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Original

Methodological Proposal to Calculate Environmental Indicators of Fattening Bovine Males under Grazing Conditions

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ABSTRACT

Background: Recently, there has been an increase in the global demand of beef. As a result, a higher number of cattle farms have been established to meet the commercial demands. Consequently, it would lead to an increment in the number of anthropic actions. Aim: to define a method of analysis related to the environmental implications of fattening systems for grazing cattle, through a new set of environmental indicators (EI).

Methods: This study helped determine a global fattening indicator under grazing conditions, named Environmental Grazing Indicator (EGI). It was quantified using an environmental risk factor between 0 and 100, with eight partial indexes, each of them corresponding to a particular cattle raising activity. A Likert-type scale was applied, and the weights estimated for each partial index were calculated according to the data provided by different experts.

Results and conclusions: This new method enables the study and evaluation of environmental impacts on cattle fattening systems under grazing conditions. The results of this study lay solid groundwork for the construction of environmental indexes in other production systems, which might replace fattening cattle-related activities by more specific ones, depending on the conditions. This method is a valuable tool for impact detection, and the application of mitigation measures in any production area.

Key words: Environmental impact, beef, cattle, natural resources, (Source: *BIREME)*

INTRODUCTION

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Quite a few studies in relation to the environmental impact of livestock raising have been published (Arcos, Lascano, and Guevara, 2018). Some of them include the ecological footprint (Nogueira 2019), energy balances (Halberg, Verschuur, and Goodlass, 2005), and life cycle analysis (Molina, Olea, Galindo, and Arriaga, 2019).

Within cattle raising, beef production and its environmental impact, are particularly significant (Hyland, Styles, Jones, and Williams, 2016). Carbon footprint is a methodology expressed in kg, CO_2 equivalent (CO_2-e), in which the emissions of CO_2, methane (CH_4), and nitrous oxide (N_2O), are included. It also enables estimation of greenhouse gas emissions (GHG) during part of the whole life of cattle (Röös, Sundberg, and Hansson, 2014). Based on this methodology, Nijdam Rood, and Westhoek (2012) determined the carbon footprint of beef. They found it varied between 9 and 129 kg of CO_2-e per kg of meat produced. Subsequent studies done by Ripoll, de Boer, Bernués and Vellinga (2013), and Ruviaro *et al.* (2015) considered that the previous research revealed that the variation range found in the carbon footprint of beef, may be attributed to various factors like the type of production, the location, management practices, the cutoff values of the study, and the resources included.

Lately, there has been an increase in the consumption demands in countries of Asia, Africa, and the Americas (Rodríguez and Morales, 2015). Naturally, this situation involves a rise in production systems to meet the demands of society (Tilman and Clark, 2014). Hence, a greater demand of beef would lead to an increase of anthropic actions, and an ensued pressure on the natural resources of ecosystems from agroecosystems (water, soil, and air), and on biodiversity.

This research focuses on the implications of fattening systems of cattle on the environment. It was based on environmental indicators (EI), to define the method of analysis associated to environmental impacts linked to the most biodiversity-invasive activities, soil degradation, and the pollution of water and air that these fattening systems have.

MATERIALS AND METHODS

Designing an EI methodology for fattening of cattle in grazing conditions

The methodology proposed in this study to build environmental indicators was based on the theoretical criteria described by OECD (2008). A global indicator was defined to estimate the environmental risk factor in fattening systems of bulls in grazing conditions. The Environmental Grazing Indicator (EGI), which relies on potentially environmental negative grazing-related activities on natural resources, is quantified through an environmental risk factor between 0 and 100. The systems with values between 0 and 33 have a low environmental risk; between 33 and 66, the risk is moderate; and over 66, the systems have a high risk to the environment.

The data used to calculate this indicator were gathered through a structured survey to farm owners or managers. The activities for EGI evaluation comprised eight indicators or partial indexes (EGI_1, EGI_2, .., EGI_8). These indexes include the environmental effects of the following: plantation of grass, pasture management and nutrition, the inclusion of treelike leguminosae, grazing in mountainous areas, and access to surface water resources. These activities are based on three different and excluding alternatives, which are also considered as low, mid, and high environmental impact. Consequently, the alternative used by the farmer on his premises value will be given a value between 0.50-100, depending on the corresponding partial index, upon identification by the farmer.

To design EGI, the information in reference to the eight partial indexes is summarized, using a weighted mean. Since not all the partial indexes have the same importance in the global impact, each of them should be weighted to some extent. These values were established following a survey to 13 environmental cattle production experts. Each expert answered a question associated to every partial indicator, according to the Likert-type scale (Likert, 1932; Cuervo, 2009). The questions were related to environmental risk values between 1 and 5; 1: risk was considered low; 2: risk was moderate; 3: risk was considered intermediate; 4: high risk; 5: very high risk. Finally, the weights (w) were calculated according to the responses.

Depending on the farm and the system, EGI is calculated through the weighted sum of the values with the initial indicators, multiplied by their estimated weights (Table 2). This procedure generates an estimated global measure of the environmental risk level of each farm. Below is the general equation:

$$EGI_i = \sum_{i=1}^{n} I_i * w_i$$

Where:

I_i= is the value of each partial indicator in the i^{th} unit (j=1,..,n)
w_i=weight assigned to each partial indicator in the i^{th} unit (j=1,..,n)

RESULTS AND DISCUSSION

Table 1 shows the EGI indicator on the first column. The second column shows the partial indicators that make up EGI, and the third column shows the management or category alternatives. The values of 0, 50, and 100 shown on the fourth column in every category are considered low, moderate, and high, respectively. The estimated weight and impact on natural resources and biodiversity are shown on columns 5 and 6. Regarding the estimated weights (w) of every partial indicator, the values achieved were homogeneous, corresponding to the criteria stated by the experts consulted in the surveys. EGI_1, EGI_2, and EGI_6 had the highest scores, indicating that the activities of these indicators pose a greater environmental risk in these systems, according to experts.

Indicators EGI_1 and EGI_2 (mechanical tilling on flat and uneven lands, respectively), comprise mechanical labor done to the soil to plant grass for consumption of fattening cattle. This enables estimation of environmental risk caused by mechanical tilling on the soil, which corresponds to the reports of Mora, Ríos, Ríos, and Almario (2017), and Oviedo and Cruz (2018). For instance, in EGI_1, the greatest environmental risk was caused by conventional tilling, then cutting down and burning trees, which scored 100 points.

As to EGI_2, conventional tilling down the slopes was the riskiest activity. These activities have serious repercussions on the soil and air pollution, as a result from CO_2 emissions from machinery and fires. Moreover, according to DeClerK (2011) and Iraola, Muñoz, García, and Hernández (2015), a reduction in vegetation affects biodiversity of agroecosystems.

Table 1. Environmental indicator of fattening systems of grazing cattle

	Partial indicators	Categories	Environmental risk value	Weigh t (w)	Impact
Environmental grazing indicator (EGI)	**EGI_1:** Mechanical tilling on flatland	Minimal tilling	0	0.14	S, A, BD
		Conventional tilling	50		
		Conventional tilling after cutting down and burning trees	100		
	EGI_2: Mechanical tilling on uneven terrains	Minimal tilling using contours	0	0.15	S, A, BD
		Conventional tilling across the slope	50		
		Conventional tilling down the slope	100		
	EGI_3: Grassland restoration	Restoration with rest management	0	0.12	S, A, BD
		Restoration using harrows and chemical fertilizers	50		
		Restoration with controlled fire	100		
	EGI_4: Grassland nutrient contribution	Introduction of leguminosae	0	0.11	S, WR, A, BD
		Organic fertilization	50		
		Agrochemical fertilization	100		
	EGI_5: Grazing pressure	Without overgrazing	0	0.11	S, WR, BD
		Overgrazing in the dry season (DS)	50		
		Overgrazing throughout the year	100		
	EGI_6: Slope of the grazing area	Grazing on 20% slopes	0	0.14	S
		Grazing on 20-60% slopes	50		
		Grazing on greater than 60% slopes	100		
	EGI_7: CH_4 mitigation while grazing	Inclusion of 50 and 100% leucaena SSP	0	0.11	A
		Inclusion of 50% SSP leucaena	50		
		Only graminaceae	100		

	EGI$_8$: Access to surface water sources	Controlled access	0	0.11	WR, S, BD
		Semi-controlled access	50		
		Free access	100		

Legend: Risk factor of EGI$_1$; EGI$_2$; EGI$_3$; EGI$_4$; EGI$_5$; EGI$_6$, EGI$_7$, EGI$_8$ (0: low; 50: mid; 100: high); Environmental impact: (S: soil; A: air; WR: water resources; BD: biodiversity)

EGI$_3$ values the restoration of grasslands. Frequently, farmers utilize machinery, and chemical fertilizers to perform these activities; occasionally, the degraded grasslands can be restored with controlled fire. This indicator shows the effects of these practices on the soil, the air, and biodiversity. In turn, most cattle fattening in Cuba is done on farms under grazing conditions. The utilization of machinery with sets of harrow disks and induced burning to establish new plantations contribute to grassland rehabilitation, and are frequently implemented by cattle farmers. Accordingly, it is important to reduce the use of machinery for tilling to minimal levels. This will help minimize damage to the environment, and achieve greater sustainability of cattle areas (Iraola *et al.*, 2016).

EGI$_4$ summarizes the actions associated with the incorporation of nutrients for gramineous development. Among these actions is the excessive use of synthetic agrochemicals to increase yields of grasslands, becoming the riskiest activity within this partial indicator. According to Börnecke (2014), this practice increases the risk of pollution of the soil, water, ground and surface water near these ecosystems. Moreover, the use of agrochemicals can affect biodiversity.

In this work, EGI$_5$ is associated to overgrazing, and it is useful to estimate the effects on natural resources and biodiversity. In grassland management, the anthropic factor is a determining element in every productive process taking place on farms. In that sense, inadequate management practices may lead to a reduction of vegetable covering, derived from an increase in grazing pressure, and the existence of different degradation levels in the grasslands (Senra, Soto, and Guevara, 2010; Milera *et al*., 2019). This situation may favor soil erosion caused by the wind and water, compression, deficient draining, the emergence of rills, and the reduction of biodiversity.

Another aspect associated to grazing system management is analyzed in EGI$_6$. This indicators is associated to grazing in areas with slopes. Many cattle areas are established on terrain with over 20% slopes, which are considered mountainous, where management and grazing may have a strong influence on soil erosion and compression.

According to Benítez *et al.* (2008), the topography of the terrain interacts with the way grazing is managed, and together, both exert pressure on the needs for herd maintenance, reducing the productive capacity of animal raising. Besides, the greater the slope the higher the possibilities of soil erosion. Consequently, grazing may compress soil, reduce the capacity of water infiltration, and increase runoff water and risks of erosion. Therefore, grazing management in these conditions is held accountable for soil degradation.

Within EGIs, EGI_7 includes variables associated to the emission of methane through grazing. In this case, the introduction of SSP with leucaena in gramineous grasslands, may contribute to the mitigation of methane emissions. The tannins present in the plants contribute to a reduction of populations of methanogenic bacteria, and mitigate the emissions of CH_4 into the environment, as a result of ruminal fermentation (Ku *et al*., 2012). The utilization of ssp leucaena, also enhances the productive capacity of gramineous grasslands, and improves the levels of protein consumed by animals. To some extent, this indicator helps estimate the environmental risk caused by farms, using ssp leucaena or not.

The grazing animals may access different sources of water on the farm, which may or may not be protected from other animals. EGI_8 indicates the actions associated to access to different water sources, such as rivers, streams, dams, and lagoons. Free access of animals to water sources poses a potential risk of contamination, and may lead to soil degradation, and affect biodiversity of ecosystems (Murgueitio *et al.,* 2015; FAO 2019).

Practical calculation of the environmental indicator of fattening systems based on grazing

The intention is to demonstrate the functionality of the method for estimation of environmental risk developed in this paper for EGI, through a practical exercise. Accordingly, ten farms engaged in cattle fattening under grazing conditions were compared, and the global risk of pollution, was estimated.

In this exercise, each farm is assumed to handle specific conditions of the place, and the farmer's experience. In that sense, all the partial indicators of EGI are present on all the farms, according to the surveys performed to owners or managers.

The baseline data, and the results from the calculation of the EGI index in the practical case used as an example of the method, are shown in table 2. Columns from 2 to 9 correspond to each of the partial indexes, from EGI_1 to EGI_8. The row with the *w* contains the weight assigned to each of them, depending on the survey to experts on every partial index. Rows from 3 to 12 belong to a single farm, and show the value of such index on the column corresponding to each partial index, depending on the farm's practice, consisting of a value from each of the three alternatives. 0, 50 or 100.

Column 10 refers to the global EGI from each farm, which is calculated as a weighted mean of its values on the eight columns, by using weights (w) as adjustments. Hence, for instance, the calculation of farm 5 is 50*0.14+100*0,15+…+0*0.11=58.

Row 13 *Average*, shows the average of contributions ($EGI_{i*}w_i$) from every partial index, and total EGI. Finally, row 14 shows the contribution per cent of each EGI_i to the total EGI on the farms analyzed.

Table 2. Per cent estimations of environmental risk on farms engaged in cattle fattening in grazing conditions

	EGI_1	EGI_2	EGI_3	EGI_4	EGI_5	EGI_6	EGI_7	EGI_8	EGI
w	0.14	0.15	0.12	0.11	0.11	0.14	0.11	0.11	
Farm No. 1	100	100	100	100	100	0	100	100	85
Farm No. 2	50	0	0	50	0	50	50	0	25
Farm No.3	0	100	50	100	100	50	100	100	72
Farm No. 4	0	100	50	50	100	50	100	50	61
Farm No. 5	50	100	0	100	50	100	50	0	58
Farm No. 6	50	0	0	50	50	0	0	50	23.5
Farm No. 7	50	100	0	50	0	50	50	0	40
Farm No. 8	0	50	50	50	100	100	0	50	49.5
Farm No. 9	100	50	100	100	100	100	50	100	86
Farm No. 10	100	50	100	50	100	50	100	100	79
Average	7	9.75	5.4	7.7	7.7	7.7	6.6	6.05	57.9
Contribution %	12.09	16.84	9.33	13.30	13.30	13.30	11.40	10.45	100

Legend: w (estimated weight of each partial indicators); Source: self-made

Farms No. 2 and 6 produced values under 33, with four minimal impact levels each (0), and no maximum value (100), thus rendering a low environmental risk in EGI. However, farms No. 4, 5, 7, and 8 produced values between 33 and 66, considered moderate environmental risk. The other farms produced values above 66. This might mean that the activities performed by farmers from the last group of farms tended to produce a higher environmental risk, than the risk found on the other farms.

In turn, the global average of EGI on the farms studied, showed a moderate environmental risk (57.9). Perhaps this might pose the need for training and improvement actions in the areas studied, aimed to reduce the number of practices in cattle raising which are potentially harmful to the environment.

Upon calculating the impact average, it was interesting to know the aspects this global level (57.9) depended most on. To achieve that, the per cent contributions of each partial index to the EGI, were calculated. EGI_3 had a 5.4% contribution, and EGI_8 contributed with 6.05%. Hence, these two partial indexes were the ones with the least negative contribution to global EGI. These indexes comprise actions associated to nutrient contribution in grasslands, and cattle access to surface water resources. In that case, it would be inferred that cattle farmers are more knowledgeable of this practice and the negative effects on natural resources.

The other partial indicators showed higher averages, which might be associated to inadequate management practices or little sensitivity during the productive process. Lastly, EGI_2, which involves tilling of uneven terrains, contributed with 16.84%. This indicator is associated to training and improvement actions of the most striking factors, particularly in relation to the soil.

CONCLUSIONS

This research involved the design of indicators that enable the estimation of environmental impacts on production systems. A methodology based on fattening systems of male ovines under grazing conditions was designed and specified. The indexes were related to environmental impacts on the natural resources and biodiversity

A global indicator was defined (Environmental Grazing Indicator) for fattening systems based on grazing, and it was quantified by means of an environmental risk factor between 0 and 100. The estimation of impact through indicators defined in that manner (0-100), with the properties of synthetic indexes, allowed researchers to evaluate desired aspects, and compare impacts that take place on different farms.

The methodology suggested is also compatible with breaking down the total impact caused by different production activities, depending on the nature of the production system investigated. This paper was centered on fattening male cattle under grazing conditions, so EGI was divided into eight partial indexes. An impact breakdown is an appealing strategy, since very concrete farming actions can be properly corrected.

The partial indexes were estimated through adjustments depending on valuable opinions compiled from a panel of experts in environmental impacts of cattle production systems. The survey to experts concluded that despite the existence of a similar severity in all the management actions, some are more harmful than others.

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AUTHOR CONTRIBUTION

Author participation: (include the initials of each author separated by comas): Conception and design of research: JI, RDP data analysis and interpretation: JI, RDP, redaction of the manuscript: JI, RDP, MBR.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.