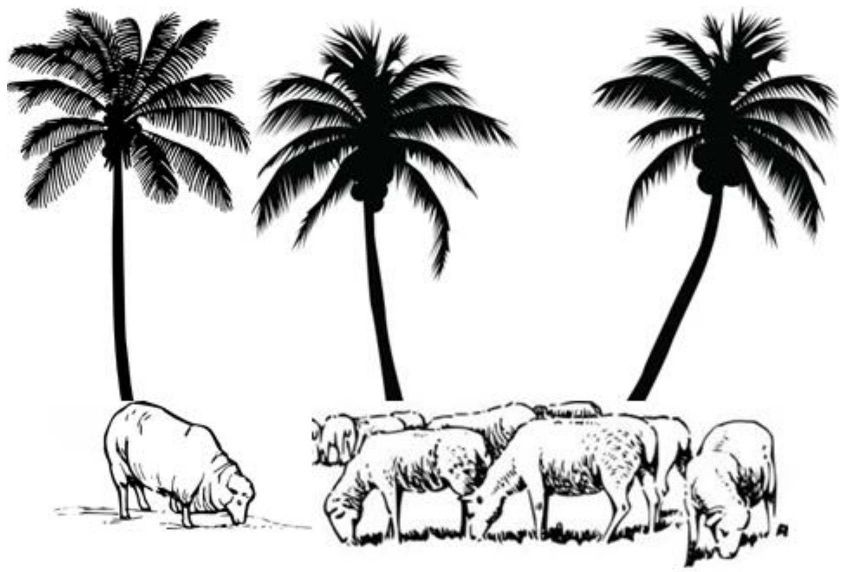
COCONUT-ANIMAL PRODUCTION SYSTEMS



Technical Report

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COCONUT-ANIMAL PRODUCTION SYSTEMS (CAPS)

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(Unreferenced diagrams and photographs by Compton L. Paul)

1. Introduction

The coconut-animal production system is based on the premise that the animal component is beneficial to coconut production and productivity and that the income from the integrated system is greater (Reynolds, 1988). Coconut farmers can increase their profitability while reducing financial risks by adopting an integrated farming system that include animals or intercrops.

In coconut-animal production systems, the general rule is to plant the coconut component at the traditional spacing and adjust the animal stocking rate to the available understorey space. The animal component is often treated as an aid (especially in weed control and the provision of additional income) to the coconut enterprise which takes priority. Mixed farming by raising fodder grasses such as hybrid napier or guinea grass along with leguminous fodder crops has been found to be profitable (Model coconut profile, India).

Liveweight gains of animals under coconut-animal production systems has been found to be associated with a number of management and environmental factors such as light transmission, pasture species and forage quality, soil type, fertiliser use, animal size, stocking rate, supplementary feed and, grazing system. Other factors include coconut varieties, density, age and height. Coconut yields, on the other hand, depend on pasture species, fertiliser use, soil moisture, grazing system, stocking rate, nut collection system, height of forage, legume introduction, weed control, cultivation methods and IPM practices (Reynolds, 1988).

Studies done in Sri Lanka show that there are no adverse effects on nut yield by intercropping coconut with pasture provided both crops are adequately fertilised and grown under adequate soil moisture conditions. The studies further showed that in fact there was a long term beneficial effect on nut production by intercropping with certain pasture species. These beneficial effects were thought to be due to the pasture's improvement of soil structure, better recycling of nutrients, and improved water percolation (Ferdinandez, 1978).

2. Ecological considerations for maximum yields

Coconut palms can grow in various environments, although certain ecological conditions limit their growth. According to Darwis (1990), limiting ecological factors include rainfall, altitude, swamp area, and soils. Several agro-climatic factors thus affect productivity, including altitude, rainfall, temperature, relative humidity, wind, sun radiation, day length and, soil type including its physical and chemical properties (Waney and Tujuwale, 2002).

Coconut requires suitable annual rainfall ranging from 1200 to 2500 mm/year (Darwis, 1990; De Taffin, 1998). Monthly rainfall also plays a key role in determining coconut growth and production. The mean annual temperature for optimum growth and maximum yield is stated to be 27°C with a diurnal variation of 6°C to 7°C and relative humidity at 80 - 90%. An average ambient temperature of 27°C is good (less than 20°C and less than 34°C not suitable). When the average monthly minimum temp is less than 18°C, growth is reduced and female flowers abort. However, some varieties may produce satisfactorily at temperatures less than 18°C. Optimum sunlight is 2000 - 2200 hours per annum with the minimum being 1500 hours/annum or 125 hours per month (Waney and Tujuwale, 2002).

Coconut does best in loose well-drained soils about 50 - 100 cm deep with good moisture-holding capacity. Production is limited by shallow and compacted soils, heavy clays, waterlogging and drought.

Altitude affects coconut production and oil content. The higher the elevation, the lower the temperature. Optimum altitudes are below 400m at latitudes between 20° and 30° north and south of the Equator but coconut plants can grow well up to an elevation of 900 m at this same latitude. Trees that grow at elevations above 500 meters produce a thin endosperm and low oil content (Waney and Tujuwale, 2002).

3. The coconut component

There are two recognised types of coconut variety, namely, dwarf and tall types. These are simply distinguished according to their height. Dwarf varieties are usually early maturing and produce nuts earlier in their life compared to the tall varieties. Tall varieties, however, yield more nuts than dwarf varieties (Agfishtech Portal, 2012).

Commercial cultivars can be sorted mainly into tall cultivars, dwarf cultivars and hybrid cultivars (hybrids between talls and dwarfs) (Fig. 2). Some of the dwarf cultivars such as *Malayan Dwarf* has shown some promising resistance to lethal yellowing while other cultivars such as *Jamaican Tall* is highly affected by the same plant disease. Some cultivars are more drought resistant such as *West Coast Tall* (India). Other aspects such as seed size, shape and weight and solid endosperm thickness are also important factors in the selection of new cultivars (Wikipedia, 2015).

Trees that produce more than100 nuts per tree per year are considered to be very productive. The most popular dwarf cultivars are the Malayan Green, Red and Yellow. Hybrids of tall types such as Panama Tall and Jamaican Tall x Dwarf Malayan are popular (Pilgrim, 2011). Tall types come into bearing at 7-10 years of age and have a productive life span of 70 years while dwarf types take 1.5 to 3 years to come into bearing and have a productive life span of 30 years.

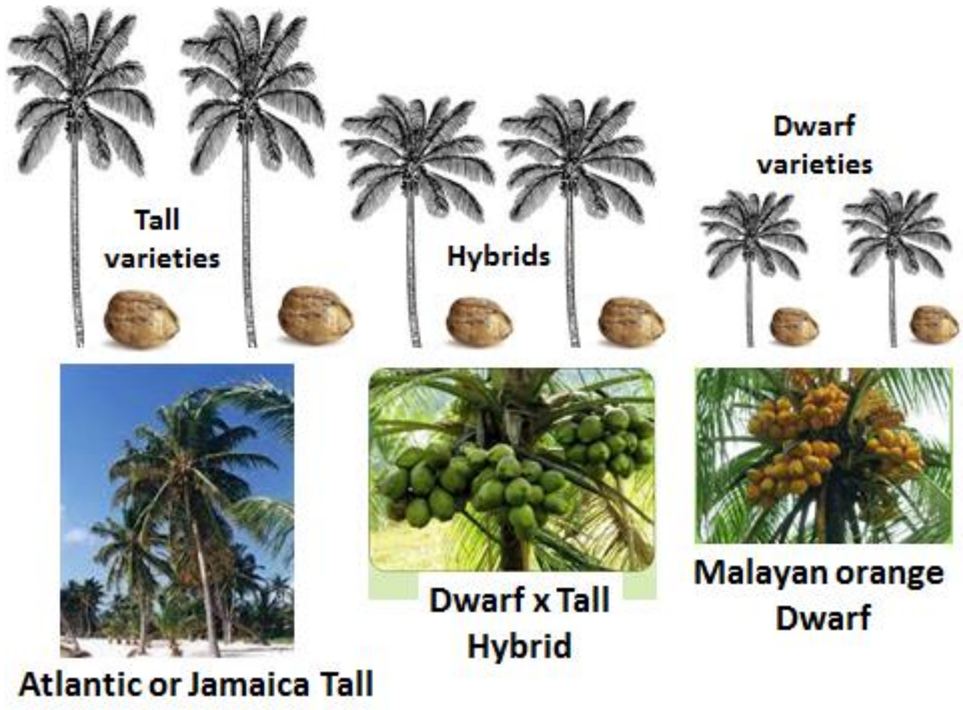

Figure 2. General types of coconut.

- **<u>Nursery establishment and management</u>**
  Sturdy planting material (seedlings at 6-9 months old or those with 6-8 firm healthy leaves) should be obtained from nurseries where dry mature nuts are selected from high-yielding healthy trees and propagated in seed beds or polybags. Early germination and good vigour of seedlings is important.

(i) **<u>Seed preparation</u>** (De Taffin, 1998)

Select healthy and uniform seeds. Store in heaps no higher than 1.5m. Store no more than 10 days for dwarf types and no more than 21 days for tall types.

(ii) **<u>Planting in the seedbed (pre-nursery)</u>**

Pare nuts at end where shoot emerges and sow 1/3 in soil of fine tilth.
On non-rainy days, apply 0.5 litre water to each seedling every day. Each bed must consist of only one cultivar and all must be of same age. 80% germination acceptable. After about 4 months (sprout a few cm long) germinated nuts are selected for transplanting into nursery beds. Early germination is correlated with early yield. Selected sprouts should be single, sturdy, straight and well set into the husk. Plants with thin or spindly sprouts, 2 or 3 stems and leaves with shortened lamina are discarded. Off-colour sprouts are discarded (since green colour of tall parent is dominant, yellow or red sprouts resulting from hybrid crosses of red or yellow dwarfs x talls should be discarded). A maximum of 12% discards is acceptable at this seedbed stage.

(iii) Planting in the nursery proper

Selected germinated nuts are lifted out of the seedbed and transferred to polybags for placement in nursery beds or placed directly into nursery soil of fine tilth. On non- rainy days, apply 1 litre to each seedling every 2 days and control weeds and insects. Space plants 60 x 60cm for 6 months stay in nursery; 80 x 80cm for 9 months stay; and, 100 x 100cm for 12 months stay.

Apply fertiliser mixture (1 unit urea + 2 units TSP + 2 units KCl + 1 unit $MgSO4$) at 30 g/plant (1 month), 60g/plant (3 months), and 75g/plant at 5, 7 and 9 months.

(iv) Transplanting to field plots

At 6 to 8 months, dwarf x tall hybrid is 18 - 20cm circumference at collar and 110 – 120cm tall with 7 - 8 leaves and the youngest already differentiated into leaflets. Discards at this stage should not be more than 15%. Overall, 100 plantable seedlings for field plots should be obtained from about 172 nuts entering the nursery (about a 42% loss of nuts from nursery to field plots).

An acaricide should be used to treat the seedlings against Red Palm Mite.

The seedling should be planted in a 60 - 90 cm deep hole 30cm x 60 cm. Organic material such as dry coconut husk should be placed at the bottom of the hole and covered with a 3:1 mixture of soil and pen manure. Approximately 100g of NPK fertilizer should be placed at the base of the seedling (Pilgrim, 2011). Thereafter, NPK fertiliser should be applied every 3 months for the first year at the respective rate of 0.5 kg, 1 kg, 1.5 kg, and 2 kg per plant. From the second year onwards, compound fertilisers high in potassium should be applied at the rate of 1 kg per plant every 6 months (Pilgrim, 2011).

- **Spacing and arrangement**

The most important management tool in achieving optimal overall system productivity is appropriate coconut spacing since this determines the amount of light that penetrates the canopy. The density of coconuts per hectare determines how much sunlight will get through to the understorey. The optimal spacing for good overall pasture and coconut production is reported to be 10 x 10 m on flat or gently rolling terrain and 9 x 9 m on slopes (Guzman and Allo, 1975; Opio, 1987). Compare this to the recommended spacing for maximum nut production alone on flat land which is 8 x 8 m. Nair (1979) estimates that even at this spacing, only 20% of the total soil area under the coconuts is effectively utilised by their roots.

A general spacing of between 7.6m x 7.6m and 9.1m x 9.1m is recommended with a pineapple planting configuration. Dwarf types and hybrids are often planted at the closer spacing since their larger and denser fronds cover the ground much more than tall types. Wider spacings also favour intercrops or pastures.

A triangular (Fig. 3) as opposed to square-spacing arrangement is now recommended by most experts because it allows for more coconuts, more canopy interlock/overlap, and thus more effective interception of sunlight at any given spacing. One would suspect, then, that a square arrangement is preferred where pasture production is an objective. With a square arrangement, more light reaches the understorey pasture. However, this extra light is concentrated through wide gaps in the canopy so that some spots in the pasture receive much more light than others. Because uniformity of growth and species mix is one goal of pasture management, the triangular arrangement is still be preferred here. Coconuts in this arrangement, shade the ground more uniformly.

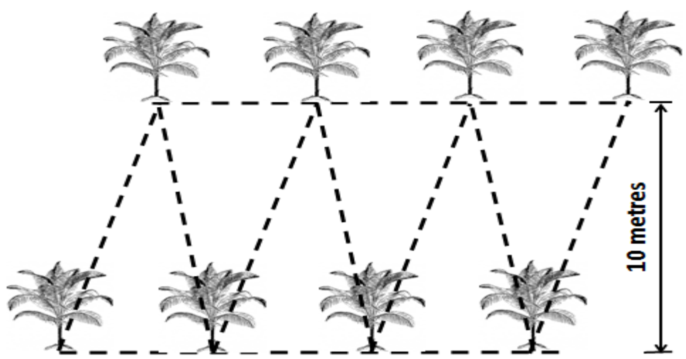

Figure 3. Triangular spacing arrangement for coconut.

- **The age factor**

A stand of coconuts casts varying degrees of shade depending upon its height and thus its age. In young plantations, plenty of light reaches the ground. Shading gradually increases until the palms are about 10 years old. Thereafter, understorey sunlight gradually increases to a maximum level when the palms are approximately 20 years old. It may be best to plant different crops in the understorey at these different coconut growth stages.

- **Crop nutrition**

Coconut palms require adequate nutrition during the early years, prior to flowering, to promote vigorous growth, early bearing and high yields. The most rapid growth occurs between the second and fifth year in the life of the coconut palm. The soils on an old coconut plantation are expected to be impoverished if there was not a fertilizer programme in place. Planting new and improved palms to replace old coconut groves makes little sense if adequate nutrients are not supplied to the plants.

Nitrogen is important in promoting leaf growth and development. Deficiencies in phosphorus retard palm growth and delay flowering. In potassium deficient soils, potassium fertilisers have a positive effect on the number of inflorescences, bunches, nuts per bunch and total nut production. Ideally, fertiliser recommendations are based on soil tests and tissue analyses.

The fertiliser recommendations (Ramkhelawan, 2013) per palm at different ages based in coconut growing areas in Trinidad and Tobago, along with the nutrients required to produce 100 nuts per year are shown in Table 1.

Table 1. Rate of Fertilizer application of 15-5-20 NPK/palm/year

Age of palm	Application * (lb/tree/year)	Number of applications
Adult >4 years	5	2 (June & December)
1 year and less	1/10th of adult dose	At planting & 6 months later
2 years	1/3rd of adult dose	2 (June & December)
3 years	2/3rd of adult dose	2 (June & December)

* 1 kg = 2.2lb

The fertiliser should be broadcasted 1m to 2m from the trunk and 0.5m to 1.0 m for young palms. On sloping lands, the fertilizer should be incorporated to a depth of 15 cm at various points at the same radius described before. In addition to the recommendations shown in Table 1, where soils are acidic, 2kg of finely ground dolomite limestone should be applied per adult tree per year.

Coconut husks are high in potassium. Burying fresh or dried husks 2m around the palm may reduce fertiliser cost through nutrient cycling. It can also increase retention of moisture and would benefit drought-prone areas. The application of fully decomposed farmyard manure, where available and economic, has also been found to be beneficial to the palms.

- **Irrigation**

Irrigation is necessary to provide sufficient water and mineral soil conditions and so result in good growth, development and yield. During periods of drought, there is high mortality of transplanted seedlings, shedding of young nuts, drying and hanging down of older fronds and young fronds fail to open. It is important that rainfall be well distributed throughout the year for optimum coconut production. Coconut responds well to dry season irrigation i.e. in the dry months, irrigation @ 40 litres per palm per week can increase the yield of nuts by as much as 50%. Where water is scarce, a drip irrigation system is recommended and can make more efficient use of water, labour and energy.

- **Weed management**

Heavy weed growth makes the collection of fallen nuts a difficult exercise. Control may be done by tractor-drawn brushcutters, hand-held brushcutters along with herbicides. Any self-sown seedlings should be removed.

4. The animal component

The management of cattle and coconuts together is a more complex undertaking than simply managing each as a separate enterprise. In many areas, there may be other, more appropriate or necessary uses for the coconut understorey. Where human population densities are extremely high and land area very scarce, food production must be the priority.

The various factors in a coconut-animal production system which influence coconut yields include: amount and intensity of light, pasture species, available soil nutrients and moisture, grazing system, stocking rate, nut collection system, height of forage, legume component, weed control, cultivation damage to coconut roots, animals causing soil compaction and producing toxic wastes and manure; animal dung serving as a breeding ground for Rhinoceros beetle and, the degree of competition between the forage species and the coconut plants (Reynolds, 1988).

Cattle are important for weed control (Fig. 4) and this has been the traditional use of cattle in coconut plantations. Light transmission in the commonly used tall coconut varieties decreases from over 90% in recently planted coconuts to a minimum of around 40% at an age of 5-15 years, and then increases again with time until the coconuts are due for replanting at age 50-60 years. Light transmission obviously varies depending on variety (with dwarf or hybrid varieties intercepting more light than the tall varieties), tree spacing and management (Reynolds, 1988).

As far as animal production is concerned the provision of shade and thus lower heat loads on animals is likely to have a positive effect on animal productivity. The nutritive quality of forages grown in partially shaded environments such as old coconuts is comparable to those grown in full sun (Norton *et al*. 1991). Incompatability of cattle and coconuts is likely to be caused by unacceptable damage to young trees or interference in the management of coconuts. Damage to fronds of young coconuts could be caused by grazing animals and it is usual practice to keep cattle away from young coconuts until fronds are out of reach of the grazing animals. The time required for coconuts to grow beyond the reach of cattle varies, but periods of 3-8 years have been mentioned in the literature. Small ruminants such as sheep have been successfully grazed in 2-year old coconuts (Simonnet, 1990). Damage to stems of coconuts is minimal although there are concerns over possible soil compaction and increased erosion that may occur when the understorey vegetation is overgrazed (Reynolds, 1988).

Figure 4. Cattle grazing under coconut trees useful for weed control (FAO, 1992)

- **<u>Production systems</u>**

Smallholder farmers often have one or two cattle which are grazed on whatever feed resources are available in their area (Fig. 5) and do not seek to optimise the coconut-animal system that might require a high labour input and other investment costs. However, in intensive farming systems, cattle are generally fed supplementary ration and shortfalls in feed are overcome by cutting naturally occurring grasses and tree legumes from communal areas such as roadsides (Reynolds, 1988).

A factor of great importance in animal production in the tropics is the high environmental temperature which is responsible for low voluntary feed intake and reduced grazing period of temperate breeds leading to reduced liveweight gains and milk yields. Jersey and Holstein breeds of cattle have been found to reduce their consumption of total digestible nutrients at temperatures above 24°C; Zebu, above 32°C. On the other hand, the temperature in the space under coconuts is generally lower by about 6°C than in the open and this is suitable for the rearing of better breeds of animals (Ferdinandez, 1978). Cattle thus benefit from the presence of coconut palms overhead.

Figure 5. Cattle grazing under coconuts (Rozotte,2013).

- **<u>Livestock management</u>** (Dalla Rosa, 1993)

Cattle do best in cool weather**.** Heat has a greater effect on the wellbeing of most cattle breeds than any other climatic factor (Plucknett, 1974). Rising body temperature suppresses animal metabolism causing lack of movement, loss of appetite, and a marked reduction in productivity (Guzman and Allo, 1975).

- **<u>Cattle nutrition</u>**

With the appropriate species mix and cattle stocking density, pastures in the partial shade of coconuts can provide adequate feed. Pasture under the relatively open, mature stand, can produce liveweight gains and milk yields comparable to those from pasture under open conditions (Reynolds, 1988).

- **<u>Potential problems</u>**

Cattle must usually be kept off coconut plantations until the palms are at least 5 years old. Otherwise the animals will chew fronds, stunting growth. They can also kill a young palm if they damage or remove the growing point. Another potential problem is the gradual compaction of soil by trampling. One preventative practice is disking every 4 to 5 years (Guzman and Allo, 1975). This will also stimulate coconut root function if limited to the upper 30 cm.

The rhinoceros beetle (*Erects rhinoceros*) has a tendency to make its home where there is a lot of cattle dung. Free ranging cattle may thus increase the incidence of this serious coconut pest.

Although trial results demonstrate that good liveweight gains can be achieved from grazing cattle under coconuts, the major problem identified is the question of sustainability which appears to be related to the degree of persistence of species and control of unpalatable weed infestations (Ohler, 1992; Shelton, 1991a, 1991b).

A key factor hampering the development of more commercially oriented cattle production systems under coconuts is the lack of marketing facilities in the more remote coconut plantation areas.

5. The forage component

The main factor likely to limit the growth of pasture under coconut is light. Studies have indicated that light intensity in 30 year old coconut plantations was about 50 - 60% of that in open areas; this could increase to 85% in older (and taller) coconut stands.

In general terms, yield of forages is linearly related to the amount of light available, provided that other factors affecting growth are not limiting. Thus in a coconut plantation with 50% light transmission, the yield of a highly productive grass like *Panicum maximum* will be approximately 50% of the yield achieved in full sunlight. Animal production is likely to be affected similarly by light transmission.

Light transmission through the coconut canopy depends on the age of the plantation, spacing of the palms, system of planting, level of soil fertility, soil type, orientation of the plantation in relation to the incident light, time of day, season of year, and cloud cover. Although it has been shown that herbage will produce maximum yields only under conditions of full solar radiation, there are forage species that exhibit varying degrees of shade tolerance and this should be an important factor for consideration in the choice of pasture species (Ferdinandez, 1978).

Generally, naturally-occurring pasture species in coconut plantations are unproductive and do not respond sufficiently to added fertilisers (Ferdinandez, 1978). They also have a carrying capacity of no more than one animal to 2.3 ha. Consequently, improved species should be introduced. Their suitability is measured in terms of production during the growing season, palatability, nutritive value, digestibility, and tolerance to extremes of soil moisture conditions (Ferdinandez, 1978).

Some grasses and legumes are more shade tolerant than others. When light transmission values fall below 40 or 50% then both production values and the range of species are severely reduced. Unless there is control of the stocking pressure there may be changes in pasture composition over time with undesirable weed species gradually dominating the sward. Using cattle as "sweepers" or "weeders" without additional selective weed control measures may control the weeds in the short term but allow tough unpalatable species to become dominant. Productivity may vary from low to moderate depending on the relative percentage of productive grass, legume species and weeds, particularly bush weeds (Reynolds, 1995a).

Where the aim is to do more than merely keep weeds under control, so that fallen nuts can be located, then various exotic grass and legume species are available. Grass species most suited to the reduced light conditions under coconut palms are sod forming stoloniferous grasses that form short to moderate height swards. They provide moderate carrying capacity, allow fallen nuts to be quickly located, are inexpensive and easy to establish from cuttings, compete well with aggressive weed species, maintain a reasonable balance with companion legumes under grazing and do not compete excessively with coconut production. Palisade grass *(Brachiaria brizantha*), Signal grass (*B. decumbens*), Cori grass *(B. miliformis*), Para grass (*B. mutica*), Pangola grass (*Digitaria decumbens)* and Guinea grass (*Panicum maximum*) have been shown in several countries to perform well under coconut canopies (Ferdinandez, 1978; Dalla Rosa, 1993; Reynolds, 1995a).

- **Mixed pastures**

Legumes increase the nutritive value and digestibility of pastures and transfer fixed nitrogen to the grass. Legumes also maintain adequate levels of protein, palatability, digestibility and voluntary intake as grasses mature and have greater fibre content and lower crude protein and digestibility particularly during the dry season (Ferdinandez, 1978).

The legumes that have been found to perform well in mixed pastures under coconuts and are, therefore, most suited to coconut plantations include Centrosema (*Centrosema pubescens*), Siratro (*Macroptilium atropurpureum*), Puero (*Pueraria phaseoloides*), Stylosantes *(Stylosantes guianensis)*, Desmodium *(Desmodium triflorum* L.), Vigna (*Vigna unguiculata*), and Mimosa (*Albizia julibrisin*). Legumes that combine particularly well with *B. brizantha* and *D. decumbens* include *D.heterophyllum*, *D. triflorum* L. and *Alysicarpus vaginalis*. An important tree legume is *Leucaena leucocephala* but this does not have a good shade tolerance under coconut (Ferdinandez, 1978).

- **Fertiliser requirements of pasture under coconut**

The key to obtaining high pasture yields combined with high coconut yields is to eliminate competition for nutrients between the two crops. Split NPK fertilisation is essential for optimum yields; in the case of the coconut, the fertiliser is placed at the base of the plants while it is broadcast in the pasture. A nitrogen application of 60 kg/ha/year has been found to give optimum yields of pasture species (Ferdinandez, 1978).

- **Grazing control**

Proper grazing control is the key to any productive livestock operation. In the coconut system, grazing can be used both as a tool both to maximise pasture yield, and to minimise competition between the pasture plants and the coconuts for soil nutrients and moisture. The regular and properly timed grazing of top growth can greatly reduce excessive pasture plant transpiration and thus competition for water. Cattle recycle plant biomass and return nutrients to the system in organic manure.

Grazing control is especially important for "local" pasture. Local pasture vegetation can often prove just as productive as improved pasture mixes, with a well monitored rotational grazing program, some seeding of leguminous forage species, and an occasional addition of NPK fertiliser (Dalla Rosa, 1993).

Grazing can reduce competition from the understorey vegetation by recycling nutrients locked up inside the standing biomass (Reynolds, 1988). Short-grazed vegetation also permits a higher recovery rate of nuts. Shading by the coconut plants provides a lower heat load on animals and positively affects animal productivity. Grazing should not be permitted in young coconut plantations until fronds are out of reach of grazing animals.

Grazing can reduce competition from the understorey vegetation by recycling nutrients "locked up" in the standing biomass. A near doubling of coconut yield was reported by several researchers when previously ungrazed coconut plantations were grazed. This was probably only partly related to increased nutrient cycling; the main effect of grazing being related to a higher recovery rate of nuts in short grazed vegetation. Negative effects of any understorey vegetation on coconut yield must be expected if rainfall or soil fertility is marginal for coconut growth, although the latter can be ameliorated by sufficient fertilisation. Competition for moisture is likely to occur where annual rainfall is below 1750 mm, particularly if rainfall is not evenly distributed (Reynolds, 1988).

Cut-and-carry systems extract a considerable amount of nutrients from the forage production area so particular care is required to not remove the forage away from the coconut understorey so as to return nutrients to the forage area. Such removal may result in loss of coconut yield and cause a sharp decline in forage yield.

Ploughing or disking every four years or so is advised for any pasture. This will prevent excessive soil compaction from animal traffic. The shallow cultivation of coconut land to about 25 cm also prunes the uppermost coconut roots. This is reported to stimulate the roots which tend to explore the deeper soil layers (Asghar, 1987; Dalla Rosa, 1993).

- **The pasture block rotation system** (Dalla Rosa, 1993)

There are periods during the coconut life cycle when grazing and/or pasture production are not feasible due to possible seedling damage or dense shading. For this reason, pasture block rotation is obviously the most suitable management regime. There are basically three stages in the coconut growth cycle. During each of these stages, the understorey can be used differently to the greatest advantage. In this way, the entire system is steadily maintained at optimal productivity.

- *Stage 1*: 0 to 5 years. Cattle must be kept off to prevent damage to young coconuts. Plenty of sunlight reaches the ground between the coconuts. Sun-loving forage crops can be raised as "cut and carry" animal feed. Alternatively, more light-demanding food crops can be grown, such as chilies, cabbage, cassava and ginger.

- *Stage 2:* 5 to 20 years. Pasture productivity will be relatively low due to dense shading. More shade-tolerant food/cash crops can be grown, such as cacao and kava.
- *Stage 3:* From 20 years until coconut replacement. Ideal conditions for pasture and cattle production.

The lengths of these coconut growth phases are determined by the cattle breed and growing environment. They can be shortened or lengthened to suit management goals, size of the herd, size of pasture and other factors.

The farmer can incrementally convert the different blocks to improved pasture or introduce improved coconut hybrids, as able, or in response to market trends and opportunities.

- **Future** (Reynolds, 1995b)

The following factors serve as guides as to the future of coconut-animal production systems based on past experiences of livestock production integrated in coconut plantations.

i) For the immediate future, the large majority of coconut areas will remain planted at traditional spacings, so there is a continuing need to identify grass and legume species for reduced light situations (and especially less than 50% light transmission).

ii) Where high yielding hybrids are planted at even closer spacings than those traditionally used it remains to be seen if intergrazing is feasible prior to canopy closure may be the main intercropping activity.

iii) The identification of forage species better adapted to the low light environment of coconut plantations (less than 50%) which are capable of persisting under heavy grazing pressure.

iv) The adoption of coconut planting (rectangular) configurations with wide between-row spacing which allow for maximum light penetration, encourage cultivation, improve forage yields and to which, to a large extent, forage species already available would be well adapted.

v) More detailed and systematic studies of the pasture-livestock-crop-coconut system and to develop management options for the farmer.

vi) Better utilisation of existing by-products and alternative feed resources for livestock in the smallholder coconut based farming systems.

vii) Continued efforts to identify alternative tree legumes to supplement Leucaena where infestation of the Leucaena psyllid (*Heteropsylla cubana*) has devastated production and severely affected smallholder cattle feeding systems.

- **Research Needs** (Dalla Rosa, 1993)

There is a need for research to identify good pasture species combinations, optimal coconut stand densities, and appropriate spatial and temporal arrangements in a variety of environments. Further screening and evaluation of shade-tolerant pasture species that will not compete aggressively with coconut palms would assist interested farmers immensely. Promising species must then be tested under various cutting, grazing and fertilisation regimes. Also, economic studies comparing the cattle-under-coconut system to cattle and coconut production as separate enterprises are urgently needed.

6. Socio-economic aspects of production

The following factors must be taken into account:

- Financing
- Information systems
- Plantation infrastructure (machinery and equipment, irrigation and drainage system, access roads)
- Labour availability and cost compared to coconut monoculture.
- Marketing system, cost of production, net income.
- Environmental impact (animal grazing changing pasture composition and destroying other useful vegetation, toxic animal wastes, animal manure, soil compaction, animal destruction of young coconut plants).

7. System constraints (Reynolds, 1995b)

The following can place constraints on the coconut-animal production system:
drought, flooding, lack of financing, technical know-how and lack of information on coconut/animal systems, price instability, cost and availability of labour, availability of improved animal stock, transportation, pests and diseases, toxic animal wastes, animal destruction of young coconut plants, soil compaction, animal interference with harvesting operations and, marketing.

8. Disadvantages of coconut-animal production systems (Reynolds, 1995b)

i. Competition between intercropped pasture species and coconut for water or plant nutrients.
ii. Intercropped pastures may be uneconomical (losses to farmer) when planted where light is insufficient because coconut trees are too close together.
iii. Intercropped pastures may harbour diseases or attract pests harmful to coconuts.
iv. Raising more than one crop (e.g. coconut and pasture species) on the same land area could increase the need for fertiliser, which may not be available.
v. Initially, as palms are shallow-rooted, tillage and cultivation operations required for intercropped pastures may cause root damage to the main crop thereby reducing yields.
vi. The growth habit of some intercropped pasture species may cause difficulty in certain coconut management operations (e.g. fertiliser application, harvesting).
vii. Where grazed pasture is the intercrop, cattle can damage young palms or cause soil compaction. This disadvantage should be compared with possible soil erosion and declining soil fertility where other intercrops are used.
viii. Coconut-animal production systems often demand a greater input of labour.

ix. Grazing cattle under coconuts also requires the farmer to learn additional techniques associated with animal husbandry and pasture management. Lack of such skills may lead to failure. Invasion of unpalatable weeds can compete for moisture and nutrients, hinder nut collection and make the cattle-coconut system unviable.

x. While technically feasible, the integration of ruminants with tree crops may not be socially acceptable or may require labour resources which the farmer wishes to use elsewhere or require initial capital investment which the farmer cannot afford.

xi. Cattle dung may serve as a breeding place for rhinoceros beetle (*Oryctes rhinoceros*), a major insect pest of coconut.

9. Potential benefits of coconut-animal production systems (Reynolds, 1995b; Dalla Rosa, 1993)

i. Increased and diversified farm income, greater employment, reduced market and financial risks, weed control and, increased soil fertility.

ii. Increased coconut and animal yields and increased food production

iii. Increased stability for coconut farms through diversification and reduced dependence upon products with unstable market prices such as, copra, coconut oil, coir and others.

iv. Care and attention given to management of intercropped pasture tillage, weed control, use of fertilisers, among others, may lead to improved growth and yields of coconut and ease in finding the fallen nuts. Coconut yields may receive more of a boost resulting from clearing undergrowth from existing areas than by planting large areas of new trees.

v. As management of the ground under coconuts is necessary, income-producing pastures are preferable to weeds.

vi. Reduced use of weedicides.

vii. Young palms require six or seven years to produce economic yields. Using animals and intercropped pastures between the young coconuts, for food or sale, may help to offset the cost of coconut establishment and reduce the time to full bearing through improved palm growth.

viii. There may be better utilisation of underemployed labour throughout the year and the coconut farmer's skill level may be raised.

ix. Possible reduction of the effect of natural calamities such as hurricanes, pests and diseases on total production since these do not usually affect all crop species to the same extent or at the same time.

x. Helpful in conserving foreign exchange by supplying the domestic market with essential food products thus reducing the need to import.

xi. Using legumes as intercropped pastures may lead to increased soil fertility while cattle fertilise (with manure and urine) the soil. This can increase the life of the plantation.

xii. Better use of scarce land resources.

xiii. Coconuts may provide a better grazing environment for cattle than open areas. The temperature under coconut shade is approximately 4 – 6°C lower than in open areas; Robinson (1983) suggested that the effects of heat stress reduction by shade trees on animal production are numerous, the extent depending on the animal breed and the climate. He postulated that animals eat and graze longer; need less water; feed conversion efficiency is improved; growth rate, milk yields and wool production are improved; reproduction rates should be improved and offspring survival rate will be higher. In Australia, Davison *et al*. (1988) demonstrated that the provision of shade increased milk yield; Daly (1984) has stressed the importance of shade trees in beef production and Roberts (1984) showed that ewes in a shaded paddock produced significantly more lambs than those in an unshaded paddock

xiv. Coconut canopies may result not only in lower air temperatures (beneath the canopy) but also in lower soil temperatures which may be important for better seedling survival, soil water relations and possibly rate of litter breakdown and nitrogen mineralisation. Also, air relative humidity will be higher and soil water availability for pastures will be maintained at a higher level than in the open because of less evaporation from the soil and lower crop transpiration rates.

xv. Many by-products from tree crop processing are readily available and potentially valuable for ruminant feeding and strategic supplementation.

10. Institutional support

This is required in areas of policy, credit, subsidies, incentives, industry strategy, land availability and tenure, farmer associations' formation and strengthening, marketing and import/export facilitation for coconut and animal products, technical assistance, extension service and, training.

In the Caribbean, research and development thrusts are necessary for coconut-animal production systems, product standards, food safety and, environmental impact.

11. Concluding remarks

- The coconut producer must consider need to increase coconut plant spacing (adjust plant density) to better accommodate pasture-livestock-coconut systems in new plantations. This would likely compromise coconut yield in favour of animal production. The answer lies in the income generated from the integrated system and the management inputs required.
- An important question is whether coconut monoculture or coconut intercropping systems should replace the coconut-animal production system instead. If the farmer practises these alternative systems on his existing plantation, he/she could conduct an analysis of the comparative yields of the various crop and animal components as well as the constraints, benefits and incomes in an attempt to maximize profitability. This would also inform on the technical and socio-economical feasibility of the coconut-animal production system.
- Coconut plantations offer an excellent opportunity for the integration of cattle and a tree crop, particularly in the less populated areas where the land under coconuts is not fully utilised and is weed infested.
- Given the appropriate tree spacing there are few major constraints and, provided that adapted forages are planted to ensure a high quality of sustainable

feed resource, cattle production under coconuts can be a profitable and sustainable form of land use.

- Unfortunately, in many areas tree spacing is such that reduced light availability restricts the range of forage species and their productivity. Also, there has been little work on developing farming systems which allow farmers to choose from various management options. While research work is ongoing to identify alternative feed sources there is a need to develop and apply low input systems in many coconut areas where poor farmers are faced with feed shortages especially in the dry season (Reynolds, 1995b).

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