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TYPOLOGY AND SUSTAINABILITY ASSESSMENT OF RABBIT FARMS IN THE URBAN AND PERI-URBAN AREAS OF SOUTHERN BENIN (WEST AFRICA)

MEDENOU E.H.*, KOURA B.I.†, DOSSA L.H.*

*Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 03 BP 2819 Cotonou, Benin.
†Ecole de Gestion et d'Exploitation des Systèmes d'Elevage, Université Nationale d'Agriculture, BP 43 Kétou, Benin.

Abstract: Analysis of production systems allows scientists to identify their weaknesses, particularly concerning production practices which require improvements at economic, social, and environmental levels. The present study aimed to characterise rabbit farms in the urban and peri-urban areas of South Benin and assess their sustainability using the DIAMOND method, a multicriteria sustainability assessment tool. Ninety-eight farmers were surveyed and individually interviewed. Categorical principal component and two-step cluster analyses were performed on information collected for a typology of farms. Sustainability scores were generated using the scoring scale of the DIAMOND tool. Five types of rabbit farms were identified as follows: modern extensive polyculture, traditional extensive monoculture, modern extensive monoculture, semi-intensive polyculture, and traditional extensive polyculture. Overall, all the rabbit farms had good scores for the economic sustainability pillar but were socially limited. They were all similar in their economic and environmental performances. In particular, semi-intensive farms were the most socially sustainable, whereas traditional farms (either in polyculture or monoculture) showed the lowest social performances. Furthermore, there were significant differences between farms for criteria relating to consumers' demands and resource use. Semi-intensive farms responded best to consumers' demands, whereas the traditional polyculture farm type was the most resource use efficient. Overall, in the urban and peri-urban areas of South Benin, the most sustainable rabbit farms were semi-intensive. Irrespective of farm type, positive coefficients of correlations were recorded among the three pillars of sustainability, being significant between the social and economic pillars on one hand, and between the social and environmental pillars on the other hand. These results suggest that efforts to improve farm social performance would also positively affect their economic and environmental performances and improve overall farm sustainability.

Key Words: *Oryctolagus cuniculus*, small-scale farm, sustainable agriculture, city fringes.

INTRODUCTION

In developing countries, and especially in sub-Saharan Africa and Asia, smallholders are responsible for the largest share of total food production (HLPE, 2013). With the rise in the urban population and the related rising food demand in sub-Saharan African cities in the last two decades, farming and affiliated services have considerably increased in adjacent peri-urban areas (Mwasi *et al.*, 2017). However, relatively little is known about the sustainability of these peri-urban and urban farming activities (Hamilton *et al.*, 2014; Specht *et al.*, 2014; McDougall *et al.*, 2019).

The agricultural sector plays a significant role in Benin's economy, with a contribution of around 28% to the national Gross Domestic Product (INSAE, 2019). It presents many opportunities for reducing youth unemployment and raising economic growth. This is particularly true of its livestock subsector, which offers employment possibilities along many value chains, as well as for other economic sectors such as transport, trade, and veterinary and consulting services.

Correspondence: L.H. Dossa, *hippolyte.dossa@fsa.uac.bj*. Received *March 2020* - Accepted *September 2020*.
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Breeding short-life-cycle farm animal species (small stock), such as rabbits (*Oryctolagus cuniculus*) and poultry, requires little capital and offers possibilities to rural and urban poor people to benefit from high and increasing demands for animal products and by-products (Biasca *et al.*, 2012; FAO, 2014). Indeed, compared with other livestock species commonly kept in Benin (sheep, goats, cattle and poultry), the rabbit offers several advantages, including its small body size, short gestation period, high rate of reproduction and prolificacy, adaptability to inexpensive housing and high feed conversion efficiency (Lebas *et al.*, 1996). Furthermore, its raising presents desirable socioeconomic characteristics (Adedeji *et al.*, 2015), with possibilities for feeding forages and crop by-products that are non-competitive with human food requirements. Combined with its high nutritional quality, these attributes make rabbit an ideal meat-producing animal (Cullere and Dalle Zotte, 2018), especially for the most vulnerable rural and urban populations.

In Benin, the promotion of small stock has benefited from institutional and financial support provided by both national and international organisations through several projects. One of the most recent projects is the Food and Agriculture Organisation (FAO) project implemented in 2019 with the aim of supporting the professionalisation of rabbit production in Southern Benin (FAO, 2018a,b).

However, reliable data on the production and consumption of rabbit meat are still lacking because of the preponderance of diverse and traditional production systems. In addition, the insufficient organisation of the rabbit sector (Adanguidi, 2019) limits the efficiency and effectiveness of actions for its promotion (FAO, 2018a). Although the importance of implementing sustainable rabbit production practices has been widely acknowledged worldwide (Fortun-Lamothe *et al.*, 2012, Cesari *et al.*, 2018, Li *et al.*, 2018), little has been done to measure and determine practical indicators of sustainability at the farm level, especially in the low-input production systems in Africa (Oseni and Lukefahr, 2014). Considering the three pillars (environmental, economic and social) of sustainability, van Veenhuizen (2007) defined sustainable agricultural systems in urban and peri-urban areas as those that are inclusive and productive, provide food and nutritional security and are environmentally friendly. In addition, Lukefahr (2004) first described the same three pillars via the external aspects of his Small-Scale Rabbit Production Model.

Several methods and models have been used to assess sustainability in agriculture and include monodimensional and multicriteria approaches (Bockstaller *et al.*, 2009). Auberger *et al.* (2016) advocated multicriteria assessment methods, as they can be used at different spatial scales according to objectives and target audiences and also facilitate the identification of strengths and weaknesses of studied systems in order to compare or to improve them. The conception of a multicriteria assessment method and particularly the choice of criteria and indicators must integrate local stakeholders' vision on sustainability (De Mey *et al.*, 2011; Coteur *et al.*, 2016). Some multicriteria assessment methods target only the environmental and economic dimensions of sustainability (INDIGO, Life Cycle Analysis), whereas others such as RISE (Hani *et al.*, 2003), IDEA (Vilain *et al.*, 2008), and DIAMOND (Fortun-Lamothe, 2012) include all three dimensions.

The very few studies carried out on farm performance in Benin targeted all agricultural sustainability dimensions (Agossou *et al.*, 2019). However, most of them focused on crop production (Batonon-Alavo *et al.*, 2015; Pougoué *et al.*, 2019). To date, no sustainability assessment studies have been carried out in the smallholder livestock sector in general and in the rabbit production sector specifically. Hence, the main objective of the present study was to assess the sustainability of rabbit farms in urban and peri-urban areas of Southern Benin.

MATERIALS AND METHODS

Study Area

The study area covered the peri-urban and urban zones in the Atlantique, Littoral, and Ouémé departments. This area is geographically situated between 6°22' and 6°40' north latitude and between 2°15' and 2°36' east latitude and includes mainly the municipalities of Abomey-Calavi, Tori-Bossito, Toffo, Allada, Kpomassè, Ouidah, Cotonou, Sèmè-Kpodji, Porto-Novo, and Akpro-Missrété (Figure 1). According to a recent technical report (FAO, 2018b), the Atlantique/Littoral and Ouémé/Plateau departments were the major areas of rabbit meat production, with 30% and 27% of national production, respectively.

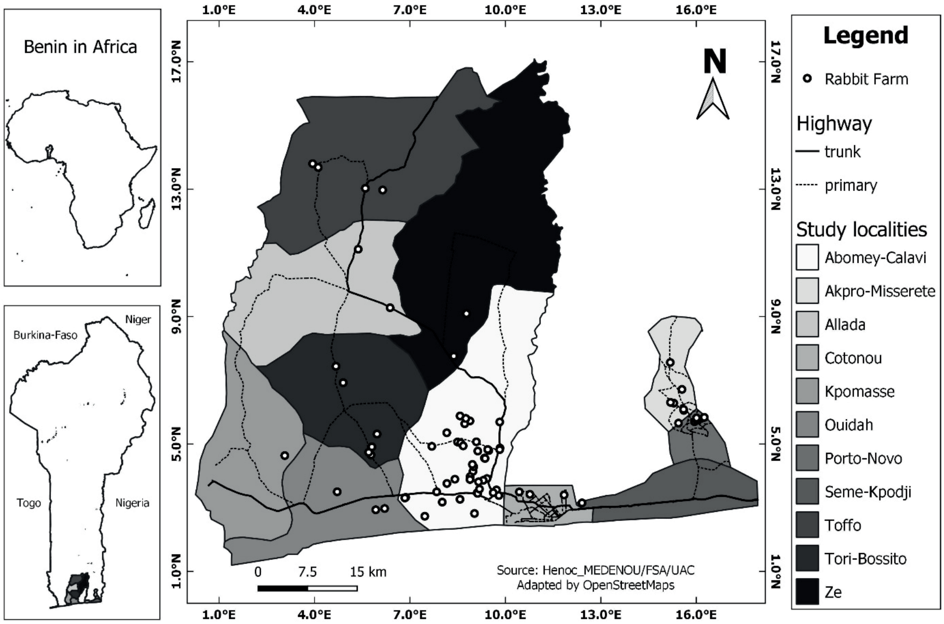

Figure 1: Study area in Southern Benin.

Sampling and Data collection

A total of 98 rabbit keepers were surveyed between October 2018 and February 2019 using a questionnaire based on the DIAMOND method grid and containing, inter alia, questions related to farmers' socioeconomic conditions, rabbit farming practices and farm environment. Snowball sampling, which is a nonprobability sampling approach, was used to select farmers with at least eight does in order to have sufficient economic data about investments and sales.

DIAMOND method

DIAMOND (DIAgnosis of sustainability of rearing units for MONogastric animals, aDaptable to species) is a multicriteria sustainability assessment method applied to monogastric animal production which was developed by Fortun-Lamothe (2012) to evaluate the sustainability of French rabbit production systems. DIAMOND was structured around three sustainability pillars: economic, social, and environmental. It was based on an objectives grid and a set of indicators. A total of six objectives were defined, two for each pillar, and sustainability criteria or indicators were identified for each objective (Table 1).

To adapt the DIAMOND method to the prevailing production context in Benin, some indicators were deleted or carefully modified to maintain the appropriateness of the criteria. Adaptations were made as follows:

- Labour use efficiency (Eco2): This criterion was calculated as follows: number of animals sold per year per rabbit work unit (animal/work unit/year). The "rabbit work unit" is the average time spent by a worker on the rabbit farm; 1 rabbit work unit was equivalent to 2.64 h. The average number of female breeding stock (does) per surveyed production unit was 29. For example, with a standard of 35 saleable young rabbits (kits) per year per doe in tropical conditions (Kpodekon *et al.*, 2018), baseline values have been established.

Table 1: Objectives and criteria for the DIAMOND method.

Pillars	Sustainability objectives	Criteria (10 points)	
Economic (100 points)	Be economically profitable (50 points)	Eco1	Economic viability
		Eco2	Labour use efficiency
		Eco3	Efficiency of the production process
		Eco4	Technical independence
		Eco5	Economic profitability
	Be flexible and adaptable (50 points)	Eco6	Economic specialisation
		Eco7	Sensitivity to public support/financial aids
		Eco8	Financial autonomy
		Eco9	Transferability
		Eco10	Multifunctionality
Environmental (100 points)	Use resources sparingly and/or produce renewable resources (50 points)	Env1	Fossil energy uses
		Env2	Biomass use
		Env3	Water use
		Env4	Link to land
		Env5	Production of renewable energy
	Protect and manage ecosystems (50 points)	Env6	Maintenance of biodiversity and genetic resources
		Env7	Hygienic measures
		Env8	Prophylactic measures
		Env9	Use of antibiotics
		Env10	Management of effluents
Social (100 points)	Preserve the producer's life quality and working conditions (50 points)	Soc1	Socioeconomic viability
		Soc2	Rest and time-off organisation
		Soc3	Intensity of farm tasks
		Soc4	Involvement in professional life
		Soc5	Integration in local community life
	Respond/meet citizens' and consumers' demands (50 points)	Soc6	Product quality and traceability
		Soc7	Animal welfare and living conditions
		Soc8	Practices and animal welfare
		Soc9	Preservation of employment/modes of marketing
		Soc10	Other services

- Technical independence (Eco4): Because of difficulties in using baseline values of the original tool (which are in Euros), the indicator "feeding cost" was replaced by a new indicator that is "share of feed costs in the total production costs", with scores ranging from 0 for share over 80% to 10 for share under 40%.
- Economic specialisation rate (Eco6): Most of the surveyed farms did not keep records of their activity or the workers' contribution to rabbit farming tasks. Hence, two indicators of this criterion were combined into one named "permanent and salaried workforce for the production unit". This criterion is related to specialisation with a farm without any permanent workforce being considered as less specialised than a farm with a permanent workforce. A score of 10 was attributed when there was no salaried and permanent workforce and zero in the opposite case.
- Sensitivity to public support/financial aids (Eco7): This criterion is defined as the farm's flexibility and adaptability to various situations. In the local context, financial aid took many forms, such as equipment loans or donations, and their monetary value was difficult to evaluate. Hence, this indicator was changed to "financial assistance", whereby a score of 10 was given to a farm which did not receive any assistance and 0 otherwise.

- Financial autonomy (Eco8): Loans made to farmers for rabbit production were generally difficult to estimate, especially for those which had diversified their economic activities. This indicator was changed to “loan”, with 10 and 0 points for negative and positive responses, respectively.
- Transferability (Eco9): Indicators for this criterion were arranged and adapted. Indicators related to “transferability of farms according to farmers” were deleted and its scores were distributed over other indicators for the same criterion. In the local context, the children of most of the surveyed farmers were involved in all activities related to rabbit farming. This indicator therefore seemed useless. It was deleted and its scores were distributed over other indicators of the same criterion.
- Use of fossil energies (Env1): Most farms were located on the farmer’s homestead, making it difficult to distinguish between farm energy consumption and farmer’s household energy consumption. Indicators for this criterion were therefore changed to “energy sources”, with a grading scale from 0 to 10 according to the type of energy source.
- Biomass use (Env2): Indicators for this criterion were grouped into only one named “fodder distribution”, with two responses (yes or no). A “yes” response was scored 10 points against 0 for a “no” response.
- Water use (Env3): Only one indicator was reviewed and divided into two indicators —“amount of drinking water” and “water source”— with a grading scale from 0 to 5 for each. The amount of drinking water was estimated based on the amount of feed consumed using the ratio of water/amount of feed developed by Eberhart (1980) and suggested by Gidenne and Lebas (2005) under conditions close to a tropical environment.
- Link to land (Env4): This criterion should rather be seen as “a link to the territory” and it takes into account the distances between the farm and its main input suppliers and consumers. Considering the local context, some indicators were deleted and the grading scale was adapted for the remaining ones. Indeed, there was no specialised centre for supplying selected does/breeders to rabbit farmers. The practice of artificial insemination was almost non-existent. Most breeder rabbit used in natural mating were bought from other farms. Furthermore, all slaughtering activities were farm based. Finally, for this criterion, the indicators “distance between farm and main slaughterhouse (in kilometres, km)”, “distance between farm and rabbit breeder supply centre (kilometres)”, “distance between the farm and the closest insemination centre”, and “distance between farm and the manure spreading place” were replaced by “distance between farm and closest vegetable gardens” and “distance between farm and closest veterinary services”. All the indicators were scored with a grading scale ranging from 0 to 2 except for the indicator “distance between farm and main animal feeding manufacturers”, which was scored based on a scale of 0–3.
- Production of renewable energy (Env5): In the local context, the two original indicators relating to solar hot water and presence of wind turbines on the farm were not relevant. A new indicator “Does the farm possess a solar water pump?” was developed with scores of 0 and 4 for negative and positive responses, respectively.
- Hygienic measures (Env7): One indicator “presence of manure hole under cages” was created to replace the two original indicators relating to sanitary rooms. Its score was 0 for a “no” response and 2 for a “yes” response. Moreover, two indicators related to the sanitary gap period were combined into one named “frequency of sanitary gap”. Indeed, on most of the surveyed rabbit farms, there was no differentiation between doe and kit barns. Hence, the sanitary gap period was the same for both does and kits. The scores for this indicator were 0 for low frequency and 4 for high frequency.
- Prophylactic measures (Env8): Instead of myxomatosis, Viral Haemorrhagic Disease was the priority rabbit disease under monitoring in Benin. Therefore, the indicator relating to myxomatosis was deleted. Similarly, the farms had neither disposal containers nor cadaver freezers. A new indicator “presence of disposal area” was created to combine the latter. Its scores were 0 and 2 for negative and positive responses, respectively.
- Use of antibiotics (Env9): The indicator relating to medicated feed and non-medicated feed was deleted. In the local context, there were no manufactured medicated feeds. Veterinary drugs were mainly administered in drinking water and farmers did not treat does and kits separately. Therefore, the indicators relating to frequency of antibiotic treatment for breeding does and kits were combined into only one indicator, “frequency index of

antibiotic treatments'', and their original grading scale that ranged from 0 to 10 was transformed into an index with scores from 0 to 3.

- Management of effluents (Env10): All original indicators were deleted and replaced by two new ones: "effluents collection for selling" and "effluents use on own farm", with respective grading scales from 0 to 4 and 0 to 2.
- Socioeconomic viability (Soc1): Score calculation was made according to the official national minimum wage in Benin (40 000 FCFA=68 $US).
- Intensity of farm tasks (Soc3): Indicators related to rate of disability, transfer of weaned rabbits and time for the three most painful types of work were deleted because of the difficulty of obtaining such information. The remaining indicators were scored 0 for a negative response and 2 for a positive response.
- Involvement in professional life (Soc4): Other modalities, such as certificate of primary school and university degree, were added to the original modalities. The grading scale ranged from 0 for the lowest education level to 3 for the highest.
- Integration in local community life (Soc5): Indicators such as "use of products to eliminate bad odours on the farm" and "involvement in collective activities" were deleted and their scores distributed over the other indicators. The grading scale was 0 and 5 for negative and positive responses, respectively.
- Product quality and traceability (Soc6): The original indicators were replaced by new ones: "use of custom packaging for the farm", "farm input record", "apparent hygiene condition", and "prophylactic data records". Grading scales were adapted according to their most appropriate indicators.
- Animal welfare and living conditions (Soc7): Indicators related to types of cages were modified as well as their modalities. The new grading scale ranged from 1 for wooden cages to 4 for galvanised wire netting cages.
- Production practices and animal welfare (Soc8): Modalities and the grading scale for the indicator "use of reproductive hormones" were reviewed with "yes" (0 points) and "no" (2 points).

Data analysis

Farm typology

The information collected included both metric and nominal variables. Therefore, categorical principal components analysis (CATPCA), implemented in the module categories in SPSS 21 (SPSS Inc., 2012), was performed to reduce the set of original variables into a smaller number of non-correlated variables (Table 2). Only variables that loaded greater than 0.5 for at least one of the components were selected. The variables retained were then used in the two-step cluster analysis procedure to identify homogeneous clusters of rabbit farms. The groups were then characterised and named. Cross-tabulations, with calculation of Chi-square statistics, were used to compare the obtained farm types for the qualitative variables, whereas means and standard deviation values of the quantitative variables were calculated and compared across types using the nonparametric Kruskal–Wallis test.

Sustainability Assessment

Economic parameters and sustainability scores were calculated for each farm type so that correlation coefficients for pillars scores could be estimated. Finally, farms were compared using the nonparametric Kruskal–Wallis test for pillars and objectives of sustainability. The results are presented using radar, cross-tabulations and histograms.

RESULTS

Rabbit farm typologies

Among the variables selected from the CATPCA (Table 2), watering system, investment level in cages and number of breeding does were used in the two-step cluster analysis, which revealed five types of rabbit farms: modern extensive polyculture (MEP, 31%), traditional extensive monoculture (TEM, 11%), modern extensive monoculture (MEM, 13%), semi-intensive polyculture (SIP, 28%) and traditional extensive polyculture (TEP, 17%) (Table 3).

Table 2: Variables used in categorical principal components and two-step cluster analyses.

Variables	Description (Modalities)	Use in two-step cluster procedure (1=Yes; 2=No)
Nominal variables		
Watering system	Automatic; Manual; Automatic and manual	1
Fodder distribution	Yes; No	2
Other agricultural activities	Yes; No	2
Feed source	Commercial; Self-production; Commercial and self-production	2
Investment level in cages	High; Moderate; Low	1
Use of familial workforce	Yes; No	2
Use of permanent salaried workforce	Yes; No	2
Farm logo	Yes; No	2
Distribution channels	Short; Long	2
Prophylactic programme against VHD	Yes; No	2
Metric variables		
Kits' age at weaning	Day	2
Duration of fattening	Day	2
Farmer's experience in rabbit farming	Year	2
Distance between farmer's homestead and farm	Metre	2
Number of working hours per day	Hour	2
Rabbits sold/doe/year	Kilogram	2
Breeding does	Head	1

Type 1 (MEP, n=30): This farm type had a medium investment level in cages and used mainly a family workforce. In all farms, rabbit raising was associated with other agricultural activities. Most of the farms in this group had no preventive measures against Viral Haemorrhagic Disease (VHD) and had a manual watering system. The breeding does stock was quite high (25.83±19.08 head).

Type 2 (TEM, n=11): This was the least represented group of farms. Those farms showed many similarities with the MEP type, having a medium investment level in cages and using a manual watering system. These units kept rabbits exclusively and an average number of 19.73±10.17 does. The workforce was exclusively familial. Almost all farms in this group had no prophylactic measures against VHD.

Type 3 (MEM, n=13): Similar to TEM farms, farms in this group kept rabbits exclusively but had a high investment level in cages. The stock of breeding does was the smallest (10.85±5.79 head, $P<0.001$) and the workforce was mainly familial. Similar to the TEM farm type, most farms in this group had no preventive measures against VHD.

Type 4 (SIP, n=27): Farms in this group kept the largest ($P<0.001$) number of breeding does (55.70±50.85 head). They were also characterised by a high investment level in cages and practiced the use of an automatic watering system. Rabbit raising was associated with other agricultural activities. In contrast to the other types, a permanent salaried workforce was used in half of the farms and about 52% of farms in this group had preventive measures against VHD. It also had the highest number of work hours per day ($P<0.05$).

Type 5 (TEP, n=17): This group was characterised by a low investment level in cages as well as a small number of breeding does (12.76±5.44 head). Rabbit raising was associated in all the farms with other agricultural activities. The watering system, as in TEM type, was exclusively manual and the familial workforce was predominant; however, those farms had the lowest number of work hours per day. Most of the farms in this group had no preventive measures against VHD.

Table 3: Characteristics of the five types of rabbit farms identified in the urban and peri-urban areas in Southern Benin.

Variables	MEP (n=30)	TEM (n=11)	MEM (n=13)	SIP (n=27)	TEP (n=17)	Chi²	*P*-value
	Types of rabbit farms						
Frequencies (%)							
Investment level in cages						182.907	0.000
High	0.0	0.0	84.5	100	0.0		
Medium	100	100	0.0	0.0	0.0		
Low	0.0	0.0	15.4	0.0	100		
Other agricultural activities						88.499	0.000
Yes	100	0.0	0.0	92.6	100		
No	0.0	100	100	7.4	0.0		
Watering system						27.620	0.001
Automatic	0.0	0.0	7.7	37.0	0.0		
Manual	96.7	100	92.3	63.0	100		
Automatic and manual	3.3	0.0	0.0	0.0	0.0		
Prophylactic programme against VHD						17.247	0.002
Yes	16.7	9.1	7.7	51.9	11.8		
No	83.3	90.9	92.3	48.1	88.2		
Familial workforce						21.001	0.000
Yes	80.0	100	92.3	48.1	94.1		
No	20.0	0.0	7.7	51.9	5.9		
Permanent salaried workforce						19.563	0.001
Yes	30	0.0	7.7	51.9	5.9		
No	70	100	92.3	48.1	94.1		
Means±standard deviation							
Working hours per day	$2.53^{ab}\pm1.07$	$2.36^{ab}\pm0.81$	$2.15^{ab}\pm0.80$	$3.00^{b}\pm1.30$	$1.88^{a}\pm1.05$	-	0.042
Breeding does stock (head)	$25.83^{bc}\pm19.08$	$19.73^{abc}\pm10.17$	$10.85^{a}\pm5.79$	$55.70^{c}\pm50.85$	$12.76^{ab}\pm5.44$	-	0.000

MEP=Modern extensive polyculture; TEM=Traditional extensive monoculture; MEM=Modern extensive monoculture; SIP=Semi-intensive polyculture; TEP=Traditional extensive polyculture.

[a,b,c]Different letter on the same row is related to significant differences between means according to the Kruskal–Wallis test.

Overall performance of rabbit farms for the three sustainability pillars

Table 4 shows the sustainability performance of rabbit farms in the urban and peri-urban areas in Southern Benin. Overall, all the farms, irrespective of their type, showed a low value on the social pillar. In contrast, most of them were strong on the economic pillar. Indeed, most of them were financially autonomous, insensitive to financial aid and had a good level of transferability, despite the fact that many of them were not viable or profitable (Figure 2). Therefore, they had a better appreciation of resource use than ecosystem protection. The correlations among the three sustainability pillars were positive and low to moderate (Table 5), being statistically significant between the social and the environmental ($P<0.05$) pillars on the one hand, and between the social and economic ($P<0.01$) pillars on the other.

Table 4: Sustainability performances (scores) of rabbit farms in urban and peri-urban areas in Southern Benin (n = 98).

Sustainability pillars	Minimum	Maximum	Mean	Standard deviation
Economic	33.0	88.0	62.959	12.930
Environmental	32.0	81.0	52.240	10.318
Social	28.5	73.0	46.138	10.390

Table 5: Correlations between the three economic, environmental and social sustainability scores (n=98).

Pillars	Economic	Environmental	Social
Economic	1	0.188	0.402**
Environmental	-	1	0.240*
Social	-	-	1

Correlation is significant at *P<0.05, **P<0.01.

Comparison of sustainability performance across the different types of rabbit farm

There were no significant differences among farms for the economic and environmental pillars. TEM and TEP farms showed the lowest (P<0.001) scores for the social pillar and SIP had the highest score (Figure 3).

All types of rabbit farms were similar for all sustainability criteria except for consumers' demands and resource use (Figure 4). Regarding resource use, TEP showed the highest (P<0.05) score and MEM had the lowest. The highest (P<0.001) value for consumers' demands were obtained in the SIP type and the lowest in TEM and TEP farms.

Furthermore, the SIP farm type showed the highest score for profitability, ecosystem protection and farmers' demands criteria and the lowest for flexibility–adaptability, while the difference with the other types was not significant.

DISCUSSION

Diversity of rabbit production farming

In this study, five types of farms were identified in the urban and peri-urban areas of Southern Benin. This typology was based on three criteria: investment level in cages, other farming activities and the number of breeding does. These criteria were related to farmers' technical capabilities. This finding is in line with those of Colin and Lebas (1995), who proposed three families of criteria for classification of rabbit farming systems, as follows: farmers' technical level, farm social and economic orientation, and farm location. Our findings have some similarities and differences with the typology used in the technical report produced by FAO in Benin (FAO, 2018a,b). Indeed, this report, using production rhythm, feeding improvement and breeding doe stock as the main classification criteria, distinguished three types of rabbit farming, described as traditional, traditional improved and semi-intensive. The first

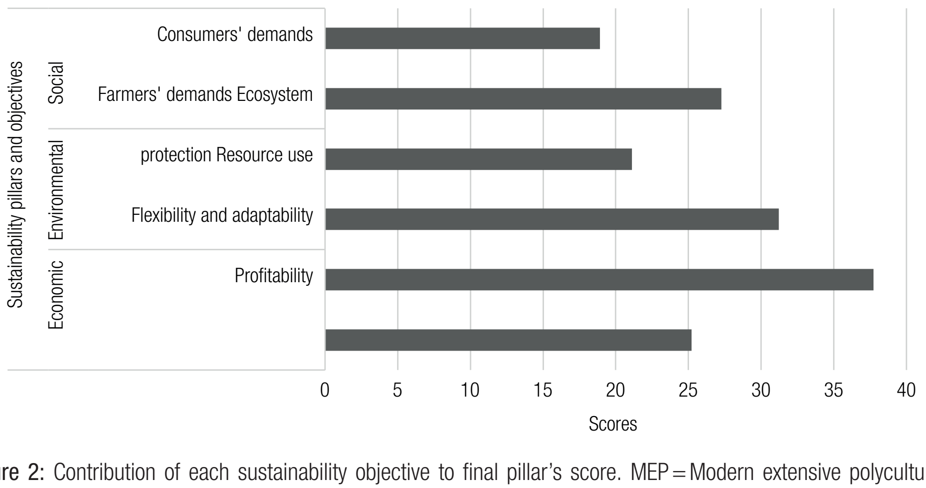

Figure 2: Contribution of each sustainability objective to final pillar's score. MEP=Modern extensive polyculture; TEM=Traditional extensive monoculture; MEM=Modern extensive monoculture; SIP=Semi-intensive polyculture; TEP=Traditional extensive polyculture.

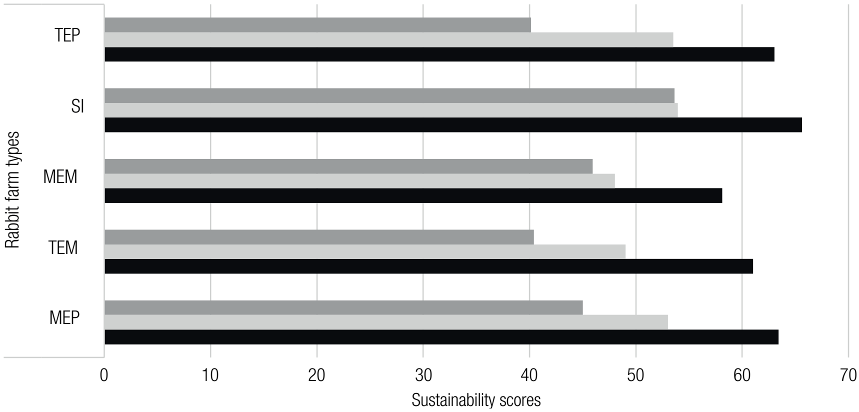

Figure 3: Performances of the five rabbit farm types based on the three sustainability pillars. MEP = Modern extensive polyculture; TEM = Traditional extensive monoculture; MEM = Modern extensive monoculture; SIP = Semi-intensive polyculture; TEP = Traditional extensive polyculture. ■ Social; ■ Environmental; ■ Economic.

two types were respectively similar to the traditional extensive breeding (monoculture and polyculture) and modern extensive breeding (monoculture and polyculture) found in the current study, whereas semi-intensive polyculture was common to both studies. The number of breeding does and the origin of the farm labour were also important discriminating variables in our typology. These two variables were previously used by Serem *et al.* (2013) in Kenya and Kimse *et al.* (2017) in Côte d'Ivoire.

Sustainability Assessment of rabbit farms

Overall, although low to moderate, the coefficients of correlation among the pillars were positive, implying an absence of antagonism between pillars. These results are in line with previous findings of Forthun-Lamothe *et al.* (2011) and Forthun-Lamothe (2012).

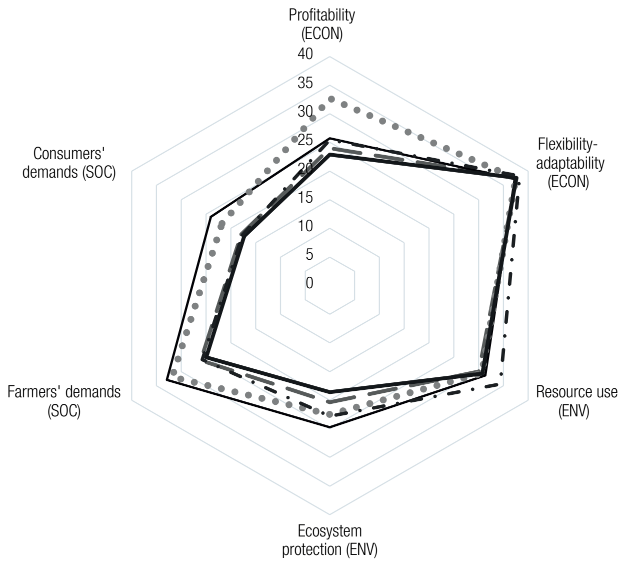

Figure 4: Comparison of the five rabbit farm types for each sustainability criterion. — — MEP; —— TEM; • • • • MEM; —— SIP; – • – TEP.

Irrespective of farm type, the social pillar was the weakest in terms of performance among the three sustainability pillars. This finding is in line with the results of a previous farm sustainability study reported by Agossou *et al.* (2019) in Southern Benin using the IDEA method (Farms Sustainability Indicators - *Indicateurs de Durabilité des Exploitations Agricoles*). Similar results were also reported by Fortun-Lamothe *et al.* (2011) for French rabbit farms. Many reasons could explain the low social performance of farms recorded in the current study. First, most rabbit keepers were neither affiliated with any professional organisation nor associated with any production certification or labelling initiative which could guarantee traceability and good product quality. Secondly, many farms did not include agritourism activities or non-agricultural services for the local communities. They thus failed to meet some of the citizens' and consumers' demands. In addition, while raising rabbits is a labour-intensive endeavour, most of the daily tasks performed on these farms were done manually. The level of intensity of some daily farm activities carried out by hand has been previously reported by Mahmoudi *et al.* (2019) as the main factor that weakens the level of socioeconomic sustainability of layer poultry farms in Algeria.

The social pillar was also the one that best discriminated the identified rabbit farm types regarding their overall sustainability. Semi-intensive farm types were the most sustainable, followed by modern ones (MEP and MEM). The traditional farms (TEM and TEP) were revealed as the least sustainable. The semi-intensive rabbit farms were likely better than the others in meeting citizen and consumer demands. Indeed, the investment level in cages in the traditional farms was low and did not allow improving the management practices, which would address animal welfare. Moreover, the family workforce was dominant in these types of farms. Consequently, few jobs were created on these farms.

Overall, the environmental pillar obtained good scores for almost all types of rabbit farm, even though their scores for ecosystem protection were weak. This could be explained by the fact that most farmers did not put in place any strategy to preserve biodiversity, including the management and conservation of farm animal genetic resources, and to transform their waste into renewable energy. Indeed, although literate, the farmers might have limited knowledge and awareness of these environmental issues. There is thus a need for awareness raising and an improvement in rabbit farmers' ability to achieve durable environmental management through specific training. Moreover, most of the extensive farms did not have any preventive measures against VHD, or for maintaining proper hygiene or waste management. Nevertheless, the criterion related to resource use discriminated different farm types. The modern extensive monoculture and traditional extensive polyculture farms obtained, respectively, the lowest and highest scores for this criterion, confirming the associations between farm diversification and their resource use efficiency (Kansiime *et al.*, 2018). Furthermore, in contrast to the findings of Fall *et al.* (2004), the present study showed that in urban and peri-urban areas, the traditional extensive polyculture and semi-intensive farms had similar resource use practices. Indeed, in addition to the biomass consumption factor examined by Fall *et al.* (2004), other factors such as use of fossil energies and management of water resources were considered in the current study to analyse resource use in production systems.

Overall, the economic pillar was revealed as the strongest of the three sustainability pillars of rabbit farms in the urban and peri-urban areas of South Benin, although most of these farms were not economically viable. This could certainly be explained by their high flexibility and adaptability.

Furthermore, the significant coefficients of correlation between the social and economic pillars on the one hand and between the social and environmental pillars on the other hand suggest that efforts to improve farm social performance would also positively affect their economic and environmental performances and improve overall farm sustainability.

Limitations

The current study was carried out to assess the sustainability of rabbit farms in the urban and peri-urban areas of Southern Benin. To achieve this, the DIAMOND method, developed in the French context, was used after some adaptations to the local production situation. However, quantitative data, especially those related to the economic aspects of production, were difficult to obtain under field conditions, as the farmers do not keep adequate farm records. Thus, there is a need to further refine the different indicators in concert with farmers' cooperatives and associations, as well as independent farmers, in order to improve the adaptation of this model to the production situation in Benin. Furthermore, due to the lack of a formal sampling frame, a snowball sampling approach was used, which proved to be very useful in reaching the farmers. Hence, the interviewed rabbit farmers were not randomly drawn but were dependent on the subjective choices of the respondents first accessed. There was therefore a lack of control on the sampling, as the samples could have been biased towards the inclusion of individuals with similar characteristics, thus limiting the generalisation of the findings.

CONCLUSIONS

Our study revealed the existence of five types of rabbit farm in the urban and peri-urban areas of Southern Benin. These farm types were distinguished according to their level of investment in cages, their watering system and the number of female breeding stock. Among the three pillars of sustainability, the social pillar was the weakest for most farms, being the main factor that discriminated among them. The traditional farm types, either in monoculture or polyculture, were the least socially sustainable, whereas the semi-intensive system was the most socially sustainable. With regard to the economic and environmental pillars, all the rabbit farm types identified in this study were similar except for resource use, in which traditional farms in polyculture ranked the best. Taking into account all three pillars, the semi-intensive polyculture farms seemed to be the most sustainable. Nevertheless, perspectives to improve rabbit production in the study areas should focus on improving the social integration aspects for all the farm types identified.

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