG%	TS%	Weeds%
2	24.3	75.7	-
4	43.6	55.6	0.8
8	48.7	50.8	0.5
16	30.3	65.3	4.4

Based on the pattern of yield responses obtained by Rayment et al. (1979) in south-eastern Queensland, molybdenum and lime appeared to be the only nutrients likely to have influence on legume (Greenleaf Desmodium) persistency in that region. These experiments also suggested that the current nutrient availability in soil greatly affected the influence of fertilizer application on pasture persistence or stability.

2.2 The Influence of the Grazing Systems and Stocking Rate on Animal Performance

INTRODUCTION

Successful management of an established pasture aims to maximise animal production and to maintain pasture stability and at the same time minimise the cost. For this it is necessary to establish a complex balance between efficient feed utilisation, maintenance of satisfactory animal liveweight gains and maintenance of the pasture in a productive state (Middleton and Teitzel, 1978).

Animal production is directly affected by daily intake of digestible dry matter ('t Mannetje and Ebersohn, 1980). Pasture is generally the main feedstuff for livestock and hence animal production is influenced by herbage present, herbage allowance, legume content, canopy structure, digestibility, proteins, mineral and vitamin content. These factors interact to determine animal productivity.

Various grazing systems have been practised for long periods in the tropics but there is still uncertainty as to the best system to give stable animal performance, especially for the wet tropics region.

The most important feature of any grazing system is the supply of adequate nutrition throughout the entire life of the animals. Failure to obtain a satisfactory compromise between the animals' requirements and suitable conditions for pasture growth results either in low animal production or in sward deterioration or sometimes both. Therefore the choice of feeding systems is very important to reach the optimum animal production from pasture.

Native pastures in the wet tropics have very low carrying capacities and poor cattle fattening abilities because these pastures, in general, are low in nutritive value and are frequently unpalatable. This poor performance, however, can be greatly improved in many instances by controlled pasture management and grazing (Jarret, 1977 and Teitzel & Middleton, 1979).

The grazing systems discussed in this paper are restricted to continuous and rotational grazing systems and will be compared with respect to their effect on animal productivity and in turn compared with cut and carry or zero-grazing.

2.2.1 CONTINUOUS GRAZING SYSTEM

Definition and Grazing Process

Continuous grazing is the term used to describe the situation where animals are kept on an area continuously and where the number of animals is kept constant for the whole or a major part of a grazing season (Hodgson, 1979).

Continuous grazing is the simplest system of handling animals and pasture and since it allows the animals free range, encourages selective grazing. The animals choose the more nutritious portions of the plant and select a diet of higher food value than an analysis of clipping shows. Wier and Torrel (1959), found that sheep under this system selected herbage containing 4.1% more protein and 3.5% less crude fibre than found in hand-clipped herbage, while Hardison *et al.*

(1954), found that cattle selected a diet containing 23% more crude protein, 37.3% more fat, 25.6% more ash and 16.8% less crude fibre than the hand-collected samples. These data indicate that selection by the animal improves its diet.

Continuous grazing also often has advantages in parasite control, and incurs less expenditure on fencing and water 1977).

Animal Production from Pasture under Continuous Grazing System

Animal production from pasture, under continuous grazing, is affected greatly by stocking rate. Increased stocking rate usually is reflected in lower liveweight gain per animal which is compensated for by increased animal numbers to give higher liveweight gain per hectare as shown on Table 2.9.

Table 2.9 Cattle Liveweight Gains from Different Stocking Rates Under a Continuous Grazing System on a Buffel Grass Pasture Fertilized with 100 kg N ha^{-1} yr^{-1} at Narayen Research Station, Qld., 1979/80 (After 't Mannetje, 1980).

Yearly Stocking Rate (beasts ha^{-1})	Liveweight gain		
	kg hd^{-1} day^{-1}	kg hd^{-1} yr^{-1}	kg ha^{-1} yr^{-1}
1.1	0.47	171	190
1.4	0.43	157	224
2.0	0.33	121	242

An experiment conducted by Winks et al. (1980), has shown that stocking rate had a marked effect on legume content of the pastures during the course of the study. In this experiment, which was situated at Rain Research Station, Atherton, North Queensland, under continuous grazing, the legume content of the available dry matter in April 1979, was 18% and 11% on basaltic and granitic areas respectively. The values recorded in March, 1976, of 0.3 to 2.8% and in July of 2.4 to 13.7%, indicate a marked decline in legume content. The decline was greatest at the highest stocking rate (5.0 steers per hectare). The pattern of liveweight change over the three year period was consistent. While animals gained weight virtually throughout at the light stocking rate, the period of weight gain was progressively shortened with successive increases in stocking rates. The failure of animals to gain weight on the heavily-stocked areas after July in 1971 and 1972 was undoubtedly due to a lack of available dry matter.

Jones (1972) also found that the legume yield component was reduced under heavy stocking rates in continuously grazed pasture as shown in Table 2.10.

Table 2.10 Effect of Stocking Rate on Animal Gain, Gain per Hectare and Legume Percentage for a Siratro setaria Pasture Under Continuous Grazing System in South East Queensland (after Jones, 1972)

Stocking Rates (Beasts ha^{-1})	Liveweight Gains for the Period Nov. 1970 to Nov. 1971 (kg)		Percent Siratro (May 1971)
	Gain $head^{-1}$	Gain ha^{-1}	
1.1	178	198	37
1.7	163	282	21
2.4	151	355	25
3.0	93	277	12

Unlike the perennial twining legumes described above, the annual Townsville stylo appears to thrive under heavy grazing, the grass-legume balance being governed mainly by stocking rate (Shaw and Norman, 1970). These patterns were also found by Austin (1970) from an experiment conducted in the Northern Territory of Australia as shown in Table 2.11.

Table 2.11 The Effects of Stocking Rate on Gain per Head, Gain Per Hectare and Percentage Townsville stylo in a Urochloa mosambicensis -Townsville stylo pasture grown in the Northern Territory of Australia under Continuous Grazing System (after Austin, 1970)

Stocking Rates (Beasts ha^{-1})	Liveweight Gains for the Period June 1969 to May 1970 (kg)		% Townsville stylo (March 1970)
	Gain $Head^{-1}$	Gain ha^{-1}	
0.62	122	76	8
1.25	124	153	35
2.65	145	363	75

Under Ugandan conditions, Stobbs (1970) has shown that increasing the stocking rate decreased the percentage of *Hyparphenia rufa* and *Panicum maximum* in pastures, while the associated legumes *Stylosanthes gracilis* and Siratro increased. This indicates that the response of the associated grass to grazing can modify the response by the legume to grazing pressure.

Jones (1979), also found that Siratro yield and total yield declined markedly with increased stocking rate, with an increased invasion of prostrate species such as the blue couch (*Digitaria didactyla*), while Evans and Bryan (1973), showed that the greatest liveweight gain per head was at 1.23 beasts per hectare. There was a significant positive correlation between liveweight gain and legume content of the pastures. Stocking rate also affected the quality of carcass produced.

In an experiment conducted over 3 years in Northern Cape York Peninsula, Winter et al. (1977) found that liveweight gain per hectare was similar (0.54 kg per day) at 1.7 and 1.9 beasts per hectare, but was significantly less at higher stocking rates. The pastures used in this experiment were a mixture of Brachiaria decumbens cv. Basilisk sown with Stylosanthes guianensis cv. Endeavour and Macroptilium atropurpureum cv. Siratro. At the highest stocking rate liveweight gains were greater during the wet season and losses greater during the dry season than those at the lowest stocking rate.

Thus, a continuous grazing system allows animals to be selective in their grazing behaviour, and if practised on pastures of good quality, palatability and persistence, high levels of animal productivity can be attained. Seasonally, pasture production in the wet tropic region must be followed by adjustments in stocking rate if this system is still to be used. The major factor that can be manipulated in this system is grazing pressure via stocking rate. In general, pasture yield and stability decrease with increasing stocking rate. However some species have been identified which are able to produce and persist under high grazing pressures. Brachiaria decumbens and Pangola grass (Digitaria decumbens are examples of these.

2.2.2 ROTATIONAL GRAZING SYSTEM

Definition and Grazing Process

A rotational grazing system is a regular sequence of grazing and rest for particular areas of sward, with either fixed or moveable divisions (Hodgson, 1979). This system requires more control of animals and pasture, and is generally associated with small paddocks, so that it involves more fencing and water supplies. It also enables pastures to be used quickly at their highest nutritive value or to be heavily grazed to force animals to eat unpalatable species and weeds.

Animal Production from Pasture at Different Stocking Rates under a Rotational Grazing System

Interactions between stocking rate and grazing system have been revealed in many experiments on sown pastures. In general, rotational grazing systems produce little or no benefit at low stocking rates, but potentially greater benefits at higher stocking rates (Robinson & Simpson, 1975).

Conway (1963), working on temperate pastures also found that this system had no significant effect on animal performance at stocking rates of 2.47 and 4.32 beasts ha^{-1}. At a higher stocking rate of 6.18 beasts ha^{-1} significant increases in animal performance in favour of the rotational system were achieved (Table 2.12). An increase in stocking rate of 75% from low to medium resulted in a decrease in individual animal performance of 19% and 16% in 1960 and 1961 respectively.

Table 2.12 Liveweight Gain per Hectare for Whole Period, 1960-1962 at Grange, Dunsany, Ireland (after Conway, 1963).

Stocking Rate (cattle ha^{-1})	1960 Rotat.	1960 Contin.	1961 Rotat.	1961 Contin.	1962 Rotat.	1962 Contin.
	Grazing System ($kg\ ha^{-1}$)					
(low) 2.47	445	464	477.3	526	456	511
(med.) 4.32	630	571	704	679	792	771
(high) 6.18	867	650	697	364	797	657

Denny et al. (1977) compared two intensive rotational grazing systems involving twelve-paddocks-to-one-herd with a four-paddocks-to-three-herds rotational resting system in which three of the four paddocks were grazed continuously in any one year, and the fourth rested and burned in rotation. In the twelve-paddock system the stocking rate was 3.4 hectares per steer compared with 5.4 hectares per steer in the four-paddock system. Subsequently, the periods of stay differed in the two systems. In one, the steers remained in each paddock for two weeks, and in the other they were kept in each paddock until all but the most unpalatable grasses had been grazed to a height of 4 to 8 cm. The results showed that no differential changes in botanical composition or in the density of the perennial grasses occurred in either of the trials. Except in the early growing season, the performance of individual steers in the twelve-paddock system was depressed compared with steers in the four-paddock system. The degree of depression increased with increasing period of stay and was attributed primarily to the reduced opportunity for the steers to select a diet of adequate quality and quantity.

In a further experiment, Denny and Steyn (1977), compared a 16-paddocks to one herd intensive rotational system with a four-paddock to one herd rotational resting system. They found that there were no differential effects of grazing systems on grass species composition until the later stages of the trial when the density of perennial grasses on the lithosols was lower in the 16-paddocks system than in the 4-paddocks system, indicating that, in this instance, intensive grazing was harmful.

Subsequent work (Denny and Barnes 1977) investigated liveweight gains in the mid and late growing season with six grazing procedures at two stocking rates as shown in Table 2.13.

Table 2.13 Effects of Six Grazing Procedures Applied at two Stocking Rates on Body-Mass Gain per Steer During the Mid and Late Growing Season* (After Denny and Barnes, 1977)

Stocking Rates (Steer ha^{-1})	Liveweight gains per steer (kg)					
	8 Paddocks Period of stay in each paddock (days)			4 Paddocks Period of stay in each paddock (days)		
	5	10	20	5	10	20
(low) 0.2	72	63	54	73	75	68
(high) 0.4	53	56	34	75	70	48

* Period of a mid and late growing season is 160 days.

Differences between treatments in terms of gain per steer were greater at the high than at the low stocking rate, but, in general, the patterns of response were similar. Except for one treatment combination, involving the five-day period of stay, eight paddocks and the low stocking rate, the use of eight paddocks resulted in lower production than the use of four paddocks. The 20 day period stay, especially at the higher stocking rate and with the use of eight paddocks instead of four, resulted in a marked reduction in gain per steer. Overall, the four-paddock system, produced higher animal performance than the eight-paddock system.

Thus it can be seen that rotational grazing systems have little or no benefit at low stocking rates, but can be beneficial at higher stocking rates. As with continuous grazing, increasing stocking rate under rotational grazing results in a decrease in individual animal performance but an increase in production ha^{-1}. There is no conclusive experimental evidence to indicate the superiority of any one form of rotational system over any other. Current indications are that systems with eight or more paddocks per group provide little or no advantage over systems with fewer paddocks.

2.2.3 CUT AND CARRY SYSTEM OR ZERO GRAZING OR FORAGE FEEDING

Definition

This system is the practise of cutting herbage from a sward and feeding it fresh to animals (Hodgson, 1979). In this system animals are housed in stalls throughout their life and receive fresh feedstuff which is cut daily. As such it usually requires more attention and results in a higher cost for items such as yards, labour and animal waste handling than the other systems.

The cut and carry system is also known as green-feeding, mechanical grazing, silage, zero-grazing, the feeding of cut forage or forage feeding (Raymond, 1970).

Animal Production under the Cut and Carry System

The value of any feed depends on the quantity eaten and the extent to which the food consumed supplies the animal with energy, protein, minerals and vitamins (Minson, 1977). In experiments conducted by Tayler and Rudman (1965), the amount of herbage organic matter and component of the sward fed to yarded steers affected their consumption or daily intakes, as shown in Table 2.14. The steers in this experiment increased their daily consumption when they received a higher quantity of herbage. These differences in D.M. intake were reflected in liveweight gain as shown in Table 2.15.

Table 2.14 Effect of Quantity of Herbage Fed and Fraction of Sward on Consumption of a 250 kg steer (O.M.kg per head per day) (After Tayler & Rudman, 1975)

O.M. Fed (kg)		Daily Consumption (O.M. kg per head per day)			
	Season:	Spring		Summer	
	Portion of Sward:	Top	Bottom	Top	Bottom
8.1 (3.2% of LW)		5.6	4.1	6.1	6.1
4.6 (1.8% of LW)		4.3	3.9	4.1	3.8
Mean		5.0	4.0	5.1	5.0

Table 2.15 Effect of Component of Sward on Liveweight Gain of Yarded Steers (kg per head per day) (After Tayler & Rudman, 1965)

Experiment Period	Top	Bottom
	Liveweight gain (kg hd^{-1} day^{-1})	
Spring	0.89	0.58
Summer	0.74	0.64

The higher intake of the top fraction of the sward by yarded steers (Table 2.14) was reflected in their higher liveweight gain. In the same experiments differences in harvesting method and height of cutting affected the liveweight gain of yarded steers as shown on Table 2.16.

Table 2.16 Effect of Method of Harvesting Fresh Herbage on Liveweight Gain of Yarded Steers, kg per head per day (after Tayler & Rudman, 1965)

Treatment	Mower Chopper-Blower	Forage Harvester
Cut at 10 cm above ground	0.91	0.84
Cut at 6.5 cm above ground	0.81	0.71

The higher level of cutting resulted in a high liveweight gain in these yarded steer. Fresh herbage from mower with chopper-blower herbage gave higher liveweight gains than forage harvested material. The high weight gains found in the experiments of Tayler and Rudman (1965) have been found in other trials conducted using this method of feeding and these are summarised in Table 2.17.

Liveweight gains from cut and carry systems are influenced by many factors such as species of herbage, methods of harvesting, quality and quantity of herbage given daily involving both digestibility and palatability of the feedstuffs and the type of animal. This system is generally more costly than the other systems.

Table 2.17 Animal Performance from Some Experiments Under Cut and Carry System, Summary

Pastures Type	Animals Used	Quantity of feedstuffs given hd day	Daily Feed Intake kg DM hd day	LW Gain kg hd day	Reference
Leucaena leucocephala	1-2 yr. old bulls	2% liveweight (LW) + molasses + urea (ad. lib)	-	0.79	Hulman, et al., 1978
		3.5% of LW + molasses + urea (ad.lib)	-	0.85	"
		5% of LW + molasses + urea (ad.lib)	-	0.74	"
Bentland Oats & Festiquay Wheat	16 mths steers	+ 60g urea	7.45	0.90	Rowan & Fletcher, 1968

2.2.4. COMPARISON BETWEEN FEEDING SYSTEMS

Comparison of Continuous Grazing and Rotational Grazing Systems and Their Effect on Animal Production

Grazing management system is an important factor influencing the efficiency with which grassland herbage is converted into animal products. It has been defined by McMeekan (1960) as controlled by three factors that can be manipulated by man: (a) grazing method or grazing system, (b) stocking rate and (c) kind of stock used.

Higher levels of animal production from pastures have frequently been attributed to the use of rotational grazing systems. However, few experiments have shown consistent advantages for rotational grazing in comparison to continuous grazing. In any comparison of management systems pasture utilization is a factor of prime importance (Robinson & Simpson, 1975).

Conway (1963) found that at low stocking rate animals in a rotational grazing system had 4, 9 and 11 percent lower liveweight production than the continuously grazed animals for 1960, 1961 and 1962 respectively (see Table 2.12). These differences were not significant. The decrease in animal performance was possibly due to lowered herbage intake caused by confining the cattle within the paddock until the sward was grazed bare. At the medium stocking rate there was an increase for the three years of 10, 3 and 3 percent, respectively, for the rotational system of grazing. This difference was again not significant for the whole grazing system of any year but there was a significant difference for the final 10 weeks of the grazing season in 1960 in favour of the rotational grazing. At the high stocking rate there were increases of 33,92 and 21 percent for 1960, 1961 and 1962 respectively in favour of the rotational grazing, differences which were significant for the whole 1960 and 1961 grazing seasons. In 1962, there was an interaction between the system of grazing and stocking rate. This was due to the poor performance of the continuously grazed high stocked group.

A two-paddock rotational resting system was tested against a continuous grazing system at one stocking rate for 9 years in Canada (Smoliak, 1960). Steer gains were better under the continuous grazing system due to higher summer gains, which were associated with higher protein content of the herbage under this system. Similar vegetation improvement was recorded from both treatments but it is noteworthy that the degree of forage utilization amounted to only 44% and 46% in the rotational grazing and continuous grazing systems respectively. In contrast, Hyder and Sawyer (1951) noted more even pasture utilization under rotational grazing.

In an experiment conducted over 6 years by Hubbard (1951) it was found that at a high stocking rate there was no difference in steer gains, whereas, at the moderate rate, gains were poorer under a three-paddock rotation.

Stobbs (1969) found that there was no significant difference in liveweight gains between continuously grazed plot and a three-paddock system except during a severe dry season. When weight losses were heavier for the continuously grazed system, indicating that where feed is limiting, a rotational grazing system is beneficial.

Comparison of the Effect of Grazing System with Cut and Carry System or Zero-Grazing on Animal Production

Feeding trials conducted by Halga *et al*. (1978) at Secuinei, Romania, showed no significant difference in liveweight gain per head per day in cattle which were fed with fresh grass and perennial legumes and concentrates (*ad libitum*) with cattle from grazed paddocks.

Logan *et al*. (1960), working in a temperate environment, also found that no significant differences occurred on average daily milk production per cow between zero-grazing or cut and carry system and strip grazing system.

SUMMARY AND CONCLUSIONS

The grazing systems aim, as far as possible, to match the quantity of forage available with the nutrient requirements of the particular livestock being fed. This presents problems because the rate of growth of forage differs markedly and often unpredictably, between different seasons of the year, and the daily nutrient requirements of animal populations also vary throughout the year (Raymond, 1970).

Continuous grazing systems are the simplest and the cheapest system of grazing available, and it is considered as a standard against which other systems should be measured (Bransby et al., 1977).

From the experiments reported above, it is concluded that no consistent benefits result from rotational grazing systems over continuous grazing. However at high stocking rates rotational grazing has been shown to produce better animal performance than continuous grazing.

The inconsistency of the results of grazing trials can be related to several factors including the limitations imposed by the particular experimental conditions. For example, paddocks used have often been unrealistically small, which may result in uniform grazing relative to large areas. This reduces the selectivity of the animals raised under a rotational system, possibly leading to their productivity being below their potential.

Pasture species have a major influence on animal productivity. Partridge (1980) has shown that Hetero (Desmodium heterophyllum) increased in frequency and percentage contribution to total pasture under heavier stocking rate. Hetero contributed over 45% of the total herbage yield in an open sward of grazed mission grass (Pennisitum polystachyon) at a stocking rate of 3.5 beasts per hectare and also combined well with the creeping Nadi blue grass (Dichantium caricosum).

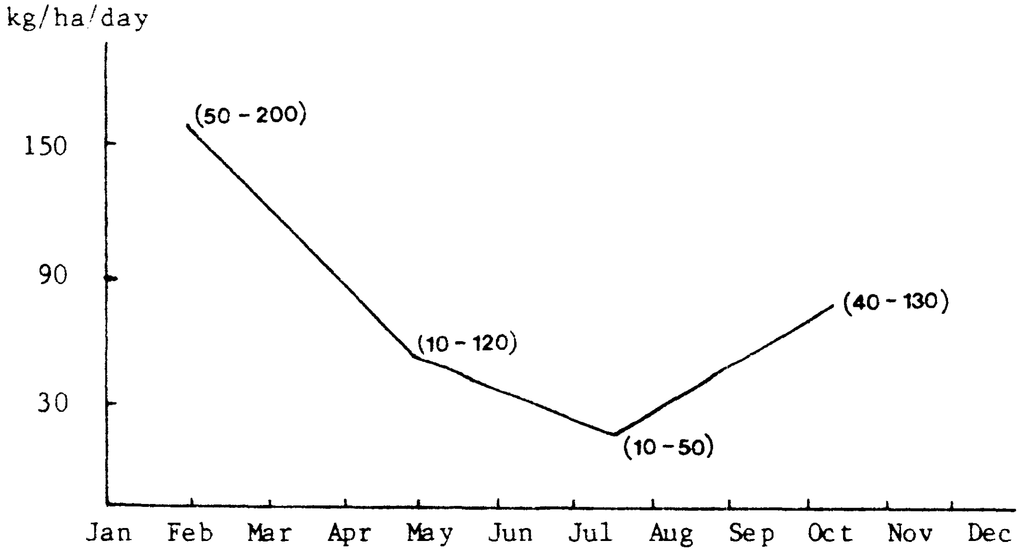
Partridge (1979) also found that the mixture of Hetero and Mission grass pastures at a stocking rate of 3.5 beasts per hectare under continuous grazing gave a liveweight gain of 525 kg per hectare per year whilst Hetero and Nadi blue grass pastures only produced 400 kg liveweight gain per hectare per year under the same system. This indicates that the species characteristics involving their ability to persist on differing conditions have a large effect on herbage production which is reflected in animal productivity.

Intake and animal production are asymptotically related to total dry matter in the pasture where the herbage consumed is a constant proportion of herbage present or allowance ('t Mannetje and Ebersohn, 1980) and the distribution pattern of tropical grassland is largely determined by the interaction of climatic and soil factors, although precise composition and productivity are modified by biotic factors (Davies & Skidmore, 1966). The wet tropical zone, where the mean rainfall is often above 1500 mm per annum, is conducive to high dry matter yields and the seasonal pattern of pasture production in these regions exerts a dominant influence on pasture growth.

Middleton et al. (1975) state that the absolute yield of pasture is less important than its seasonal distribution. The normal pattern of production and the range of values is typified by common Guinea grass as shown in Figure 2.1.

The necessity for, and benefits from, periods of rest in rotational grazing systems have been generally accepted. However, if a pasture is rationed to animals by grazing subdivisions in rotation, and the pasture over the whole area is already growing faster than the animals can consume it, no gain is made (Morley, 1965). Therefore, length of grazing and stocking rate should be adjusted by considering the availability and persistency of pastures used to give a correct stocking pressure. Correct stocking is a situation in which the quantity of pasture consumed daily is approximately equal to that grown daily.

Figure 2.1 Mean Seasonal Yield of Common Guinea Grass in the Wet Tropics (Nos. represent range of values recorded) (After Middleton et al., 1975)



The cut and carry system is more effective as a harvester than grazing animals. However, differences are not always reflected in animal performance (Halga et al. 1978; Runcie, 1960 and Logan et al., 1960).

Therefore, whatever the relative merits of feeding cut herbage versus grazing, the final decision of the individual farmer must be based on an economic evaluation of both methods in relation to his own particular circumstances.

The marked influence of quantity and quality of pasture on livestock productivity has been widely accepted. There are many types of pasture within the wet tropics region, each having an individual carrying capacity and livestock fattening ability. The relatively low quality and quantity of the native pastures in the wet tropics (as reported by Harding, 1972; Falvey and Andrew , 1979; Vilela et al., 1977, and Teitzel and Middleton, 1979) has encouraged the initiation of pasture improvement through the introduction of pasture species, fertilizer application, or both.

Many experiments have investigated the adaptability of pasture species at various sites. Generally, it has been reported that climate (mostly rainfall, temperature and day length) and soils (types and current nutrient status) greatly affect growth of pasture species both in the establishment phase and in the productive phase. Because soil factors, especially nutrient content, can be manipulated, the climate is seen as the critical determinant of the choice of sown species. A classification of sown tropical pastures based on the performance of sown species for the wet tropics has been listed in Table 2.2.

The wet tropic regions have many resources to support livestock productivity throughout pasture improvement, such as adequate rainfall and sunlight. Generally, however, lack of management skills has resulted in low animal productivity. Pasture management practices should be improved to ensure successful pasture establishment and maintenance.

Cook and Lowe (1977) and Humphreys (1978) have defined many factors affecting pasture establishment including temperature, plant competition, soils, pests and diseases, time of sowing, seeding rate and burning and grazing. These factors act individually or in combination and directly affect the growth rate and density of sown species. Experiments conducted to examine such problems should clearly define the problem and solution before any particular pasture can be managed.

When the pasture is established, fertilizer application and grazing management become the main factors controlling the maintenance of a stable pasture to assure an adequate supply of forage. Crop or pasture response data from fertilizer trials on different types of soil would ideally be needed to make recommendations on rates of fertilizer application. Fertilizer costs, expected prices of livestock products sold, pasture plant growth, soil moisture regimes and grazing patterns also influence the amount and method of fertilizer application.

Soils and pastures in the wet tropics region are often reported to have mineral deficiencies, not only of major nutrients but also minor nutrients. The marked effect of nutrient supply on botanical composition, yield and growth of pasture plants has been reported in many trials. There are large differences between species in nutrient requirement for maximum growth. However, the nutrient status of the soils varies between soil types, so that pasture management should be modified for each situation to ensure the maintenance of highly productive, stable pastures.

Grazing management systems have different effects on animal productivity for various pastures. The difference between the systems depends on the grass and legume species, the kinds of livestock and the initial condition of the pasture used in the experiments.

Different pasture mixtures often result in different responses in animal performance under the same grazing systems. This can generally be explained by differences in species persistence.

The grass/legume pasture with high persistence should be more beneficial under a continuous grazing system, when heavy stocking rates are used. Conversely, for species with low persistence, rotational grazing systems should be used to maintain the stability of the pasture by controlling the frequency and intensity of defoliation of the preferred plants, and reduce selective grazing.

If pastures species that are resistant to grazing are available then free range grazing may be utilised. Where such species are unavailable, a cut and carry system is usually preferable, provided certain economic factors, such as herd size and labour availability, justify the capital investment involved.

The seasonality of pasture production in the wet tropics means that more attention needs to be given to grazing management to give an adequate balance between animal requirements and feedstuffs available and ensure a reasonable output of animal products. To achieve these ends we should not be restricted to one system for one herd, but need to evaluate which combination of feeding systems give the most benefits. From this, it should be possible to develop a flexible system of feeding which would take advantage of the benefits of each system.

This review of literature has led to the proposal of several hypotheses. These are that

i) the addition of appropriate fertilizer to the existing pastures, which are dominated by alang-alang (Imperata cylindrica), will increase the quantity and quality of the pastures, decrease the population of Imperata in the pasture and improve animal production.

ii) stocking rate and its interaction with the pastures will have a major influence on animal productivity.

iii) the low quality of available feed and unsuitable grazing management systems are major factors restricting animal productivity in the wet tropics.

The first two of these hypotheses were tested in this thesis in an experiment in which native and oversown pastures were grazed by beef cattle. The legumes sown were Stylosanthes guianensis (Schoffield and Cook cv.) and Calopogonium spp. Because of the lack of land and labour provided, the third hypothesis was not tested. Since Blair et al. (1978) have reported low plant sulphur levels in this region, sulfur fertilizer was applied to investigate this observation and to test its effect on animal production under a grazed situation.