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Fodder, Nitrogen, and Energy Balances in Grasslands with Algarroba Trees (*Prosopis juliflora* (S.W.) DC.) under Dairy Cow Grazing

Alex J. Roca Cedeño; Paola J. Lascano Armas**; Cristian N. Arcos Álvarez**; Nancy M. Cueva Salazar**; Elsa J. Molina Molina**; Lino M. Curbelo Rodríguez****; Raúl V. Guevara Viera***; Guillermo E. Guevara Viera***; Francisco Hernán Chancusig**; Carlos S. Torres Inga***; Pedro E. Nieto Escandón***; Guillermo V. Serpa García****

*** Higher Polytechnic School of Agriculture, Manabí, MFL, Sitio El Limón, Calceta, Republic of Ecuador**

**** Academic Unit of Agricultural Sciences and Natural Resources (UA-CAREN), Veterinary Medicine Degree, Technical University of Cotopaxi, Latacunga, Ecuador**

***** Faculty of Agricultural Sciences, School of Veterinary Medicine and Zootechnical Studies, University of Cuenca, Yanuncay Campus, Ecuador**

****** Center for Animal Production Studies (CEDEPA), Faculty of Agricultural Sciences, University of Camagüey, Cuba**

rguevaraviera@yahoo.es

ABSTRACT

The purpose of this study was to evaluate the effect of algarroba (*Prosopis juliflora* (S.W.) DC.) on fodder, nitrogen and energy contents in Ecuadoran dairy farm grasslands. The study was made at ESPAM bovine facility, 15 meters above sea level, in Manabí, 00º49'23'', south latitude, and 80º11'01" west longitude, with 962.4 mm of annual precipitation, between September 2011 and December 2014. The stocking rate was 1.09 LU/ha. The areas were populated with 1-4 algarroba trees/ha by 2011, and 8-35 trees/ha, in 2014. Fodder, nitrogen, and energy balances depended on the arborization degree. As a result, 52 t of DM were estimated in 2014, in comparison to the 21 t produced in 2011. Nitrogen was higher with increased arborization between 2011 (60.9 kg/ha), greater nutrient intake from external sources, and 2014 (39.3 kg/ha), with less use of supplements and mineral fertilizers, and greater N2 contribution by arborization. The energy values were higher in 2014, with an increase in algarroba population/ha. The rise in trees/ha in 2014 favored forage yields, with improved N_2 and energy efficiency, which was linked to the benefits acquired by the grassland, the contribution of nitrogen to the ecosystem, and the reduction in feed and fertilizer consumption, which led to energy savings.

Key words: *trees, grasslands, livestock, energy, nitrogen*

INTRODUCTION

Livestock raising in lower tropical regions requires special attention to grasslands, not only due to the vast land extensions worldwide, but also because rational and scientific use of arborization may help solve deterioration and limited resilience caused by droughts and desertification. Hence, their potential to sequester and store carbon while supporting forest grazing, and contributing with vital resources to man could be raised (Morales and Sarmiento, 2008; Reyes, 2010; Ulf, 2012; Altieri and Funes-Monzote, 2012).

The poor nutritional level of prairie graminaceae, and the little persistence and yields of native legumes is a major issue to be addressed, according to Ruiz *et al*. (2014), which can be overcome with adapted species of improved legume genuses, like *Acacia*, *Bauhinia*, *Cratylia*, *Calliandra*, *Gliricidia*, *Leucaena and Prosopis*, and others with higher protein contents, whose contribution to organic matter, nitrogen, and other nutrients to the soil favor increased contents of graminaceae protein in the animal diet (CIAT, 2012; Milera, 2013).

CIAT (2012) and Altieri and Funes Monzote (2012) suggested possible preservation measures, like multiple crops (agroforestry), for the benefits of grasslands from increased arborization. They evaluated the possible productions of cows/day, between 8 and 14 kg, with protein banks of tree-like legumes, such as Leucaena cv Perú and cv Australia, along with graminaceae *Panicum*, *Cynodon*, *Chloris* and *Pennisetum*, covering 20 and 50% of the area with legumes (Milera, 2013; Ruiz *et al.*, 2014). In that sense, the aim of this paper was to evaluate the role of arborization with algarroba (*Prosopis juliflora* (SW) DC.) in fodder, nitrogen, and energy balances of grasslands with dairy cows in the low tropical regions, in Ecuador.

MATERIALS AND METHODS

The balance studies were made at a teaching, research and vocational bovine facility (UDIV), Manuel Felix Lopez Higher Polytechnic School of Agriculture of Manabí (ESPAM MFL) situated 15 m above sea level, El Limón, Calceta parish, Bolivar canton, province of Manabí, on 00º49’23’’ south latitude, 80º11’01” west longitude. The local weather data was,

Annual mean precipitation	962.4 mm
Annual mean temperature	25° C
Annual relative humidity	87 %
Annual sun radiation	1 325.4 (h/sun)
Annual evaporation	1 739.5 mm

The study began in September 2011 and ended in December 2014. Dry matter, energy and nitrogen balances were carried out.

Procedure

This dairy farm has 102 bovines (Holstein x Zebu, Brown Swiss x Zebu, and Gyroland). Milking is done by hand once a day, the total land area is 24 ha distributed as follows,

- 8 ha with portable and fixed electric fences, with pasture.
  Pastures: *Panicum maximum* Jacq. (Saboya) and *Cynodon nlenfuensis* Vanderyst (African Bermudagrass).
- 5 ha with cutting grass.
  Pastures: *Pennisetum purpureum* (*Napier grass*); *Saccharum officinarum* (sugar cane) and *Pennisetum purpureum* (purple elephant grass).
- 6 ha for grazing with barb wires.
  Pastures: *Brachiaria brizantha* (Hochst ex A. Rich.) Stapf in Prain; *Brachiaria decumbens* Stapf in Prain and *Brizantha* and *Panicum maximum* Jacq (guineagrass).
- 4 ha without pastures.
  Pastures: *Erythrina crista-galli* L. (cockspur coral tree); forage from arborescent and tree-like resources (*Gliricidia Guazuma*).
- 1 ha with sugar cane.
  Pastures: *Saccharum officinarum* (sugar cane).

The global stocking rate was 1.09 LU/ha. The daily animal consumption of feedstuffs was based on 16% CP (0.46 kg starting from the third kg milk/cow), of milled stalks of whole maize plants (66-75 % kernel formation), and about 22.5 kg/cow/day of heavy fresh fodder.

Water was supplied *ad libitum*. Arborization was 1-4 trees of algarroba/ha (*Prosopis juliflora*) in 2011, then it increased to 8-35 trees/ha in 2014 due to natural regeneration and transplantation. The predominant grass species were *Panicum maximum* (Guinea grass) and *Cynodon nlemfuensis* (Star grass); and others, like Texan grass (*Paspalum notatum* Flugge). The predominant native creeping legumes were species of genuses *Centrosema*, *Desmodium*, *Macroptilium* and *Teramnus*. Dry matter, nitrogen, and energy balances were determined as follows,

Fodder balance

It depended on the arborization degree and the years of evaluation of the dairy farm, using the above described handling procedure, as yields and availability in the cutting and grazing areas, respectively. The method suggested by Guevara (1999), with changes in some indicator coefficients was applied, which enabled calculation of the forage produced, and balance by the difference between the forage produced and the forage required for the entire herd (LU) on the farm (tons of DM).

Nitrogen balance

The method described by Kirchmann, Torsell and Roslon (1988) was applied by means of nitrogen input and output variables, and intermediate variables (circulation), modified for tropical areas (Guevara, 1999).

Input variables

- Nitrogen as fertilizer (kg/ha/year)
- Nitrogen from rainfall, according to the data form the Animal Science Institute, approximately 1 kg of N_2/52.5 mm of precipitation (Cuesta, 1995).
- The nitrogen supplied by native legumes that reached 30% of the population was estimated in 60 kg of N_2/ha/year (CIAT, 1990).

Intermediate or system circulation variables

- Nitrogen from local grassland legumes determined by bromatological analysis, or literature review (CIAT, 1990).

- Nitrogen excreted in feces-urine (considered as 1.54% of N in feces, and 1.10 % in urine), at a rate of 25 kg of fresh feces (3.3 kg in DM), and 9.0 L of urine/cow/day (Arteaga, Mojena and Espinoza, 1985).
- Nitrogen in the grass, according to DM percent and yields.
- Nitrogen in the animal (2.4 % live weight).
- Nitrogen consumed and transformed into milk N_2 (40 % of consumption, Kirchmann, Torssell and Roslon, 1988).
- Nitrogen that is not consumed by the animal, and recirculates in the grass (often 75% of N consumption, CIAT, 1990).

Output variables of the system.

- Output nitrogen from milk produced, according to CIAT (2012) (3.42-3.58 % of milk CP).
- Nitrogen in the animal removed from the system (2.4 % of live weight is N).
- Nitrogen lost in the excreta (feces-urine), close to 75% (CIAT, 1990).
- Nitrogen which is excreted in the milking parlors and milking sleeves and does not return to the grass.
- Rain nitrogen that is lost (approximately 60% is volatilized).

Energy balance

The data of animal production, reproduction, forage production, and resources were collected from the farm records. Social information was collected by interviewing farm workers. Table 1 shows the indicators used to evaluate energy use on the farm.

Energy input

The total energy value incorporated was calculated, distinguishing between direct and indirect energy inputs. Direct energy was consumed in production, including fuel, lubricants, electricity, and human labor. Indirect energy included the energy involved in fertilizer, herbicide, pesticide, feedstuff production, and machinery manufacturing. Energy input was calculated by multiplication of each input/year/ha, according to their corresponding energy contents.

Energy output

Energy output was calculated considering the annual milk production/ha in the system, and it was multiplied by its energy content. Energy input and output were expressed in MJ/ha.

Staff and management of the teaching, research, and vocational unit of Manuel Félix López Higher Polytechnic School of Agriculture in Manabí were interviewed to support the data provided by productive and reproductive records. No particular statistical technique was used for year comparisons, because the values were unique and estimated as mentioned above; mathematical differences were observed between years.

RESULTS AND DISCUSSION

Fodder balance

Table 2 shows a comparison of fodder balances between 2011 and 2014, with positive values in the latter, due to greater association between legumes and graminaceae. It marked a difference from the 268 t of total forage produced in 2014, in comparison to the 212 t produced in 2011, according to Vera and Riera (2003), when they put trees in grasslands in the north of Ecuador.

Other reports of these effects (Pérez Infante, 2010) were made after evaluating an increase in forage supply in grazing tests using Leucaena, *Kudzu*, *Gliricidia* and *Siratro*, which were better than single graminaceae in more than 2 kg of milk/cow/day. It proved the necessity of a system that supplies limitless amounts of forage, reducing feedstuff consumption (Guevara, 1999; Altieri and Funes-Monzote, 2012).

The previous has been confirmed in CIAT trials (2012) under the R+D+r, known as Tropileche, for livestock raising systems in Colombia, Nicaragua, Costa Rica, and Peru, in double-purpose cattle (mid dairy potential). Real systems were tested with grass, plus Arachis *pintoi Krapov* and W.C.Greg., *Kudzu* with *Cratylia argentea* (Desv.) *Kuntze* and *Saccharum officinarum* L. with some local supplements, which demonstrated that legume systems had higher fodder and nutritional balances. Although these included more agrotechnical costs of operations for establishment, they are more sustainable and profitable when productions are over 1 700 milk kg/ha/year.

The fodder balance output was proportional to increased arborization, and coincided with similar systems in Cuba, Costa Rica, and Colombia, which have reported advantages in graminaceae-legume associations, and supplementation with forages (Sánchez, 2007; Lamela, 2010).

Nitrogen balance

Table 3 shows the nitrogen balance made, with system inputs (86.01 kg of N_2/ha/year), and outputs (below 32.47 kg of N_2/ha/year). The high N_2 values observed in the intermediate element pool, between inputs and outputs accounted for N_2/ha/year.

Regarding the input variables, N_2 contribution from fertilizers was higher, followed by native legumes (21.68 kg of N_2/ha/year). These results coincided with Hristov, Hazen and Ellsworth (2006), who noted that the contribution of N_2 through legumes may be the second in importance. Later, a comparison of output variables showed that milk accounted for more than the 16.69 kg of N_2/ha/year that exited the system, in comparison to other variables.

Hernández and Sánchez (2006) on evaluation of the behavior of several chemical and biological indicators of several cattle farms in the west of Cuba, found that the introduction of trees in grasslands contributed increased density and biomass of soil microorganisms. Accordingly, the contents of nutrients in the soil-grassland and soil were higher in forest-grazing systems, with higher contents of organic matter and N_2 in comparison to graminaceae alone, coinciding with the results of Dueñas *et al.* (2006).

Grass species differ mainly in dry leaf quantity and quality (Bardgett and Walker, 2004). Thus C/N and lignin/nitrogen relations in graminaceae are higher than in legumes, making decomposition slower. In this particular case, greater arborization with P. juliflora allowed the dry leaves of plants with high C/N to make a stable covering that contributed to improved organic matter contents and N_2, enhanced soil structure, and protection from the rain and solar radiation. This high C/N ratio also promoted development of the root system, gall formation, and symbiotic fixation of nitrogen (Yadava and Tobouda, 2008).

Studies of grassland ecosystems in Cuba indicated that the rate of dry leaf decomposition had marked variations among grass species, and it was faster in shrub legumes than in graminaceae (Crespo, 2013; Crespo, 2015). According to Sánchez (2008), dry leaf decomposition dynamics was more intense in the forest-grazing systems than in graminaceae systems alone; N_2 intake was also higher.

The results observed with higher arborization indexes may be associated to the favorable microclimate created in a system with more trees, which favored the action of decomposing organisms. The introduction of arboreal legumes in grasslands with graminaceae is essential to increase dry leaf production with a different nature, providing an intermediate C/N ratio. It also favored moisture contents in the soil, and ensured a slower mineralization of nitrogen. It led to a greater synchrony among easily available nutrient assimilation processes and the content of humus in the soil. According to Ruiz *et al.* (2003) and Alonso (2004), trees have increased soil fertility in Cuban livestock raising areas by means of production and decomposition of dry leaves and trimming residues.

Other sensitive contributions to nitrogen fertilizers and feedstuffs were reduced in 2014 in comparison to 2011 and 2012; it was linked to grazing in associated areas, thanks to increased quality of the diet, with more crude and digestible protein. This was also observed after improvements in the quality of forages, which contributed to a reduction in consumption of other complementary feeds (Orskov, 2005; INIAP, 2012; Milera, 2013; Roca, 2014).

The amount of organic fertilizers applied in the last two years was small, but still higher than the values of 2011 and 2012, and contributed to an improved balance in the system as well (Peña, Guevara, Guevara and Vidal, 2006). The N_2 outputs of the system rose in the 2013-2014 period as an effect of increased milk production; they were inferior to biological N_2, which also included rain N_2. They differed less from the 2014 inputs, near 80 kg (79.6 kg/ha/year), and outputs (40 kg of N_2/ha/year), with a balance of 39.3 kg, (50 % efficiency of the system in both years); natural N_2 was prevalent. It coincided with reports of February and Higgins (2010) in dry savannah ecosystems in South Africa, where space distribution and tree density were fundamental to achieve higher N_2 contents in the soil (CIAT, 2012; Sánchez, 2007).

Energy balance

Table 4 shows the energy balance made on the farm between 2012 and 2014, where various aspects that produced a positive balance were observed to have been caused by proper environmental management. These results coincided with Denoia, Bonel, Montico and Di Leo (2008) and Fernández (2010), who stated that the integration of livestock raising and crop farming made a favorable integration compared to other entities that only engaged in animal production.

Fernández (2010) noted that the contribution to energy input produced by human labor was a small portion of the total income, and fell short from Asian levels. It was higher than the Cuban and other tropical systems in Latin America, though (Funes-Monzote, 2009; Botero and de la Ossa, 2010; Funes-Monzote, 2013).

These results confirmed the expected efficiency reports for livestock raising systems with arborization, by Ruiz *et al*. (2014) and Altieri and Funes-Monzote (2012), in which energy use was more efficient by reducing the application of fertilizers, agrotoxic substances, and machinery in legume-associated grasslands, and for the recovery of the ecosystem through arborization.

CONCLUSIONS

Increased algarroba density by 2014 improved forage yields and efficiency of N_2 and energy.

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REFERENCES

ALONSO, J. (2004). *Factores que intervienen en la producción de biomasa de un sistema silvopastoril con Leucaena (L. leucocephala, vc. Perú) y guinea (P. maximum vc. Likoni)*. Tesis de doctorado, Instituto de Ciencia Animal, La Habana, Cuba.

ARTEAGA, O.; MOJENA, A.; ESPINOSA, W. (1985). Efectividad del estiércol vacuno y otras fuentes comerciales en la nutrición fosfórica de la Bermuda Cruzada 1. *Pastos y forrajes*, *8* (2), 65-68.

BARDGETT, R. D. y WALKER, L. R. (2004). Impact of Coloniser Plant on the Development of Decomposer Microbial Communities Following Deglaciation. *Soil Biology and Biochem., 35* (1), 55-58.

BOTERO, A. y DE LA OSSA, V. (2010). *Un sistema de producción silvopastoril con enfoque agroecológico, departamento del Magdalena, Colombia*. Retrieved on June 1, 2013, from http://www.recia.edu.co/documentosrecia/recia3nuevo/estudio de caso/Agroecol_Botero.pdf.

CIAT (1990). *Relación suelo-planta y reciclaje de nutrientes. Programa de pastos tropicales*. Cali, Colombia: Centro Internacional de Agricultura Tropical.

CIAT (2012). *La promesa de la agricultura tropical hecha realidad. El árbol, el bosque y los sistemas agroforestales*. Cali, Colombia: Centro Internacional de Agricultura Tropical.

CRESPO, G. (2013). *El reciclaje de nutrientes y su impacto en sistemas ganaderos en el occidente de Cuba*. Tesis de doctorado, Instituto de Ciencia Animal, Universidad Agraria de La Habana, Cuba.

CRESPO, G. (2015). Factores que influyen en el reciclaje de nutrientes en pastizales permanentes, avances en el desarrollo de su modelación. *Revista Cubana de Ciencia Agrícola*, *49* (1), 1-11.

CUESTA, O. (1995). *Caracterización de las concentraciones de los principales compuestos del nitrógeno atmosférico en Cuba y su relación con los tipos de situaciones sinópticas*. Tesis de doctorado, La Habana, Cuba.

DENOIA, J.; BONEL, B.; MONTICO, S.; DI LEO, N. (2008). Análisis de la gestión energética en sistemas de producción ganaderos. *Revista FAVE, 7* (1-2), 43-56.

DUEÑAS, G.; RODRÍGUEZ, N.; IRIGOYEN, H.; MUÑOZ, R.; HERNÁNDEZ, M. y PASCUAL, J. (2006). *Manejo sostenible de suelos dedicados a la ganadería en la provincia La Habana*. VI Congreso de la Sociedad Cubana de Ciencias del Suelo (CD-ROM), La Habana, Cuba.

ESPAM MFL (2015). *Informe meteorológico*. Ecuador: Estación Meteorológica, Campus Politécnico El Limón, Calceta.

FEBRUARY, E. C. y HIGGINS, S. I. (2010). The Distribution of Tree and Grass roots in Savannas in Relation to Soil Nitrogen and Water. *South African J. Botany*, *76* (1), 5-10.

FERNÁNDEZ, E. (2010). *Metodologías para la evaluación y mejora del impacto ambiental de los sistemas ganaderos: análisis comparado y posibilidades de aplicación en el sector de los pequeños rumiantes de Andalucía*. Retrieved on May 28, 2013, from http://www.uco.es/zootecniaygestion/img/pictorex/20_10_02,Trabajo_de_Master.pdf.

FUNES-MONZOTE, F. (2009). *Eficiencia energética en sistemas agropecuarios: Elementos teóricos y prácticos*. Retrieved on May 28, 2013, from http://www.actaf.co.cu/index.php?option=com_mtree&task=att_download&link_id=682&cf_id=24.

FUNES-MONZOTE, F. (2013). *Sistemas agroecológicos. Movimiento Faros Agroecológicos en la Agricultura Cubana*. Cuba: ACTAF.

GUEVARA, R. (1999). *Contribución al estudio del pastoreo racional con bajos insumos*. Tesis de doctorado, La Habana, Cuba.

HERNÁNDEZ, M. y SÁNCHEZ, S. (2006, abril). *Evolución de la composición química y la macrofauna edáfica en sistemas silvopastoriles*. IV Congreso Latinoamericano de Agroforestería para la producción pecuaria sostenible. III Simposio sobre Sistemas Silvopastoriles para la Producción, La Habana, Cuba.

HRISTOV, A.; HAZEN, W. y ELLSWORTH, J. (2006). Efficiency of Use of Imported Nitrogen, Phosphorous, and Potassium and Potential for Reducing Phosphorous Imports on Idaho Dairy Farms. J. Dairy Sci, *89* (9), 3702-3712.

INIAP (2012). *El Sistema silvopastoril una alternativa sostenible del uso de la tierra*. Retrieved on May 30, 2013, from http://www.iniap.gob.ec/nsite/index.php?option=com_content&view=article&id=799:el-sistema-silvopastoril-una-alternativa-sostenible-del-uso-de-la-tierra&catid=97&Itemid=208.

KIRCHMANN, H., TORSSELL, B. y ROSLON, E. (1988). A Simple Model for Nitrogen Balance Calculations of Temporary Grassland Ruminant Systems. *Swedish J. Agric. Res.*,*18* (1), 3-8.

LAMELA, L. (2010). *Problemas de la adopción de la tecnología de silvopastoreo*. Ecuador: Campus Politécnico El Limón, Calceta.

MILERA, MILAGROS (2013). *Principios de manejo y utilización de gramíneas, leguminosas y otras forrajeras para la producción de leche y carne vacuna en Cuba*. La Habana, Cuba: MINAGRI.

MORALES, A. y SARMIENTO, D. (2008). *Árboles del bosque seco tropical en el área del Parque Recreativo y Zoológico Piscilago-Nilo Cundinamarca*. Retrieved on July 10, 2013, fromhttp://www.ecosistemassecos.org/doc/Cartilla_final.web[1].pdf.

ORSKOV, E. R. (2005). *Nutrición de rumiantes*. Camagüey, Cuba: Universidad de Camagüey.

PEÑA, I.; GUEVARA, R.; GUEVARA, G.; VIDAL, F. (2006). *Software para el balance de nitrógeno en rebaños bovinos*. Retrieved on July 10, 2013, from http://www.veterinaria.org/revistas/redvet/n121206/120603.pdf.

PÉREZ INFANTE, F. (2010). *Ganadería eficiente, bases fundamentales*. La Habana, Cuba: ACPA.

REYES, L. (2010). *Ciclo biológico de la polilla del algarrobo, Prosopis juliflora. En un sistema silvopastoril del Valle Del Cauca*. Retrieved on July 16, 2013, from http://bibliotecadigital.univalle.edu.co/bitstream/10893/3911/4/CB-0439250.pdf.

ROCA, A. (2014). Efecto del estrés calórico en el bienestar animal, una revisión en tiempo de cambio climático. Bolívar, Manabí. *Revista ESPAMCIENCIA*, *1* (1), 15-25.

RUIZ, T. E.; FEBLES, F.; JORDÁN, H.; CASTILLO, E. y MEJÍAS, R. (2003, junio). *Valoraciones sobre el proceso de introducción de Leucaena leucocephala en el sector ganadero*. Taller Internacional Ganadería, Desarrollo Sostenible y Medio Ambiente. Modelos alternativos, La Habana, Cuba.

RUIZ, T.; FEBLES, G.; CASTILLO, E.; JORDAN, H.; GALINDO, J.; CHONGO, B. *et al.* (2014). *Tecnología de producción animal mediante Leucaena leucocephala asociada con pastos en el 100 % del área de la unidad ganadera*. Retrieved on July 10, 2015, from http://www.produccionanimal.com.ar/produccion_y_manejo_pasturas/pasturas_cultivadas_megatermicas/112-leucaena.pdf.

SÁNCHEZ, J. (2007). *Utilización eficiente de las pasturas tropicales en la alimentación del ganado lechero*. Retrieved on May 30, 2013, from http://www.feednet.ucr.ac.cr/bromatologia/forrajes.pdf.

SÁNCHEZ, T. (2008). *Producción de leche con vacas Mambí de Cuba en pastoreo y complementando en bancos de proteínas*. Matanzas, Cuba: EEPF IH.

ULF, O. (2012). *Importancia del árbol en la producción animal (subtrópico seco argentino)*. Retrieved on June 1, 2013, from http://www.produccionanimal.com.ar/produccion_y_manejo_pasturas/manejo%20silvopastoril/129-IMPORTANCIA_ARBOL.pdf.

VERA, A. y RIERA, L. (2003). *Desarrollo de alternativas silvopastoriles para rehabilitar pastizales en zona norte de la región amazónica ecuatorina*. Retrieved on May 30, 2013, from http://www.iniap.gob.ec/nsite/images/documentos/desarrollo_alternativas_silvopastoriles_rehabilitar_pastizales_zona_norte_regi%c3%93n_amazonica_ecuatoriana.pdf.

YADAVA, R. S. y TOBOUDA, N. S. (2008). Plant Litter Decomposition and Soil Respiration in the Natural Grassland Ecosystems of Kangpolpi, Maniput. En P. C. Missa (Ed.), *Advances in Ecology and Envirom. Sci*. New Delhi, India: Asbush Publishing House.

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Table 1 Energy coefficients of inputs and products

Concept	Farm	MJ/U
Diesel	L	43.30
Gasoline	L	3.40
Lubricants	L	3.60
Human labor force	h	1.00
Electricity	KWh	14.40
Urea	Kg	58.00
Herbicides	Kg	238.00
Organic fertilizer	Kg	0.30
Feedstuff	Kg	16.33
Milk	Kg	0.059
Pastures	Kg	10.86

Source: Funes-Monzote (2009)

Table 2. Fodder balances in 2012 and 2014 with arborization of 1-4 trees/ha, and 8-18 trees/ha, respectively

2012 (1-4 trees/ha)				
Indexes	Pastures-legumes	Permanent forage	Temporary forage	Total
Area/species/animals	22.5	2.1	3.2	29.8
Number of LU	-	-	-	42.0
Forage yield (t/ha)	8.3	14.6	15.6	
Used forage %	41	77	91	
Forage produced according to usage %				212
Forage need (t)				191
Fodder balance (t) (forage prod.-forage needed)				+21
2014 (8-35 trees/ha)				
Indexes	Pastures-legumes	Permanent forage	Temporary forage	Total
Area/species/animals	23.3	1.6	4.9	29.8
Number of LU	-	-	-	46
Forage yield (t/ha)	12.6	16.4	20.3	
Used forage %	48	86	93	
Forage produced according to usage %	129.9	47.2	90.1	268
Forage need (t)				216
Fodder balance (t) (forage prod.-forage needed)				+52

Table 3. N_2 **balance (kg/ha/year) overtime, according to the arborization degree (1-4 trees/ha in 2011, to 8-35 trees/ha in 2014)**

Input variables of N_2	2011	2012	2013	2014
Fertilizers (Urea)	49.1	7.9	26.2	10.2
Organic fertilizers	-	-	9.1	5.2
N_2 in the rain	15.2	27.1	18.3	14.1
Legumes	14.6	10.3	21.7	29.6
Feedstuffs	25.1	23.6	14.2	10.5
Total inputs	104.0	68.9	89.5	69.6
Output variables of N_2				
Motion N_2	10.6	7.9	12.1	7.5
N_2 in the milk	11.2	12.3	16.7	18.2
N_2in animals	5.6	10.9	3.1	1.8
N_2excreted in urine	2.9	3.5	2.6	2.7
N_2excreted in houses	0.5	3.2	0.2	0.5
N_2 carried away by rain	14.1	20.3	11.0	9.6
Total outputs	44.9	58.1	45.7	40.3
N_2balance (inputs and outputs)	59.1	10.8	43.8	29.3

Table 4.Energy balances between 2012 and 2014 on the farm

Energy parameters	2012 balance	2013 balance	2014 balance
Assimilation of direct energy(IEd)	11 229.92	7 013.20	7 061.28
Electricity	1 596.00	1 080.00	1 209.34
Feedstuffs	1279.33	751.51	708.22
Fuel	6 812.41	4 330.00	4 017.00
Human labor force	1 542.18	851.69	1 126.72
Assimilation of indirect energy (IEi)	21 546.16	16 276.10	12 305.76
Mineral fertilizers	21 419.00	16 240.00	12 102.45
Organic fertilizer	---	2.10	184.05
Herbicides	127.16	34.00	19.26
Assimilation of energy(IE=IEd+IEi)	32 776.08	23 289.30	19 367.04
Energy egression(EE)	1 112.61	1 356.48	4 130.38
Indicators			
Energy balance (IE-EE)	31 663.47	21 932.82	15 236.66