Evaluation of small ruminant systems sustainability. From conceptual frameworks to implementation

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Evaluation of small ruminant systems sustainability. From conceptual frameworks to implementation

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Abstract. As small ruminant system sustainability appears to be of great importance in and for the Mediterranean Basin context, the conceptual, ethical and methodological bases which could be central for its assessment are explored, with special emphasis on the multi-criteria approaches. Tools such as the Sustainability Tree, MOTIFS, IDEA, MESMIS, are analysed with reference to the nature of the objectives, principles, criteria, and indicators which characterise them and their mode of implementation. Case studies of sustainability assessment of small ruminant systems conducted with the IDEA approach (original or adapted) in Lebanon, Algeria and France, and with the MESMIS methodology in Spain are described. There appears to be a need to develop a generic and robust evaluation method which could be operational in different contexts, as well as references relative to Mediterranean situations.

Keywords. Small ruminant – Farming systems – Sustainability – Assessment – Multi-criteria.

Évaluation de la durabilité des systèmes de production de petits ruminants. Des cadres conceptuels à la mise en œuvre

Résumé. *Alors que la durabilité des systèmes de production des petits ruminants apparaît comme ayant une grande importance dans et pour le bassin méditerranéen, les bases conceptuelles, éthiques et méthodologiques centrales pour son évaluation sont explorées, avec une attention particulière envers les approches multicritères. Des outils tels que l'arbre de la durabilité, MOTIFS, IDEA, MESMIS, sont analysés en ce qui concerne la nature des objectifs, des principes, des critères et des indicateurs qui les caractérisent, ainsi que leur mode opératoire. Des études de cas d'évaluations de la durabilité de systèmes de production de petits ruminants conduites à l'aide de la méthode IDEA (originale ou adaptée) au Liban, en Algérie, et en France, et par la méthodologie MESMIS en Espagne sont décrites. Il apparaît qu'il existe un besoin de développement d'une méthode d'évaluation générique et robuste pouvant être opérationnelle dans différents contextes, ainsi que de références spécifiques aux situations rencontrées dans le bassin méditerranéen.*

Mots-clés. *Petits ruminants – Systèmes de production – Durabilité – Évaluation – Multicritère.*

I – Introduction

Small ruminant farming systems are characterised by a great diversity, in terms of types of production, breeds, levels of intensification, and are, by the fact, adapted to a wide range of situations. The link to the tradition and the territory, their role in maintaining the vegetation, as well as social activities, are assets in less favoured areas, with a special mention to the Mediterranean Basin. While goat systems experienced a regular development in the second part of the 20th century (Morand-Fehr *et al.*, 2004, Devendra, 2010), sheep evolution is more contrasted (de Rancourt *et al.*, 2006) and depends deeply on the common policies and subsidies. The capacity of these systems to be maintained in the long term is linked to their impact (positive or negative) on the environment, to their aptitude to support changing (environmental, economical, social) conditions and to support social and economical development (Dyrmundsson, 2006). Evaluation of such potentials goes beyond the classical technical-economical evaluation (Toussaint, 2006), for a broader (going beyond the limits of the technical system) and deeper (in the long term) analysis aimed at evaluating the sustainability of the systems (Gibon *et al.*, 1999).

We will consider here the concurrent views on sustainability, the ensuing assessment methods, and their application to Mediterranean small ruminant systems in order to identify the main trends and, in a methodological point of view, to question the adaptation of these methods to the small ruminant context.

II – The sustainability concept

First expressed in 1987 in the Brundtland report (WCED, 1987), the sustainability concept was then defined as "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This is in line with the ideas developed by Jonas (1979), emphasizing "the disruption of the symbiotic equilibrium between man and nature" and wording his imperative of responsibility as following: "Act so that the effects of your action are compatible with the permanence of genuine human life on Earth". This formulation extends the moral duty to nature and the future generations and gives sustainability a strong ethical basis. Other ethical considerations link sustainability to values such as humanism (Oliveira de Paula and Negrão Cavalcanti, 2000; Appleby, 2005), stewardship of nature (Worrell and Appleby, 2000), equity, following a Rawlsian principle (Beekman, 2004), ecological care of environment (Vavra, 1996) and system approach (Alrøe and Kristensen, 2003). When the main conception of sustainability is centred on resource availability, it may be considered, after Thompson (1997) and Thompson and Nardone (1999), in terms of "resource availability", a practice being sustainable "when the resources needed to carry on this practice are foreseeable available, which requires the identification of rates at which resources are being consumed". This can be evaluated by an analytical approach and in terms of a dynamic balance of elements.

Later on, other views on sustainability arose (Mebratu, 1998). The International Institute of Environment and Development, keeping the need satisfaction goal, took into account three basic subsystems: the biological, the social, and the economic. This point of view, which is now widely agreed, can be interpreted as the basis of specific analytical approaches, complemented by interdisciplinary collaborations, or as a need for systemic, holistic approaches. With the dramatic environmental, social or economic changes observed nowadays, the capacity of systems to maintain in an uncertain context led to the development of the notions of flexibility, adaptiveness, and resilience (Darnhofer *et al.*, 2010). This is in accordance with what Thompson names the "functional integrity" of a system, presupposing the reproduction over time of crucial elements of this system (Thompson, 1997; Thompson and Nardone, 1999), which requires the analysis of the system as a whole and of the complex interactions between its elements and external conditions.

The diversity, and often the complementariness, of views on sustainability and of the underlying values (Hansen, 1996; von Wiren-Lehr, 2001), makes it difficult to be univocally assessed, and explains the diversity of the assessment methods and of their conceptual frameworks.

III – Conceptual frameworks

A conceptual framework, as visual representation of an approach allows to identify elements such as the definition of a problem, the objectives, the objects, the knowledge, the methodology, and their relationships. Applied to the concept of sustainability and the assessment methodologies, different representations have been proposed. A now classical representation of sustainability in terms of the three components identifies the biotic (or agro-environmental), social (or socio-territorial) and economic pillars, and their interactions: viability, liveability, and equity, all elements necessary to achieve the global sustainability. In such representations, the circles representing the tree pillars can be secant or included, indicating either analytical-multidisciplinary, or holistic approaches.

The identification and computation of indicators (Mitchell *et al.*, 1995; Girardin *et al.*, 1999; Van Cauwenbergh *et al.*, 2007) is described as a process beginning by the definition of goals (objectives) assigned to the system, leading to principles which are general conditions for achieving sustainability, then to criteria which are specific objectives (de Wit *et al.*, 1995), the compliance of which being measured by indicators, which are variables representing more complex information not directly available, these indicators being oriented in connection with references (Fig. 1).

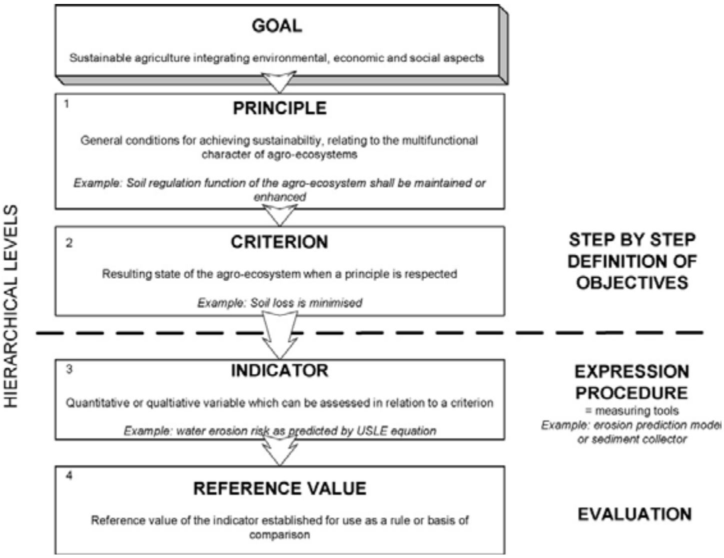

Fig. 1. Identification of indicators (van Cauwengergh *et al.*, 2007).

Indicators can be specific of single parts of the system, or systemic, describing key function of the system as a whole; they can be direct or indirect, mean-oriented, or goal-oriented. The progressive level of aggregation of the indicators provide tools of interest respectively for scientists, farmers, or policy makers (Phillis and Andriantiatsaholiniaina, 2001; Pacini *et al.*, 2003). References can be (i) absolute, corresponding either to target values defined by experts or scientifically-based, or threshold normative values, or (ii) relative, by comparison between groups, or in terms of desirable trend. An example of criteria identification in the case of land use sustainability is given by Bosshard (2000) (Fig. 2). Lopez-Ridaura *et al.* (2005a, 2005b) presented a framework for multi-scale (farm, municipal, sub-regional and regional) sustainability evaluation with a definition of contextualised objectives, criteria and indicators specific to each scale, the principles being common (Fig. 3). Bossel (2000, 2002) (Fig. 4) presented a set of principles associated to self-organizing systems (environmental or others), called basic "orientors", crucial for the viability of these systems: existence (the system must be able to exist in the normal environmental state), effectiveness (it should on balance be effective in securing scare resources), freedom of action (ability to cope with the challenges posed by environmental variety), security (able to protect itself from effects of environmental variety), adaptability (able to learn, adapt and self-organise), and coexistence (able to modify its behaviour to account for behaviour and interests of other systems). This framework is, more than others, consistent with the functional integrity approach.

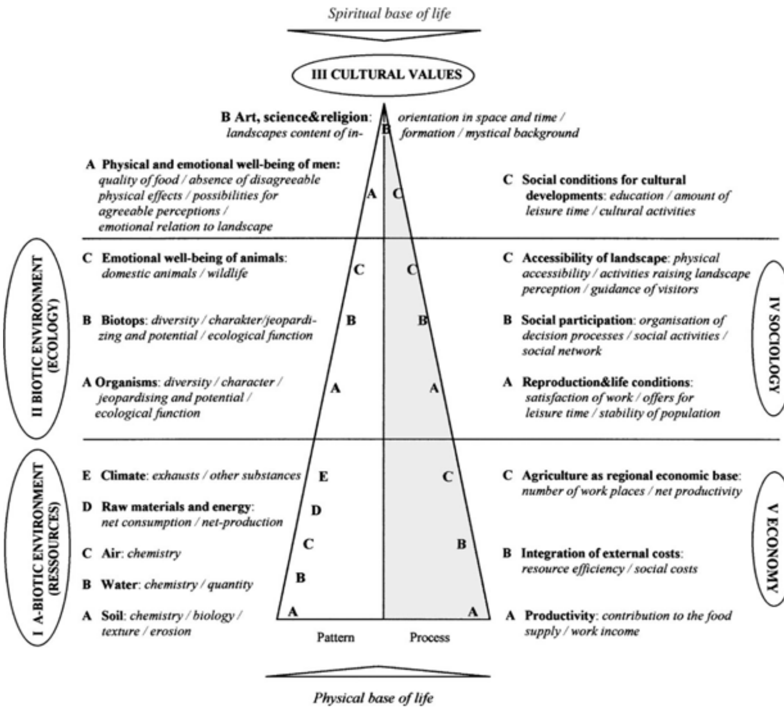

Fig. 2. Criteria for the assessment of land-use sustainability (first level: Bold capital; second level: bold; third level criteria: italics) (Bosshard, 2000).

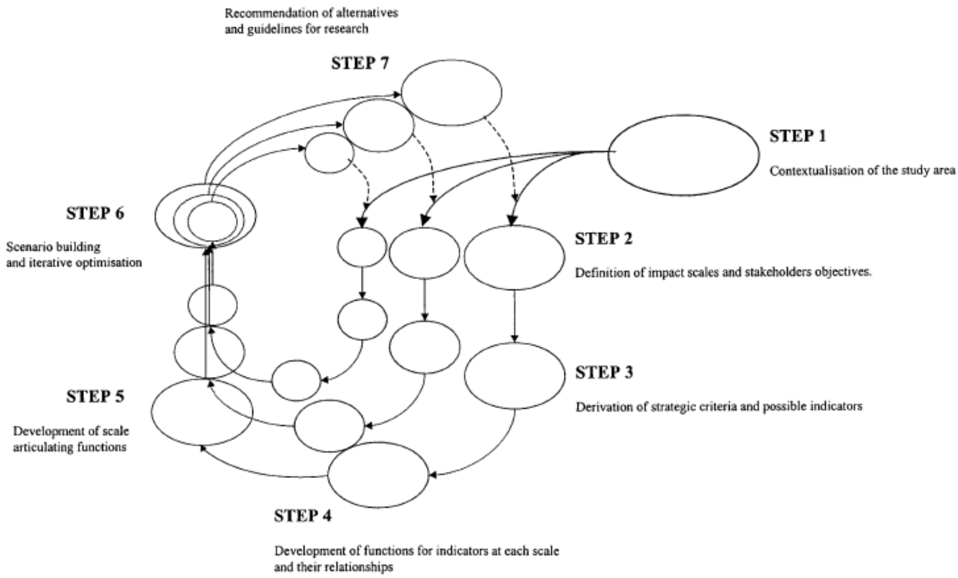

Fig. 3. Multi-scale sustainability evaluation framework proposed by López-Ridaura *et al.* (2005a).

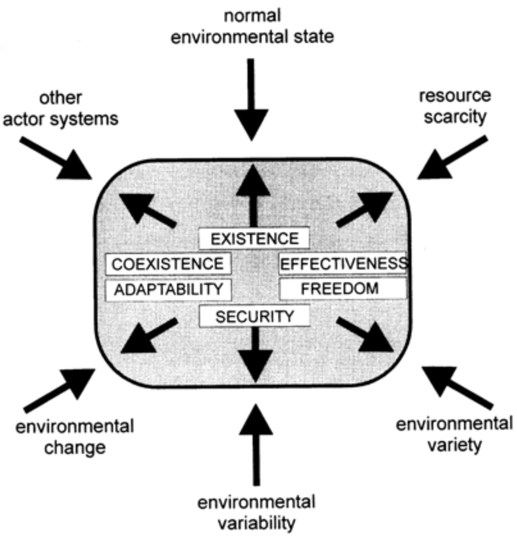

Fig. 4. Basic orientors of a self-organising system in relation to its environment (Bossel, 2000).

IV – Multi-criteria assessment methods

Among the sustainability assessment tools (Ness *et al.*, 2007), three main categories have been intensively used for the analysis of agricultural systems: life-cycle assessment, which is product-related, and modelling and multi-criteria analysis, which are integrated methodologies.

Life-cycle assessment evaluates the environmental impacts of a product throughout its life cycle. It has been applied on livestock farming systems in Germany (Haas *et al.*, 2001), Netherlands (Thomassen *et al.*, 2008) or France (van der Werf *et al.*, 2009) for example. Classically, the indicators are related to environmental aspects, which are typically land use, energy use, green house gases, eutrophication and acidification potentials, which are expressed in different units and relatively to a quantity of product (kg of milk) or a surface (ha). So this method does not draws a global image of the system in all its dimensions, even if some studies include supplementary indicators such as biodiversity, landscape image or animal husbandry (Haas *et al.*, 2001).

The modelling methodology applied to animal farming systems has been reviewed during the last Seminar of the FAO-CIHEAM Subnetwork on Sheep and Goat Production Systems (Tichit *et al.*, 2009, Jouven *et al.*, 2009) and will not further be developed here. It is a way to analyse the behaviour of a system and predict its evolution over time in different hypotheses. As such, modelling allows the ex-ante evaluation of the consequences of a decision or of a situation, and the building of scenarios.

Multi-criteria assessment methodology combines and aggregates competing evaluation criteria in order to give global, intermediate or detailed quantification of the achievement of the objectives. The existing methods (van der Werf and Petit, 2002, Galan *et al.*, 2007, Bockstaller *et al.*, 2008, 2009) differ according to the intended users, the scale considered (field, farm, watershed, region, etc.), the sustainability dimensions, principles and objectives, the mode of construction of the indicators (input, emission or system state-related, means- or effects-based), or the method of aggregation. To illustrate this diversity, we present hereunder some characteristic approaches.

The "Sustainability farm tree" (Pervanchon, 2006) takes into account the three dimensions of sustainability by asking farmers 60 qualitative questions relative to their practices and the state of their system, which results in colouring the different part of the tree (representing environment-reproducibility, transmissibility, economy-viability, territory, liveability-social aspects, governance) in order to give a global image of the sustainability of the farm and of its strengths and weaknesses. This gives the opportunity to exchange between actors, generally inside a group of farmers, in a cooperative process. Another participatory exercise aimed at identifying economic, ecological and societal issues in egg production sustainable development has been presented by Mollenhorst and de Boer (2004) on the basis of a SWOT analysis performed by a group of stakeholders.

The Monitoring Tool for Integrated Farm Sustainability (MOTIFS: Meul *et al.*, 2008, 2009) is based on 47 weighted indicators with scores between 0 to 100, grouped in 10 themes: use of inputs, quality of natural resources, biodiversity (ecological), productivity and efficiency, profitability, risk (economic), internal social sustainability, external social sustainability, disposable income, entrepreneurship (social), with three levels of aggregation. The method has been applied to Flemish dairy farms and the validation of ecological indicators has been implemented.

Van Calker *et al.* (2001, 2005) identified in a participative way attributes and indicators for sustainability assessment of dairy farming in The Netherlands including economic, internal social, external social and ecological aspects, then used them to evaluate the overall sustainability by a multi-attribute utility theory method (van Calker *et al.*, 2006) and to apply a linear programming model in order to test different scenarios (van Calker *et al.*, 2004). It is a good example of the combination of the structure of a multi-criteria framework with modelling.

The French farm sustainability indicators method IDEA ("Indicateurs de durabilité des exploitations agricoles") (Vilain *et al.*, 2008, Zahm *et al.*, 2008) is based on 41 indicators and 10 components covering the three dimensions of sustainability: diversity, organisation of space, farming practices (agro-environmental), quality of the products and land, employment and services, ethics and human development (socio-territorial), economic viability, independence, transferability, efficiency (economic) (Table 1). Sixteen objectives have been identified as sustainability principles: coherence, biodiversity, soil conservation, water preservation, atmosphere preservation, management of non-renewable resources, animal well-being, food quality, ethics, local development, landscape preservation, citizenship, human development, quality of life, adaptability, and employment. The objectives and indicators are interconnected in a matrix, each objective being represented in different indicators (from 4 for employment or animal welfare to 27 for coherence) and each indicator being associated to different objectives (from 2 to 8). This method, designed in the context of French / European situations and references, has been used in south Mediterranean countries (Marie *et al.*, 2009) and appeared to be robust, at least as far as its basic assumptions and concepts are concerned.

Developed in Mexico and tested in different Latin America countries, the Framework for assessing natural resource management systems incorporating sustainability indicators, also called MESMIS, (López-Ridaura *et al.*, 2002) is based on five general attributes associated to sustainability: productivity (capability of the system to provide sufficient goods), stability (reaching and keeping a stable and dynamic balance), adaptability (finding new balance in changing environmental conditions), equity (fair intra- and inter-generational distribution of costs and benefits), autonomy (or self-management). The steps of the method are: (i) the characterization of the system; (ii) the identification of the crucial points which enhance or constraint its attributes; (iii) the identification of a set of diagnostic criteria, then the selection of strategic indicators; (iv) the measurement of indicators; (v) synthesis and integration of results; and (vi) conclusions and recommendations. Such a method is close to Bossel’s conception of the systemic approach, and is flexible because it is contextualized and uses indicators relevant to the situation under investigation.

Table 1. The 3 scales, 10 components and 41 indicators of the IDEA method (Vilain *et al.*, 2008; Zahm, 2008)

Agro-Environmental (19)	Socio-territorial (16)	Economical (6)
• *Diversity* ♦ Diversity of annual or temporary crops ♦ Diversity of perennial crops ♦ Diversity of associated vegetation ♦ Animal diversity ♦ Conservation of genetic heritage • *Organization of space* ♦ Cropping patterns ♦ Dimension of fields ♦ Organic matter management ♦ Ecological buffer zones ♦ Measures to protect the natural heritage ♦ Stocking rate ♦ Fodder area management • *Farming practices* ♦ Fertilization ♦ Effluent processing ♦ Pesticides and veterinary products ♦ Animal well-being ♦ Soil resource protection ♦ Water resource protection ♦ Energy dependence	• *Quality of the products and land* ♦ Quality of foodstuffs produced ♦ Enhancement of buildings and landscape heritage ♦ Processing of non-organic waste ♦ Accessibility of space ♦ Social involvement • *Employment and services* ♦ Short trade ♦ Services, multi-activities ♦ Contribution to employment ♦ Collective work ♦ Probable farm sustainability • *Ethics and human development* ♦ Contribution to world food balance ♦ Training ♦ Labour intensity ♦ Quality of life ♦ Isolation ♦ Reception, hygiene and safety	• *Economic viability* ♦ Available income per worker compared with the national legal minimum wage ♦ Economic specialization rate • *Independence* ♦ Financial autonomy ♦ Reliance on direct subsidies from CAP and indirect economic impact of milk and sugar quotas • *Transferability* ♦ Total assets minus lands value by non-salaried worker unit • *Efficiency* ♦ Operating expenses as a proportion of total production value

V – Implementation in small ruminant systems

1. Lebanon

A sustainability assessment with a modified IDEA method based on 37 indicators has been performed on 129 small ruminant farms in Lebanon (Srour, 2006, Srour *et al.*, 2009), considering 5 different types of systems: zero grazing, sedentary, vertical transhumance, horizontal transhumance, and semi-nomad (Fig. 5). Environmental scores were the lowest ones (40%), from 32% for zero-grazing and vertical transhumance, due to the lack of cultures, to 50% for the sedentary system, vegetal and animal diversity being low. The socio-territorial dimension (score: 53%) was less valued in semi-nomad case (46%) while sedentary (57%) and zero-grazing (62%) presented better performance. The overall economical score was the best (55%), with contrasted situations: low viability linked to low income, high independency for all systems due to the absence of economical support, and contrasted performances for transmissibility and efficiency.

Preservation of local or regional breeds, low use of imported inputs (apart from zero-grazing) with the use of natural rangeland, high level of transmissibility, the quality of the products mainly transformed in the farm and locally consumed, the use of an efficient water management are positive characteristics of this sector. On the other side, the multi-functionality, the level of training, the diversity of annual and perennial cultures, or the lack of forage cultures are weaknesses.

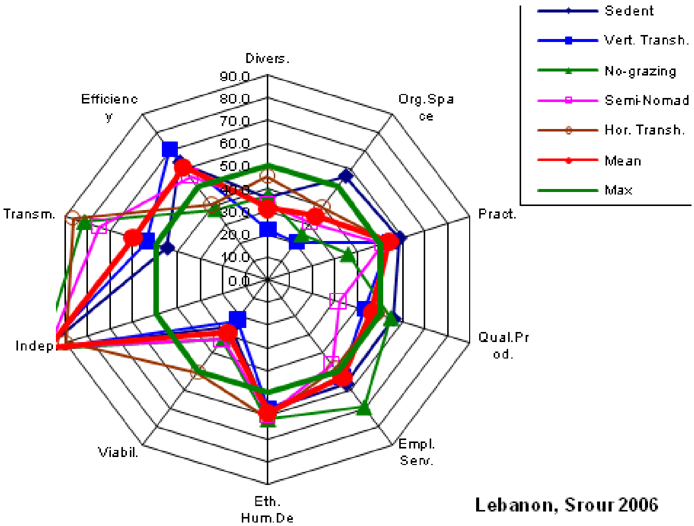

Fig. 5. Evaluation of sustainability of small ruminant systems in Lebanon (Srour, 2006).

The IDEA framework has been conserved, but a high number of modifications have been done in order to adapt the method to the context: variables or scaling of indicators have been modified. Nevertheless, the indicators stocking density, soil fertilisation have not been computed, and hygiene and security concept is not in use in this context.

2. Algeria

The emergence of the phenomenon of settlement in Algerian steppe raises several questions about the impact of settlement on the sustainability of production systems and perenniality of natural resources. In this context, Benidir (2009) conducted an evaluation of the sustainability of 50 sheep farms in the region of Djelfa (Center Algeria plateau) using the IDEA method.

The typological analysis revealed five groups: large farm size with mixed cropping-livestock system, average farm size with ruminant livestock system, average farm size with mixed cropping- small ruminants system, average farm size with cereal crops-small ruminants system, small farms with cereal crops-small ruminants association.

The diversification of productions associated to a shift from pastoral to agro-pastoral mode was associated with agro-ecological and economical good sustainability scores, but lower performances in the socio-territorial dimension (Fig. 6). In fact, in the long-run the environmental component is put at risks by the degradation of the rangeland and of vegetal resources, and the economical performance is weakened by a strong dependency on state subsidies.

Some indicators have not been calculated due to the pastoral conduct of the flock: the stocking density, due to the difficulty to estimate the rangeland forage production (but the stocking rate was estimated as high, resulting in range degradation and loss of plant biodiversity). The nitrogen balance is also difficult to estimate and the fertilisation indicator also has not been measured.

The question of the crop rotation modalities has also to be reconsidered in extensive-arid conditions. The contribution to employment, the question of the economic viability and the minimal level of wages, the economical transmissibility of the farm in relation to inheritance regulations and taxes, all deserve special attention and adaptation to local situation.

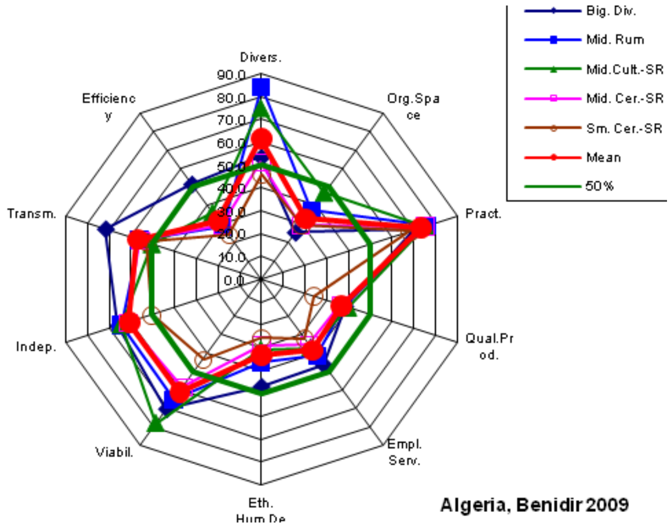

Fig. 6. Evaluation of sustainability of small ruminant systems in Algeria (Benidir, 2009).

3. Spain

Nahed *et al.* (2006) analysed the sustainability of 25 dairy goats systems in the Sierra de Cádiz with the MESMIS methodology. They considered for each of the five attributes those of the 44 indicators more pertinent for this attribute, giving each indicator a score relative to an optimum, derived either from the most favourable observed value or from expert opinion, by a linear relationship. The indicators chosen in this study are reported in the Table 2. The final value of the attribute is obtained from the mean of the scores of all indicators associated to this attribute, which implies a full compensation between indicators and the same weight for each of them.

Three types of production systems have been studied, with different degrees of intensification (semi-extensive, semi-intensive, or intensive), and the scores for each attribute for the three types of systems are reported in Fig. 7. The global sustainability score decreases with increasing intensification (SES: 57.3%, SIS: 55.7%, IS: 53.1%); adaptability is higher in intensive systems due to investment and external inputs, self-management is better for semi-extensive systems, and equity for semi-intensive systems. All systems have low scores for owned area per goat, goat mortality, somatic cells in milk, and diversity in animal species.

In this approach, the question of the aptitude of the indicators used to really evaluate sustainability arises, as these indicators are mainly of economical or biotechnical nature, giving only indirect information relatively to environmental or social issues.

Table 2. Indicators relative to each of the sustainability attributes in the MESMIS assessment method (Nahed *et al.*, 2006).

Productivity (8)	Stability (17)	Adaptability (6)	Equity (4)	Self-management (9)
• Concentrate/milk produced (kg) • Milk sold/goat and year (l) • Fat in milk (%) • Protein in milk (%) • Kids sold/goat and year (heads) • Net margin/l milk produced (€) • Net margin/goat and year (€) • Net margin/family worker/ year (€)	• Presence of Payoya breed or its crosses (% of farm) • Owned area/goat (ha) • Natural pasture area/goat (ha) • Brush area/goat (ha) • Stubble area/goat (ha) • Goats present (heads) • Goat mortality (%) • Kid mortality (%) • Goat replacement rate (%) • Bacteria in milk (_1000/ml) • Somatic cell count in milk (_1000/ml) • Good cataloguing of brucellosis control (% of farms) • Milk price (€/l) • Average kid price (€/head) • Cows/goat (heads) • Sows/goat (heads) • Sheep/goat (heads)	• Farmer's age (years) • Heritage continuity (% of farms) • Formation courses attended by family members (days) • Milking technology (degree of implementation) • Inventory variation/goat and year (€) • Relationship investment/net margin (%)	• Total labour/100 goats (Man Work Unit, MWU) • Family beneficiaries without occupation (no.) • Total family beneficiaries (no.) • External work offers (no.)	• Net energy from grazing (%) • Total area/goat (ha) • Cultivated pasture/goat (ha) • Rented area/goat (ha) • Concentrate/goat and year (kg) • Forage in stable/goat/year (kg) • Proportion of family workforce in relation to total workforce/100 goats (%) • Associations to which he belongs (no.) • Subsidies/goat and year (€)

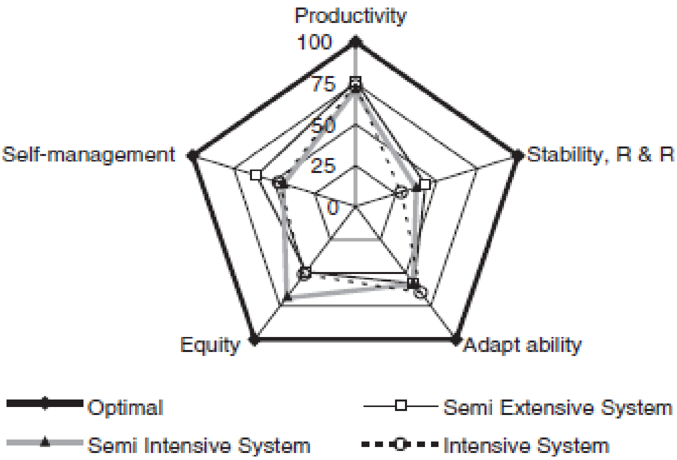

Fig. 7. Evaluation of sustainability of small ruminant systems in Spain (Nahed *et al.*, 2006).

4. France

In a study conducted in the West of France (Poitou-Charentes and Pays de Loire), Bossis (2004) analysed milk goat systems with the IDEA method. Environmental, social and economical mean scores were respectively 68%, 56% and 47%, with large differences among types of modes of production. The low economical scores are explained by a high specialisation of the production and low incomes, particularly in the case of exclusive milk systems (Fig. 8), and by a dependence on subsidies and inputs. The social performance of specialised systems is hampered by the heavy workload, but reinforced by the provision of employment. Generally speaking, the environmental performance is good, particularly for mixed crop-livestock systems where forage is provided on-farm, or for pasture-based systems.

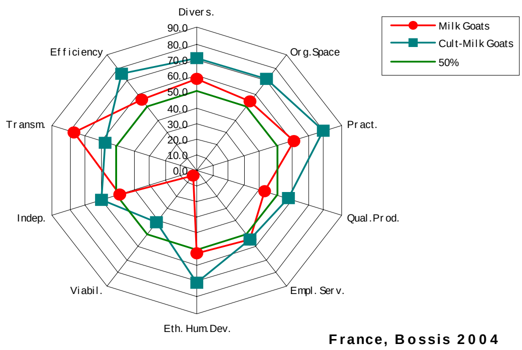

Fig. 8. Evaluation of sustainability of small ruminant systems in France (Bossis, 2004).

In this study, covering either intensive no-grazing, or semi-intensive and mixed crop-livestock systems, the method has been used without major difficulties, relying on well-established references. But, surprisingly, the farms displaying good sustainability and viability scores, such as mixed systems, tend to disappear in this area, when low-rated modes of production (goat-cattle associations), indebted and inputs-dependent, are developing.

VI – Conclusions

Generally speaking, the sustainability assessment of agricultural systems is still in development and has not yet reached its maturity stage. The diversity of approaches is linked to different interpretations and definitions of the concept of sustainability. This led to concurrent methods which have not the same assumptions and objectives, and none of them has yet clearly imposed. Furthermore, most of them need to be validated. Nevertheless, significative progress have been done toward a refinement of the assessment methodology.

In term of small ruminant systems, few sustainability assessments have been conducted, and when it has been done with the same methodology, different adaptations of the method make the comparisons difficult. The multiplicity of small ruminant systems, according to the degree of intensification, the type of production, the mode of production (specialised, mixed), and the environmental context, makes it difficult to use a common tool for their evaluation, apart from considering a generic and holistic approach (which remains to be set). Also, we can notice a lack of available references relative to the Mediterranean context. For example, the nutritive value of the rangeland relatively to the time of the year and the area is generally not documented, which prevents the evaluation of the optimal stocking rate; the organic elements balance is also difficult to measure in a pastoral context, and the social and economical specificities have also to be taken into account.

In order to design a sustainability assessment tool adapted to this context, a participative, multi-disciplinary and multi-centred initiative could lead to the definition of a framework of reference and of tools adapted to the Mediterranean conditions.

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