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Article

Adaptability of cattle raising to multiple stressors in the dry tropics of Chiapas, Mexico

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Abstract: Using the sustainable livelihoods analytical framework, adaptability of cattle raising to multiple stressors (e.g. climate change and market conditions) in the dry tropics of Chiapas, Mexico was evaluated. Three case studies located in the Frailesca region of Chiapas were analyzed: (I) peasant cattle raising in a rural village in the Frailesca Valley; (II) peasant cattle raising in a rural village in a natural protected area in the Frailesca Highlands; and (III) holistic cattle raising by farmers with private land ownership in the Frailesca Valley. Adaptability was evaluated using an index on a scale of one to a hundred; average values were: case I = 20.9 ± 1.4; case II = 32.1 ± 1.8; and case III = 63.6 ± 3.5. In order to increase farms adaptability and reduce the vulnerability of cattle raising families, there is a need to modify public policy to take into account the conditions of the most vulnerable farmers (cases I and II). Given the economic, environmental, and social context of Mexico´s dry tropics, establishing ecological or organic cattle raising and silvopastoral systems may reduce the vulnerability of farm families and increase their level of adaptability of their farms to multiple stressors.

Keywords: adaptive capacity; multiple stressors; sustainable livelihoods; organic cattle raising

1. Introduction

Cattle raising is significant to the way of life of many peasant families in Latin America and the Caribbean, and currently provides 46% of agricultural GDP in this region, which provides over a fourth of the world´s beef [1]. However, cattle raising has been associated with environmental impacts, including deforestation, soil and water contamination, and greenhouse gas emissions [2].

Despite the fact that 63.5% of Mexico´s cattle are raised in tropical areas, productivity is low; while tropical areas comprise 37% of Mexico´s surface area, they provide only 17% of milk produced [3] and approximately 28% of meat produced [4]. Therefore, there is a need to increase productivity of tropical cattle raising in a sustainable manner in order to reduce environmental impacts and mitigate rural poverty in a context in which structural adjustments such as free trade and elimination of subsidies have worsened farmers´ economic and social situation - particularly the poorest farmers.

Farmers commonly face problems such as volatility of the prices of their products, increase in input prices, and dependence on intermediaries, as well as on large national and transnational businesses that control purchasing of products and input sales. Furthermore, they also confront effects of climate change, such as temperature increases, changes in distribution and frequency of precipitation, and an increase in hurricanes [5]. Climate change is expected to gradually reduce productivity of tropical agroecosystems [6]; changes in precipitation and temperature may affect

tropical livestock raising due to increased droughts and floods that may reduce water availability, quantity and quality of fodder, and biodiversity, while increasing pests and diseases in both humans and animals [7]. Such environmental, economic, and social stress factors that jointly affect farmers over time are known as multiple stressors [8, 9].

From a sustainable livelihoods approaSch, reducing vulnerability of farm families´ and taking advantage of new opportunities resulting from multiple stressors involves changes in livelihood strategies - or adaptation. Most disciplines conceive vulnerability to be the extent to which a system, subsystem, or component of a system is likely to undergo damage due to exposure to a threat [10]. In the field of climate change, vulnerability results from exposure to a threat (stress factor) or threats (multiple stressors) and varies according to the system´s sensitivity and its ability to respond to these stressors (adaptability or adaptive capacity) [11]. Adaptability or adaptive capacity is defined as the ability of a system to modify itself to avoid negative effects of a variety of stressors or to respond to disturbances [12]. Adaptive capacity also involves a system´s ability to take advantage of opportunities that arise in the context of stress factors [6].

Within the sustainable livelihoods framework of analysis, evaluations of adaptability provide information regarding availability of capitals (natural, physical, financial, social, and human) which may contribute to natural resource management, as well as factors which limit farmers´ abilities to access these capitals in order to adapt to change. Cattle farms´ levels of vulnerability and adaptability will depend on a variety of factors, including farmers´ organizational capacity; their access to resources such as technology, information, and financial services; the sociopolitical environment [11, 13]; and knowledge construction and transmission [14].

The sustainable livelihoods approach allows for identifying causes of vulnerability of groups of people or systems in order to suggest measures for reducing this vulnerability and improving the system´s adaptability.

This study analyzes those factors that determine the adaptability of cattle raising systems to multiple stressors in three cases in the dry tropics of the Mexican state of Chiapas, and proposes ways of increasing local adaptive capacity as well as increasing the effectiveness of public policy.

2. Materials and Methods

2.1. Study area

The present study was carried out in the municipality of Villaflores, in the Frailesca region of the Mexican state of Chiapas. This region includes two geographic areas with contrasting climates, forms of agriculture, and histories: the Highlands and the Valley. With the aim of evaluating cattle raising units of both areas, we designed a comparative study of three cases: I) peasant cattle raising of the Calzada Larga ejido in the Frailesca Valley; II) peasant cattle raising of the Los Angeles ejido in the Frailesca Highlands, within the buffer zone of the natural protected area La Sepultura Biosphere Reserve (REBISE according to its Spanish initials); and III) holistic cattle raising by farmers with private land ownership in the Frailesca Valley. An *ejido* is a rural community in which residents have private land ownership as well as communal property belonging to the entire community.

2.2. Methodology

The sustainable livelihoods analytical framework [15] was used to analyze those factors which determine the level of adaptability to multiple stressors of the above-mentioned cases of cattle raising. Information was obtained by applying a questionnaire to 38 cattle farmers of the Los Angeles ejido, 31 of the Calzada Larga ejido, and six of the region´s seven holistic cattle raisers. This questionnaire addressed the following aspects of the farmers´ livelihoods: I) natural, physical, financial, social, and human capitals, II) agricultural and non-agricultural income sources, III) the vulnerability context, IV) multiple stressors affecting the farms, and V) farmers´ relationships to government agencies and public policy. In order to gather additional information regarding III), IV), and V), we also consulted secondary information sources.

From information gathered through the questionnaires and secondary information sources, we determined those multiple stressors that affect the farmers of the three cases evaluated, and identified

their reserves of capitals, their current livelihood strategies, and related governmental policies and programs. We then evaluated the level adaptability of cattle raising to multiple stressors identified in the three case studies.

2.2.1. Index of adaptability

With the aim of determining the current level of adaptability of each type of capital (natural, physical, financial, social, and human) of the farms to multiple stressors, we developed an index of adaptability, on a scale of 1 to 100%.

In order to determine those variables that would integrate the index, we referred to other authors who have evaluated adaptive capacity of natural resource management systems (eg. farming, forestry, and fishing) which have a similar focus to that of the present study [16, 13, 17, 18, 19, 20]. Of those variables that these authors have used to evaluate farms´ adaptive capacity, we included the following in our index of adaptability: (I) total surface area, (II) flat surface area, (III) forested surface area, (IV) diversity of agricultural activities; (V) total income; (VI) membership in farmers´ organizations; (VII) farmer´s formal education level; and (VIII) farmer´s participation in training courses.

The units of measure of the eight variables selected were standardized to percentage values. For this, we determined that for each variable, the maximum value observed among all cattle raising units evaluated would be 100 %. The value of the index of adaptability of each cattle raising unit was the average of the standardized percentage values of the eight variables.

2.2.2. Statistical analysis of information

Information was systematized in a data base and statistically analyzed using version 15.0 of the Statistical Package for Social Sciences (SPSS) program. Once normality in data distribution was verified, a contrast of means was carried out among the three groups of cattle farms evaluated using one-way analysis of variance (ANOVA). Variables showing significant differences in the ANOVA were submitted to a posteriori contrasts (multiple comparisons) using the Tukey´s HSD method ($p < 0.05$) in order to identify among which groups statistical differences were found.

3. Results and discussion

3.1. Regional vulnerability and multiple stressors

The principle stress factors identified were related to climate change (particularly drought) and market conditions (low product prices, increase in input prices, and involvement of intermediaries).

3.1.1 Climate change and drought

Within Mexico, Chiapas has one of the highest levels of physical and social vulnerability to natural disasters, including extreme climatic events such as hurricanes, heavy rains, and floods, which have increased in frequency and intensity in recent decades [21], as well as volcanic eruptions, earthquakes, and landslides. For example, in 2005 Hurricane Stan damaged 208,064 hectares of crops and grasslands [22]. Such phenomena usually have dire consequences for farmers in mountainous environments, such as those of the Los Angeles ejido. Such landscapes typically contain Lithosols and Rendzinas, which are highly susceptible to erosion, especially in deforested areas.

The phenomena “el niño” and “la niña” are opposite phases of what is known as the El Niño-Southern Oscillation (ENSO) cycle and affect intensity and frequency of rain. In Chiapas, “el niño” inhibits rains, causing prolonged droughts, while “la niña” generally provokes heavy rain [23].

Over the past hundred years, average annual temperature in the Frailesca region has increased 1.4° C, and total annual precipitation has decreased by 200 mm [22]. Farmers state that droughts have become increasingly severe in the Frailesca region. Drought generally leads to an increase in overgrazing, and in turn soil compaction and degradation [24], and propitiates malnutrition and even death of cattle. Dry tropical cattle raising systems which principally depend on grazing - such as those of all three case studies - are particularly vulnerable to drought [25].

3.1.2. Market conditions

Farmers of all three case studies generally feel they receive unfair prices for their products. This is largely due to the fact that globalization of agribusiness has led large corporations to gain control over all stages of the food production process, from cultivation to marketing. This has principally impacted small-scale farmers who have little land, infrastructure, and financial resources. According to the USDA [26], seven businesses (Sukarne, Grupo Arias, Frigorifica Contreras, Procarne (Don Fileto), Carnes ViBa, Carnes el Alba, Consorcio Dipsen, and Frigorífico Tabasco) control all processes from fattening animals to marketing for 75% of beef from cattle sacrificed in Mexican government licensed slaughterhouses. Meanwhile, over 60% of Mexico´s milk production is controlled by seven businesses (Grupo Lala, Alpura, Nestle, Sigma Foods, Dannon, Derivados de la Leche La Esmeralda, and Yakult Honsha) [26].

Corporate control of the market for cattle products results in farmers receiving unfair prices, while consumers pay unfairly high prices and the majority of profits end up in the hands of corporations [27]. The North American Free Trade Agreement (NAFTA) has also harmed small-scale cattle raisers, as it led to competition by imported products, resulting in price decreases for Mexican farmers. Farmers state that in the Frailesca region, intermediaries control prices and marketing of products – principally for live cattle and milk.

3.2. Capitals

Table 1 presents farm families' capitals and their corresponding variables in three cases studied.

Table 1. Average values (± standard error) of variables that integrate five capitals of cattle raising families in three case studies in the dry tropics of Chiapas, Mexico

	Case study			
Capitals	**Calzada Larga**	**Los Angeles**	**Holistic farms**	**F; p value**
N	31	38	6	
Natural capital				
Total surface area (ha)	16.3 (± 1.7)^{c}	58.3 (± 8.1)^{b}	112.7 (± 17.4)^{a}	20.5; 0.0001
Flat surface area (ha)	9.7 (± 1.0)^{b}	1.6 (± 0.3)^{c}	95.2 (± 17.3)^{a}	161.2; 0.0001
Forested surface area (ha)	0.6 (± 0.3)	5.4 (± 3.0)	15 (± 4.1)	3.0; NS
Physical capital				
Total animal units (AU)	31.2 (± 3.1)^{a}	28.9 (± 3.3)^{a}	180.4 (± 28.1)^{b}	94.1; 0.0001
Possession of non-mechanized equipment (% of maximum possessed)	19.0 (± 4.3)^{b}	6.5 (± 1.0)^{a}	88.7 (± 8.6)^{c}	58.8; 0.0001
Possession of infrastructure (% of maximum possessed)	19.6 (± 3.4)^{b}	6.2 (± 1.0)^{a}	83.3 (± 4.6)^{c}	84.5; 0.0001
Possession of machinery (% of maximum possessed)	14.8 (± 4.3)^{a}	10.3 (± 3.4)^{a}	98.3 (± 1.6)^{b}	43.7; 0.0001
Financial capital				
Diversity of agricultural income sources (num.)	1.4^{b} (± 0.1)	3.2^{a} (± 0.2)	1.3^{b} (± 0.2)	0.0001
Total income (MX $)	244,138^{b} (± 32,739)	113,086^{c} (± 10,816)	1,529,718^{a} (± 413,185)	0.0001
Social capital				
Per-farm membership in farmers´ organizations (num.)	0.22 (± 0.076)^{a}	1.13 (± 0.077)^{b}	1.16 (± 0.16)^{b}	37.2; 0.0001
Farmers/community belonging to farmers´ organizations^{+} (%)	22.6	92.1	100	
Family labor (num.)	1.2^{b} (± 0.1)	1.8^{a} (± 0.2)	2.2^{a} (± 0.3)	0.001
Human capital				
Farmer´s formal education level (years)	3.5 (± 0.7)^{a}	4.2 (± 0.6)^{a}	12.7 (± 0.9)^{b}	16.3; 0.0001
Time raising cattle (years)	15.87 (± 1.11)^{a}	15.39 (± 1.40)^{a}	31.83 (± 3.70)^{b}	12.1; 0.0001
Level of technical assistance and training (% with some level)	12.90 (± 6.12)^{a}	31.58 (± 7.64)^{a}	100.0 (± 0.0)^{b}	11.8; 0.0001

Different letters ($^{a, b, c}$) in the same row indicate significant differences ($p < 0.05$). $^{+}$ The x^2 test proved significant ($p < 0.01$).

Table 1 shows that holistic cattle raisers have higher levels of all capitals than do those of both ejidos. Those of Calzada Larga have a higher level of physical capital - specifically in flat surface area

and total family income – than do those of Los Angeles. Farmers of all three cases use over 80% of their land for cattle raising, with the holistic farmers using the highest percentage for this purpose.

Calzada Larga farmers generally have the lowest levels of most capitals; they have the least land surface area, although a majority of their land is flat (60%) and well-suited to agriculture. With respect to natural capital, they have a low percentage of forest cover in their agroecosystems (< 5%). With respect to human capital, these farmers have the least formal education and training, and with respect to social capital, only seven of the Calzada Larga cattle raisers interviewed belong to farmers´ organizations.

Los Angeles farmers have intermediate levels for two of the three variables of natural capital. While they have a greater number of hectares than those of Calzada Larga, this land is more difficult to cultivate as most (> 95%) is sloped. The landholdings of Los Angeles farmers include forest patches – on average 10% of total surface area. These farmers make more diversified use of their land than do both other groups: besides raising cattle on 81% of their land (on average), they cultivate maize (on 2.8% of land), beans (0.7%), and shade coffee (1.3%). Thirty-five of the 38 Los Angeles farmers interviewed belong to farmers´ organizations.

The holistic farmers in general have greater surface areas of land than do the other two groups of farmers, and their land is of higher quality: the majority (83%) is flat with deep soil. These farmers have the greatest surface area of forest; each has over 10% of their agroecosystem forested. Each also has more animal units (cattle and horses) than all farmers of the other two groups. Furthermore, in general they have more hand tools (e.g. machete, hoe, shovel), non-mechanized equipment (sprayer, wheelbarrow), infrastructure (corral, milking parlor, warehouses, sanitary equipment, electric fence), and more machinery (truck, hay-cutter, grain mill, feed mixer, mechanical milker, milk tank, tractor) than the farmers of both ejidos. All of the holistic farmers belong to farmers´ organizations.

With respect to human capital, the holistic farmers have the greatest ($p < 0.05$) formal educational level and the most years raising cattle, and have received the most technical assistance and training.

3.3. Index of adaptability of cattle farms to multiple stressors

The index of adaptability takes into account some variables which determine farms´ adaptability to multiple stressors. Figure 1 compares the values of the index of adaptability of the three cases evaluated. Another determining factor of adaptability which was not considered in this index was to what extent policies and organizational structures and processes mediate families´ access to the capitals and influence their vulnerability context [28].

Figure 1 shows that Calzada Larga farms have the lowest index of adaptability. This is principally due to scarcity of land, low forested surface area, low income level, low formal educational level, and low level of technical assistance and training. The average rate of adaptability of Los Angeles farmers lies between those of Calzada Larga farmers and the holistic farmers.

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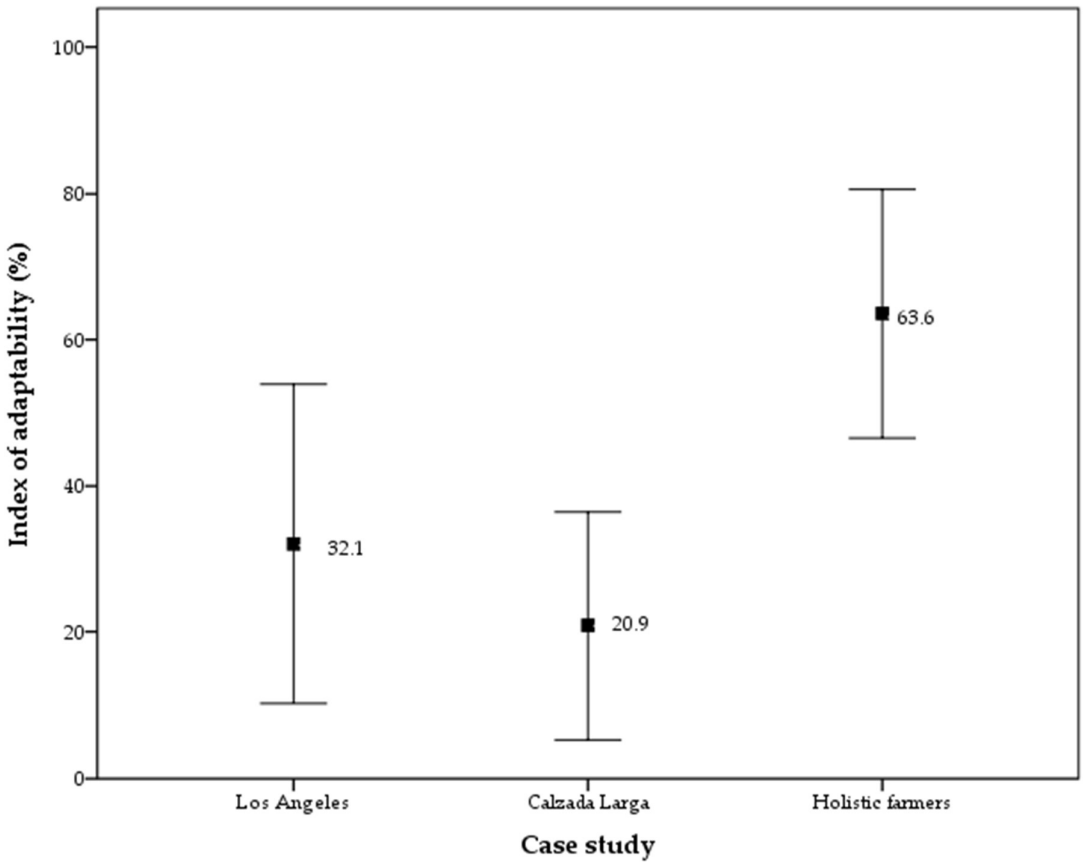

Figure 1. Index of adaptability of cattle farms to multiple stressors in three case studies in the dry tropics of Chiapas, Mexico

The holistic farms have the highest rate of adaptability. As these farmers have the largest surface area and highest quality land, they have been able to increase all their capitals, which has favored their rate of adaptability. Their high level of social capital is largely due to their membership in formal and informal farmers´ organizations, which has facilitated access to subsidies as well as technical assistance and training. Access to farm subsidies has increased their physical capital, as they have acquired agricultural equipment, while technical assistance and training has increased their human capital, which in turn has improved their natural capital, as they have adopted agroecological practices such as silvopastoral systems, use of green manures, and conservation of forest patches.

Holistic farmers´ higher level of formal education as compared to farmers of both ejidos has contributed to the greater level adaptability of their farms. In a study in Bangladesh [19], was found that families with greater formal educational levels were more likely to take on and adapt sustainable agricultural practices.

3.4. Livelihood strategies

The current livelihood strategies of the cattle raising families of the three cases studied are determined by historical, economic, and environmental processes; socio-cultural interactions; and particular government policies. In the early XX century, Mexico´s agrarian policy fomented land settlement; in Chiapas, this led to foundation of many ejidos [29], including Calzada Larga, as well as small private cattle ranches in the Frailesca Valley. The level geography of the Frailesca Valley favored implementation of green revolution agriculture based on mechanization, high agrochemical use, and improved seeds, and this model still prevails today. Demographic growth in the Frailesca Valley led to settlement of the Frailesca Highlands. The Los Angeles ejido, founded in 1960, is one of

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the first such settlements. In the early years, farmers principally grew maize on sloped land using slash and burn techniques. Later, with the increase in maize production in the Frailesca Valley (1970-1994), the green revolution also permeated the highlands, leading to deforestation of large areas to cultivate maize with high agrochemical use. Later, the abrupt fall in maize prices as a consequence of NAFTA and an increase in remittances by migrants - principally in the United States - contributed to development of cattle raising in the Frailesca Highlands. In 1995, the REBISE natural protected area was created in the highlands, resulting in regulations regarding natural resource use which have often been prohibitive to farmers.

Despite the dominance of the Green Revolution agricultural model in the Frailesca Valley, in 1994 seven farmers with private landholdings formed an informal organization to train themselves in intensive grazing practices, and thereby transitioned from conventional to holistic cattle raising [30] with the help of training in Mexico and abroad as a result of their own expense as well as government funding.

The current livelihood strategies of the farm families in the three case studies are differentiated based on the percentage contribution of each income source to their total income [31]. Table 2 presents the income strategies of the farm families of the three cases evaluated.

Table 2. Income strategies of cattle raising families of three case studies in the dry tropics of Chiapas, Mexico

Strategies	Cases study						F; p value
	Calzada Larga		Los Angeles		Holistic farms		
n	31		38		6		
	Average contribution to income		Average contribution to income		Average contribution to income		
	(MX $)	(%)	(MX $)	(%)	(MX $)	(%)	
Income from staple foods	22,995[a]	11.4	21,207[a]	19.5	0.0[b]	0.0	8.2; 0.0001
Income from shade coffee	0.0[b]	0.0	3,516[a]	2.8	0.0[b]	0.0	1.5; NS
Income from cattle raising	202,116[b]	79.0	45,401[c]	38.0	1,248,382[a]	83.8	53.7; 0.0001
Subtotal of agricultural income	225,111[b]	90.4	70,124[c]	60.3	1,248,382[a]	83.8	51.2; 0.0001
Income from non-agricultural labor	1,529[b]	0.8	11,015[b]	10.8	156,667[a]	9.0	11.1; 0.0001
Income from welfare subsidies	4,280[a]	2.6	4,967[a]	5.9	0.0[b]	0.0	7.7;0.0001
Income from agricultural subsidies	8,883[c]	4.3	18,375[b]	17.3	33,003[a]	2.9	15.9; 0.0001
Income from loans	4,335[b]	1.9	1000[b]	1.0	91,666[a]	4.3	14.7; 0.0001
Income from remittances	0.0[b]	0.0	7,605[a]	5.2	0.0[b]	0.0	2.6; NS
Subtotal of non-agricultural income	19,027[b]	9.6	42,963[b]	39.7	281,336[a]	16.2	14.3; 0.0001
Total Income	244,138[b]	100	113,087[b]	100	1,529,718[a]	100	60.0;0.0001

1. Different letters ([a, b, c]) in the same row indicate significant differences ($p < 0.05$).2. Income from production of staple foods (maize and beans) includes monetary as well as non-monetary income (self-provisioning) from maize and beans. Income from non-agricultural labor includes paid work (such as construction and driving public transport) and income from self-employment in commerce and services (such as grocery stores, tortilla shops, butcher shops, and restaurants). Welfare subsidies are provided through the government programs Oportunidades, Nuevo Amanecer, and Setenta y Más, the latter two of which are provided to senior citizens. Agricultural subsidies are provided through the government programs PROCAMPO and PROGAN. 3. For all strategies, income refers to gross income.

Table 2 shows that almost 80% of income of families of both cases in the valley comes from cattle raising. Families of the Los Angeles ejido also receive a majority of their income from cattle raising, although their income sources are somewhat more diversified than those of the other two cases. Cultivation of staple foods (maize and beans principally for self-provisioning) provides over 10% of income of families of Calzada Larga and Los Angeles, while the holistic farmers hardly cultivate any

maize or beans. Eighteen percent of Los Angeles farmers also cultivate shade-grown coffee, as their land is suited to this crop.

With respect to non-agricultural income, families of Calzada Larga and Los Angeles depend more on government subsidies (welfare and agricultural subsidies) than do the holistic farmers, and Los Angeles farmers depend more on non-agricultural income than do those of the other two cases (see Table 2).

Calzada Larga families practice an extensive grazing strategy. They devote 13.9 ± 9.6 ha of land to cattle raising; stocking rate is 2.5 ±1.30 AU/ha; and they have 21.4 ± 12.4 cows in production. These farmers use high levels of agrochemicals for fodder production, and given scarcity of grass during the drought (December to May), they also purchase feed, including chicken manure, hay bales, and maize grain. These farmers reinvest a large part of their income in cattle raising: annual average investment in agrochemicals for pastures of is 40 times greater than that of Los Angeles farmers. While this strategy addresses a specific short-term stress (lack of grass due to drought), it may have harmful medium- and long-term effects. Calzada Larga farmers also devote small plots of land to maize (8.2%), beans (0.4%), and sorghum (0.5%); as with their pastures, they also use high levels of external inputs for these crops.

Compared to Calzada Larga families, those of Los Angeles depend more on non-agricultural income (40% vs. 60% from agricultural income) for their livelihood strategy. They devote 45.9 ± 6.5 ha to cattle raising; have a lower stocking rate (0.8 ± 0.3 AU/ha) than both groups of the valley; and have 18.3 ± 13.5 cows in production. In general, they use less external inputs in cattle raising than both valley groups. During the drought, cattle directly feed on maize harvest residues in the field. Los Angeles farmers carry out a variety of agricultural activities in addition to cattle raising, which contributes to their adaptability. As Dedieu points out [32], diversity (of activities, resources, and products) is key to adaptation over time.

In the Los Angeles ejido, land use has been regulated by the National Commission of Natural Protected Area (CONANP according to its Spanish initials) since the REBISE was founded in 1995. A variety of national and international universities, research centers, and NGOs have promoted natural resource and biodiversity conservation in the reserve, while state and federal agricultural agencies have fomented agriculture, although without necessarily fomenting sustainable practices. This has impacted farm families' social capital, as these agencies have fomented that they join farmers' organizations or other efforts to learn sustainable practices to conserve the reserve and receive agricultural subsidies.

The holistic farmers' livelihood strategy principally depends on cattle raising. Holistic cattle raising is based on sustainable principles and techniques [33]. For example, all the holistic farms include a reserve to conserve flora and fauna, and grow a diversity of fodder species. They rotate pastures according to a planned rotational grazing scheme, and make little use of agrochemicals. These farmers devote 92.1 ± 30.2 ha to cattle raising; stocking rate is 2.1 ± 0.7 UA/ha; and they have 95.8 ± 35.3 cows in production. They obtain the highest average cattle raising income ($p < 0.05$) - approximately 6 and 18 times, respectively, that of Calzada Larga and Los Angeles farmers.

3.5. Ways of adapting to multiple stressors

Aside from the communities' levels of capitals, an important aspect of analysis of adaptability using the sustainable livelihood approach is analyzing farmers' access to resources and their ability to use these resources to undertake strategies of adaptation [16]. This may involve local organization to obtain training and funding to improve their production systems. Government agencies may also foment adaptation strategies for farmers by modifying their policies (planned adaptation).

The following sections present possible scenarios involving the two principle stress factors in the cases studied, and propose steps to reducing farmers' vulnerability and increasing their adaptability.

3.5.1. Scenarios and strategies for facing the climatic stress factor of drought

Estimations reported by the Intergovernmental Panel on Climate Change [34] indicate that by 2100, Earth´s temperature could increase by 0.3 to 4.8° C. It is predicted that in tropical dry regions, temperature increases will reduce agricultural productivity, and Latin America is expected to face increased drought as well as loss of forests and biodiversity. In particular, hydric stress would provoke a crisis in fodder production and therefore lead to decreased livestock production [35].

Given this scenario, if Calzada Larga farmers continue their current practices, they would likely increase their stocking rate and purchase more external inputs (fodder, chicken manure, agrochemicals) to maintain production levels. Nevertheless, given scarcity of land and deforestation, these responses would likely be insufficient and could even increase farmers´ vulnerability to future disturbances as a result of soil degradation and environmental contamination, which would compromise their survival as farmers.

Meanwhile, for Los Angeles farmers who follow an extensive cattle raising strategy with low use of external inputs, given an increase in hydric stress in their agroecosystems, only the wealthier farmers could purchase enough fodder to feed their cattle during droughts. Cattle mortality would likely rise during droughts due to malnutrition, especially for the poorest farmers. Given such a scenario, farmers would likely reduce stocking rate, and cattle raising would no longer be profitable.

The holistic cattle raisers would likely be the least affected given increased drought, as they have been implementing sustainable techniques in their agroecosystems such as maintaining forest patches, conserving trees in pastures, and planting fodders for cutting. Furthermore, they have the greatest ability to invest in improvements their farms – for example establishing irrigation systems, which could mitigate the effects of climate change.

Despite the holistic farmers´ relative advantages, the generally discouraging scenario demonstrates the need to implement sustainable livestock raising practices that could help farmers face crises provoked by droughts. One viable alternative for all three cases studied is implementation of silvopastoral systems.

Silvopastoral systems - or agroforestry systems with a livestock component - consist of different forms of land use and agronomic arrangements which combine food crops; grasses, shrubs, and trees for fodder and other purposes; and animals, simultaneously or successively [36].

The many types of silvopastoral systems allow for a variety of livestock products, including meat, milk, fiber, manure, animal traction, timber, and firewood. Silvopastoral systems allow for adapting to - while also mitigating - climate change, as they increase tree and shrub cover, provide shade which reduces climate stress, increase pasture yield and quality, increase fodder nutrient levels and efficiency of use, fix atmospheric nitrogen in the soil, and allow for reducing use of chemical fertilizers [37, 38]. They also provide a variety of environmental services, such as climate regulation, as well as regulation of CO2 emissions, nitrous oxide, and methane, and contribute to nutrient recycling, restauration of degraded soils, biodiversity conservation, watershed protection, improvement of water quality, increased connectivity among ecosystems, and scenic beauty [38].

Aside from implementing silvopastoral systems [39] propose the following to adapt livestock agroecosystems to – and mitigate - climate change: (I) plan land use according to the characteristics of each plot of land, (II) conserve, store, and efficiently use water, (III) implement soil conservation practices, (IV) increase tree, shrub, and weed cover, (V) introduce locally adapted plant varieties and animal breeds, (VI) implement agroecological practices that allow for reducing agrochemicals and petroleum use, and (VII) avoid unsustainable practices such as controlled burnings which lead to deforestation and soil degradation.

In the three cases studied, silvopastoral systems could be developed to suit farmers´ needs and expectations by making use of local resources. However, it could be more difficult to for Calzada Larga farmers to transition to silvopastoral systems, as the farmers with fewer economic resources are more reluctant to invest in long-term benefits [40].

Mexican government agencies that promote agriculture and conservation could provide incentives to farmers to develop silvopastoral systems in exchange for their ecological benefits, as some nations have done with respect to environmental services provided by silvopastoral systems and use of other sustainable agricultural techniques.

3.5.2. Scenarios and actions to confront the economic stress factor of undesirable market conditions

Given the likelihood that prices of livestock products continue to decrease and input prices increase, farmers face an economic challenge. In such a scenario, as Calzada Larga farmers are more dependent on external inputs than the farmers of the other two cases, they would likely be more affected as 80% of their income - with which they are able to reinvest in their current farm system by purchasing inputs - comes from cattle raising.

Enhancing social capital is key to improving farmers´ collective capacity to respond to market adversities. Upon increasing their social capital, farmers would increase their capacity to negotiate with other actors involved in marketing chains for their products. Furthermore, they would increase their capacity to strengthen the rest of their capitals [41]. As Dedieu points out [32], construction of social networks plays a key role in adaptive capacity.

By enhancing their physical capital, farmers with few economic resources, such as those of both ejidos in the present study, may reduce their disadvantage in marketing relationships with intermediaries who often control product prices based on quality. For example, farmers´ organizations may fund construction of rooved areas with cement floors which are protected from rain and mud and therefore improve milking hygiene and safety. These organizations may also fund farmers´ efforts to add value to products - for example by purchasing equipment and building facilities to make cheese. Such initiatives may also be financed by the farmers themselves through cooperatives, or with the support of government agencies.

Farmers´ organizations may influence the government to carry out regional projects which would improve communities´ physical capital, such as highway construction to facilitate marketing products [20]. This would be particularly useful for Los Angeles farmers as deficient highway infrastructure makes marketing milk difficult.

An increase in consumer awareness of health, illnesses associated with dietary and other lifestyle changes, and new zoonosis - as well as concern regarding methods of food production; the environment; animal well-being; and use of antibiotics, hormones and other growth promoters - may increase the demand for healthy (e.g. organic) animal products.

For the Los Angeles farmers, who raise livestock within a natural protected area and use few chemical inputs, it could be easier than the Calzada Larga farmers to enter the organic niche market. For the same reason, they could receive support from conservation-oriented government agencies and NGOs.

Entering such markets requires complying with standards regarding animal feeding, sustainable grassland management, ecological pest and weed control in pastures, ecological fertilization, natural animal reproduction, animal well-being, use of medications, agrifood safety, and ecological farm management. Many of these areas require farmer consciousness-raising and training, which involves building human capital. There is also a need for a high level of social capital in order to collectively undertake the process of transitioning to - and marketing of - organic or ecological products.

Holistic livestock management is highly compatible with the organic farming model, as it involves agroecological technologies. However, unlike the Los Angeles producers, the holistic farmers are located in a region in which many farmers use high levels of chemical inputs, which could make it difficult for them to enter ecological markets.

There is also a need for government agencies to adapt their program guidelines – which generally favor large-scale farming - to the context and needs of small-scale farms [42].

4. Conclusions

The index of adaptability of cattle raising to multiple stressors was greater for the holistic farms located in the Frailesca Valley, followed by those of the Los Angeles ejido of the highlands, and lastly those of Calzada Larga in the valley. The low level of adaptability of Calzada Larga farmers is due to the fact that they have little land; deforestation of their agroecosystems; their low income; and low levels of formal education, technical assistance, and training. The holistic farmers´ situation is quite opposite, as reflected in their high value for the index of adaptability. Given the possibility of increased drought and market crises, under their current production system, Calzada Larga farmers

would have to further increase agrochemical use to sustain productivity, which would put their economic survival at risk as well as deteriorate their farmland.

This study reveals the need to implement adaptation strategies - such as organic cattle raising and silvopastoral systems - that reduce families´ vulnerability and increase their adaptability to multiple stressors. This would require public policy which responds to the conditions of the most vulnerable farmers.

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