Journal of Animal &Plant Sciences, 2015. Vol.25, Issue 1: 3814-3827
Publication date 4/5/2015, **http://www.m.elewa.org/JAPS**; *ISSN 2071-7024*

Improving small-scale farmers' endogenous crop-livestock practices in rural, peri-urban, and urban areas of Benin

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Keywords: Mixed farming, Manure, crop residues, sustainable agriculture, urbanization.

1 SUMMARY

This study aimed at a describing indigenous crop-livestock systems used in rural, peri-urban and urban areas of Benin for their improvement. A socioeconomic survey was conducted in three areas and two hundred and forty (240) farmers were interviewed on their practices. Three integration levels were identified; no integration (NI, 36%), partial integration (PI, 55%) and total integration (TI, 9%) and the obtained groups were characterized. Then, a multiple correspondence analysis was performed to identify partial integration subgroups. Main Integrated Crops Livestock Systems (ICLS) identified ranged from Low external input agriculture (LEIA) to High external input agriculture (HEIA). While rural farmers preferred Mixed Crop-Livestock Farming with enhancement of cereals and legumes residues (PI) and Mixed Crop-Livestock Farming with utilization of manure and crop residues (TI), those from peri-urban area preferred Mixed Crop-Livestock Farming with value ascribed to roots/tubers residues (PI). Urban farmers' practices were Mixed Crop-Livestock Farming with utilization of bought poultry dejections (PI). Improvement of these systems can be done through a better adequacy of production systems to valorise available crop residues and manure. This is a good issue for smallholders' empowerment and nutrients recycling in farms.

2 INTRODUCTION

The challenge of agriculture today is to ensure food security in a safe environment. Ongoing crises in agriculture characterized by decreasing soil fertility in farms (Dercon, 2002), feed scarcity in livestock (Coulibaly, 2007; Koura *et al.*, 2015) and reduction of space allocated to production (Vall *et al.*, 2006; Koura *et al.*, 2015) imposes changes in farmers' practices. A good way to ensure intensive production with ecological benefits on environment is in integrating cropping and livestock rearing (McIntire *et al.*, 1992; Rufino, 2008; Franke *et al.*, 2010; Vall *et al.*, 2012). These systems are known to improve small farmers' adaptation to ongoing risks in sub-Saharan Africa (Smith *et al.*, 1997 and Vall *et al.*, 2012). Integrated crop–livestock systems (ICLS) are wild-spread in southern Africa and many scientific works reveal diversity in practices (Vall *et al.*, 2012). While in the developed countries, there is a trend to return to agricultural practices of the past (Lemaire *et al.*, 2014) and improve them, in the developing countries, on the contrary, producers remain with traditional practices that they are unable to improve (Dugue and

Dongmo, 2004; Vall *et al.*, 2012). In Benin, crop-livestock systems have received little scientific attention up to now. In addition, like all agricultural systems, integrated practices may be influenced by environmental ongoing changes. Beyond climate change, urbanization is one the biggest process that influences production systems (Chaibou et al., 2011; Koura et al., 2015). From an analysis of links between agriculture and livestock rearing through manure and crop residues utilization, our study aims at a characterization of indigenous crop-livestock practices and an identification of ways for their improvement in rural, peri-urban and urban areas of Benin.

3 MATERIALS AND METHODS

3.1 Study area: The study was conducted in rural, peri-urban and urban areas of Benin where two municipalities were randomly chosen in each area. Characteristics of the three areas (figure 1) are presented in table 1.

Table 1: Characteristics of the surveyed areas

Areas	Rural	Peri-urban	Urban
Climate (Akoègninou *et al.*, 2006)	Sudan type with one rainy season of among 900-1300 mm/year	Guinean type with two rainy seasons and about 800 to 1.400 mm of rain per year	Guinean type with two rainy seasons and 1000 to 1400 mm of rain
Soil (Volkoff, 1976)	Tropical ferralitic type	Ferralitic and hydromorphic types	hydromorphic and sandy types
Crop production (INSAE, 2014)	Food crops: Yams, cereals, peanuts; Industrial crops like soybean and cotton	Food crops: Maize, cassava, peanuts; Industrial crop: pineapple and oil palm trees	Gardening crop, maize, peanuts, cassava production
Animal production (INSAE, 2014)	Poultry, cattle, small ruminants and pigs	Poultry, small ruminant and pigs	Poultry, small ruminant, rabbit, pigs.
Localization of interviewed municipalities	Bembereke (North 09°58' to 10°40 and East 2°04' to 3°) and N'Dali (North 09°29' to 9°51' and East 2°10' to 2°43')	Ze (North 6°32' to 6°87' and East 2°13 to 2° 26) and Tori-bossito (North 6°25' to 6°37' and East 2°1' to 2°17')	Seme-podji (North 6°22' to 6°28' and East 2°28' to 2°43') and Cotonou (North 6°15' to 6°22' and East 2°20' to 2°27')
Distance from urban centres	0 km	30 km	90 km

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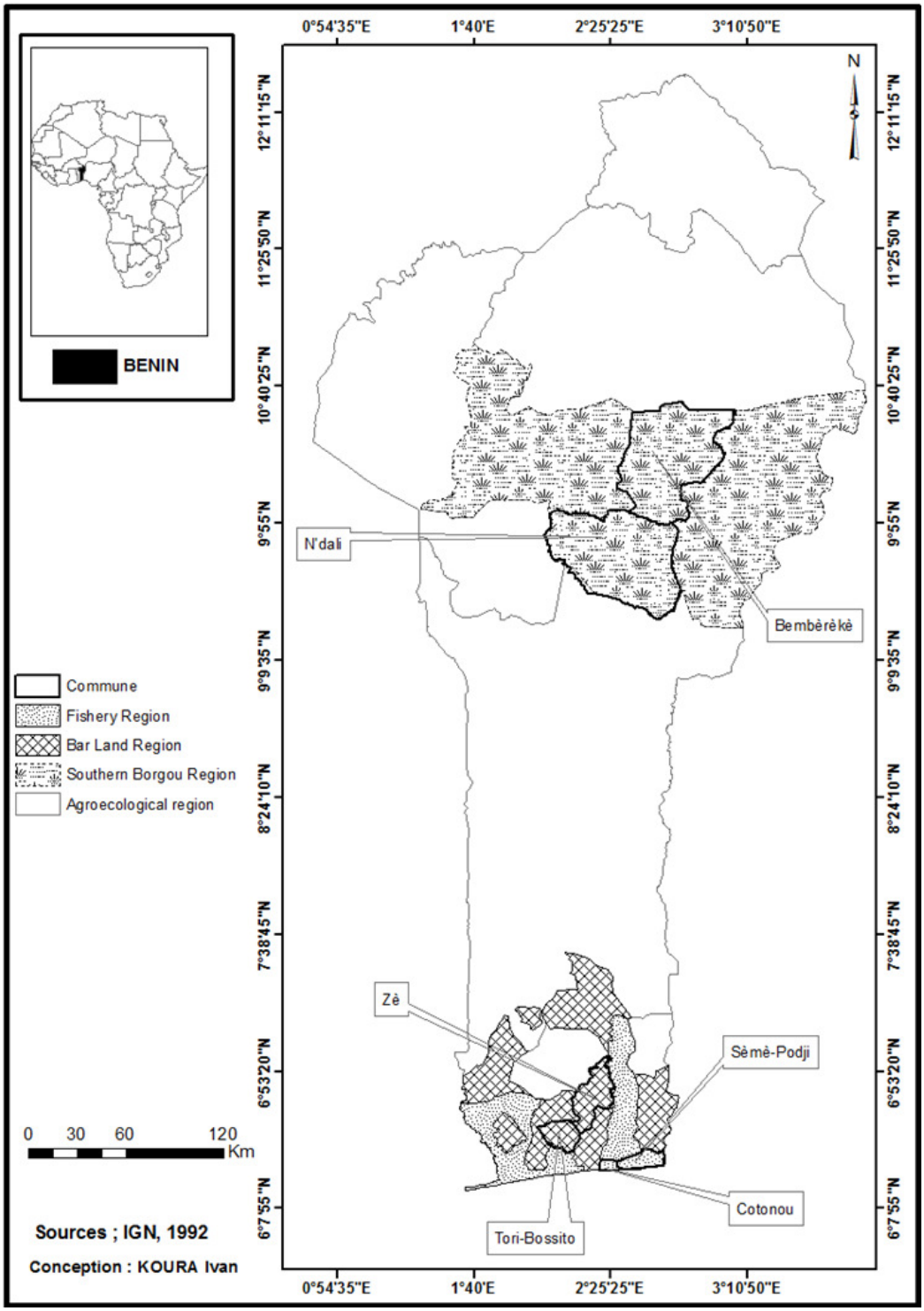

Figure 1: Map of the study area showing the surveyed municipalities

3.2 Data collection: From July to October 2013, 240 farmers were surveyed in the three areas. A snowball sampling procedure (Babbie, 2009) was used to randomly select and interview 40 farmers per municipality. A semi-structured questionnaire including information on farmer's characteristics and their productions practices was used for the survey. Table 2 shows variables that were included in this questionnaire.

Table 2: Description of variables used for farms integration practices characterization

Variables	Description
AREA	Socio-economical characteristics of the area *(rural, Peri-urban, urban)*
EDUC	Formal education level of the head of household *(none, primary, secondary)*
LITERACY	The head of household is literate *(yes, no)*
ASSOMEMB	The head of household is member of an association in the village *(yes, no)*
UR_CER	Cereal residues utilization *(yes, no)*
UR_LEG	Legume residues utilization *(yes, no)*
UR_RT	Roots/tubers residues utilization *(yes, no)*
UR_VEG	Vegetables residues utilization *(yes, no)*
UD_CATTLE	Manure utilization *(yes, no)*
UD_SRUM	Small ruminants dejections utilization *(yes, no)*
UD_POULTRY	Poultry dejections utilization *(yes, no)*

3

.3 Data analysis: Statistical analysis was implemented in the module categories SPSS / PASW 17 (SPSS Inc., 2010). Based on practices of "manure for fertilization" and "crop residues for feeding", three levels of integration were identified: (1) No integration (NI: utilization of neither crop residues nor manure), (2) partial integration (PI: utilization of either manure as fertilizer or crop residues for feeding purposes) and (3) total integration (TI: utilization of both manure and crop residues). As all the variables were qualitative, cross-tabulations and χ^2 statistics were used to compare the use of residues with respect to integration levels in the three areas. Then, a multiple correspondence analysis (MCA) was performed to identify homogenous sub-groups of farmers with partial integration practices. The area where the farm is located; the utilization of residues from cereals, root/tubers, legumes; and the use of manure ; the educational level, the literacy and the association membership of farmers were used as characteristics of variables. Variables that were loading one of the two components were more than 0.5, likely to be retained for sub-groups characterization.

4 RESULTS

4.1 Valorisation of manure and crop residues : Crops residues used as feedstuffs were from cereals (maize: *Zea mays*, sorghum: *Sorghum bicolor*), legumes (bean: *Vigna unguiculata*, peanut: *Arachis hypogea*, soybean: *Glycine max*), roots and tubers (yams *Dioscorea spp.* and cassava *Manihot esculenta*) and vegetables. Manure on the other hand was commonly from cattle, small ruminants and poultry.

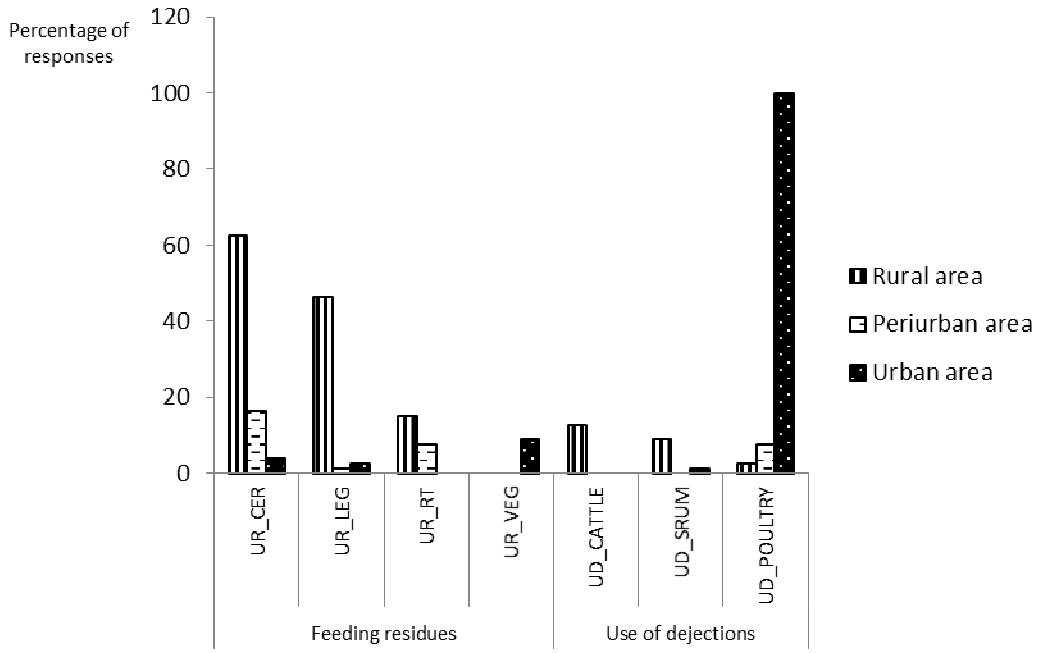

Figure 2: Use of residues and manure in the three areas (Rural, Peri-urban, Urban)

Regarding figure 2, utilization of crop residues and manure varied significantly ($p<0.001$) according to areas. In general, crop residues were more used in rural than urban areas (69% of farmers against 16% for manure) and manure were more used in urban than rural areas (100% of farmers against 9% for crop residues). Residues and manure were less used in peri-urban area (respectively 19% and 8% of farmers). In rural areas, residues of cereals (63% of farmers), legumes (46%) and roots/tubers (15%) (Yam) and manure from cattle (13%) were mainly used. In peri-urban area, on the other hand, residues of root/tubers (8%) (cassava ones) were used, though by very few farmers. Soil fertility restoration was ensured in these areas by the utilization of residues from legumes in priority on the one side. Urban farmers mainly used residues from vegetables (9%) and manure (100%) bought from peri-urban semi industrial poultry production on the other side.

4.2 Crop-livestock integration: Farmers integrated mainly through "manure for fertilization" and "crop residues for feeding" in Benin. However, the use of draught powered animals existed in rural area of the northern Benin. In the three areas, only 9% of interviewed farmers had admitted total integration practices, while around 55% of farmers admitted partial integration and 36% of farmers, no integration. These integration levels varied significantly ($p<0.001$) with the urbanization level of the areas (figure 3).

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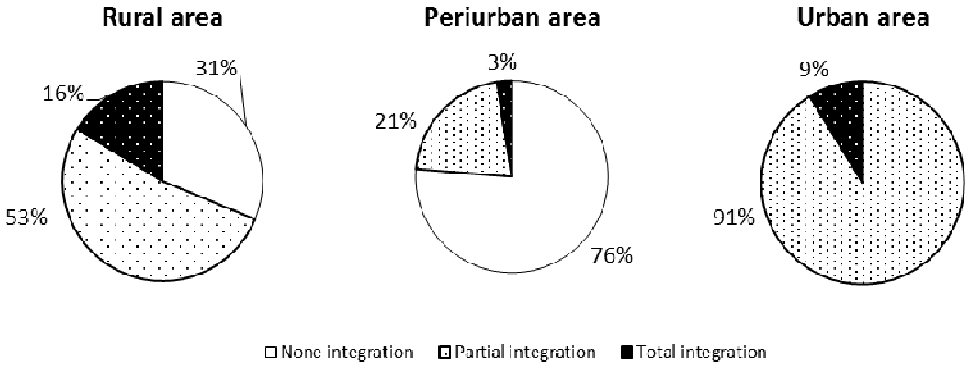

Figure 3: Distribution of farmers' integration practices levels according to the three areas

Integration practices were systematically used in urban area. Few farmers, on the contrary, use the two integration types (PI, 21% and TI, 3%) in peri-urban areas. Partial integration was common in urban area (91%), while total integration practices were more used in rural (16%) than area. In general, the proportion of partial integration was higher than that of total integration in the three areas.

4.3 Valorisation of manure and crop residues in integration: Manure and crop residues were differently ($p<0.001$) valorised for each integrated system in the different areas. Manure was often used, more than crop residues. Also, there was a trend of farmers to use each of those by-products alone (PI type). In rural area, crop residues were mainly used alone (76%), while manure (100%) was full used in total integration system. At the opposite of rural areas, urban farmers used all crop residues (100%) in total integration system and 91% of them only used manure (PI type). Peri-urban farmers used the two by-products, each on its own (87% used residues and 67% use manure).

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Table 3: Valorisation of crops residues and manure in the three areas

Variables	**Rural**				**Peri-urban**				**Urban**				***Overall***			
	n	PI	TI	*sig*	n	PI	TI	*sig*	n	PI	TI	*sig*	n	PI	TI	*sig*
		%				%				%				%		
UR_CER				*ns*				*ns*				***				**
No	5	60	40		6	83	17		79	92	8		88	92	8	
Yes	50	78	22		13	92	8		3	0	100		66	79	21	
UR_LEG				*ns*				*ns*				***				***
No	18	83	17		18	89	11		78	94	6		114	91	9	
Yes	37	73	27		1	100	0		2	0	100		40	70	30	
UR_RT				*ns*				*ns*				-				*ns*
No	43	77	23		13	92	8		80	91	9		136	87	13	
Yes	12	75	25		6	83	7		0	0	0		18	78	22	
UR_VEG				-				-				***				***
No	55	76	24		19	89	11		73	100	0		147	90	10	
Yes	0	0	0		0	0	0		7	0	100		7	0	100	
UD_CATTLE				***				-				-				***
No	45	93	7		19	89	11		80	91	9		144	92	8	
Yes	10	0	100		0	0	0		0	0	0		10	0	100	
UD_SRUM				***				-				***				***
No	48	88	12		19	89	11		79	92	8		146	90	10	
Yes	7	0	100		0	0	0		1	0	100		8	0	100	
UD_POULTRY				**				*				-				*ns*
No	53	79	21		13	100	0		0	0	0		66	83	17	
Yes	2	0	100		6	67	33		80	91	9		88	88	22	

na: not applicable; ns: not significant; *: ($p < 0.05$); **: ($p < 0.01$); ***: ($p < 0.001$)

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Partial integration (PI, 132 farmers): All kind of residues except vegetables were mainly used in partial integration (Table 3). Rural farmers used residues of cereals (78% of farmers who use cereals in integration), legumes (73%) and yams (75%) for feeding small ruminants. Those residues came from either their farm or village farms. Farmers from peri-urban areas preferred the use of purchased manure from poultry (67%) to fertilize field for pineapple production than other dejections. Alike peri-urban farmers, urban farmers used purchased poultry manure (91%). Those urban producers of vegetables could not manage production on their poor sand soil without organic fertilizers. Subgroups of farmers using partial integration practices were identified. Table 4 gives a description of practices with residues of cereals, legumes, root/tubers and animal manure at different rates. Results of multiple correspondence analysis suggested three groups of farmers (table 5); (i) *Mixed Crop-Livestock Farming with valorisation of cereals and legumes residues* (32% of PI farmers) present in rural area; (ii) *Mixed Crop-Livestock Farming with valorisation of roots/tubers residues* (13%) in peri-urban area and (iii) *Mixed Crop-Livestock Farming with purchased poultry manure* (55%) mainly practiced in urban area.

Table 4: Results of MCA analysis on PI system farms

Mean Cronbach's Alpha[a]	0.730	
Mean Eigenvalue	2.770	
Mean % variance	34.627	
	Dimension	
	1	2
Cronbach's Alpha	0.856	0.410
Total Eigenvalues	3.981	1.559
% total variance	49.762	19.493
Label	**Component loading**	
UR_CER	0.855	0.005
UR_RT	0.249	0.232
UD_POULTRY	0.921	0.002
UR_LEG	0.523	0.128
EDUC	0.106	0.225
LITERACY	0.114	0.397
ASSOMEMB	0.286	0.061
AREA	0.926	0.511

a. Mean Cronbach's Alpha is based on the mean Eigenvalue

Table 5: Subgroups of farmers that used partial integration practices

Area	MF_CL	MF_D	MF_RT	*N* farmers
		%		
Rural	**79**	21	0.0	42
Peri-urban	0.0	**77**	23	17
Urban	0.0	0.0	**100.0**	73

MF_CL: Mixed Crop-Livestock Farming with valorisation of cereals and legumes residues; MF_RT: Mixed Crop-Livestock Farming with valorisation of roots/tubers residues; MF_D: Mixed Crop-Livestock Farming with purchased poultry manure.

Total integration (TI, 22 farmers): All kind of manure except that from poultry was only used in total integration (Table 3). Rural farmers (59% of TI farmers) were more likely to use these practices. Manure was totally used for fertilization of cotton, maize or soybean commercial production. In turn, ruminants grazed residues from the food crops and those commercial crops in the farm. Farmers using total integration practices relied on animal traction power in place of tractors to cultivate more land for cotton and maize. This system is a *Mixed Crop-Livestock Farming with manure and crop residues*. Peri-urban farmers (9% of TI farmers) used purchased manure as organic fertilizer for pineapple production and they used in turn residues of cereals and roots/tubers for feeding small ruminants. In urban area, farmers purchased manure as organic fertilizer for vegetable production and some of them (9% of TI farmers), who bred pigs, fed them with residues of vegetables. Those farmers admitted using in addition to poultry manure, pig dejections as fertilizers. Some other farmers (23% of TI farmers) sold those vegetables residues to peri-urban breeders of pigs. This is a *Mixed Crop-Livestock Farming with exchange of by-products between agriculture and breeding.*

5 DISCUSSION

5.1 Crop-Livestock integration:

Integrated crop-livestock systems were analyzed according to the main links between cropping and livestock rearing observed in sub-Saharan productions systems. As farmers' interviewed showed heterogeneous characteristics, investigations mainly focused on links by Manure for fertilization and Crop residues for animal feeding as described by Franke *et al.* (2008). According to this author, those two links represented good practices used by sub-Saharan farmers for efficiency purposes in the utilization of resources. Vall *et al.* (2012), while recognizing those links in west-African mixed farming practices, added the links made of Draught power and Capitalization of agricultural surplus in breeding. Wolmer (1997), on his side, added to all those links, links of other fodder sources like growing forage crops (uncommon in smallholder mixed farming practices in Africa) and leguminous trees, links of agro-industrial by-products (in peri-urban areas). Beninese farmers may have some of those practices, but their heterogeneous characteristics hardly allowed taking account of all of them. Regarding the utilization of organic fertilizers, this study results did not show diversity in the production techniques of organic fertilizers like dried night soil and compost as mentioned in west and central Africa by Blanchard (2010). Those practices were unused by many farmers in Benin, while researchers and extension services have advocated them later in the past. In fact, those farmers still less know importance of these practices and they avoid additional work create by the use of those techniques. Also, farmers who were concerned with profit production strategies (urban commercial vegetable producers, peri-urban pineapple producers and cotton, soybean and maize producers in rural areas) were likely to use those organic fertilizers. In fact, field fertilization was mainly oriented to commercial crops and the choice of lands to be fertilized did not depend on the fertility gradients as described by Vall (2009) in northern Cameroun, but depended here on the crop to be cultivated. Importance of ICLS in cash-crop production was well acknowledged (Vall *et al.*, 2006; Bonaudo *et al.*, 2014). On the other hand, in the Beninese ICLS, crop residues were fed to ruminants and pigs. Many works (Ayantunde et al., 2007; Onyeonagu *et al.*, 2010) revealed its use and these could constitute the main feedstuff in dry seasons in sub-Saharan Africa. During years, crop and livestock productions had been linked by draught power for cotton production and the other links appeared with the necessity to intensify production in the context of increasing fertilizer prices and the

reduction of pasture areas (Vall *et al.*, 2006). Animals therefore facilitated the recycling of resources and their efficient usage (Schiere *et al.*, 2002; Dugue and Dongmo, 2004).

5.2 Diversity of crop-livestock practices : Integration practices were diverse in sub-Saharan Africa and different modes existed (Schiere and Kater, 2001; Thornton and Herrero, 2001; Herrero *et al.*, 2010; Vall *et al.*, 2012). Our study revealed two large groups of integration practices in Benin and their description showed a diversity of practices. From Low external input agriculture (LEIA) to High external input agriculture (HEIA) practices described by Schiere *et al.* (2002), various practices were identified. LEIA is an *On-farm mixing* system with high level of integration between crops and livestock, which allows a high rate of recycling of natural resources and requires a low amount of input whereas HEIA type is *a between farms mixing* system with high inputs (Schiere and Kater, 2001). In our study, *Mixed Crop-Livestock Farming with valorisation of residues of cereals and legumes (PI)* and *Mixed Crop-Livestock Farming with valorisation of manure and crop residues (TI)* identified in rural areas, and *Mixed Crop-Livestock Farming with valorisation of residues of roots/tubers* (PI) in peri-urban area were close to LEIA system. However, as TI practices in rural area was a closed system where great quantities of residues and manure were recycled, integration was real here. This mixed system was similar to group of agro-pastoralist farmers with middle production size identified by Vall *et al.* (2006) in Burkina. On the other hand, *Mixed Crop-Livestock Farming with purchased manure* (PI) and *Mixed Crop-Livestock Farming with exchange of by-products between agriculture and breeding* (TI) of urban areas, and *Mixed Crop-Livestock Farming with purchased manure and residues for valorisation* of peri-urban area were of HEIA types. These mixed systems were oriented to intensive production and used purchased animal manure. Rural farmers were likely to use LEIAs practices and urban farmers the HEIAs' ones. In fact, rural farmers had access to village farm residues whereas that was impossible in urban areas. However, for all farmers of the three areas, organic fertilizers were precious, rural farmers used manure from their own production, while peri-urban and rural famers purchased animal manure. Those Integrated soil fertility management systems (ISFMS) were spread (Somda *et al.*, 2002). Mixed crop-Livestock Farming in our areas remained a risk-coping strategy of farmers or breeders (Williams et al., 1999) using wastes of the other production.

5.3 Improving cropping and livestock integration practices: Integration practices of rural farmers, more than a simple utilization of by-products, were strengthened by cattle breeding for draught power. The two productions were well mixed in the same space and the mixing system was closed. While in the peri-urban and urban area, the mixed system was opened. Animal dejections which were valorised scarcely derive from residues obtained on the same fields, and crop residues were not from crops that benefit from organic fertilizers. Particularly in the urban case, an exchange of by-products between farmers and breeders was observed and ensured their resilience. As animal breeding played a key role in integration (Vall et al., 2006), improving breeding strategies and herd size in crop productions systems could improve ICLS. Contractual arrangements between farmer and transhumant herders to benefice respectively of manure and crop residues, described by Williams et al. (1999) in Niger sudanian area, no more existed in our rural sudanian area. In fact, farmers' practiced the two productions and can usedby they own, those waste. Rural farmers can therefore extend their animal traction to a larger cattle size that allows the availability of more manure for crop production while more residues of produced crops will be fed to animals. Also stabling livestock in field can allow better utilization of residues and dung, and limit nutrient losses during animal moving. Investigation on mixed farming in urbanization context is

quiet new and less acknowledged. In peri-urban area, the link between agriculture and breeding in the direction of full integration is weak. Peri-urban farmers with low available land can insert tree forage cultivation practices in their cropping strategies and extend small ruminant production for the valorisation of residues and manure. In addition, integration can be improved through utilization of pineapple by-products in pig feeding. In urban area, pig breeding can be an asset to the use of residues of vegetables and the increase of organic fertilizers. Therefore, promotion of integration can be done through a better adequacy of production systems to valorize available crop residues and manure. Further research works would emphasize the other links like economic ones for the description of ICLS.

6 ACKNOWLEDGEMENT

The authors are grateful to the University of Abomey-Calavi of Benin for funding the present work through the project "Productivity of integrated Crop-livestock systems in Benin" (PROSAEI/PFCR2).

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