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Livestock Sustainability: A perception analysis and SWOT application in Colombian municipalities

[1]A Duarte, [2]J Espinosa, [3]J Bolívar, [4]A Yanes

[1]Universidad de la Costa, Civil and Environmental Department, Barranquilla, Calle 58 # 55-66. Colombia, aduarte2@cuc.edu.co
[234]Universidad de la Costa, Civil and Environmental Department, Barranquilla, Calle 58 # 55-66. Colombia

Abstract

This study aimed to characterize and carry out an awareness program in terms of implementation of environmental management good practices in three municipalities with livestock activity of Atlantico department located in Colombia. By means of a closed question survey addressing/including water, soil, energy and waste management, an overview of the current situation was obtained. The survey was applied to managers of roughly 44% of the total farms registered population. It was also used a SWOT analysis to identify aspects related to internal and external factors at livestock sector. Results indicate that there is an inappropriate management of waste as well as water and energy resources, which may lead to misuse of existing available resources, pollution, and losses of money to stakeholders. After the characterization process, workshops with farms managers were carried out with the aim of sharing environmental management concepts, give suggestions and discuss day – to – day situations from the productive field, in order to create strategies for the stakeholders to apply in their daily livestock activities. Despite the present research will certainly shorten the gap between local farmers and big companies from livestock sector by providing the formers with concepts of environmental management which could help them to enhance their production process, there is still a large gap considering the differences to access to high technology control systems and more technified processes. The results of this investigation may offer valuable information to local decision-makers in terms of creating plans for small livestock farmers in rural areas to implement more elaborated sustainable strategies and therewith increase competitiveness of small farmers.

Keywords: Environmental management, cattle ranches, farms, rural cooperatives.

INTRODUCTION

World population has already reached 8 billion people, and continues growing at an accelerated rate, exerting pressure on natural resources, specifically on the land use changes, mainly by agricultural and livestock sectors which resulted in ecological degradation (Gerber et al 2010 and Nahed-Toral et al 2013) and the need for resources is increasing every day. Population growth consequent demand for food points to an increase in such demand of up to 70% in the next three decades (Fiala 2008 and Opio C et al 2013). Unobjectionably, the current food system, its related consumption, and production processes generate an increasing pressure over environment, threatening with resource's depletion and breaking the balance (Rohmer et al 2018). Dairy and beef products generate some of the highest environmental burdens (Steinfeld et al 2006 and Notarnicola et al 2012). As a matter of fact, livestock activities cause an enormous impact over environment: livestock production and its derivates account for up to 18% of total greenhouse gas emissions (Appuhamy et al 2016); it is responsible for roughly 35% of

anthropogenic methane and CO2 worldwide (Steinfeld et al 2006 and Tauseef et al 2013), as well as 2/3 of global N2O anthropogenic emissions (Tauseef et al 2013); it represents a major source of land-based pollution, releasing enormous quantities of nutrients, pathogens, and waste into soils and bodies of water (Aarnink et al 1995, Losey and Vaughan 2006 and Fiala 2008), being one of the main drivers of eutrophication in them (Pan et al 2016); it alters vast extensions of landscapes and affects biodiversity(Abbasi and Abbasi 2010, 2016); and generates deforestation by providing the space needed for housing and grazing areas (Gallegos Rivero and Daim 2017).

Environmental threats and climate change have led to an urgency to establish practices to minimize influence of food production on global warming (Beauchemin et al 2011 and Bonesmo et al 2013).

Latin-American countries that produce animal protein are in aware of livestock farming impact over environment (Alfaro-Arguello et al 2010) and are also interested in becoming more efficient in terms of production (Palhares et al 2019). In many countries, production is based on small producers. Unlike great livestock producers, small and even medium – sized ones rarely apply environmental management good practices, account on enough resources to purchase technology, nor formation to technify their production process and reduce environmental burden. Financial issues, as well as cultural, educational and even social ones influence this situation.

Livestock producers at Atlántico department (here in also referred to as Atlántico), Colombia, are mainly small and medium – sized producers (Lerner et al 2017) carrying out their activity because of tradition and/or business, but without a truly corporative projection or vision, and applying classical techniques (which have already proved inefficiency in land use (Roebeling and Hendrix 2010). Further, specific characteristics of the department influence cattle rancher's perspective and context. For instance, Atlántico has a great inequality in terms of satisfying citizen's basic needs (Promigas 2016), including cattle ranchers, affecting their economy. There has been reported that small farms have low levels of technology as well as the capacity and knowledge of producers to modify their practices constitutes one of the barriers to implement better livestock practices (Lerner et al 2017). Calderón García et al (2014) also stated in a Colombian case study that transition from a traditional livestock to a more ecological one is hindered due to lack of willingness to change, motivated by reticence to change and lack of information. Additionally, 2010 flood which sunk 10% of Atlántico's total area (Sánchez Jabba 2011), impacted significantly in socioeconomic dimensions of more than 175.000 people, caused a loss of more than 60.000 tons of agriculture production and affected more than 61.000 bovines, distributed among 15.000 hectares (Promigas 2016).The abovementioned situations (still) hinder cattle rancher's capability to incorporate proper environmental management to their production.

Despite these issues, there are ways to improve cattle production in terms of environmental management. It is necessary to count on traditional practices due to the knowledge the offer, and finally, strategies proposed should be checked due to regional singularities (Dick et al 2015) and these practices must be adapted in terms of improving efficiency and reduce environmental impacts (Gallegos Rivero and Daim 2017).

The aim of this study is it then to characterize environmental management from small and medium cattle ranchers of Atlántico department, Colombia; and to carry out an awareness program within, related to the implementation of good practices in the production process.

Methodology

Study Area

Atlántico is located in northern Colombia with an approximate population of 2,489,709 inhabitants (IDEAM et al 2011), being the most populous department of the Colombian

Caribbean Coast. The main economic activities of the department include agricultural, fisheries and aquaculture, forestry, and livestock sectors. Atlántico has an area of 3,388 km2 and is made up of 23 municipalities, some with a recognized livestock vocation (Gobernación del Atlántico 2012).

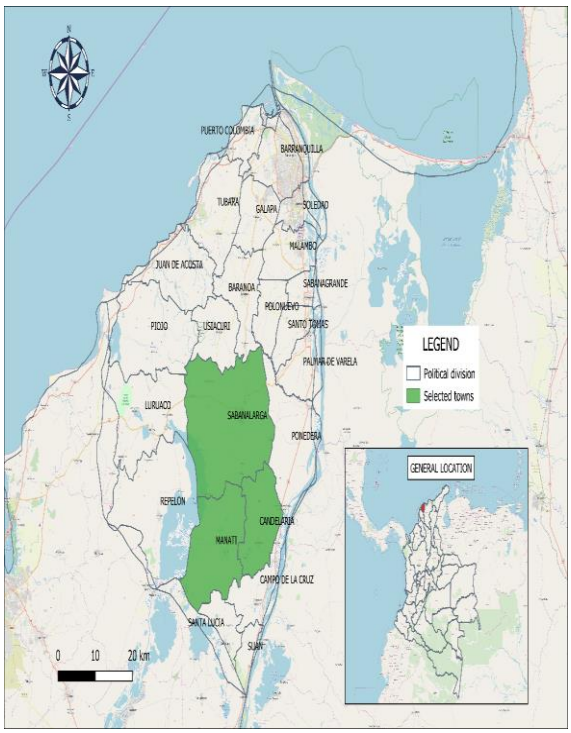

Figure 1. *Municipalities with livestock vocation analyzed in Atlántico Department, located in the north part of Colombia.*

Excluding the metropolitan area of Barranquilla (capital city), the department of Atlántico has livestock as its main economic base, highlighting in this area the municipalities of Sabanalarga, Manati, Luruaco, Ponedera, Repelón, Campo de la Cruz and Candelaria (UNINORTE 2011)

Of the total area of the department of the Atlantico, 255,225 hectares are occupied by livestock activities (UNINORTE 2011) and the livestock inventory is close to 230,000 heads and with an average production of approximately 185,000 liters per day of milk (Gobernación del Atlántico 2012).

Data gathering

The research was divided into three phases: planning, data gathering and situational diagnosis, and socialization of strategies. The planning phase comprised an identification of the current livestock active farms in Atlantico department. The Corporacion Autonoma Regional del Atlantico (CRA) (institution in charge of the execution of policies, plans, and projects related to environment and natural renewable resources in Atlantico) provided a database of farms with current operation under its jurisdiction. Three (Sabanalarga, Manatí, and Candelaria) of the seven towns with livestock activity in Atlantico department were chosen (Figure 1). Through the municipal units for technical and agricultural assistance (UMATA), five cooperatives where every small and medium cattle rancher are registered were contacted. By means of a preliminary meeting with cooperatives, a socialization of the aims of this study was made and a database with information related to cattle ranchers (ID, ranch name and location, and cell phone number) was obtained.

Afterward, a yes/no – question survey addressing the use and management of soil, water, energy and ranch waste was formulated. Topics such as the control of resources used, gathering of information related to the amount of resource used, calculation of invested money in equipment maintenance, current infrastructure, and machinery in the ranch, characterization of waste, among others, were considered. Besides personal information of polled people, a total of 58 questions were included in the survey. The cooperatives contacted reported that there are 438 ranches registered; despite there are numerous methods to estimate the sample size, , in this study an arbitrary non probabilistic sample (Severo et al 2015) of 193 surveys (which accounts for approximately 44% of total population) were applied. It is worth to mention that in almost every case, the manager – person in charge of the cattle ranch was surveyed. Based on survey results, a diagnosis of the management of resources in ranches was made, for every town and in general.

Finally, an educative strategy for cleaner production was implemented through a total of 12 workshops distributed as follows: a total of 4 workshops were carried out in every town, of

which 3 were theoretical and 1 was participative. In these interaction spaces, participants exchanged experiences, opinions and by way of guided discussions, strengths, weaknesses, opportunities, and threats were identified. This information was used to construct a SWOT matrix. "SWOT analysis method is an analysis method concerning competitive situation, largely used for strategic analysis process" (Xingang et al 2013 p. 605). It allows to identify strengths, weaknesses, opportunities and threats, through analysing the incidence of external and internal factors. Such analysis is the basis for proposing strategies of management (Pazouki et al 2017). Considering this, a set of strategies were suggested for future implementation in the cattle ranchers analysed.

Results and Discussion

Water quality and consumption

Production intensification increases the demand and competition for limiting natural resources, especially water and land resources (Herrero et al 2010 and Bosire et al 2015). To assess the implications for the environment, water and land footprints can be used as indicators (Bosire et al 2019). The key will be to develop intensification methods that improve efficiency gains to produce more without using more land, water and other resources (Herrero et al 2010).

Considering above, 193 owners were asked several questions related to Water broaching its use, care and quality. 95% do not have water concession, stating the lack of control by local authorities regarding protection of water sources in the municipalities analyzed.

According to respondents, they do not apply techniques to save or reduce water consumption, neither to analyze its physical and/or chemical parameters (98%). Cattle ranchs owners also do not estimate the water volume required for each process. In addition, most of the owners (62%) do not check water leaks and/or waste. Water requirements for livestock drinking and serving is very small and represent only 0.6% of global freshwater use (Weindl et al 2017).

Nonetheless, as stated by Palhares et al (2019) "accurate measurement is necessary to water management". Simple measurements such as re – use of non – potable water in allowed sections would improve the management of this resource. Grimble (1999) suggests that a real pricing of water for consumers would incentive the development and use of more efficient technologies.

Likewise, interactions between livestock and water are crucial in the challenges as livestock production uses a large amounts of water for feed production and is partly responsible for environmental degradation due to overgrazing (Descheemaeker et al 2010). It is important to highlight that 64% of cattle ranch owners have infrastructure for water storage, as well as great care for preventing water pollution. More than 80% take precautions to use chemicals and organic compounds and also avoid wastewater discharge in water sources. However, 52% of the respondents do not prevent water sources evaporation, especially in a land with high temperatures, implying a significant amount of water lost due to this process.

Energy Saving

In this item were analyzed time saved at work, fuel savings and animal energy saving. More than 90% of owners care a lot about their animals by having live barriers that prevent losses or temperature rise in them, exercising or making them move and, they are also well treated and make their routines safe and easy. The distribution of livestock drinking points determines animals' access to feed resources, livestock densities in rangelands, and the energy spent by animals to access the water (Descheemaeker et al 2010).

Nevertheless, the opposite happens with energy saving, less than 10% of the owners have quantified energy for each process besides money losses on the waste of energy. Additionally, no more than 16% have registered monthly fuels inputs and outputs. Use of renewable energies also have been considered by merely 36%, perhaps they should

use passive cooling systems like green roofs or artificial shading in order to maintain animals' temperature and in the same time reduce energy consumption (Vitt et al 2017 and Firfiris et al 2019)

Concerning fuel and energy saving, less than 29% make maintenance of their machinery or avoid using them for long hours and they do not check if lights are on or off.

Waste Management

The population sample surveyed affirms that 53% are aware of the types and quantities of waste generated in livestock activities. Likewise, a high percentage, 78%, of respondents who use herbicides and fertilizers was obtained. However, a large part of the respondents ensures that products (milk and meat) and pastures are free of agrochemicals.

Fires have traditionally accompanied agricultural practices on livestock farms; however, 90% of the population surveyed has reduced these activities of burning grass and crop residues, as well as 86% also claim to have reduced the burning of solid waste, the latter being one of the critical practices in the rural sector, due to solid waste collection problems (as service operator and collection frequency).

On the other hand, Reuse is considered as one of the strategies that most reduces environmental impacts compared to recycling (Kunamaneni et al 2019). In the case of the livestock population surveyed, it was found that 50% reuses the water from the manure as fertilizer for the meadows, while in the case of composting techniques, which has positive effects on the physicochemical biological properties of the soil (Liu et al. 2019), it is an area of opportunity to be strengthened, since only 22% claims to reuse waste of their farms with this kind of techniques.

Waste is considered an environmental problem due to the impacts involved in its disposal and treatment, in addition to the fact that poor waste management is widely recognized as a source of economic costs, risks to health and the environment (Zorpas 2020). A large part of the difficulties encountered in the correct management of the waste generated from livestock activities is that the population in general does not know other alternative methods for their management, for example, in the case of manure reuse, 79% states in unknowing other techniques that promote the management of this type of waste.

Regarding the processes of waste separation and storage that can be recycled and those that cannot, a large part of the respondents, 91%, do not perform the segregation and collection of this waste, being another area of opportunity identified in the sector. Similarly, waste management that has been in contact with or containers where agrochemicals have been stored, 92% of the surveyed population affirms that they do not do the washing of these containers and do not deliver them to companies for an adequate final disposal, being the same situation for veterinary drug residues.

Finally, for the waste management of sharps and/or pointed objects, 72% of the respondents use a guard container for their storage, thus avoiding their disposal as an ordinary waste and potential risk for the operators that carry out the waste collection work.

Land use and soil quality

In its entirety, the sample population claims to work in areas derived from the livestock sector in accordance with Land Use Plan, which is positive since this environmental management instrument seeks to promote sustainable development by ensuring the preservation and proper use of lands (Carrion Barrero 2008). However, a high percentage of the population does not carry out soil analysis which is essential since this type of activity generates soil compaction, reduces soil cover, decreases productivity and promotes the accumulation of waste (Jeddi and Chaieb 2010). Therefore, it leads to a reduction in soil quality parameters as a direct effect of grazing (Tessema et al 2011).

A high percentage of the surveyed population that manages the optimal load capacity on the farms was obtained, allowing sustainable livestock production without generating serious

effects on soil fodder. However, 27% does not handle the optimal load capacity affecting the efficient use of resources and probably generating an excessive manure in a small area leading to a risk of environmental pollution (Deng et al. 2020). Despite this, almost all the farmers and ranchers handles the frequency and intensity of grazing in winter where the growth of the meadow is slow and its availability is always limited, thus allowing the maintenance of healthy soil, flora, fauna and water resources (Bailey et al 2019).

Organic matter in soils has an important role in the physical, chemical and biological health of soils. A high percentage (73%) incorporates organic matter into the soil, which improves the cation exchange capacity by increasing the retention capacity of nutrients in the soil and can even help reduce the leaching of nitrogen from the urine of cattle (Malcolm et al 2019). The use of fertilizers was also considered; more than 50% of the population uses organic and green fertilizers produced from waste, maintaining soil fertility. Likewise, the use of organic fertilizers improves the absorption and drainage of water in the soil, facilitating thus the fixation of carbon on the ground and the formation of nutrients (Vayssières and Rufino 2012). These fertilizers are excellent alternatives to replace the prolonged use of chemical fertilizers that accelerate the degradation of soil quality and decrease the sustainability of crops (Choudhary et al. 2018).

Finally, the aspect of grassland renewal was evaluated, where 72% of the surveyed population affirmed that it was carried out on farms. This practice allows improving soil conditions by promoting its conservation, water infiltration and its aeration (Necpálová et al 2013).

The overgrazing is another problem that should be considered and resolved in livestock activities, due to the soil degradation caused by the excessive number of animals in the same place. In this case, more than 65% does not perform compaction tests on the pastures leaving only 35% that if handled, therefore, there is no concern about the degradation induced by soil compaction in a large part of the population interviewed.

Cattle grazing accelerates soil erosion, but it was obtained that 68% protects river rounds from landslides, 75% that protects areas susceptible to erosion and 58% uses livestock farming techniques conservation to prevent erosion. This demonstrates that farmers and ranchers seek soil preservation handling the erosion problem induced by the continuous grazing of livestock activity. Thus, almost all the sample population has live barriers in their pastures to maintain soil degradation due to erosion at admissible levels, as well as other soil management and conservation practices such as coverings, fertilizers green and incorporation of organic matter among others.

Regarding chemical degradation of the soil, a percentage of 83% carries out pH amendments in their farm, this is important to control the acidity in the soil since it represents a problem for the growth of grasslands with their respective nutrients (Liebig et al 2017). Likewise, 68% performs inter-planting of species in their pastures, which allows fertilization and planting in a single operation, preserving agricultural sustainability. Finally, 85% applies chemical and organic inputs according to the recommendations trying not to contaminate the soil and 66% of the population monitors that the soils are not salinizing.

SWOT analysis

For SWOT analysis participants identified aspects related to internal and external factors considering the following elements: key internal strengths, decisive internal weaknesses, relevant external opportunities and key external threats (Table 1).

Table 1: SWOT matrix with internal and external factors

Internal Factors	
Strengths	Weaknesses
S1: Quality of final product (meat and milk)	W1: Lack of policies to exploit resources
S2: Organization of regional cooperatives	W2: Inadequate cost benefit ratio of products

S3: Region with inherited livestock vocation	W3: Lack of culture towards change. W4: Inadequate management of waste and agrochemicals. W5: Lack of commitment to the empowerment of implemented projects

External Factors	
Opportunities	Threats
O1: Soil diversity, water richness, pasture variety that facilitate the handling of livestock	T1: Lack of financial support T2: Lack of support from government and environmental authorities
O2: Road infrastructure in good condition	T3: Lack of articulation of instructions between stockbreeders and farmers
O3: Climatic conditions suitable for livestock	T4: Contamination of water and soil bodies T5: Ignorance of soil types

Considering this, strategies were formulated in order to promote sustainable management in the farms and cattle ranches analyzed (Table 2). However, they cannot reach adequate environmental goals only by themselves, they need control from environmental authorities, as well as support from government.

As stated in the table 1, they already have the experience, vocation and specially the organization, so they can cooperate with better techniques for preserving resources without losing product quality or economic benefits. It is also important not to lose their vocation to learn or be instructed in policies, other techniques and environmental issues so they can improve their activity.

Table 2: SWOT strategies proposed to promote sustainable management

	Strengths	**Weaknesses**
Opportunities	S3O1: Implementation of sustainable livestock farming, taking care of natural resources. S2O1: Conducting soil studies to identify their natural resource's characteristics and type of pasture that can be sown	W1O1: Establish clear and appropriate policies for natural resources management W4O2: Design and implement with inter-institutional support the post-consumption programs of agrochemicals in the region.
Threats	S2W2: Establish inter-institutional working groups that allow the design of programs to be carried out in an effective manner that the needs of the sector. S2W4: Training by co-operatives for the care and proper use of natural resources. S3W5: Monitoring the environmental quality of the area.	W3T4: To design accompaniment programs in the implementation of cleaner production programs. W1T1: Study the financial viability of the sector and look for strategies that allow its improvement.

Despite the existence of support tools and potential institutional organization to apply adequate environmental management, willingness to implement appropriate strategies is crucial. Environmental culture and awareness are important to implement environmental friendly strategies in Colombia (Vanegas Hurtado 2014)

The environmental impact of food products is highly influenced by the production system behind them (Rohmer et al 2018). Therefore, environmental management also aids at creating a cleaner consumption of food products. Adequate sustainable practices do not act immediately nor eliminate environmental pollution completely. There is still impact upstream and downstream the production/consumption chain. Rather, it contributes by raising awareness of the power of each actor to contribute to a more sustainable world (Ashton et al. 2017).

Conclusion

As stated by Wells (2013), sustainability requires the creation of a system through which social, natural and economic capital are preserved or increased. World population dietary habits and food demand make mandatory that farms, whether small or big, compel to evolve regarding technology and techniques used in production (Gallegos Rivero and Daim 2017). In this sense, Latin America contributes to global economy moderately through resources extraction and unsustainable practices. Thus, there is a need to raise awareness in consumers and producers such that patterns and habits of consumption and production shift towards a sustainable perspective (Ashton et al 2017).

Considering all of this, environmental management was characterized in small and medium cattle ranchers in Atlántico municipalities in Colombia, by studying its soil, water, energy and waste practices. Current situation in these ranchers was established by a SWOT analysis which allowed to propose strategies socialized through workshops to be implemented, in order to improve sustainability in their production process. Carrying out the strategies and practices discussed in this paper requires complementary actions aimed to encourage their adoption. Further accompaniment by local authorities in the process of practice and financial support such that cattle ranchers have the necessary resources to fulfill environmental management is needed.

Methodology and results of this work will help small and medium cattle ranchers by allowing them to understand their current situation regarding resources management. In addition, it could also contribute to local authorities and government by providing them a detailed characterization of existing conditions and even more importantly, a set of strategies addressing educational, financial, technical and monitoring topics associated with livestock production process and interaction with the environment. This research constitutes valuable information for government leaders since it would aid at economic planning and management, by addressing ongoing problems and impacts of livestock sector activities.

Future studies might address related issues, such as determining the accessibility of cattle ranchers to required technology to implement proposed strategies, describe current links between institutions and producers and identify gaps, recognize drivers to the adoption (or not) of proposed strategies, among others.

Though government and authorities play a key role to truly put into effect environmental management intended for a more efficient and environmentally responsible production process, cattle rancher's willingness to adopt proposed strategies and other related measures is critical too. The change of paradigm towards a more sustainable one involving different practices requires first the comprehension of the transcendence of such actions regarding self – economy, local economy, environment and society. Such a shift is a process that starts with awareness, as we intended to reach through our workshops and dialogues. However, 'environmentally friendly' practices sometimes require incentives for producers, as a strategy to encourage them. Incentives may represent direct subsidies or advantages when aspiring to other related subsidies (Luo et al 2014).

Technical and economic characteristics of the cattle raising units show limits and potentials which should be addressed to improve sustainability.

Reference

[1] AAarnink A J, Keen A, Metz J H M 1995 Ammonia emission patterns during the growing periods of pigs housed on partially slatted floors. J Agric Eng Res 62:105–116

[2] Abbasi T, Abbasi SA 2016 Reducing the global environmental impact of livestock production: {The} minilivestock option. J Clean Prod 112:1754–1766. https://doi.org/10.1016/j.jclepro.2015.02.094

[3] Abbasi T, Abbasi SA 2010 Biomass energy and the environmental impacts associated with its production and utilization. Renew Sustain Energy Rev 14:919–937. https://doi.org/10.1016/j.rser.2009.11.006

[4] Alfaro-Arguello R, Diemont S A W, Ferguson B G, Martin J F, Nahed-Toral J, Álvarez-Solís J and Ruíz R P 2010 Steps toward sustainable ranching: An emergy evaluation of conventional and holistic management in Chiapas, Mexico. Agric Syst 103:639–646. https://doi.org/10.1016/j.agsy.2010.08.002

[5] Appuhamy J, France J, Kebreab E 2016 Models for predicting enteric methane emissions from dairy cows in North America, Europe, and Australia and New Zealand. Glob Chang Biol 22:3039–3056. https://doi.org/10.1111/gcb.13339

[6] Ashton W S, Hurtado-Martin M, Anid N M, Khalili N R, Panero M A and McPherson S 2017 Pathways to cleaner production in the Americas I: bridging industry-academia gaps in the transition to sustainability. J Clean Prod 142:432–444. https://doi.org/10.1016/j.jclepro.2016.03.116

[7] Bailey D W, Mosley J C, Estell R E, Cibil A F, Horney M, Hendrickson J R, Walker J W, Launchbaugh K L and Burritt E A 2019 Synthesis Paper: Targeted Livestock Grazing: Prescription for Healthy Rangelands. Rangel Ecol Manag 72:865–877. https://doi.org/10.1016/j.rama.2019.06.003

[8] Beauchemin K A, Janzen H H, Little S M, McAllister T A and McGinn S M 2011 Mitigation of greenhouse gas emissions from beef production in western Canada – Evaluation using farm-based life cycle assessment. Anim Feed Sci Technol 166–167:663–677. https://doi.org/10.1016/j.anifeedsci.2011.04.047

[9] Bonesmo H, Beauchemin K A, Harstad O M, Skjelvåg A O 2013 Greenhouse gas emission intensities of grass silage based dairy and beef production: A systems analysis of Norwegian farms. Livest Sci 152:239–252. https://doi.org/10.1016/j.livsci.2012.12.016

[10] Bosire C K, Ogutu J O, Said M Y, Krol M S, Leeuw J and Hoekstra AY 2015 Trends and spatial variation in water and land footprints of meat and milk production systems in Kenya. Agric Ecosyst Environ 205:36–47. https://doi.org/10.1016/j.agee.2015.02.015

[11] Bosire CK, Rao J, Muchenje V, Van Wijk M, Ogutu J O, Mekonnen M M, Auma J, Lukuyu B and Hammond J 2019 Adaptation opportunities for smallholder dairy farmers facing resource scarcity: Integrated livestock, water and land management. Agric Ecosyst Environ 284:106592. https://doi.org/10.1016/j.agee.2019.106592

[12] Calderón García A, Tobón Orozco D, Cardona Nieto V and Agudelo Viana G 2014 Características, incentivos a la producción y disponibilidad a pagar por leche ecológica en Medellín. Semest Económico 17:43–74

[13] Carrion Barrero GA 2008 Debilidades del Nivel Regional en el Ordenamiento Territorial Colombiano. Aproximación desde la Normatividad Política Administrativa y de Usos del Suelo. Arquit Ciudad y Entorno 145–165

[14] Choudhary M, Panday S C, Meena VS, et al (2018) Long-term effects of organic manure and inorganic fertilization on sustainability and chemical soil quality indicators of soybean-wheat cropping system in the Indian mid-Himalayas. Agric Ecosyst Environ 257:38–46. https://doi.org/10.1016/j.agee.2018.01.029

[15] Deng M, Hou M, Zhang Q and Bellingrath-Kimura S D 2020 Critical livestock densities and manure management for the typical paddy rice and corn cropping systems in an intensive livestock watershed, Japan. Agric Syst 177:

https://doi.org/10.1016/j.agsy.2019.102722
[16] Descheemaeker K, Mapedza E, Amede T and Ayalneh W 2010 Effects of integrated watershed management on livestock water productivity in water scarce areas in Ethiopia. Phys Chem Earth 35:723–729. https://doi.org/10.1016/j.pce.2010.06.006
[17] Dick M, Da Silva M A and Dewes H 2015 Mitigation of environmental impacts of beef cattle production in southern Brazil - Evaluation using farm-based life cycle assessment. J Clean Prod 87:58–67. https://doi.org/10.1016/j.jclepro.2014.10.087
[18] Fiala N 2008 Meeting the demand: An estimation of potential future greenhouse gas emissions from meat production. Ecol Econ 67:412–419. https://doi.org/10.1016/j.ecolecon.2007.12.021
[19] Firfiris VK, Martzopoulou AG and Kotsopoulos TA 2019 Passive cooling systems in livestock buildings towards energy saving: A critical review. Energy Build 202:109368. https://doi.org/10.1016/j.enbuild.2019.109368
[20] Gallegos Rivero AR and Daim T 2017 Technology roadmap: Cattle farming sustainability in Germany. J Clean Prod 142:4310–4326. https://doi.org/10.1016/j.jclepro.2016.11.176
[21] Gerber PJ, Vellinga T V and Steinfeld H 2010 Issues and options in addressing the environmental consequences of livestock sector's growth. Meat Sci 84:244–247. https://doi.org/10.1016/j.meatsci.2009.10.016
[22] Gobernación del Atlántico 2012 Plan Departamental de Gestión del Riesgo Atlántico
[23] Grimble R J 1999 Economic instruments for improving water use efficiency: theory and practice. Agric Water Manag 40:77–82. https://doi.org/10.1016/S0378-3774(98)00107-3
[24] Herrero M, Thronton P K, Notenbaert A M, Wood S, Msangi S, Freeman H A, Bossio D, Dixon J, Peters M, Van de Steeg J, Lynam J, Parthasarathy Rao, P, Macmillan S, McDermott, J, Seré C and Rosegrant M 2010 Smart investments in sustainable food production: revisiting mixed crop-livestock systems. Science (80-) 327:822–825. https://doi.org/10.1126/science.1183725
[25] IDEAM, DANE and IGAC 2011 Reporte final de áreas afectadas por inundaciones 2010-2011 con información de imágenes de satélite a Junio 6 de 2011. Sist Inf Ambient Colomb 35
[26] Jeddi K and Chaieb M 2010 Changes in soil properties and vegetation following livestock grazing exclusion in degraded arid environments of South Tunisia. Flora Morphol Distrib Funct Ecol Plants 205:184–189. https://doi.org/10.1016/j.flora.2009.03.002
[27] Kunamaneni S, Jassi S and Hoang D 2019 Promoting reuse behaviour: Challenges and strategies for repeat purchase, low-involvement products. Sustain Prod Consum 20:253–272. https://doi.org/10.1016/j.spc.2019.07.001
[28] Lerner AM, Zuluaga AF, Chará J, et al (2017) Sustainable Cattle Ranching in Practice: Moving from Theory to Planning in Colombia's Livestock Sector. Environ Manage 60:176–184. https://doi.org/10.1007/s00267-017-0902-8
[29] Liebig MA, Ryschawy J, Kronberg SL, et al (2017) Integrated crop-livestock system effects on soil N, P, and pH in a semiarid region. Geoderma 289:178–184. https://doi.org/10.1016/j.geoderma.2016.11.036
[30] Liu L, Wang S, Guo X and Wang H 2019 Comparison of the effects of different maturity composts on soil nutrient, plant growth and heavy metal mobility in the contaminated soil. J Environ Manage 250:109525. https://doi.org/10.1016/j.jenvman.2019.109525
[31] Losey J E and Vaughan M 2006 The Economic Value of Ecological Services Provided by Insects. Bioscience 56:311. https://doi.org/10.1641/0006-3568(2006)56[311:TEVOES]2.0.CO;2
[32] Luo L, Wang Y and Qin L 2014 Incentives for promoting agricultural clean production technologies in China. J Clean Prod 74:54–61. https://doi.org/10.1016/j.jclepro.2014.03.045
[33] Malcolm B J, Cameron K C, Curtin D, Di H J, Beare M H, Johnstone P R and

Edwards G R 2019 Organic matter amendments to soil can reduce nitrate leaching losses from livestock urine under simulated fodder beet grazing. Agric Ecosyst Environ 272:10–18. https://doi.org/10.1016/j.agee.2018.11.003

[34] Nahed-Toral J, Sanchez-Muñoz B, Mena Y, Cámara-Cordova J and Grande-Cano, D 2013 Feasibility of converting agrosilvopastoral systems of dairy cattle to the organic production model in southeastern Mexico. J Clean Prod 43:136–145. https://doi.org/10.1016/j.jclepro.2012.12.019

[35] Necpálová M, Casey I and Humphreys J 2013 Effect of ploughing and reseeding of permanent grassland on soil N, N leaching and nitrous oxide emissions from a clay-loam soil. Nutr Cycl Agroecosystems 95:305–317. https://doi.org/10.1007/s10705-013-9564-y

[36] Notarnicola B, Hayashi K, Curran M A and Huisingh D 2012 Progress in working towards a more sustainable agri-food industry. J Clean Prod 28:1–8. https://doi.org/10.1016/j.jclepro.2012.02.007

[37] Opio C, Gerber P, Mottet A, Falcucci A, Tempio G, MacLeod M, Vellinga T, Henderson B and Steinfeld H 2013 A global life cycle assessment Greenhouse gas emissions from ruminant supply chains. Food and Agriculture Organization of the United Nations (FAO), Rome. On-line version: http://www.fao.org/3/i3461e/i3461e.pdf

[38] Palhares J C P, Afonso E R and Gameiro A H 2019 Reducing the water cost in livestock with adoption of best practices. Environ Dev Sustain 21:2013–2023. https://doi.org/10.1007/s10668-018-0117-z

[39] Pan D, Zhou G, Zhang N and Zhang L 2016 Farmers' preferences for livestock pollution control policy in China: A choice experiment method. J Clean Prod 131:572–5582. https://doi.org/10.1016/j.jclepro.2016.04.133

[40] Pazouki M, Jozi S A and Ziari Y A 2017 Strategic management in urban environment using SWOT and QSPM model. Glob J Environ Sci Manag 3:207–216. https://doi.org/10.22034/gjesm.2017.03.02.009

[41] Promigas 2016 Sur del Atlántico: Una Nueva Oportunidad, Manuel Alv. On-line version: http://www.fundacionpromigas.org.co/es/Biblioteca/Documents/Libros/Sur%20del%20Atlantico%20-%20Version%20Digital.pdf

[42] Roebeling P C and Hendrix E M T 2010 Land speculation and interest rate subsidies as a cause of deforestation: The role of cattle ranching in Costa Rica. Land use policy 27:489–496. https://doi.org/10.1016/j.landusepol.2009.07.002

[43] Rohmer S U K U K, Gerdessen J C C, Claassen G D H D H, Bloemhof J M M and Van't Veer P 2018 A nutritional comparison and production perspective: Reducing the environmental footprint of the future. J Clean Prod 196:1407–1417. https://doi.org/10.1016/j.jclepro.2018.06.125

[44] Sánchez Jabba A 2011 Después de la Inundación. Banco de la República, Colombia

[45] Severo E A, De Guimarães J C F, Dorion E C H and Nodari C H 2015 Cleaner production, environmental sustainability and organizational performance: An empirical study in the Brazilian metal-mechanic industry. J Clean Prod 96:118–125. https://doi.org/10.1016/j.jclepro.2014.06.027

[46] Steinfeld H, Gerber P, Wassenaar TD, Castel V, Rosales M and Haan C 2006 Livestock's Long Shadow: Environmental Issues and Options. Food & Agriculture Org.

[47] Tauseef S M, Premalatha M, Abbasi T and Abbasi S A 2013 Methane capture from livestock manure. J Environ Manage 117:187–207. https://doi.org/10.1016/j.jenvman.2012.12.022

[48] Tessema Z K, de Boer W F, Baars R M T and Prins H H T 2011 Changes in soil nutrients, vegetation structure and herbaceous biomass in response to grazing in a semi-arid savanna of Ethiopia. J Arid Environ 75:662–670.

https://doi.org/10.1016/j.jaridenv.2011.02.004
[49] UNINORTE 2011 Una Oportunidad Para Mejorar Sur Del Atlántico : 3–5. Universidad del Norte, Barranquilla, Colombia.
[50] Vanegas Hurtado C V 2014 ¿Producción Limpia? Un Elemento Clave Para La Competitividad De Las Empresas Colombianas Y Los Acuerdos Ambientales Multilaterales. 1–19
[51] Vayssières J and Rufino M 2012 Gestión de ciclos de nutrientes en sistemas de cultivo y ganadería con tecnologías verdes. Tecnol verdes en la Prod y Proces Aliment 152–182
[52] Vitt R, Weber L, Zollitsch W, Hortenhuber S J, Baumgartner J, Niebuhr K, Piringer M, Anders I, Andre K, Hennig-Pauka I, Schonhart M and Gunther S 2017 Modelled performance of energy saving air treatment devices to mitigate heat stress for confined livestock buildings in Central Europe. https://doi.org/10.1016/j.biosystemseng.2017.09.013
[53] Weindl I, Bodirsky BL, Rolinski S, Biewald A, Lotze-Campen H, Müller C, Dietrich J P, Humpenöder F, Stevanović M, Schaphoff S and Popp A 2017 Livestock production and the water challenge of future food supply: Implications of agricultural management and dietary choices. Glob Environ Chang 47:121–132. https://doi.org/10.1016/j.gloenvcha.2017.09.010
[54] Wells G 2013 Sustainable Business: Theory and Practice of Business under Sustainability Principles. Edward Elgar, Cheltenham, UK
[55] Xingang Z, Jiaoli K and Bei L 2013 Focus on the development of shale gas in China—Based on SWOT analysis. Renew Sustain Energy Rev 21:603–613. https://doi.org/10.1016/j.rser.2012.12.044
[56] Zorpas A A 2020 Strategy development in the framework of waste management. Sci Total Environ 716:137088. https://doi.org/10.1016/j.scitotenv.2020.137088