Sustainable Development and Application of Bio - Energy in Coconut Plantations

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ABSTRACT

One hectare of coconut land (156 palms ha^{-1}) planted with gliricidia (2,250 trees ha^{-1} into double rows in avenues of coconut) and available natural pasture and outside supplied paddy straw coupled with six buffaloes were mixed into a farming model to examine the total productivity and potential of green energy production by wood and biogas. Six buffaloes were maintained in a shed and the manure was collected for biogas generation. Biogas was purified from H_2S and used to run a 0.75 hp engine. Wood of gliricidia was used to energize a 3.5 kW gassifire for generating electricity.

Productivity of gliricidia in the 3rd year was 4.5 kg wood (at 20% moisture) and 3.5 kg of fresh foliage per tree/year. Each buffalo produced an average of 622 liters of milk at the first lactation (for a period of 10 months) and value of a calf was Rs. 41,244.00 at the age of 17 months.

Soils of the model were enriched by adding the effluent of biogas. The fertility of soil (N, P, K, Mg, moisture holding capacity) improved significantly over soils sampled outside the model. The effluent of biogas was more fertile than dried buffalo dung. As a result, nut yield of a coconut palm increased from 30 to 60 nuts $palm^{-1}year^{-1}$ over a period of two years.

In green energy production, the dung of six buffaloes passed thorough a biogas generator produced electricity per day equivalent to 3 liters of diesel. On the other hand gliricidia wood of one hectare of coconut land was sufficient to energize 3.5 kW gassifire – engine – generator set for 1,600 hours/year and this was equivalent to 5,000 units of electricity (kWh). Thus one hectare of coconut/gliricidia/natural pasture/paddy straw with six buffaloes was able to produce green energy equivalent to 5,700 units of electricity (kWh) or 8,550 liters of diesel, in addition to farm income derived from coconut, buffalo milk and other benefits of buffalo farming. The total return (coconut, selling of calves, buffalo milk and bio fertilizer) added up to Rs. 1,379,520 $ha^{-1}year^{-1}$. The applicability of this model for small farmer of the coconut triangle is evident from this study.

Key words: *Coconut, Gliricidia, Bio-energy and Integrated farming system*

INTRODUCTION

Along with the price increases of fossil fuels and electricity, there is also an increased realization in the country that traditional energy is going to be more expensive with time. Therefore, a greater utilization of alternatives has to be actively promoted by the state to sustain the economic growth of the country. Further, self reliance is now viewed as an importanant aspect in both food and energy in view of global political and economic developments.

Sri Lanka is fortunate to enjoy a major share of energy obtained from indigenous sources. However, the share of indigenous sources is shrinking rapidly, in view of the ever growing energy demand due to rapid economic development of the country. At present, the share of imported energy is 43% and is increasing steadily. Fossil fuel derived energy sources world over are undergoing serious market upheavals at present and there is no hope of stability in the foreseeable future. In year 2008, the sharp increase of world oil prices saw Sri Lanka's oil imports consuming more than one third of all export earnings. Hence, development of alternative energy production systems within the plantation/agriculture sector is vital for national energy security and sustainable agricultural production. The objectives of this study were to maximize farm income through an integrated (Coconut/ Gliricidia/ Paddy straw / Cattle) farming system using the theoretical model given below (Fig. 1) and to develop a sustainable bio energy system to meet energy requirement of household.

MATERIALS AND METHODS

This un-replicated study was conducted in a 22 years old coconut plantation (planted in 8m x 8m square patterns – 156 palms ha^{-1}) at the Rathmalagara Estate, Madampe (IL_1 Low Country Intermediate Zone of Sri Lanka) of the Coconut Research Institute from January, 2007 to August, 2008. The mean annual rainfall of the location is around 1,400 mm distributed over two seasons in a year. Mean annual temperature is 30°C The soil is the *Boralu series* and land suitability for coconut is S_5 (Somasiri *et al.*, 1994). Transmission of photosynthetically active radiation at the site under coconut palms was over 90 % at mid day on a cloudless day.

a). Coconut Plantation

One hectare of coconut land was selected to establish this farming model. General maintenance was carried out and palms were fertilized without urea and P, K and Mg were incorporated to soil as practiced in organic farming.

b). Gliricidia Inter Cultivation

Double rows of Gliricidia were planted in the avenues of coconut palms at a 1 m x 1 m spacing (2,250 trees ha^{-1}). Gliricidia trees were lopped periodically (8 months) for leaf and wood.

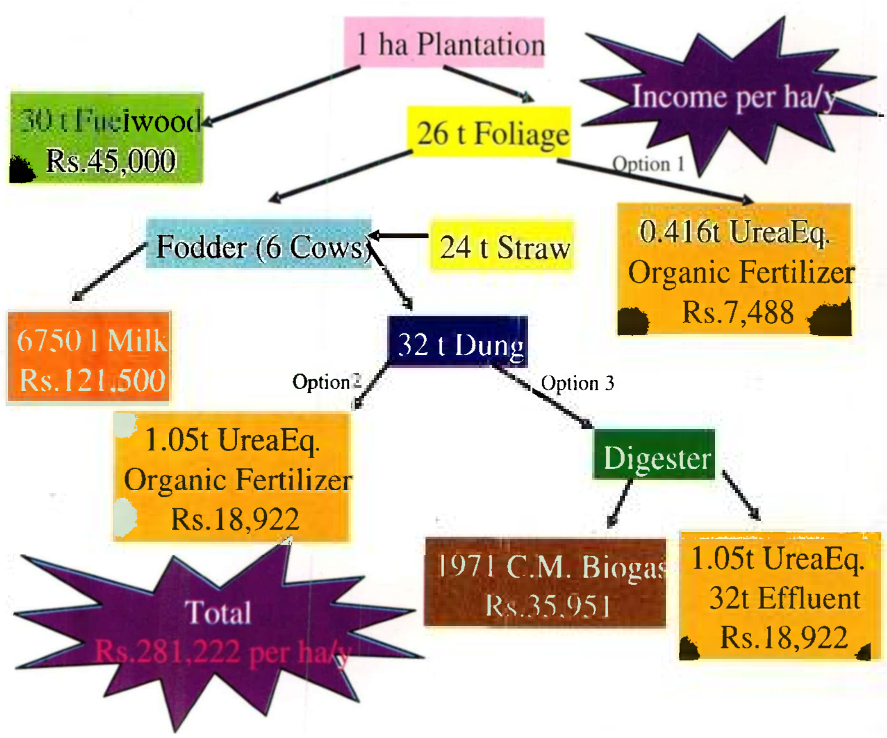


Fig.1. *Theoretical Model prior to the trials consists of coconut, buffalo, gliricidia, paddy straw and natural grasses to produce green energy.*

c). Cattle Shed

The cattle shed was designed to accommodate 12 buffaloes however, only six buffaloes were maintained in this study. The construction cost was Rs. 185,000.00. Water pipe lines were placed above the animals to moisten buffaloes by spraying water during very warm periods of the day.

d). Bio Gas Unit

A bio gas unit of 35 m^3 was constructed to generate bio gas from cattle dung. The diameter of the digester was 5 m and the depth was 2.3 m. The material cost of constructing the bio gas unit was Rs.47,500.00 and the labour cost was Rs. 23,000.00. The pressure of the gas after 20 hours of closing the pipe was 30 cm. W.G.

e). Feeding Buffaloes

Female buffaloes were selected and initial weight range was approximately 600 kg per animal. For an animal of 600 kg weight, 5.5 kg of animal feed (dry weight basis) was given daily. The feed consist of a mixture of 30% Gliricidia, 30% paddy straw and 40% pasture.

f). Buffalo Maintenance

Initially, the buffaloes were at the cattle shed throughout the day but subsequently it was realized it is inconvenient for animals during the dry season (March – April and July – September). Considering health aspects, buffaloes were released for 2 hours to the adjacent field during the day.

g). Model Farmer

The person who looked after the project was a casual labourer employed in the Ratmalagara estate. His family of 3 children and 3 adults engaged in farming and hence, the model was maintained by a family unit.

h). Use of Bio Gas

Bio gas generated from the digester was passed through a pipe placed with Iron oxide particles to remove the H_2S. The purified biogas was directed to a 0.75 hp engine generator to produce 750 W electricity. This electricity was used for daily household requirements.

i). Wood gassifire

Wood of gliricidia (at 20% moisture level) was used to energize a 3.5 kW gassifire engine generator located at Kohomba Estate, Kakkapalliya.

RESULTS

1. Productivity of Gliricidia

At the initial stage the productivity of a gliricidia tree was 1.9 kg of foliage and 1.0 kg of wood (Table 1). It was observed that both outputs increased with the present tree management system. Gliricidia produced more wood weight than foliage.

2. Calving and milk yield of buffaloes

Out of the six female buffalo herd, five females delivered 4 males and one female calves. Body weight of all calves after sixteen months of calving exceeded 270 kg (Table 2). Average selling price of a calf was Rs. 41,244.00 based on a formula given by the National Livestock Development Board.

Table 1: *Fresh foliage and wood yield of gliricidia in the bio-energy system at the Ratmalagara Estate*

	Year 01		Year 02		Year 03	
	kg/tree	kg/ha	kg/tree	kg/ha	kg/tree	kg/ha
Foliage (fresh)	1.9	4,275	2.8	6,300	3.9	8,775
Wood (as 20% moisture)	1.0	2,250	4.0	9,300	4.5	10,125
Total	2.9	6,525	6.8	15,300	8.4	18,900

Table 2: *Productivity of the buffalo unit at the Ratmalagara Estate*

Female (mother No.)	1st calf		Selling price (Rs)
	Age (months)	Live body weight (kg)	
28	14	272	
30	No calving	-	38,080.00
33	22	319	-44,660.00
35	19	278	38,920.00
36	19	312	43,680.00
37	14	292	40,880.00

Table 3. *Milk yield of the buffalo unit at the Ratmalagara Estate*

Animal number	Milk production (liters/1st calving (10months)
28	616
33	550
35	670
36	683
37	595

3. Soil Improvement

Soil analysis for several chemical and physical properties was carried out using soil in the system where animal movement and residues of the system was added and soil outside the model for comparison. The electrical conductivity, soil bulk density, moisture holding capacity of soil in the model were clearly elevated to improve the quality of the soil in the model area. This was noticed at soil depths of 15 cm and 30 cm (Table 4).

At the 15 cm soil depth levels of nitrogen in system has elevated by 30% over soils outside the system. Similarly improvement of phosphorous and potassium were one and three-fold respectively. Mg also showed a 66 % increase in soils of the system (Table 5). At a depth of 30 cm N, P, K and Mg were higher than those at a depth of 15 cm.

For example, N and P recorded a two-fold and K recorded a 4.7 fold increase. Soil pH was slightly lowered in the soil within the system.

Analysis of buffaloe dung and biogas effluent

N, P, K, Mg, pH and electrical conductivity were measured in the manure collected from the dairy and passed through the biogas unit as effluent (Table 6). N and P levels were doubled in the effluent. The K level of effluent was also higher than in the dung. Mg was slightly lower in samples of effluent.

Table 4. *Electrical Conductivity, pH, Bulk density and moisture holding capacity of soil in the model and soil outside the model at the Ratmalagara Estate*

Soil sampling area	Electrical Conductivity		pH		Soil moisture content (%)		Bulk density (g/cm³)
	15cm depth	30cm depth	15cm depth	30cm depth	15cm depth	30cm depth	
System (IN)	27.89 μs/cm	33.39 μs/cm	5.86	6.01	8.27	8.66	1.51
System (OUT)	16.18 μs/cm	17.31 μs/cm	6.29	6.10	6.80	6.93	1.56

Table 5. *Soil nutrient levels (N, P ,K, Mg, Ca and Na) within the model and outside at the Ratmalagara Estate*

Nutrient	Depth (cm)	System (IN)	System (OUT)
N (mg/kg)	15	139.6	1,068.81
	30	2,399.3	1,103.68
P (meq/100g)	15	23.99	11.43
	30	8.16	4.14
K (meq/00g)	15	1.101	0.260
	30	0.891	0.189
Mg (meq/00g)	15	1.109	0.667
	30	0.908	0.285
Ca (meq/00g)	15	1.545	1.152
	30	1.273	0.518
Na (meq/00g)	15	0.026	0.040
	30	0.025	0.022

per day giving output of two units of electricity (kWh). This is equivalent to three liters of Diesel, as 5.2 m^3 volume of bio gas was generated per day.

Energy generation by wood

In the third year, average wood production of a gliricidia tree was 4.5 kg $tree^{-1}year^{-1}$ (at 20% moisture level). Hence, total wood productivity of one ha system was 10,125 kg and this was sufficient to run a 3.5 kW gassifire – engine – generator set for 1,600 hours generating 5,000 units (kWh) of electrical energy.

Total energy output of the model

Applicable bio energy was by biogas and wood. In the third year of the system, this was equivalent 5,700 electricity units (kWh) or 8,550 liters of diesel per year.

Table 6. *Buffaloe dung and gas unit slurry analysis at the Ratmalagara Estate*

	N %	P%	K %	Mg%	EC μs/cm	pH
Cow dung	1.31	0.56	0.93	0.64	3.41	7.14
Effluent	2.96	1.08	1.02	0.52	3.07	6.69

4. Nut yield improvement

At the commencement of the experiment the average yield of a coconut palm was below 30 nuts $palm^{-1}year^{-1}$. After 2 years of field activities, the average yield was estimated as 60 nuts $palm^{-1}year^{1}$ and button nut count indicated that the potential yield of 2009 (3^{rd} year) would be over 80 nuts $palm^{-1}year^{-1}$.

5. Energy production

Biogas generation

Biogas generated from the unit was sufficient to energize a 0.75 hp capacity engine for three hours

6. Gross return of the model

As presented in the Table 7, the direct outturn of the model were coconuts, buffalo milk, calves and energy (biogas and gliricidia wood). On the other hand, biogas effluent was the fertilizer for coconut; hence it saved costs of chemical fertilizer, annual estimate of Rs. 45,000.00 per hectare of coconut. As estimated, the largest income (Rs. 855,000.00 $year^{-1}$) was the energy generated from biogas and wood. This shows that value of energy was approximately 2/3 of total gross income of the model.

Table 7. *Estimated gross return of the model at the Rathmalagara Estate at the end of 3rd year including value of energy*

Item	Actual yield/outturn	Unit price (Rs)	Gross return (Rs/ha/Year)
Coconut	9,000 nuts/ha	Rs. 20/= per nut	180,000.00
Selling of calves	5 calves	Rs. 41,244/= at the age of 16 months	206,220.00
Buffalo milk	622 liters x 5 buffalos	Rs. 30/= per liter	93,300.00
Saving of fertilizer for coconut	150 palms /ha	Rs. 300 /=per coconut palm	45,000.00
Value of energy eqaulent diesel	8,550 liters	Rs. 100/= per liter	8,55,000.00
Total gross return			**13,79,520.00**

DISCUSSION

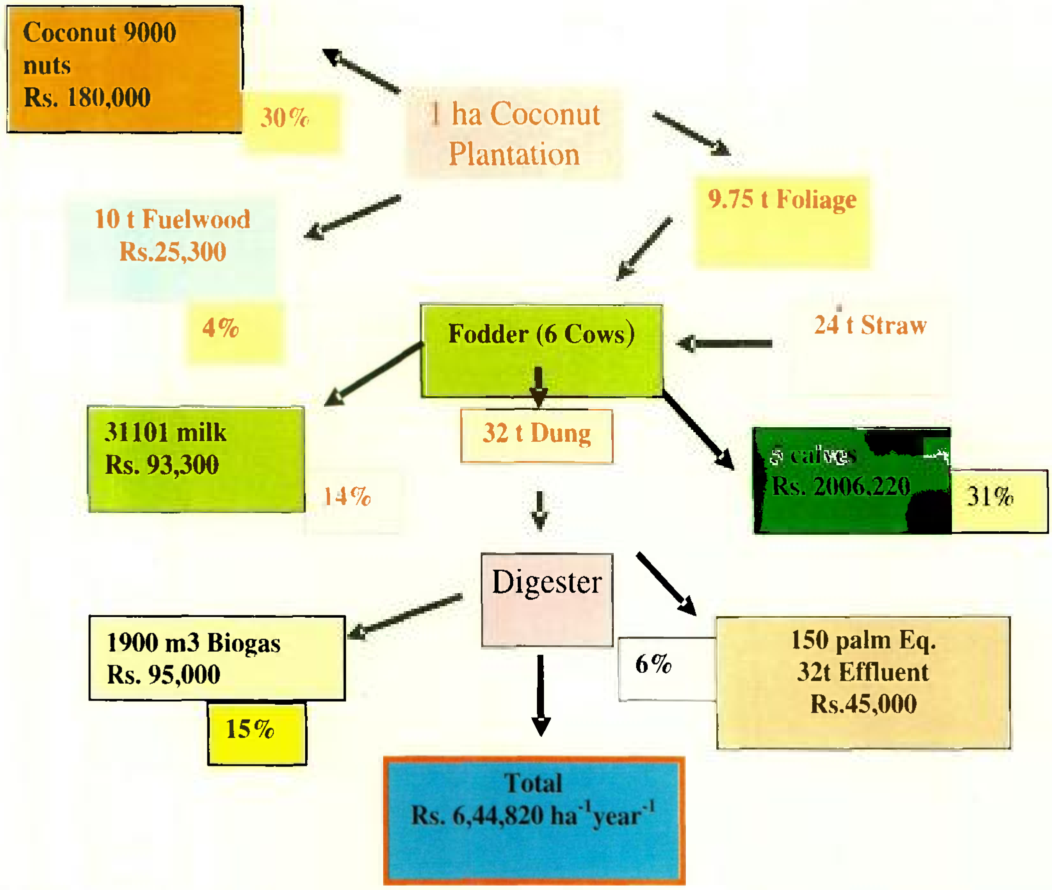
Coconut production in Sri Lanka is predominantly dependant on small and marginal farmers. More than 700,000 families grow coconut for their livelihood. Coconut utilizes only 25% of the land area and 40-45 % of the incident light. Under mono cropping coconut, resources such as sunlight, soil water, plant nutrients, and space are underutilized; hence profit maximization of unit area of land is the main constraint (Maheswarappa *et al.*, 1998).

Integrated farming combines crop production with livestock. The livestock enterprise is complementary to crop production programs so as to provide a balanced and productive system of farming (Liyanage and Fernando, 1991). In a hectare of coconut land five to six cows can be maintained. On an average, 15-25 kg of fresh manure can be obtained per day from each animal (Maheswarappa *et al.*, 1998).

In tropical agriculture there are two key issues; sustainable management of soil fertility and sustainable farm energy generation. To compete with global economic scenarios, maximization of farm income should be of high priority. Before the commencement of this study (year 2005), a theoretical model was made (Fig. 1) assuming that Rs. 281,222 $ha^{-1}year^{-1}$ could be earned from one hectare of coconut based buffalo farming integrated with gliricidia, *in-situ* pasture, paddy straw and a bio gas digester.

In the third year of implementation after installation of a gassifire or generator, (excluding value of generated electricity) actual income of one coconut hectare was Rs, 644,820.00 (Fig. 2) from coconut, milk, calves, bio fertilizers, fuel wood and biogas for house hold use. This was almost a 100% increase of the initial estimation, indicating the success of the model. Of the total income of the model, 1/3 was by coconut and 2/3 was by milk, calves, wood, bio fertilizer and biogas. Income by selling of calves doubled the income of milk indicating scarcity of improved breeds of buffaloes (Fig. 2). In general income generation in monoculture coconut plantation could be increased by 3.5 fold by integrated buffaloe farming itself.

Subsequently, data of wood based 3.5 kW gassifire was added to assess total energy outturn. In the third year, it was realized that Rs 1,524,520.00 $ha^{-1}year^{-1}$ could be earned from coconut, buffalo milk, selling of calves, saving of chemical fertilizer and from value of energy. This was appeared as 7 times over the initial estimates. Approximately, 2/3 of the gross income was derived from value of energy generated through biogas and wood (electricity then calculated into diesel) indicating the high cost of energy in the country. This is due to local energy



Basis: Milk: Rs. 30/l; Fertilizer for 1 coconut palm: Rs. 300/palm; Diesel: Rs. 100/l (1 m3 BG= 0.5 l Diesel); Wood: Rs. 2.00/kg; Calve: Rs.41,244, Coconut: Rs. 20.00 per nut

Fig. 2. *Updated Income from 1 ha Coconut /Gliricidia Plantation Integrated with a Buffalo Dairy with no involvement for power generation.*

cost valued on imported fossil fuels. Renewable energy sources, unlike fossile fuels, can be used without ever being used up. Biogas and biomass (wood) are categorized as renewable energy sources. It pollutes less, makes a county less dependence on imported fuel, requires less foreign currency and has almost no carbon dioxide emission (Lomborg, 2005). The technology applied in the model is cheap, easy to repair and ideally suited for villages and remote regions. Moreover, there is no negative social cost as involved with fossils fuels. As experienced, country's industrial sector is seriously affected by high costs of energy and this study shows that energy for coconut based industries could be met by this model (eg. Coir and copra processing). Household energy requirements could also be supplemented easily only by biogas either directly or by generating electricity. The direct use of biogas has many disadvantages such as low output, smell and the absence of the possibilities to operate household equipment such as refrigerators. In energy usage, the most convenient and popular is electricity or liquid fuel. It is important to note that in this model, the end-energy product was electricity and it was evident that it is possible to generate 5,700 electricity units (kWh) or equivalent to 8,550 liters of diesel from a hectare of coconut land. Therefore, any coconut grower will be able to make his own energy plan depending on his coconut extent and his choice of coconut based industry. Such enterprises, undoubtly reduce energy dependence of the country by increasing national energy security.

A significant development in the model is the selection of buffalo as the animal component. Buffaloes are identified as good ruminants to feed roughage, as they are able to convert many cellulose feeds into valuable items such as milk, meat etc. (Liyanage and Fernando, 1991). However, their body temperature is above normal cows and hence wallowing is needed. This was overcome by modifying the shed and moisting animals frequently. As a result, animal health and facility to produce milk was observed to be excellent. It could be stated that buffaloes could be moved from muddy fields to highly convenient sheds by artificial drizzling.

Gliricidia is now popular as the 4th plantation crop due to its multiple uses (Gunathilake and Wasantha, 2004). It has the ability to fix aerial N and enrich soils by green manuring. On the other hand, it is a valuable animal feed for protein. In this model leaves of gliricidia mixed with paddy straw, was the main feed for buffaloes, and it seems to be an ideal animal feed. Therefore it was evident that good animal feed can be blended locally for high production of milk and meat in-addition to additional benefits of manure and its recycling chain in agriculture.

Management of soil fertility in coconut plantations is now being addressed to sustain coconut yields economically. As at present, soil degradation is obvious. Application of chemical fertilizers is not the answer for management of sustainable soil fertility. Hence, the application of organic fertilizers for coconut as well as other crops is becoming a popular feature. On many occasions, cattle dung and other similar sources are called as organic fertilizers, however, it seems to be incorrect and these are virtually natural fertilizers. Today's need is not natural fertilizers, but fertilizers with easily available nutrients. Therefore, all natural fertilizers should be processed into chemical forms if possible by normal processes. In this model, gliricidia and paddy straw were fed to buffaloes to make manure and the manure was passed through a biogas digester which gave biogas slurry /effluent. The plant chemical parameters of effluent are higher than in pure manure (Table 6) and further analysis showed that plant nutrients in effluent are easily available forms of nutrients such as N, P, K. Microorganisms were not analyzed in this study but it is obvious that their association with effluent should be more over dry manure. Therefore, further studies are suggested on the role of micro-organisms in effluent and cow dung (biogas benefits). There is no doubt that, this would be the reason for doubling nut yield in a short period. Therefore, it is now worthy to consider recommendations for the application of cattle dung as a natural fertilizer for coconut, which seems to be inefficient compared to its process from biogas effluent. Studies show that 2/3 of N is lost by improper compost application to soil, but the process of biogass *in vitro* would minimize N losses. Due to continuous activities of the model, all chemical and physical parameters of soil were improved (Table 4 and 5). Soil of the model is classified in the Land Suitability Class 5 (Somasiri *et al.*, 1994) and potential yield of this soil is stated as 30 nuts palm^{-1}year^{-1} or below. However, in the model, nut yield of palm could be increased up to 60 nuts palm^{-1} year^{-1} and then to 80 nuts or more. It is evident that marginally suitable soils could be elevated by improved coconut land management systems as practiced in this model by adopting in integrated systems with combinations of livestock and crop.

CONCLUSIONS

There is a significant potential in coconut lands to increase crop productivity and to generate ecologically sound green (bio) energy. In national food security, milk production is given high priority due to high cost of imported packs of milk powder. In this regard, role of cattle/buffaloes and other ruminants play a vital role by producing natural fertilizers in addition to milk. It is now well accepted that without ruminants there is no sustainability in agricultural production. This study, proved that integration of coconut, gliricidia, pasture and paddy straw coupled with buffaloes is able to increase productivity and sustainability of coconut lands. The interesting feature is the production of a bio-energy system and the highest outturn was from the energy. All necessary technical directions are given here to develop much bio energy when is needed among local village farming communities. In conclusion, it is suggested that "Bio-energy villages" should be developed to achieve independence not only in democracy but also in national energy security.

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REFERENCES

Gunathilake, H.A.J. and Wasantha, H.G. (2004). Gliricidia for production of green manure and green energy in coconut plantations. *In*: Proceedings of the first Symposium on Plantation Crop Research. Zoysa, A.K.N. and Mohamed, M.T.Z. (Eds.). pp 43-52. BMICH, July 8-9, 2004.

Liyanage, M.de. S. and Fernando, D.N.S. (1991). Role of legume based pasture, tree fodder and paddy straw in coconut /cattle farming system in Sri Lanka. Paper presented at the International Seminar on Livestock and Feed Development in the Tropics, 21-25 October, 1991, Malony Indonesia: 56-64.

Lomborg, B. (2005). The Skeptical Environmentalist, Measuring the Real State of the World, Canbridge University Press. pp 118-135.

Maheswarappa, H.P., Dhanapal, R., Vidhan Singh, T. and Hegde, M.R. (1998). Integrated coconut based farming systems for sustainable agriculture. *Indian Coconut Journal* 29: 7-10.

Somasiri, L.L.W., Nadaraja, N. Amarasinghe, L. and Gunathilake, H.A.J. (1994). Land suitability assessment of coconut growing area in the coconut triangle. Occasional Publication Series No.3, Coconut Research Institute, Lunuwila, Sri Lanka.