

Adoption of sustainable cattle production technologies in the Lacandon rainforest, Chiapas, México

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Abstract – With the aim of knowing the level of technology adoption that has a group of cattle producers (peasants) participants of the Sustainable Rural Development program in Biological Corridors (SRDBC) in the Lacandon rainforest, Chiapas, we calculated the rate of adoption technology (RAT) and correlation tests were conducted to identify the socio-economic variables that influence with the RAT. The values obtained indicate that the level of technology adoption of the study group was intermediate (RAT = 54.83 ± 9.23); the technological components focused on animal nutrition, management of the pastureland, restoration and revegetation in pastures and livestock infrastructure obtained the highest values. The adoption of sustainable livestock technologies was related ($P>0.05$) with years of participation in the program SRDBC, the amount of bovine heads and the income from the sale of animals. The lack of credit and financing, of market structures and of knowledge regarding the management of livestock techniques were the main limiting for technology adoption. The results of this study contribute to the planning and refocusing of technology transfer programs with the aim of achieving sustainability in the production of cattle in the Lacandona rainforest (Chiapas, Mexico).

Keywords – Agroforestry; silvopastoral systems; good livestock practices; cattle; biological corridor

I. INTRODUCTION

In Mexico, the production of cattle is an economic activity of great importance since it provides food, prime materials, foreign exchange and employment [10]. Its production, processing and marketing involves more than half of the surface of the national territory [31] and covers all the ecological regions in the country [10]. The most important production system of bovine animals is the extensive or free grazing system and close to 50% of cattle population of the national level grows up under this system (28.4 million head of cattle) [18]. In the southeast of Mexico, the extensive cattle production is a vital activity for the regional economy, however, this activity has contributed to the change in land use, increasing grazing areas and affecting the forest areas, natural resources, conservation of biodiversity and contributing to greenhouse gas emissions [1].

In the framework of public policy to conserve biodiversity, the government of Mexico consolidates as national policy the promotion of biological corridors to ensure connectivity between existing protected natural areas and remnants of the original ecosystems in territories

with high rates of poverty and biodiversity in the southeast of the country (Oaxaca, Chiapas, Campeche, Quintana Roo and Yucatan) [26]. This policy was implemented using the Sustainable Rural Development program in Biological Corridors (SRDBC) with the aim of ending the change of land use in forest areas and the deterioration of natural resources on the basis of the conservation of biodiversity and in sustaining agriculture, cattle and forestry production [38]. The program SRDBC promotes, through the establishment of pilot units, the intensification of the extensive bovine production system through the use of sustainable farming techniques (silvopastoral techniques and good farming practices) with the objective of increasing tree cover in pastureland and intensify the current use of livestock ground. The adoption of agroforestry technologies is an important element of rural development policies because it is related to the increase in productivity and cattle income, the decline of the degradation of natural resources, and poverty alleviation [37], [36], [30], [13]. To know the level of technology adoption becomes an important task because it allows to know the amount of people who are most likely to continue using the promoted technologies after the technical assistance period is completed [3]. The objective of this investigation was to determine the level of adoption of sustainable livestock technologies of a group of livestock farmers who have participated in the SRDBC program in the Lacandon rainforest, one of the five areas of intervention in Chiapas, as well as to identify the socio-economic characteristics and the reasons, benefits and limitations that determine this adoption.

II. MATERIALS AND METHODS

A. The Study Area

The study area corresponds to seven ejidos (Ach'lum Monte Libano, Santa Elena, El Censo, Taniperla, Perla de Acapulco, San Caralampio and San José) located within the gorge Río Perlas, in the municipality of Ocosingo, Chiapas, Mexico, which is part of the socioeconomic region XII Lacandon Rainforest, in the east of Chiapas, Mexico (Fig. 1). This region is an area of high social-environmental complexity characterized by its high biological diversity, by the environmental services it provides and because it has the largest surface of protected natural areas in Chiapas (419,453.37 hectares) [35], [7]. The municipality of Ocosingo, with a predominantly indigenous population (61% of the population belongs to the ethnicity Tzeltal), has

a degree of marginalization considered as very high (1.25) [19]. The main economic activities that the indigenous peasants developed in this region are of the primary sector, where the extensive production of bovine has been one the main source of monetary income; this activity has been one of the triggers for the biggest change of land use in the history of the Lacandon Jungle [9]. In this region, extensive production of cattle has been kept under a constant commercial and financial instability, coupled with a low quality or absent of technical assistance, has prevented its technical-productive development, maintaining a very marginal productivity and profitability [19]. Currently, the extensive cattle exerts a strong pressure on agricultural areas, grazing areas, and protected natural areas in the Lacandon Rainforest [9], [15] and also is the main source of greenhouse gas emissions in the agricultural sector in Chiapas [11].

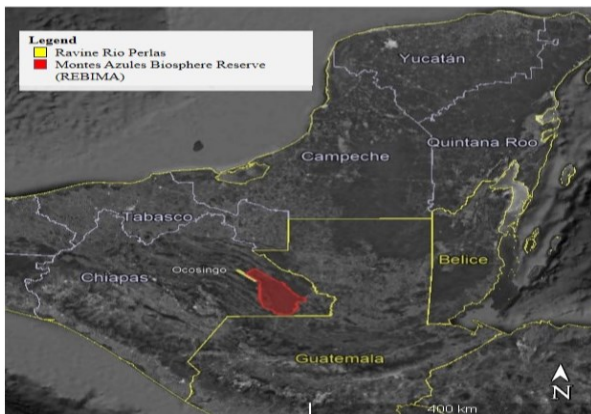


Fig. 1. Geographic location of the study area

B. Data

Between February and March 2016 a semi-structured interview was designed and implemented to 36 livestock farmers that accounted for 78% of the total population that participated within the SRDBC program in Canada Rio Perlas (Ocosingo, Chis). This interview was split into two sections: one focused on obtaining socio-economic data of the participating producers and another to the adoption of farming practices driven by SRDBC program [42], [33]. For the design of the interview 18 socio-economic variables were identified which influenced the adoption of sustainable agricultural technologies (age, schooling, distance of the ejido to the municipality, family size, labor, land tenure, years of experience in livestock production, years to participate in the government program, incomes from the sale of animals in the past year, number of bovines, total hectares of grassland, hectares of pasture with silvopastoral elements, hectares preserved and hectares rented) [42], [33]. The identification of the husbandry was carried out through the observation in the field and the review of technical reports and documents published by the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) such as the manual of good husbandry practices: Extensive and Semi-extensive Systems [32]. The interview was validated in three participatory workshops [43]. We identified 34 sustainable livestock techniques which were grouped into six technological components focused on the restoration and revegetation in pastures, the management of paddocks, animal nutrition, soil and water conservation in pastures, animal management (health and reproduction) and the improvement of the livestock infrastructure (Table 1).

Table 1. Technological components, sustainable livestock techniques and value weight for calculate the rate of adoption technology (RAT) of a group of livestock farmers in the gorge Río Perlas, Ocosingo, Chiapas.

Technological component	WV	Technological Component	WV	Technological component	WV
Restauration/ revegetation	24	Paddock manage	22	Animal feed	20
Área for conservation of vegetation	7	Pasture fertilization	1	Use of forage foliage	6
Riverside restaruation	5	Chemical control of weeds	1	Use of forage of forage bank	4
Maintain the vegetation at the edge of the river/streams	4	Manual control of weeds	3	Silage	4
Replanting trees	5	Division and rotation of the paddocks	4	Vitamins	3
Replanting pasture	2	Live fence	4	Common salt	1
		Scattered trees	5	Common and mineral salt	2
		Fooder bank	4		
Soil and water conservation	13	Animal manage	11	Infraestructure	10
Drinking water from tanks	6	Deworming/ Vaccination	2	Handling corral (concrete)	3
Nursery of forage trees	4	Tuberculosis test	2	Animal feeders (concrete)	3
Drinking water from rivers/streams	2	Vacunation and desparasitation registration	2	Chopper machine	2
		Natural reproduction	1	Tilt for the animals	1
		Artificial insemination	2	Registration in LUP	2
		Siiniga earing*	2		

*WV = weight value, *Method of individual animal identification that provides the opportunity to maintain and access other national and international markets, allows access to programs of support by the SAGARPA, LUP = livestock production unit; this key together with the earring SIINIGA are requirements to enter the National Livestock Census.

C. Level of Technology Adoption Rate

To know the level of technology adoption, the rate of adoption technology (RAT) was calculated by using the methodology proposed by Velez et al. (2013), which is based on assigning a value to each technique livestock production according to their level of relevance in relation to the scope of the objectives proposed by the SRDBC program. This index parts of a nominal value of 100 to represent the use of the 100% of the 34 grouped technologies in the six technological components mentioned above. The weight of values was carried out by a participatory workshop of experts on issues related to sustainable farming, rural development and management of the territory [42]; the weight values for each technique livestock production and technological component are shown in Table 1. Once we have assigned each variable weighting, the RAT was estimated using the following equation:

$$RAT = \sum_{i=1}^{K=6} (P_i) * (V_i) \dots \dots (1)$$

Where: RAT = rate of technology adoption, K = number of disciplines that grouped the technological components evaluated; P_i = weighting given to the i -th discipline; V_i = is the maximum value obtained by the use of technological components corresponding to each discipline, whose value is 0 to 100.

D. Data Analysis

With the data obtained from semi-estructural interview became a socio-economic characterization of livestock farmers and the identification of the reasons, benefits and limitations that farmers had for participate in the SRDBC program and for adopt the proposed techniques. The socio-economic variables were also used to identify the variables related to the level of technology adoption. For the socio-economic characterization and the identification of the reasons, benefits and limitations that livestock farmers had to participate in the program SRDBC and to adopt the techniques were used descriptive statistics tools according to the type of the variable; for quantitative variables (distance of the ejido to the municipality, age of the farmer, years of practicing the cattle, years participating in the program SRDBC, family size, land from the sale of livestock) were calculated averages destined to paddocks, quantity of animals and income, while for the qualitative variables (tenure of land, labor, schooling, and the reasons, benefits and limitations of participated in the SRDBC program and adopt the technologies proposed) were calculated percentages. To identify the socio-economic variables related to the RAT an exploratory analysis was performed using linear regression and the histogram in order to identify the possible variables related with the

RAT; once identified these variables were tested for correlation (Pearson and Spearman) to identify major socio-economic variables related to the RAT. For the statistical analysis of the data was used free software R Project.

III. RESULTS

A. Adoption of Sustainable farming Techniques

The results of the RAT are shown in tables 2 and 3. In Table 2 shows the RAT at a regional (gorge Rio Perlas) and local (ejido) level; while table 3 shows the value that each technological component obtained in the IAT and the techniques of greater adoption according to the percentage of adopters. Livestock farmers of the study group obtained in general average a 54.83 ± 9.23 RAT, being the ejido of San Caralampio which presented the lowest RAT. The technological components that obtained the highest values in the RAT were animal feed, the management of the paddock, improving infrastructure and the restoration/revegetation of the paddocks, which reached 65, 64, 60 and 50% of the total value-weighted, respectively; the components focused on animal management and the conservation of water and soil in paddocks presented low values (27 and 23%, respectively).

The techniques with the highest percentage of adopters according to the technological component were: apply vitamins to cattle (86%) and the use of forage grass (80%) in the case of animal feed; the use of live fences (97%) and scattered trees (94%), in the management of the paddocks; maintain trees at the riverside and a conservation area (80%) in the case of the restoration and revegetation of pastures; the improvement of the management fences (78%) and from the feeders (72%), in the livestock infrastructure; worming and vaccinating livestock in animal management and; that the drinking water for animals comes from the rivers/streams (100%) in the component, soil and water conservation.

B. Socio-economic characterization

The results of the characterization of the study group are shown in table 2 and are presented according to the territorial scale (ejido and region) and the type of variable (quantitative and qualitative). Livestock farmers participating in the program SRDBC had an average age of 48 ± 11.72 years old and have participated in the SRDBC program during 3 ± 1.3 years on average. The level of schooling that characterizes the study group is the inconclusive primary (58%). Respect of the land tenure, the results showed that 66% of the group are land owners (ejidatarios)¹, although there are other types of regimes as the successor of land owner (14%), co-owner (11%), "avecindado"² (6%) and land owner of enlargement (3%). The production of cattle in extensive systems is the main economic activity in all the livestock farmers studied

¹ In Mexico the "ejidatario" is a legal figure (not companies nor moral persons) owner of a territorial extension, who have the right to distribute it among between the family members for building and for cultivation, leaving other parts for the public services in agree with the law. Only the fractions of housing land designated by the General Assembly of the ejido as "solar" are full ownership of the peasant who was delivered and the latter can freely dispose of it.

² In Mexico, the "avecindado" is recognized by the agricultural law and the peasant class, it is a man or woman that has at least one year residing in the lands of the nucleus of population and must rely on the recognition of the ejido assembly or the agrarian tribunal to be able to purchase the rights of the land owners and be preferred to buy land rights from a deceased owner without successors and to receive land in common use of the population nucleus.

(100%); however, most of them do not have access to the Program of Sustainable Livestock Production and Livestock Management and Beekeeping (PROGAN by its spanish acronym) and are not involved in any livestock organizations (88%). Livestock farmers have on average 12 ± 8.14 years of experience in the production of calves for fattening and have 24.65 ± 18.94 animals on average. The predominant labor is familiar and the average family size is 5.39 ± 2.73 members. The average income from the sale of bovines was \$63,509.09 ± 50,858.06 for the last year (2016); the main way of marketing was through an

intermediary (100%). With respect to the land use it was found that the average amount of land intended to paddocks corresponds to an average of 11.46 ± 8.15 hectares, of which 4.32 ± 6.54 hectares have some silvopastoral elements (e.g. live fence, fodder bank, scattered trees). Livestock farmers of the study group also had an average 2.87 ± 3.3 hectares for the conservation of vegetation. The rent of paddocks outside the ejido was a common practice; the 80% of the livestock farmers of this study are involved in this activity.

Table 2. Rate of adoption technology and socio economic characteristics from the livestock farmers in the gorge Río Perlas, Ocosingo Chiapas.

Geographic scale		Ejidos						Region		
		Monte Libano	Santa Elena	El Censo	Taniperla	Perla de Acapulco	San Caralampio	San José	Ravine Río Perlas	
Rate of adoption Technology		56.75 ± 6.29	58.80 ± 9.93	58.50 ± 6.95	54 ± 8.90	58 ± 6.36	47.17 ± 13.47	52.80 ± 7.66	54.83 ± 9.23	
Socio economic variables	Quantitative variables	Km from ejido to municipality	50.3	54.35	59.02	64.88	70.81	79.36	83.66	
		age	50 ± 13.78	49 ± 7.42	52 ± 10.61	53 ± 12.63	46.83 ± 10.13	44.50 ± 14.57	44.20 ± 15.16	48.33 ± 11.72
		years of participation in SRDBC	3.25 ± 0.50	2 ± 0.84	2.75 ± 1.50	3 ± 1.67	3.67 ± 0.82	2.17 ± 1.33	4.20 ± 1.10	3.03 ± 1.3
		family size	6 ± 1.83	4.60 ± 3.97	4.25 ± 1.26	4.50 ± 2.07	6.17 ± 2.86	6.83 ± 3.54	5 ± 2.55	5.39 ± 2.73
		years practicing livestock	11.50 ± 9.95	11.60 ± 5.68	16 ± 11.89	14.33 ± 7.79	10.33 ± 4.80	8.33 ± 6.47	15 ± 12.25	12.25 ± 8.14
		\$ for animal sale	65,000 ± 54,574	113,500 ± 140,463	40,250 ± 47,849	35,000 ± 19,849	31,400 ± 18,201	29,020 ± 17,729	36,500 ± 14,153	50,858 ± 63,509
		quantity of animals	39.50 ± 11.82	27 ± 27.69	20 ± 7.70	34.50 ± 28.28	23.33 ± 18.74	12.50 ± 7.09	18.40 ± 7.37	24.65 ± 18.94
		he paddocks	10 ± 1.83	14 ± 14.82	11.50 ± 3.32	13.83 ± 14.43	11.75 ± 2.75	11.33 ± 5.24	7 ± 2.12	11.46 ± 8.15
		he of extensive paddocks	2.25 ± 4.50	9.20 ± 9.36	6.75 ± 4.57	5.42 ± 3.83	8.08 ± 4.08	10.83 ± 5.72	5.80 ± 1.92	7.14 ± 5.45
		he of silvopastoral paddocks	7.75 ± 5.44	4.80 ± 5.76	4.75 ± 7.54	8.42 ± 11.34	3.67 ± 5.74	0.50 ± 0.77	1.20 ± 1.10	4.32 ± 6.54
	he of conservation	3.75 ± 2.63	1.80 ± 1.79	4.75 ± 3.86	2.08 ± 1.43	1.50 ± 1.05	5.40 ± 6.73	1.80 ± 2.17	2.87 ± 3.3	
	he rent	2.25 ± 0.96	1.20 ± 1.10	1.75 ± 1.26	0.83 ± 1.33	1 ± 1.26	0	1.60 ± 0.89	1.14 ± 1.17	
	Qualitative variables (%)	land owner*	0	60	75	83	83	100	20	66
		land owner successor*	0	20	25	17	0	0	20	14
		land owner of enlargement*	0	0	0	0	0	0	40	3
		co-owner*	75	0	0	0	0	0	0	11
		avecindado*	0	20	0	0	17	0	0	6
inconcluded primary		75	60	75	66	66	83	60	58	
cattle production***		100	100	100	83	100	83	100	94	
coffe***		75	60	75	66	83	83	60	72	
milpa for self provision**		100	60	100	83	50	100	60	78	
calves production***		75	100	75	83	83	100	100	80	
comercialization by middleman	100	100	100	100	100	100	100	100		
family labour	75	80	75	83	83	100	80	78		
progan	75	20	25	33	17	0	0	22		
farmer livestock organization	0	40	0	0	33	17	60	22		
rent of paddocks	100	80	75	33	50	0	100	80		

*land tenure, **principal economic activity, ***zootechnical function

Table 3. Rate of adoption technology for each technological component and percentage of adopters for each implemented technique in the gorge Río Perlas, Ocosingo, Chiapas (A).

Technological component	Weight value	Obtained weight	%	Implemented technique	% adopters				
Paddock managment	22	14	64	Live fences	97***				
				Scattered trees	94***				
				Manual control of sweets	75**				
				Fooder bank	64**				
				Division & rotation of paddock	58**				
				Graze by ages	11*				
				Paddock fertilization	3*				
				Chemical control of sweets	3*				
				Restauracion/revegetation of paddocks	24	12	50	Maintaining trees at the edge of rivers/streams	100***
				Area for conservation of vegetation				80**	

***Technics with >90% of adopters; ** Technics between 50-80% of adopters; *techniques whith <50% of adopters (B)



Technological component	Weight value	Obtained weight	%	Implemented technique	% adopters
Restauration/revegetation of paddocks	24	12	50	Replanting tree	50**
				Replanting pasture	33*
				Riverside restauration	17*
Animal nutrition	20	13	65	Vitamins	86**
				Use of forage fodder banks	80**
				Use of foliage forage	69**
				Mineral salt	100*
				Mineral/common salt	64**
				Silage	22*
Infraestructure	10	6	60	Animal feeders	78**
				Handling corral	72**
				Chopper machine	28*
				Tilt for animals	11*
				Registration in LPU	36*
Animal managment	11	3	27	Vaccination and deworming	92***
				Vaccination and deworming registration	57**
				Vet kit	28*
				Siiniga earing	25*
				Tuberculosis test	19*
				Artificial insemination	8*
Soil and water conservation	13	3	23	Drinking water of rivers/streams	91***
				Nursery of forage trees	13*
				Drinking water of tanks	9*

***Technics with >90% of adopters; ** Technics between 50-80% of adopters; *techniques whith <50% of adopters; LPU, livestock production unit; siiniga earing, id animal system; AI, artificial insemination

C. Reasons, benefits and limitations in the Adoption of Sustainable Farming Techniques

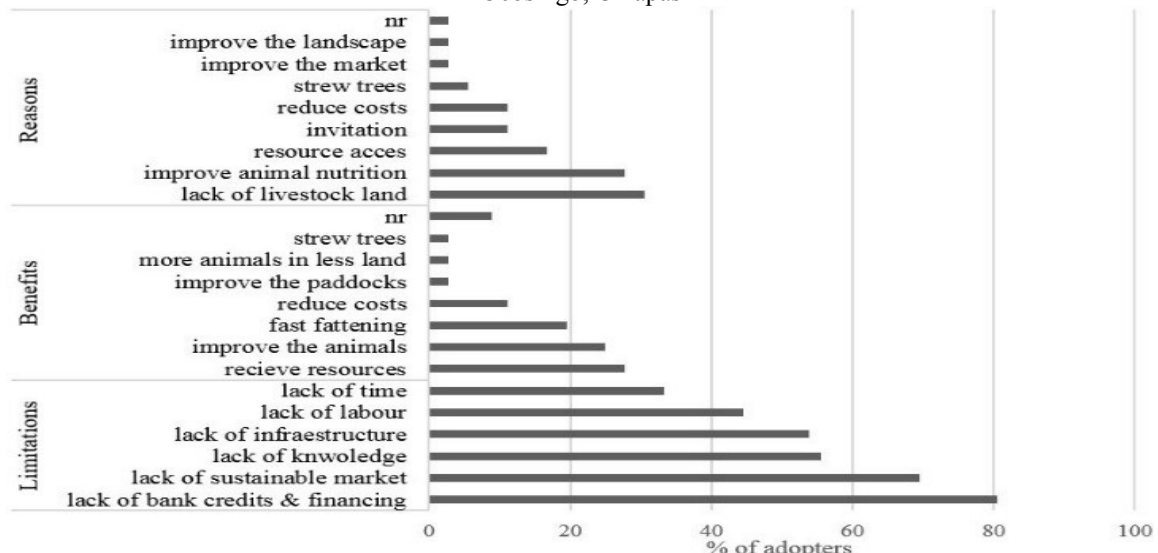
The results of the reasons, benefits and limitations that livestock farmers have had to participate in the program SRDBC and adopt the proposed techniques are shown in the figure 2. The reasons for livestock farmers to participate in the program SRDBC were diverse but included: lack of land for cattle production (30.56%), interest to improve animal nutrition (27.78%) and access to some type of economic resource (16.67%). The main benefit that livestock farmers obtained from their participation in the SRDBC program was to receive material resource (e.g. cement, rods, sheets, technical training) (27.78%); the benefits obtained from the use of sustainable farming

techniques was the physical improvement of the animal (25%) and the fattening of bovine in less time (19.44%).

D. Socio-economic factors that influence the adoption of sustainable farming techniques

The socio-economic factors that had an impact on the level of technology adoption are shown in table 4. It was found that there is no correlation (P<0.05) between the RAT and socio-economic variables such as the age of the livestock farmer, schooling, land tenure, family size, or land intended for the cattle. The socio-economic characteristics that are correlated with the level of RAT were the years of participation within the SRDBC program, the quantity of animals and the income obtained from the sale of livestock (P<0.05).

Fig. 2. Reasons, benefits and limitations for the adoption of sustainable livestock techniques in the gorge Rio Perlas, Ocosingo, Chiapas



NR= not response

Table 4. Socio economic variables regarded with the rate of adoption technology in the gorge Río Perlas, Ocosingo, Chiapas.

Socio economic variables	Correlation type	
	Lineal	No-lineal
Distance of the ejido to the municipality	-0.4476	-0.4513
Age	0.1728	0.2741
Family size	-0.0945	0.1622
Schooling	-0.1318	-0.2803
Years practicing cattle production	0.3625	0.2812
Years participating in SRDBC program	0.5022*	0.4710*
Income from the sale of animals	0.1695*	0.0649
Quantity of animals	0.4954*	0.3972*
Hectares of paddocks	0.3132	0.3026
Hectares of paddocks with silvopastoral elements	0.3430	0.3716
Hectares of extensive paddocks	-0.0950	-0.0061
Hectares of conservation	-0.1004	0.0157
Rent hectares	0.1483	0.0438

P- Value= 0.05, Variables influencing *, SRDBC, Sustainable Rural Development Program in Biological Corridor

IV. DISCUSSION

A. Adoption of Sustainable Farming Techniques

Technology Adoption is one of the most important aspects in the development of animal production systems since it increases the productivity and profitability of the production unit [33]. In Mexico, there are various investigations that explain the relationship between the socio-economic characteristics of livestock producers and technology adoption in bovine production systems [42], [41], [10], [33], [42] but there is little information on the adoption of sustainable livestock technologies in extensive cattle production systems in areas of high marginalization and with indigenous and peasant population as in the Lacandon Rainforest, where there have been multiple programs to avoid deforestation and promote the greening of extensive cattle production (Flores et al., in press).

In this investigation, the results of the RAT corresponds to an intermediate level of adoption according to the categorization made by Velez et al. [42] who established that a value between 33-66% corresponds to an intermediate level of technology adoption. Technological components focused on the improvement of the animal nutrition, the management of the paddocks and the livestock infrastructure obtained the highest levels of adoption. This results shows the intention of the SRDBC program to intensify the bovine production system through a whole management; techniques such as living fences, scattered trees and fodder banks-techniques focused on the management of the paddocks-, contribute to the fodder throughout the year with a high nutritional quality forage - techniques aimed at improving animal feed-, improve the infrastructure through the improvement of the corrals of

handling and the feeders, facilitate the feeding of animals. The improvement of the livestock infrastructure is a primary tool that allows for the development of other management activities (e.g., animal deworming, vaccination and reproduction) [37], [44] and contributes to increasing profitability and improving the competitive advantage of the production unit [13].

The results of this study, as well as other studies related to technology adoption in animal production systems [24], [14], [37], [10] [33], shows that the techniques focused on the improvement of animal nutrition have a higher level of adoption due to the interest by livestock farmers in possessing well-nourished animals that can be fattened and sold in less time. Livestock farmers mentioned that one of the benefits obtained from sustainable livestock techniques proposed by the SRDBC program was the fattening of the bovines in less time. In addition to the feeding techniques, there are techniques related to the animal management and the conservation of soil and water in paddocks that also showed a high percentage of adoptants due to their role within the production unit such as vaccination/ deworming animals and maintain vegetation of river/ stream. The deworming and vaccination of bovines is one of the techniques with a greater level of adoption in animal production systems due to the interest that exists in having animals in good health and to the positive perception that the producers have on the use of vitamins and antibiotics [13]. While maintaining the vegetation on the banks of rivers/ streams is a technique of wide use because of the need to maintain the level of water from rivers and streams because they are the main source of drinking water for animals [17].

Also, the results of this investigation shows that the adoption of technologies is closely related with the facility and the costs for the implementation. The largest percentage of livestock farmers who adopted techniques such as live fences with forage species, scattered trees in pastures, restoration of vegetation on the edge of rivers/ streams shows the tendency of livestock farmers to adopt simple practices, with low economic investment and with the use of local resources. In contrast, techniques such as artificial insemination, construction of fodder plant nurseries, silage of forage, and counting with tools such as grinders or scales for weighing the cattle, or with a first aid kit, were techniques that showed a lower level of adoption because it requires a greater amount of resources for their implementation and use. This study coincides with Jimenez et al. [22] who reported that agroforestry systems and the use of local inputs in the southeast of Mexico, are the most viable strategies for mitigation of greenhouse gas emissions due to its low cost and easy access to the producer.

B. Socio-economic Characteristics that Influence the adoption of Sustainable Farming Techniques

Various authors report that technology adoption depends on multiple factors related to the socio-economic characteristics of the livestock farmers [42], [14], [42], [13]. In this research socio-economic variables such as the years of participation within the SRDBC program, the quantity of animals and the income obtained from the sale of livestock influenced significantly the level of adoption ($P < 0.05$);

while the age of the producer, schooling, family size, labor, and the total area dedicated to livestock had no relation ($P < 0.05$).

The years of experience that a farmer acquires in any agricultural technique are related to the level of adoption of agroforestry technologies [44]. In this study the years of participation in the SRDBC program are considered as the years of experience that livestock farmers have in relation to the use of the sustainable farming techniques. This variable can explain the percentage of adoptants that have the different techniques founded in this study. The lower percentage of adoptants (50-80%) that had techniques such as the use of feeder banks, division of paddocks, the use of foliage forage in the animal nutrition, the deworming and vaccination of the animals, the artificial insemination, the improvement of the management corrals and the animal feeders; these techniques has been implemented since three years ago, time that represents the usage time and the time of participation in DRSC program. It is also important to mention that there are livestock farmers that recently participated in SRDBC program (one year). In comparison techniques like the improvement of the live fences, scattered trees and maintaining the vegetation on the edge of the river/stream obtained the higher rate of adoption. These techniques were used prior to the participation in the SRDBC program and are considered as ancestral techniques [3] and can explain their highest adoption level. The amount of years that the livestock farmer perform making use of these techniques [13] and the traditional knowledge acquired [33]. In this study livestock farmers have an average of twelve years practicing the cattle production and using these techniques.

Even though the results of this investigation show that the age of livestock farmers was not statistically related to the RAT, there is evidence that the age is related to the adoption of sustainable farmer techniques; older livestock farmers have a higher level rate of technology adoption because they have more experience, resources and authority which allows them to adopt new technologies or improving existing ones [2]. However, it has been observed that producers with an advanced age (> 58 years) have a lower level of technology adoption [42]. The livestock farmers in this study had an average age of 48 years, an age considered

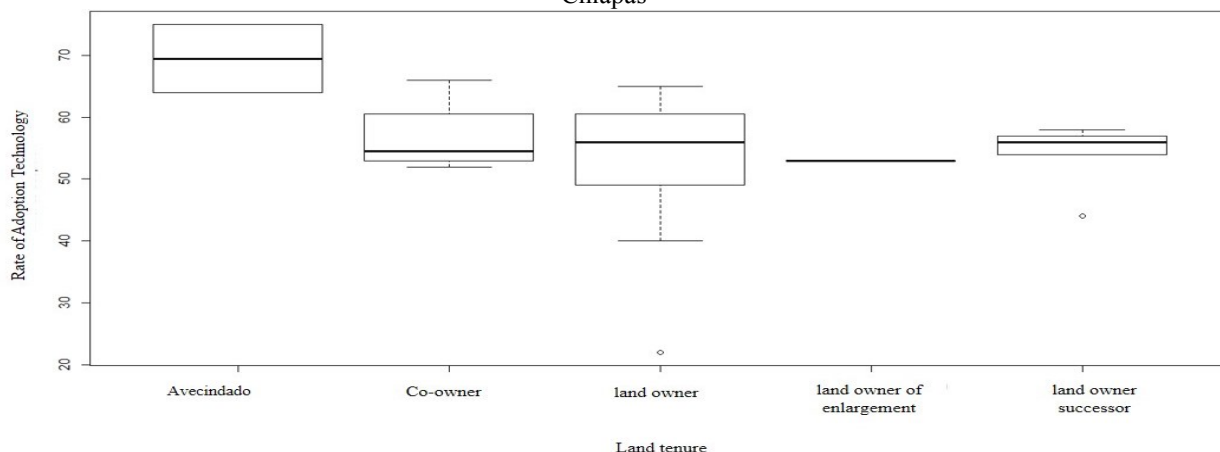
as a median for livestock producers in Mexico [41], [37], [42], [10]. A median age associated with a greater amount of resources would explain the level of technology adoption presented in this study.

The other two variables that statistically influenced the RAT are the quantity of animals that livestock farmers possess and the income obtained from the sale of animals. As equal to the number of hectares of land, the quantity of animals is a socio-economic variable related to the access to a greater economic income, either by the sale of livestock or the possibility of access to bank credits and financing [3], [37]. A greater economic capital gives the livestock farmer a greater ability to perform on-farm investments and a highest possibilities of adopting new technologies and to take leadership and a role of knowledge diffuser [40], [2].

C. Reasons, benefits and limitations for the Adoption of Sustainable Livestock Techniques

Among the reasons that motivated to livestock farms to participate in the program SRDBC and adopt the proposed techniques was the lack of land for the cattle production. This phenomenon is manifested in the largest RAT obtained by part of livestock producers who whose land tenure is catalogued as "avecindado" because of their land tenure, this group of livestock farmers have a smaller surface area for livestock and therefore have a greater need to adopt livestock technologies that allow them to intensify the use of available resources (Fig. 3). These results are consistent with those reported by Huybrechs et al. [17] who found out that farmers who owned less land had a higher level of adoption of agroforestry techniques due to the need to intensify the surface of land they owned. It is important to mention that the scarcity of land could be promoting the marketing of land for livestock use inside and outside of the ejidos in the cañada Rio Perlas; 80% of the farmers mentioned rent paddocks during the dry season, when the scarcity of forage in the region presents it self. The rent of paddocks limits the adoption of agroforestry technologies as tenants do not invest in this type of technologies because the use of the land is short term [40], [29]. In general, the marketing of the lands affects the agricultural frontier and generates a growing inequality in land distribution in time and space [17].

Fig. 3. Association between the land tenure and the rate of adoption technology in the gorge Río Perlas, Ocosingo, Chiapas



There is enough evidence of technical, economic and public policy issues that show the limitations for the adoption of technologies in silvopastoral systems in pastoral areas [4]. In this study, the main constraints for the adoption of the husbandry proposals were the lack of credit/financing, of market and of knowledge regarding the use and handling of some livestock techniques proposed by the program SRDBC. This problem also applies to the adoption of agroforestry techniques in Chiapas, Mexico [27], [43].

The other limitation for adopt sustainable livestock techniques was the lack of knowledge in the use and management of some of the tecncias proposals (e.g. the fodder banks, the use of fodder, ensijale foliage of forage, among others). These results agree with Zepeda et al. [43] who reported that the producers did not adopt the silvopastoral systems because of the lack of knowledge about their handling and use. This problem could be related to the training strategy and years of participation in the SRDBC program. The frequency and quality of technical assistance have an influence on the implementation of technological innovations after a certain number of years of work [27]. In the group study there are participants with different SRDBC membership dates, which can explain the diferent level of technical assistance; livestock farmers who had recently joined membership (19.44% of the total population of study) mentioned not receiving technical training, while the rest of the population reported having received only one training workshop during the last year of participation in the SRDBC program. The lack of information and clarity on some agricultural techniques, causes producers to be unwilling or unable to adopt the proposed techniques [27] and hinders the proper use of the technique and obtaining their profits [41]. Increasing the knowledge level regarding the use and management of sustainable farming techniques is an essential task for increasing the level of technology adoption and thus convert the extensive cattle to a sustainable stockbreeding [28], [16]. Also the knowledge of the paths of market and value chains for milk and meat fosters a high middlemen in the marketing of livestock, thus reducing the income per animal and the value added by sustainable practices which indirectly limits the possibility of adopting some agroforestry techniques [42]. In the gorge Rio Perlas the intermediarism is the principal way to comercialize the animals. The lack of technical follow-up and monitoring in the processes of adoption leads to a decrease in the interest of participants and a decrease in the chances of achieving a good understanding and mutal exchange between technicians and agricultural producers [8]. The foster participatory strategies for technology adoption in livestock areas, such as the farmer field schools, units pilots, plots, field days, collaborative networks, local organizations, can give accessibility to promoting processes of social empowerment [22], [5].

V. CONCLUSIONS AND IMPLICATIONS

The rate of adoption technology (RAT) is a powerful tool that allows to measure the impact of a project or program of livestock development that promotes a technological

transformation of a livestock production system. The results of this research showed that the RAT in the study area was intermediate. The livestock farmers of the gorge Rio Perlas (Ocosingo) obtained a general average of 54.83 ± 9.23 in the RAT. The technological components that gained importance in the RAT were animal feed, the management of the paddocks, improving infrastructure and cattle raising and the restoration/ revegetation of paddocks. The socio-economic characteristics that are correlated with the level of adoption were the years of participation within the SRDBC program, the amount of animals per producer and the amount of money obtained from the sale of livestock ($P < 0.05$). It was found that there is no correlation ($P < 0.05$) between the RAT and socio-economic variables such as the age of the producer, schooling, land tenure, family size, or land intended for the cattle. The main constraints or barriers that livestock farmers mentioned have for the adoption of the techniques proposed by the SRDBC, were the lack of funding and/ or credit, of knowledge of the market and of new techniques. The results of this study can serve the agencies of rural development, producer organizations and research institutions to strengthen sustainable livestock development strategies in areas of high marginalization.

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