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Use of indicators to evaluate sustainability of animal production systems

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SUMMARY – Few indicators for sustainability are used in studying animal production systems. Sustainability of these systems should be evaluated in a dynamic and multidisciplinary manner, and those indicators used should allow for detecting the systems' most relevant properties, as well as the tendency of those systems to change. Indicators proposed by FAO provide information regarding all attributes of sustainability, although in a manner which is overly focused on technical and economic indicators at the expense of social and environmental factors. In order to use these indicators to evaluate sustainability, it is necessary to: (i) integrate and reduce the number of indicators, balancing them for all sustainability attributes; (ii) generate indicators which show system sustainability in relation to the economic, environmental and social context; and (iii) design indicators which show system evolution and the influence of this process on that system's sustainability.

***Keywords*:** Goat and sheep production systems, sustainability, indicators.

RESUME – *"Utilisation d'indicateurs pour évaluer la durabilité des systèmes de production animale". Les indicateurs permettant de caractériser la durabilité des systèmes de production animale sont peu développés. L'évaluation de la durabilité de ces systèmes doit être dynamique et multidisciplinaire et les indicateurs utilisés doivent permettre de détecter les caractéristiques les plus importantes des systèmes et leur évolution. Les indicateurs proposés par la FAO servent à informer sur tous les attributs liés à la durabilité, mais d'une façon non équilibrée et trop centrée sur le système de production. Pour rendre possible l'utilisation des indicateurs FAO en tant qu'évaluateurs de la durabilité des systèmes, il conviendra de: (i) réduire le nombre d'indicateurs obtenus à partir des données de l'exploitation, en cherchant un équilibre entre le nombre d'indicateurs qui correspondent à chaque attribut de la durabilité ; (ii) générer des indicateurs représentatifs de la durabilité des systèmes liés à l'environnement, aussi bien physique, économique que social ; et (iii) créer des indicateurs qui renseignent sur l'évolution du système et de sa durabilité.*

Mots-clés : *Production ovine et caprine, durabilité, indicateurs.*

Introduction

An animal production system is expected to be sustainable if it is capable of reproducing itself for a reasonable length of time and of changing in a timely manner, when conditions demand, in order to continue functioning long term. For this to occur, resources and ecological and social processes central to its functioning should be capable: (i) of reproducing and self-regulating; (ii) of coordinating themselves to be mutually compatible; (iii) of absorbing the shock of adverse disturbances in a timely fashion; and (iv) of reorganizing and adapting themselves in the face of internal and external structural changes (Masera *et al*.,1999). This very general definition helps us know what we should evaluate when analysing system sustainability. However, a methodology is required in order to make this analysis operative. This methodology of analysis, synthesis, and evaluation becomes a valuable planning tool as it: (i) allows us to know tendencies for change prevailing in productive systems and their possible consequences; and (ii) contributes to defining desirable scenarios and identifying one or more planned interventions for the system which could modify undesirable tendencies (Mojica,1991).

In almost all methodologies proposed toward this end, indicators are used to define sustainability, in other words, satisfying the needs of present generations without compromising possibilities for satisfaction of future generations. According to Chevalier *et al*. (1992), an indicator is a measure of the observable part of a phenomenon which allows us to value another unobservable part of that same phenomenon. For this reason it becomes a proximal variable. Conventionally, animal systems research contemplates the use of limited variables and indicators, without the evaluation being organized in the context of, and with a perspective of, sustainability.

This study analyses conventional use of indicators in animal production, the basis for evaluating sustainability, and the possibilities of using the FAO indicators in order to evaluate sustainability of small ruminant animal systems.

Use of indicators in animal production

Depending on the scope and objective of the study, many types of indicators are used in animal production: e.g. from census data, to data on consumption of concentrates per animal per year; or from an indicator aimed at regional level decision making, to one for use in operations management. Indicators may be simple or complex, depending on the information used and calculations made. Some indicators are simply raw data while others are resolved by combining a number of different variables derived from the production system or the market (Toussaint, 2002).

If we focus on animal operations and management, indicators may refer to the system's physical or economic aspects, and their utility will depend on productive options and management models (Moyano *et al.*, 2004). In most of the studies which mention indicators, these are grouped as technical, economic, or technical-economic. Technical indicators may be further grouped into reproductive (fertility, number of offspring per pregnancy, interval between births, proportion of non-productive births, reproducers per male, % of replacement, etc.), productive (lambs or baby goats produced per female per year, milk produced per female per year, etc.) and sanitary (% of abortions, deaths of reproducers, bacteriological quality of the milk, etc.). Economic indicators express in monetary terms the level of technological and business efficiency in the operations. They also measure the results of management decisions, including income, costs, variation in inventory, and gross or net margin. Technical-economic indicators are very useful, especially those showing income or margin per reproducer, per litre, or per worker. These allow for results of operations with very different production or market conditions. Examples of this type of indicator are: income per reproducer, fixed costs per litre, and net margin per reproducer (Pérez *et al.*, 1998; Moyano *et al.*, 2004).

The use of a common methodology to generate technical-economic indicators for small ruminant animal production systems has been one of the objectives of the Sheep and Goat Subnetwork of FAO's Production Systems Network, created in 1994 with the goal of elaborating a matrix for follow-up of these systems (Toussaint *et al.*, 1999). Initially, the Observatory analysed the evolution of systems of different regions in the Mediterranean watershed in time and space. More recently, its activity has had two facets: study of the functioning of sheep and goat production systems in these regions and study of the environment. Given the heterogeneity of these systems and of existing levels of information in different zones of the Mediterranean regions, from the beginning the Observatory has had to develop a common methodology to carry out comparative (transversal) analysis. A collection of indicators has been constructed to: (i) describe the functioning of sheep and goat production systems; as well as (ii) characteristics and evolution of their environment (Toussaint, 2002).

The indicators of functioning are classified into four levels. Level 1 includes those minimal descriptive elements needed to identify the systems´ structure. These include land and labour use, products obtained, and global economic results. Level 2 includes the former as well as more detailed technical, economic, and technical-economic indicators. Level 3 includes indicators which describe the system's functioning in more detail and explain level 2 indicators. Level 3 also includes different coefficients obtained from the quantitative indicators, which may vary from one situation to another. Finally level 4 includes indicators aimed at specific studies, for which special data is needed.

The indicators of characteristics and evolution of their environment which influence system operations are still being studied by the Observatory. A preliminary proposal (Toussaint, 2002) classifies environmental indicators into two levels, and level 2 is further divided into three sub-levels (A, B and C). Level 1 includes a qualitative description of the geographic, economic, social, and political context of the operations. Levels 2A and 2B describe these factors quantitatively and level 2C describes their evolution.

Foundations for evaluating sustainability

Sustainability is a paradigm which aims to comply simultaneously with productive, economic, social, cultural, and ecological objectives (Sarandón, 2002). In order to address all these dimensions, sustainability analysis of animal production systems should focus on dynamic systems in a multidisciplinary manner (Kaufmann and Cleveland, 1995; Belcher *et al.*, 2004). Universal parameters and criteria for this approach do not exist, and appropriate tools and/or methodologies are still being developed.

In order for analysis of sustainability to be operative, the behaviour of an appropriate number of relevant indicators should be characterized. These should be adequate to the objectives and scale of the analysis, should integrate variables, should be sensitive to a wide range of conditions and changes over time, and should be readily measurable, reliable, and easy to understand (Masera *et al.*, 1999; Sarandón, 2002).

Indicators should have the capacity to detect those properties most relevant to the systems´ functioning and their tendencies to change. Such properties or attributes are necessary for the systems to be sustainable. Some basic properties described by Conway (1987), Marten (1988) and Kaine and Tozer (2005) are productivity, stability, reliability, equality, resilience, and autonomy. In this context, Masera *et al.* (1999) propose a *Framework for the Evaluation of Natural Resource Management Systems* (MESMIS in Spanish), which incorporates sustainability indicators and integrates seven general properties with which those systems should comply in order to be sustainable.

We present definitions updated by Garcia-Barrios and Pimm (in press) for the second edition of this methodology: (i) *Productivity*: This is the level of goods and services (yields, profits, environmental services, etc) which the system provides per unit of time and per unit of input invested. (ii) *Stability*: A productive system is stable if it has internal mechanisms which self-regulate the state of its critical variables, in such a manner that they are maintained at values which allow the system to function. A system is stable when one critical variable (for example, productivity) is modified by a disturbance, and this very change creates signals and systemic interactions which cause the variable to return to its previous state. (iii) *Resilience*: This is only present in stable systems, and is the rate at which the disturbed variable returns to its previous state. It reflects the efficiency of the system's self-regulating mechanisms. (iv) *Reliability*: Disturbances may cause a critical variable of the system to reach a state in which self-regulation mechanisms allowing that disturbance to be reversed cannot operate. Reliability is the probability that this does not occur. It depends on the frequency of the disturbance, on the resistance which the variable offers to change, and on the range of values in which the change is reversible. (v) *Adaptability (or Flexibility):* A productive system is adaptable if it is capable of reorganizing itself to continue functioning when it undergoes irreversible internal or external changes. (vi) *Equality*: A productive system is egalitarian if it allows for fair distribution, within and between generations, in an appropriate manner, of costs and benefits among the social agents involved. Equality not only has an undeniable ethical value, but it is also a mechanism for social self-regulation which contributes to the system persisting and evolving adequately. (vii) *Independence*: The previous properties largely depend on the extent to which behaviour of the system depends on its own resources, interactions, and internal processes in order to regulate itself and evolve, and to what extent it depends on conditions, disturbances, and external interventions which it does not control.

From these general properties, specific indicators are derived, based on technical, economic, social, and environmental variables (Masera *et al.*, 1999). Important aspects to consider for development and adequate use of such indicators are:

(i) Before choosing indicators, one should generally characterize those systems to be evaluated, considering the areas of evaluation and pertinent spatial scale(s).

(ii) Temporal scale of the evaluation: The necessary evaluation period for whether an agro-ecosystem is sustainable on a short or long-term basis should range from seven to twenty-five years (Smyth and Dumanski, 1995). If in the definition of sustainability one speaks of satisfying the needs of future generations, the temporal horizon should be at least a generation, or 25 years (Sarandón, 2002).

According to Masera *et al.* (1999), evaluation of sustainability should be carried out comparatively. There are two ways of doing this: (i) longitudinal comparison, which studies the evolution of an agro-ecosystem over time, in a retrospective or prospective manner; and (ii) transversal comparison, which simultaneously studies one or more systems of alternative management.

Pertinent information may be obtained through surveys with producers, field measurements, literature review and analysis, statistical information or a combination of the above. Once information on the indicators is obtained, results should be integrated through transparent procedures which can be consistently organized, analysed, and synthesized. In the integration stage, it is not wise to try to convert a group of indicators which are diverse in nature and scale to only one or just a few "average" indicators in order to compare systems. A minimum number of indicators necessary for understanding the system's behaviour should be managed simultaneously. Indicators may be integrated using one of several forms of multi-criteria evaluation which has been developed for this purpose (Martínez-Alier *et al.,* 1998; Munda *et al.*, 1998; Galván, 2004). These allow for simultaneously understanding the potentials and limitations of the behaviour of the evaluated systems in order to guide decision making on how to select among systems and/ or intervene in order to achieve greater sustainability.

Possibilities of using the FAO indicators to evaluate sustainability of small ruminant animal systems

Goat systems' sustainability has been recently analysed, based on the indicators proposed by FAO (Nahed *et al.,* in press). In Table 1, these indicators are grouped by attribute or system(s) properties. This resulted from collaboration between researchers of the Animal Production Area of the University of Seville and researchers of ECOSUR (Mexico), and from a project of the Seville researchers in collaboration with the FAO Observatory in which a pilot project was launched in order to create a zone of technical-economic references in Andalusia (Castel *et al.,* 2004, Mena *et al.*, 2004).

As compared with indicators used in sustainability studies (e.g. Astier-Calderón *et al.,* 2002; Nahed *et al.*, in press), FAO indicators properly consider productive and economic aspects, but only superficially social aspects, and poorly cultural and ecological aspects. Therefore, new indicators must be developed for animal production systems to varying extents. The productivity attribute complies with the MESMIS methodology (Masera *et al.*, 1999). This is logical, as it deals with technical-economic indicators. The attributes of stability, resilience, reliability, and adaptability are only partially considered, as these attributes require following the evolution of the system. Instead, they were approximated by estimating how the system *could* evolve or respond to a given change (for example, % of adult mortality, producer age, level of implementing milking technology, etc.). The equality attribute was only partially considered, while self-sufficiency was fully considered.

Sustainability is a dynamic attribute of a system. Therefore it requires following up on the most relevant indicators for several years. With respect to this, the methodology proposed by FAO is quite adequate, as it is designed for periodic follow-up of systems.

Sustainability may be evaluated for a single system or by comparing two or more systems. Occasionally, due to lack of information, time or resources, evaluation must be initiated using data from only one year, but the future possibility of broadening the study (retrospectively or prospectively) should be kept in mind. Fig. 1 presents an extreme example in order to show the advantages and disadvantages of the different types of evaluation. The horizontal dotted line represents the threshold or lowest acceptable level of a critical indicator. In this heuristic example, a net minimum margin per goat per year (50 €) is taken as a threshold at which a goat system in Andalusia, Spain is abandoned. S1 and S2 are different goat management systems.

Evaluation of a single system (S1) may be carried out in a transversal manner (e.g. in 2005), in a retrospective longitudinal manner (e.g. from 1995–2005), or in a prospective longitudinal manner (e.g. from 2005-2015). The first is easy to carry out, but only allows us to begin to identify possible critical indicators. The second specifies historical data with the advantage of suggesting possible future tendencies. The third requires more effort, but is crucial in confirming tendencies and their consequences.

Table 1. Sustainability indicators of goat systems grouped by attribute (adapted from Nahed *et al.*, in press)

Indicators	Unit
Productivity	
1. Concentrate/milk produced	kg
2. Milk sold/goat and year	Litres
3. Fat in milk	%
4. Protein in milk	%
5. Kids sold/goat and year	Heads
6. Net margin/l milk produced	€
7. Net margin/goat and year	€
8. Net margin/family worker and year	€
Stability, reliability and resilience	
9. Presence of Payoya breed or its crosses	% of farm
10. Area owned/goat	ha
11. Natural pasture area/goat	ha
12. Brush area/goat	ha
13. Stubble area/goat	ha
14. Goats present	Heads
15. Goat mortality	%
16. Kid mortality	%
17. Goat replacement rate	%
18. Bacteria in milk	Per 1000 ml
19. Somatic cells in milk	Per 1000 ml
20. Good cataloguing of brucellosis control	% of farm
21. Milk price	€/l
22. Average kid price	€/head
23. Cows/goat	Heads
24. Sows/goat	Heads
25. Sheep/goat	Heads
Adaptability	
26. Farmer's age	Years
27. Succession continuity	% of farms
28. Formation courses attended by family members	Days
29. Milking technology	Degree of implementation
30. Inventory variation/goat and year	€
31. Relationship investment/net margin	%
Equitability	
32. Total labor/100 goats	Annual work unit
33. Family beneficiaries without occupation	No.
34. Total family beneficiaries	No.
35. External work offers	No.
Independence	
36. Net energy obtained from grazing	%
37. Total area/goat	ha
38. Cultivated pasture/goat	ha
39. Rented area	ha
40. Concentrate/goat and year	kg
41. Forage consumed in trough/goat and year	kg
42. Proportion of family workforce in relation to total workforce/100 goats	%
43. Associations to which the farmer belongs	No.
44. Subsidies/goat and year	€

S1 and S2 may be compared in three different ways which produce different conclusions (Fig. 1):

(i) Transversal: S1 and S2 are compared only in 2005. It is concluded that net margin (NM) is greater in S1 than in S2. Therefore, S1 is preferred.

(ii) Longitudinal retrospective: S1 and S2 are compared from a period previous to 2005 (1990-2005). It is concluded that NM of S1 was greater in 1990, but that its advantage has declined and in 2005 its NM is almost equal to that of S2. Now it is not so clear that S1 should be preferred.

(iii) Longitudinal prospective: S1 and S2 are compared in a period starting in 2005 (2005-2015). It is concluded that the processes previously shown in the two systems have inverted the initial advantage of S1 over S2. Furthermore, S1 is nearing the critical threshold of the indicator while S2 is moving away from it. S2 should definitely be preferred.

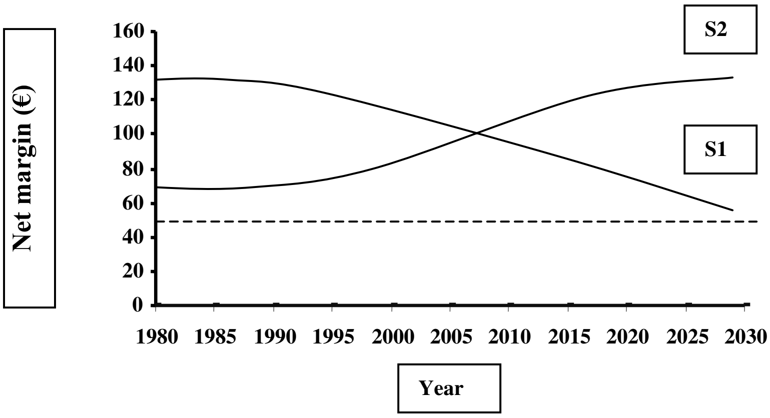

Fig. 1. Hypothetical behaviour of net margin per goat in two systems over the course of 50 years. S1 and S2 are different goat management systems.

Conclusions

Results obtained indicate that, as a first approximation of the study of sustainability, the technical-economic indicators proposed by FAO are acceptable, as they provide information on all attributes, although to different extents, and primarily focused on the operations level. There is a lack of information on how the latter interacts with the larger scale economic, environmental, and social conditions. It is necessary to develop a group of indicators which refer to the broader context.

To better consider the multidimensionality of the sustainability concept, it is necessary to further develop and better group the indicators by evaluation area and by sustainability attributes. It is also necessary to develop a plan for recording consistent long-term data on relevant indicators according to the objectives of the evaluation.

In order to make the FAO indicators viable in analysing sustainability of sheep and goat systems, several actions are necessary:

(i) Reduce the number of indicators originating from operations and keep only those which are representative of each attribute, trying to balance the number of indicators included in each.

(ii) Generate new indicators which show the sustainability of systems in relation to their economic, environmental or social context.

(iii) Work on designing indicators which, using the data obtained in the follow-up, show in a clear, synthesized manner the evolution of the system and its influence on that system's sustainability.

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