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Vulnerabilities, Environmental Threats, and Recursive Crises under COVID-19: Dilemmas for Beekeeper-Farmers in Yucatan, Mexico

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Abstract: In this article we connect theoretically the concepts of structural vulnerabilities, recursive crises, and disasters through the linking-up of the COVID-19 pandemic with extreme hydrometeorological events in three municipalities in southern Yucatan, Mexico. The main research goal was to show the effects in productive and commercial systems in beekeeper and farmer households and their coping strategies to highlight the inter-relationships between historical vulnerabilities, crises, and disasters. The methodological approach included ethnographic fieldwork, 101 semi-structured interviews, and five focal groups. In the results, we reconstruct the agro-productive and commercial vulnerabilities built up since 1960 and contextualize the health and hydrometeorological crisis to show how some 87% of households suffered severe consequences to their incomes. The prices of main products (maize, fruit, honey) reached historically low levels as a result of conditions within local markets during the crisis. Half of the households surveyed had to make use of savings and more than 60% received no support from government or from development agencies. We conclude by pointing out the need for accompanying the design and implementation of community mitigation plans, which should take as a starting point the recovery of knowledge and local organization in order to demand from government co-managed, preventive programs, and capacities that would enable communities to confront increasing negative consequences in situations of global climate change and market instabilities in local peasant contexts. Our study aims to reach policy-makers, social organizations, and communities in order to highlight the importance of developing joint capabilities to respond to growing environmental, economic, and health vulnerabilities.

Keywords: structural vulnerabilities; recursive crises; socio-environmental disasters; COVID-19; apiculture; agriculture; coping strategies; Yucatan

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1. Introduction

Since the 1990s the concept of vulnerability has been fundamental for understanding the theoretical dimensions of disasters produced by extreme hydro-meteorological events. Several disciplines departing from contrasting epistemological positions have enriched and transformed the concept but have also demonstrated its strengths and weaknesses for the management of risks in the face of disasters [1–8]. Included within the themes of food insecurity and famine, political economy, and political ecology and more recently in the discussions about climate change, global environmental change, sustainable lifeways, poverty, and socio-environmental systems, the term vulnerability has represented an articulating axis of research and public policies [9–15].

Vulnerability involves the unequal exposure of a human population to certain threats, the differential capacity to confront them, and the potential to be able to overcome them [16].

The structural dimension of vulnerabilities refers to the combination of historical and institutional factors and power relations which recreate the socio-economic inequities and make some individuals and groups more susceptible than others to disasters [4,17,18]. Vulnerability implies all the characteristics of individuals and groups in terms of their capacity to anticipate, confront, and recover from the impacts of environmental threats [17,18].

If we consider social inequalities as the axis of vulnerability, it becomes necessary to explore the origins of risk societies [19,20] in the historical ruptures between socio-environmental relations and the ability of the state to manage manufactured collective risks in contemporary societies [21]. This leads us to reconsider vulnerability not only in biophysical terms, but also in regard to social and political inequities [3,8,22].

In this article our starting point is a theoretical focus on structural vulnerabilities expressed through socio-environmental, climatic, productive-commercial, and health threats with the goal of analyzing the effects and responses of beekeeper-farmer families in the Yucatan Peninsula in the face of the Amanda and Cristóbal storms and the COVID-19 pandemic during 2020. We are interested in weaving the concepts of recursive and coupled crises together with vulnerabilities, which will allow us to deepen our understanding of both the symptoms as well as the structural causes of disasters. How are structural vulnerabilities and recursive and coupled crises generated amongst the beekeeper-farmer families in southern Yucatan? What do disasters such as storms and the pandemic cause in the productive and commercial systems of beekeeper-farmer families? What are the possible responses and alternatives available for productive and commercial reconstruction in the medium and long term?

Added to the structural-historical vulnerabilities of farmers and beekeepers, 2020 has been an atypical and complicated year for the producers of Yucatan due to the linkage and recursivity of the crisis described above. Much work has already been done on the implications of COVID-19 for agriculture and food supplies. These have concentrated on the main affectations of the pandemic: the rapid increase in the demand for food, increases in the prices of basic foodstuffs, pauses in the migratory flows of agricultural workers, restrictions in international food trade, and interruptions in social programs of food support for marginalized families due to the forced reorganization of public spending [23–27]. Despite the emergence of studies of this kind we have not yet identified any that combine the agricultural, food, and commercial effects of the pandemic with the linkage and synergy with other crises that recursively affect rural areas, such as hydro-meteorological phenomena and the constant collapses of world agricultural markets [28]. In this section we analyze at a micro-regional scale the double effects and the linkages of crises on the economic and productive means of farmer and beekeeper households, in the light of accumulated socio-environmental vulnerabilities.

The model of social vulnerabilities has been enriched by the conceptual framework of entitlements of Amartya Sen. The ability to acquire or exchange resources in a given society (relations of entitlements) determines if a person has access to food [9,29]. According to Sen, vulnerability represents a failure in entitlement relations and therefore social inequality is both a cause and an outcome of vulnerability. Consequently, to reduce the risk of famine or flooding, for example, the best way to reduce vulnerability is through institutional arrangements. In the anticipation of famines this framework has generated illustrative government policy in the sub-Sahara region of Africa. An accumulation of food in good years allows for the availability of cheap food in bad years so that the most vulnerable always have access to food [8,22].

This framework helps us understand how the cycles between good and bad years can be upset by recursive crises. The effects of these crises can be seen in a matrix of social vulnerabilities and of structural inequalities and contained in circumstances of historical inequality, more than as a result of environmental threats due to extreme hydro-meteorological events. The local social, economic, and political processes are conformed historically and define the social and geographical space of vulnerability [6,16]. The paths towards sustainable lifeways must include both a guarantee of access to alternatives as well as capacities and entitlements in the use of territory [30].

Disasters originate in the overlapping of vulnerabilities with the recursive crises caused by economic, socio-environmental, climatic, political, and/or social events. These vulnerabilities influence the control and the rights of inhabitants over territory, which in turn implies the suppression of certain voices, producing the reproduction of a circle of political and economic exclusion. Spaces of unequal distribution of risk, marginality, and vulnerability are recreated crossed with differences due to gender, generation, ethnicity, and social class. Consequently, in order to mitigate disasters, it is not only technological innovations that are needed, but institutional changes in access and control over resources and territories [17]. These are our main theoretical contributions. Faced by the consequences caused by COVID-19 and both tropical storms, we cannot analyze them as a result of a "natural" disaster or a unique social health issue, but we have to consider the interweaving of social, environmental, economic, and political vulnerabilities accumulated in the history of rural communities and the recursive crises triggered by the dominant economic model. In this sense, to mitigate events as the ones analyzed, the alternatives and strategies have to come from the collective participation of local communities and the establishment of institutions that guarantee open channels to address social, economic, environmental, and political vulnerabilities and inequities. These conditions are not constructed in the short-term, but we can start with the recognition of these underlying vulnerabilities and inequities to truly deal with meteorological or health events as the pandemia of COVID-19 and not only place a band-aid to cure a long-term and deep sickness.

Current crises are the consequence of a model that combines neoliberalism, flexibility, and globalization, and which has led to increasing polarization and socioeconomic inequities [31–33]. This has led to fragmentation of social identities and a loss of social guarantees, which in turn increases the social and cultural vulnerabilities of populations. As a consequence, food vulnerability has been aggravated at the same time as transnational agrifood corporations have taken control of productive, distributional, and commercial systems as well as consumption. The food system reconfigures itself, taking advantage of agri-food crises. In turn these agricultural crises are "solved" through substantial investments in agricultural biotechnology and agri-food industrialization, which in turn aggravates further the agri-food vulnerabilities of peasant and indigenous families.

The general purposes of our research were to elucidate (i) the ways in which accumulated structural vulnerabilities and recursive crises open channels of food dependency through the establishment of agricultural conditioned prices which are independent of supply and demand or of productive costs, and (ii) in what sense recursive crises are a reflex of the incapacities of the socio-economic system in general, and the global food regime in particular, to mitigate ecological conditions and their effects on the local productive sectors. As hypotheses to be tested in our particular context of study, we propose the following:

a. Small-scale farmers are deeply embedded in historical and structural vulnerabilities, not only in terms of agricultural production and commercial relations, but also in terms of their social ties and organizational capacities.
b. The coupling of contingencies, such as the COVID-19 pandemic, with extreme hydro-meteorological phenomena, causes recurrent crises that push the vulnerability of small-scale farmers to the limit through the historical conditioning of the prices of their crops.
c. As a result of the erosion of the social basis of peasant production, as well as the lack of concurrent and focused policies in the face of such recursive crisis situations, the response of farmer communities tends to be individualistic and often has highly negative implications, such as rural exodus, the depletion of their means of production and, consequently, the possibility of abandoning agricultural activities altogether.

2. Materials and Methods

Using qualitative methodology (semi-structured interviews, questionnaires, and focus groups), we designed a semi-structured interview with 50 open questions that could enable us to understand the interrelationships between: (a) family structure; (b) productive, commercial, and organizational characteristics of beekeeping and farming; (c) the impacts, strategies, and alternatives available in the face of storms and COVID-19 within farming and beekeeping; (d) economic costs of their production and prices for their agricultural products; (e) social organization. As our goal was to analyze the accumulated vulnerabilities and the effects of the recursive crises in the peasant economy, we centered on exploring the family members' dynamics and their participation in the labor farm organization, and the heterogeneity of the economic (productive and commercial) characteristics of their agricultural production so we could evaluate the diversity of impacts and strategies generated by the storms and COVID-19. At the beginning, as we had mainly received disaster reports of three municipalities: Ticul, Muna, and Santa Elena, we decided to undertake 100 family surveys in these three municipalities. Nevertheless, when we had conducted nine interviews in Santa Elena, we realized there was no significant difference with Muna, so we concentrated our efforts in Muna (43 interviews) and in Ticul (49 interviews). In sum, we surveyed face to face 101 peasant families in the municipalities that had most suffered in the south of Yucatán due to the impacts of the tropical storms (Figure 1).

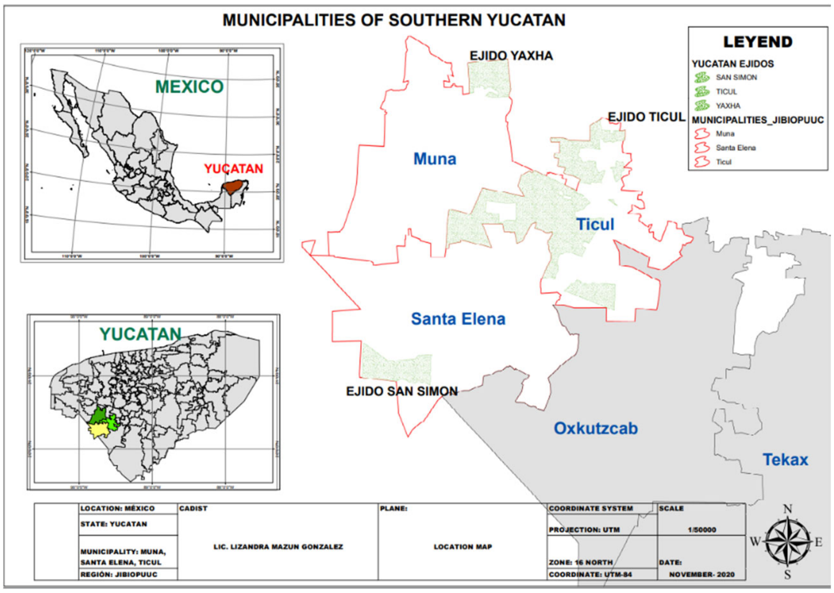

Figure 1. Studied municipalities of southern Yucatán.

Families were selected based on having access to land and being farmers and/or beekeepers. Accomplishing these factors, they were selected randomly. We walked through the streets of Muna and Ticul, asking farmers or beekeepers if they would like to share with us their experiences and strategies faced by COVID-19 and both tropical storms. We distributed ourselves in different parts of the village, so we could interview various sectors. Most of those interviewed were men with an average age of 58 years old, of whom 69% were *ejidatarios* (private landholders), and the rest were *comuneros* (common landholders) and *non-ejidatarios* (settlers). Because of the pandemic, women decided not to be exposed and they did not participate in the interviews. Questionnaires on average lasted around three hours. We proceeded to the transcription of all the information. We constructed a database with the quantitative information in excel, and we manually codified all the qualitative information in word documents organized by themes.

In addition, in-depth interviews were carried out virtually (7 cases by Zoom and Skype) and face to face (4 cases) with 11 strategic people (old farmers, community leaders, local and municipal authorities), known for their knowledge of agriculture and beekeeping. These interviews were more about the history of farming and beekeeping, the main problems to face, the recent political changes that could have affected them, and the future agricultural strategies.

Three small focus groups (3 to 5 people) differentiated by gender and generation, were carried out in Muna. The first group was composed of women aged between 45 and 65 years old, the second group of young people (between 18 and 25 years old), and the third group of old farmers aged ca. 60 years old. In Ticul, we organized two more events where men and women participated in different groups in order to discuss the economic and environmental impacts of COVID-19 and the tropical storms. Whilst paying attention to sanitary rules for the prevention of COVID-19 those participating were summoned to open spaces within the municipal offices. Although the formality of these spaces may have influenced their responses, the separation of spaces helped to obtain privacy and a high degree of confidence once dialogues had begun. We transcribed all the discussion from the focus groups, and we systematized the information by themes. The topics were centered on the effects of the tropical storms and of COVID-19 and on the challenges to construct collectively future strategies to face their vulnerabilities.

The agricultural context was analyzed with the use of the historical official statistics for the studied municipalities. The COVID-19 and extreme hydro-meteorological events impacts were measured with the use of research statistics and a database constructed by the national university of Mexico (UNAM). The agricultural price fluctuations were determined directly by the interviewed farmers and beekeepers. Although there were variations, the differences were not statistically significant.

3. Results and Discussions

(a) Environmental and health threats: Storms and COVID-19

The Peninsula has a warm sub-humid climate (Aw) with an annual average temperature between 25.8 and 26.3 °C and a frequency of rain in summer and autumn with the greatest rainfall occurring in the southeast (1400 mm) [34]. Hurricanes, storms, and droughts are a constant in the variability of rainfall in the Peninsula. However, the drought of 2019 has been one of the most intense of the last 30 years (Figure 2a). This extreme hydro-meteorological phenomenon was followed by flooding caused by the tropical storms Amanda and Cristobal in 2020, with atypical cumulative rains throughout the state (Figure 2b). The total annual rainfall in the municipalities of Muna, Ticul, and Santa Elena is similar, with normal amounts of 1045 mm, 1185 mm, and 1032 mm respectively (for the period 1981–2010). The number of days in the year with rain is 90, 102, and 86 [35,36]. Tropical storms Amanda and Cristobal were without precedent. In the four days that storm Amanda lasted (28–31 of May) the accumulated rainfall in the municipalities studied was 70–100 mm, whilst Cristobal storm left between 500 and 600 mm of rain in six days (1–6 of June). The coupling of both events can be seen in the context of the rainfall patterns of the last 30 years (Figure 2a) with data for the municipality of Muna. The figure shows the Standardized Precipitation Index (SPI), useful for detecting anomalies in rainfall patterns in contrast with averages and for determining the severity of events. Both the drought of 2019 and the accumulated rains of 2020 show higher rates than those observed since 1990 in Muna. The figure also demonstrates the recursive character of periods of rain followed by drought.

Only two months after the first confirmed cases of COVID-19 in the Peninsula, the above-mentioned tropical storms, according to the National Meteorological Service, produced more water in 10 days than the average rains for the Mexican southeast in a month. The co-occurrence of climatic events and the COVID-19 pandemic is shown in Figure 2c where one can observe the passing of tropical storm Cristobal at the beginning of June (indicated with a vertical line) followed by a sharp increase in positive cases and deaths caused by COVID-19 (Figure 2d).

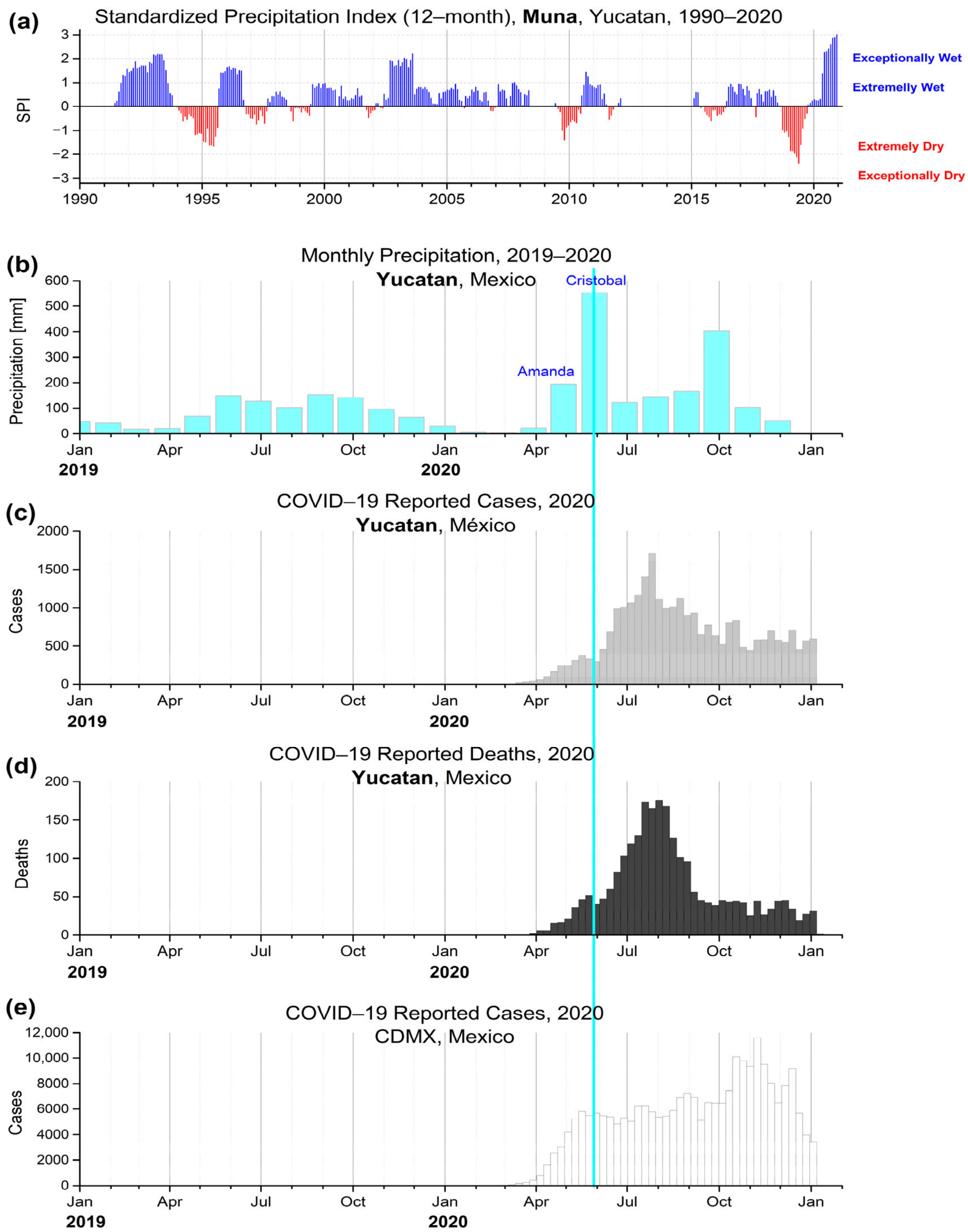

Figure 2. Coupled extreme hydrometeorological events and evolution of COVID-19 in Yucatan. (**a**) Precipitation anomalies (1990–2020) in Muna, Yucatan, one of the study sites; (**b**) Extreme precipitation brought by Amanda and Cristobal tropical storms; (**c**) Evolution of COVID-19 cases (and (**d**,**e**) deaths in Yucatan and Mexico City as reference. The vertical line shows the co-occurrence in June of the highest accumulate precipitation in Yucatan with the onset of increased COVID-19 reported cases. Source: Data from SMN-CONAGUA 2020, DGE-SSA 2020, Ghilardi et al., 2020.

In terms of health threats, of the three municipalities studied, Ticul reported the greatest number of accumulated infected people in 2020: 807 positives cases and 46 deaths according to the official federal statistics [37,38]. In Muna 78 infections were reported and 24 deaths, whilst in Santa Elena 26 cases and one death. Beekeeper-farmers interviewed reported 24 family people sick with COVID-19 and one death (data from September 2020).

Regarding the vulnerability of suffering a severe form of COVID-19 or having serious consequences, one of the most important factors is the presence of co-morbidities. Beekeeper-farmers report having family members at home with diabetes (42%), hypertension (32%), and obesity (7%). This health profile contrasts with the municipal statistics for 2018, which are similar to the state statistics for Yucatan, registering lower levels of diabetes (9–11%), 18–19% for hypertension, and higher levels of obesity (34–42%) for the three municipalities [39]. This can be explained by the under or over representation of local realities in official statistics.

The recursivity between prolonged droughts and tropical storms, as well as their coupling with the COVID-19 sanitary contingency, revealed the particular condition of environmental susceptibility faced by the Peninsula. In this sense and in the context of climate change and global environmental change, meteorological and epidemiological predictions are drastic for Yucatan. Projections for 2080 to 2099 point to a decrease in annual rainfall (from 10% to 15% and more than 30% during the dry and rainy season respectively when compared to the period 1980–1999). An increase in average temperatures of 2 to 3.5 °C for 2090 for dry season periods which could reach a reduction of 48% [40]. Likewise, the region has been identified as being especially vulnerable to an increase in droughts and hurricanes [41]. An estimated 50% of Yucatan municipalities demonstrate high or very high vulnerability to an increase in the possibility of dengue fever, for example [42]. In terms of agriculture, Yucatan is particularly sensitive to these extreme hydro-meteorological events because its karstic soils, degraded vegetation cover, and mainly convective rainfall patterns limit the capacity for the regulation of surface waters. It is estimated that between 20 and 50% of the municipalities of the Peninsula are at risk of crop and livestock production losses due to severe and prolonged flooding [42].

(b) Agri-productive, social, and commercial traits and their vulnerabilities

The southern region of Yucatan is made up of 17 municipalities, of which 11 demonstrate average marginality and six either very high or high marginality. The region has been radically transformed since 1960 by a commercially orientated farming model, which has caused agri-productive, ecological, organizational, financial, and political changes. The municipalities of Ticul, Muna, and Santa Elena have a population together in 2020 of 42,960 [43]. The indexes of marginality are −0.56, −0.59, and −0.42, respectively [44]. Regarding the selected *ejidos*, the *ejido* of Ticul possesses 15,387 hectares of land with 1,616 *ejido* members (endowed in 1925 and distributed in 1930). The *ejido* of Yaxha (municipality of Muna) has 2200 hectares, 80 *ejido* members, 224 inhabitants and was endowed in 1939 (distributed in 1979), whilst the *ejido* of San Simón (municipality of Santa Elena) was endowed in 1964 (distributed in 1980) and has 2688 hectares, 74 *ejido* members [44], and 369 inhabitants.

The southern region was subjected to several development plans which have converted it into a horticultural zone, known as the "orchard of the state". Driven by agricultural financing through diverse credits and a "desired" economic integration, commercial networks have extended towards the tourist market of Quintana Roo as well as towards the regional markets of Mérida and Campeche, and even towards the national markets of Veracruz, Puebla, and Mexico City [45,46]. Since 1970 the most significant agri-productive tendency has been a shift from a seasonal productive cycle based on maize farming, forestry, and beekeeping and aimed at self-sufficiency towards a highly commercial horticultural and fruit growing system based on irrigation. In just three decades the irrigated land in the southern irrigated district increased from 4% in 1960 to 21% in 1988 and the land dedicated to growing sweet oranges increased from 6% in 1960 to 59% in 1988. The same period saw a decrease in native maize growing from 65% in 1960 to just 10% in 1988 [47]. This movement towards oranges, although originally supported by financial banking (credit was only obtained for land dedicated to orange growing) was later further stimulated by the national and international markets (juice being exported to the United States) [47]. Clearly the control of irrigated land constituted the central focus of political relations. In those early years clientelism led to an unequal distribution of irrigated fields.

In the three municipalities, other crop transformations have also occurred. In Santa Elena and in Ticul, the land surface dedicated to lemons grew exponentially: from 0.5 hectares to 260 hectares (2003–2010) and from 63 to 192 hectares (2003–2015), respectively. The increase in maize production is due to the introduction of hybrid maize (Figure 3). In addition to the preponderance of hybrid maize, sweet orange, and Persian lemon, 30 other cash crops began to be produced regularly, such as lagunero avocados, mandarines, green chiles, habanero chiles, and saladet tomatoes [48–50].

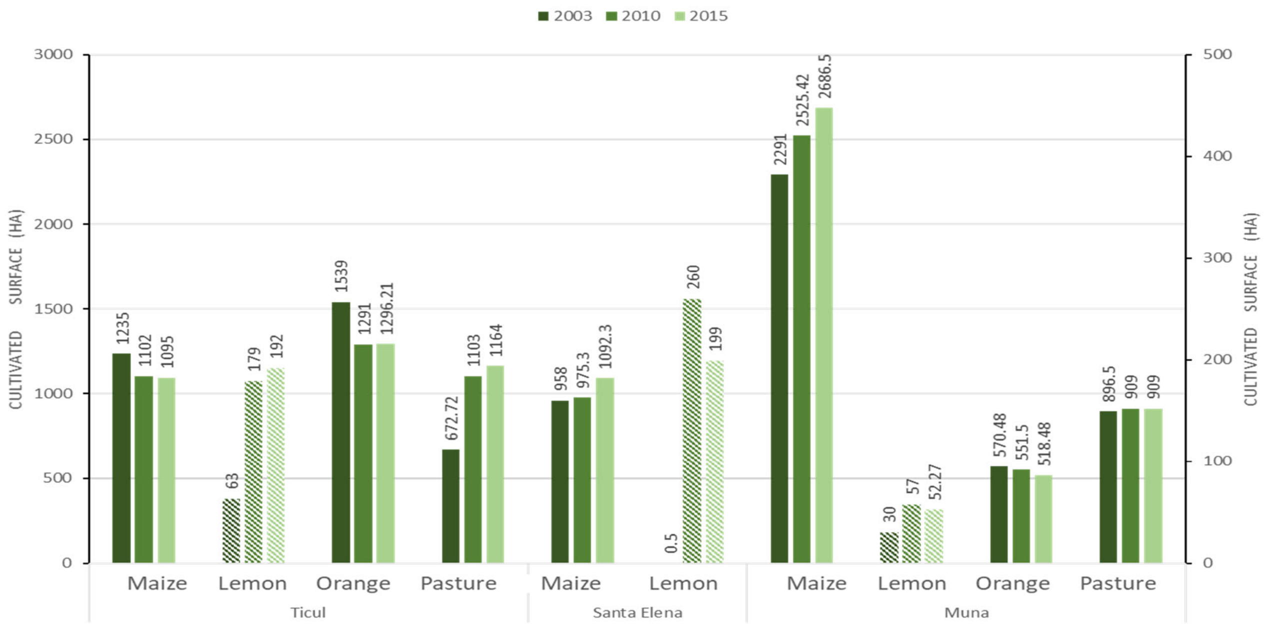

Figure 3. Surface cultivated with maize and other cash crops in Ticul, Santa Elena, and Muna (2003–2015). Source: Elaborated by the authors with data from SIAP 2003, 2010, and 2015.

Regarding beekeeping, production fluctuates strongly in the three municipalities (Figure 4). Muna reported some 110 tonnes of honey in 2006, 751 tonnes in 2010, and a decrease to 171 tonnes in 2015. These oscillations can also be observed in Santa Elena. On the contrary, in Ticul production doubled between 2010 and 2015 [48–50].

The brief agri-productive history outlined above explains to a large extent the agrarian, productive, and commercial vulnerabilities currently faced by peasant households in the Puuc region. Half those interviewed (52%) practice both agriculture and beekeeping, 32% only agriculture, and 14% only beekeeping. In relation to access to irrigation, a third of farmers have irrigated fields, 10% combine irrigated fields with seasonal farming, and the majority (57%) only practice seasonal farming. The average field size for those farmers interviewed is some 5.2 hectares, the smallest being only one hectare and the largest 21.5 hectares. Half of the farmers (56%) have one field, a quarter two fields, and the rest between three and five fields. As to the distribution of uses of fields, maize is the most commonly grown crop (52% of cultivated land, 2.5 hectares on average), followed by fruit growing (36%, 1 hectare on average), forestry (11%, 0.6 hectares on average), and horticulture (1%, 2.5 hectares on average).

Despite access to irrigation (43% of surveyed households) destined mainly for fruit and vegetables, agri-productive vulnerabilities have accumulated with the frequency of bad agricultural years resulting from climatic variations (Figure 2) between droughts and floods, affecting groundwater levels. Maize fields are located in non-irrigated areas such that yields of creole maize can fluctuate in bad years from total loss up to 1.5 tons per hectare; whilst in good years these may increase to 2.5 tons per hectare. This represents a fluctuation between 60% and 100%. In the case of hybrid maize, good years produce some 4.5 tons per hectare, whilst in bad years yields may only reach 2 tons per hectare or the whole harvest may be lost. Traditionally the agri-food system confronted risks with the sowing of small fields from different microclimatic niches and soil qualities, but was always complemented by domestic plots, hunting, or collecting of wild food plants [51,52].

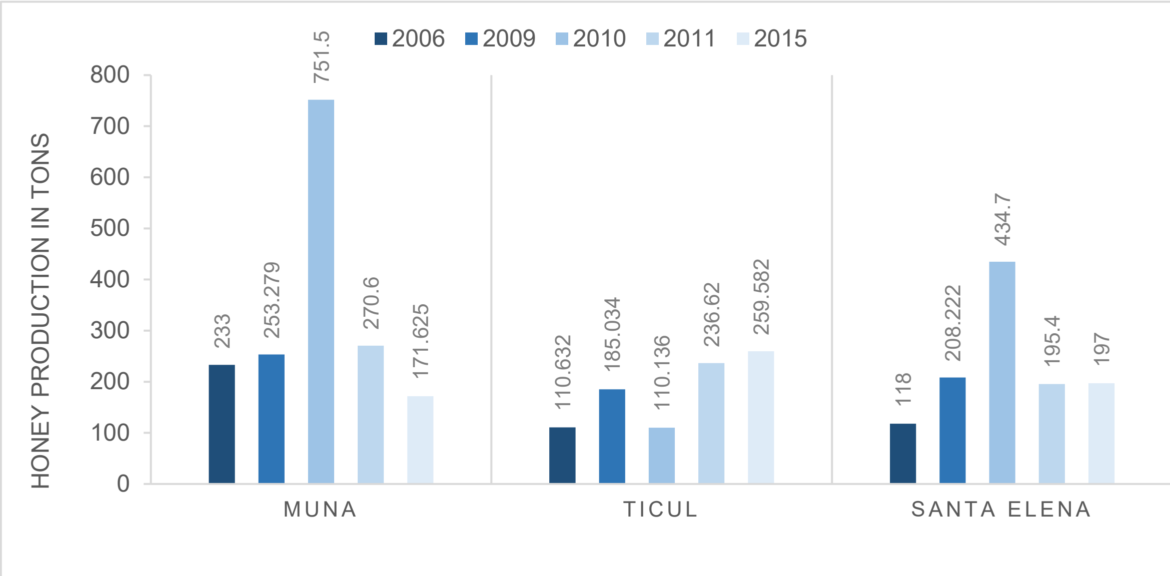

Figure 4. Historical production of honey in Muna, Ticul, and Santa Elena (2006 to 2015). Source: Elaborated by the authors with data from SIAP 2006, 2010, and 2015.

In 2020 the maize harvest was almost lost completely, first due to extreme drought, later as a result of torrential rains which resulted in replanting being necessary. Despite this, thanks to the survival of the replanting, some harvesting was possible (2 tons per hectare for creole maize; 3.5 tons per hectare for hybrid varieties). This productive decrease, added to the double investment for the purchase of seeds and labor, caused major economic vulnerability amongst many families. By contrast citrus growers were positively favored by the rains, obtaining higher yields. At the same time avocado growers lost up to 30% of their production due to the flooding of their lands. Horticulturalists face uncertainty and risks for each agricultural cycle depending on the crop chosen and environmental conditions but these farmers sow a diversity of crops (on average 7) to confront climatic and commercial risks. Nevertheless, most production (even up to 95%) is orientated towards the market.

Regarding beekeeping, 71% of those interviewed are beekeepers and have been practicing the activity for an average of 23 years. Approximately half consider beekeeping to be their principal activity. Their bees are mainly reported to be Italian (61%) and the rest are "Africanised" in different proportions. Only one beekeeper has *Melipona* bees. On average beekeepers have around 48 hives, although some have as many as 240. All produce honey and a little more than half (57%) also produce wax (Table 1). On average each hive produces some 44.4 kg of honey annually and 10 kg of wax. The total annual production per beekeeper is 1514 kg of honey and 39 kg of wax. The majority of apiaries (86%) are found on ejido or communal land at an average distance from the beekeeper's house of 13.6 km. Average production costs are mostly spent on feeding the hive (31%), followed by the purchase of equipment (28%), transport costs (22%), and pest control (8%). Beekeeper organization is basically individual: 20% of ejido members mentioned occasional collective work. Even the transport of water from their homes is carried out individually, in their own vehicles.

These productive transformations have prompted radical environmental changes: the rupture of regenerative cycles between forests and maize fields with a subsequent loss of biodiversity and fragmentation of habitats, soils deteriorated by the excessive use of chemical fertilizers, the proliferation of pests, an excessive use of agro-chemical products to control pests and weeds, the contamination of groundwaters, as well as overconsumption of the latter. In agricultural terms, although there is a relative diversity of crops and varieties (up to 30), these depend on the oscillations of the market, technical requirements (irrigation, machinery, pesticides, seed varieties), ecological requirements (soil quality, storms, droughts), an available workforce, and the existence of government programs.

Table 1. Total annual production of honey and wax per beekeeper (*n* = 70 beekeepers).

	Honey (kg)	Wax (kg)	Other Products
Average	1514	39	21
Minimum	100	3	6
Maximum	14,000	200	40

Source: Data analyzed from 101 interviews.

The combination of socio-environmental and agri-productive contraints leads to important structural vulnerabilities that can imply the continuity or disappearance of crops through the loss of native seeds, the degradation of fields, and dependency on transnational industry (machinery, agro-chemicals, fertilizers, improved seeds). These changes have generated food vulnerability. The decrease in land planted with native maize, beans, and squash (through the traditional polycrop system known as *milpa*) or given over to family gardens, produces a dependency on the purchasing of basic foodstuffs that also negatively affect the traditional Mayan diet [53].

The transformation towards a more commercial agriculture has caused a dependency towards fluctuations in market prices and the type and number of traders who arrive at the central market of the region's main commercial urban center: Oxkutzcab. Producers risk commercial deals that involve late payments, under conditions imposed by traders. This represents a loss of autonomy for local agricultural systems, which now find themselves dependent on national and global agri-food systems both for buying inputs as well as for the sale of products. This impact has resulted in a dependence on the market to the point where the latter can impose varieties to be cultivated, the area sown, and the methods used. "Here we sow what the market pays for; if the price is good, the producer will cultivate depending on the prices" (Anselmo, farmer from Muna; interview 20 October 2020).

Honey production is largely destined for the market, although on average the beekeeper-farmer families interviewed consume some 15 kg per year. Around half of beekeepers (54%) sell to the municipal capital storage center, 36% to a series of intermediaries, and a few to friends or family members. Reasons given for selling to storage centers include the proximity which helps to avoid transport costs, immediate payment in cash, and the possible financing of inputs and infrastructure. Nevertheless, being a monopoly, beekeepers depend on prices fixed by the storage center.

The interaction between these socio-environmental and economic vulnerabilities generates agri-food and commercial dependencies. This leads to considerable social inequalities amongst beekeeper-farmers, each one confronting different risks, clientelistic relationships, and daily fluctuations. The market has become a form of survival and a way of life, at the same time Mayan peasant families are subordinated to the forms and conditions of commercial capital. Under these arrangements of vulnerability, environmental threats, and threats to the health of producers, have had very different effects, generating strong social inequalities.

(c) Market and severe prices fluctuations: Effects of recursive crises

A large majority (87%) of households reported a significant decrease in income as a result of the health contingency. For 64% of peasant households the most affected economic activity was agriculture, 32% mentioned beekeeping, and for the remaining 17% both activities were affected equally. The sale price for maize as a main food crop dropped from its normal price of US$ 0.25 per kilo to US$ 0.11 per kilo at the beginning of the COVID-19 contingency. Likewise, the normal average sales price for fruit, now the main cash crops in the region, dropped from US$ 3.8 per kilo to a mere US$ 1.38 per kilo. The price of honey also suffered a decrease from US$ 1.5 a liter to US$ 1.13.

This new condition of hydro-meteorological crisis, added to the existing health crisis, caused the prices of peasant products to fall even further in the following weeks. The average price of maize fell to US$ 0.1 per kilo, for fruit in general to US$ 0.98 per kilo and honey down to US$ 0.84 per liter.

The law of supply and demand has become virtually inoperative in the commercialization of the agricultural products of small producers. This has been due to the increasing dynamic of the conditioning of markets imposed by intermediaries [54,55] to peasant families who have been unable to organize for collective commercialization, and even applies to those peasant organizations, which although they are constituted in formal associations, have been unable to build or join nested circuits of fair trade [56]. In the communities studied we have seen how this dynamic of conditioned markets has been exacerbated by the conjunctural periods of linked crises, bringing the prices for peasant products down to below the level of production costs (particularly in the case of maize). This situation is imposed on producers as the only opportunity for commercialization in order to obtain income from their production. It is also a consequence of the lack of storage capacity, for example for fruit that has to be sold before going off, or for processing in the case of maize or honey.

When the pandemic began, the number of traders reduced, and the number of sellers increased as they concentrated in Oxkutzcab as a result of restrictions on mobility. Producers from other municipalities who arrived at the market to sell were thrown out [57]. Even so traders paid low prices, provoking substantial losses in family economies. A similar situation was experienced by beekeepers.

The case of the commercialization of honey illustrates the way in which international crises in food markets link with the recursivity of local hydro-meteorological crises and the conjunctural health crisis, plunging honey prices to their lowest ever historical levels. During the last few months of 2019, a liter of honey in the south of Yucatan still fetched prices fluctuating between US$ 1.5 and 2.25, managing to compete in exports with the Asian market, given the incipient national market (with an average annual consumption of 300 grammes compared to Germany where the per capita consumption is around 1 kilo).

According to statistics of the FAO and ITC-UNCOMTRADE Latin American countries that export honey like Mexico (in third place worldwide) have experienced a considerable increase in the number of hives at the same time as a notable decrease in exports. This situation is due both to a global situation of "honey flooding" as well as the disloyal competition caused by the dilution of honey with sugar syrups carried out by certain Asian exporting countries, led by China. For the national situation the expansion of the Asian market in recent years had already meant a drop of around 50% in honey prices. The sanitary crisis, together with the hydro-meteorological crisis, in just a few months, has caused a dramatic drop in prices of a further 50%.

As well as the effects on prices in agricultural and beekeeping markets during 2020, peasant households have experienced significant losses and constraints in their productive and infrastructure systems due to the hydro-meteorological crisis (Figure 5), whose economic and alimentary effects have been noticed in the end of year harvests and in the renovation of the 2021 productive cycle (loss of seeds compromise the following cycle).

Through these agri-productive and economic vulnerabilities, the recursive crises produced largely by systems of agricultural financing and the dominant development model, added to natural threats, intensify conditions of marginality and poverty, even giving rise to vulnerabilities in health and severe food vulnerabilities. The COVID-19 pandemic has deepened social inequities, increasing the spending of family savings and leading to borrowing through pawning possessions. In this way a social disaster has been generated due to the joint factors of structural vulnerabilities, the recursive crises caused by market fluctuations, the effects of storms, and the COVID-19 pandemic.

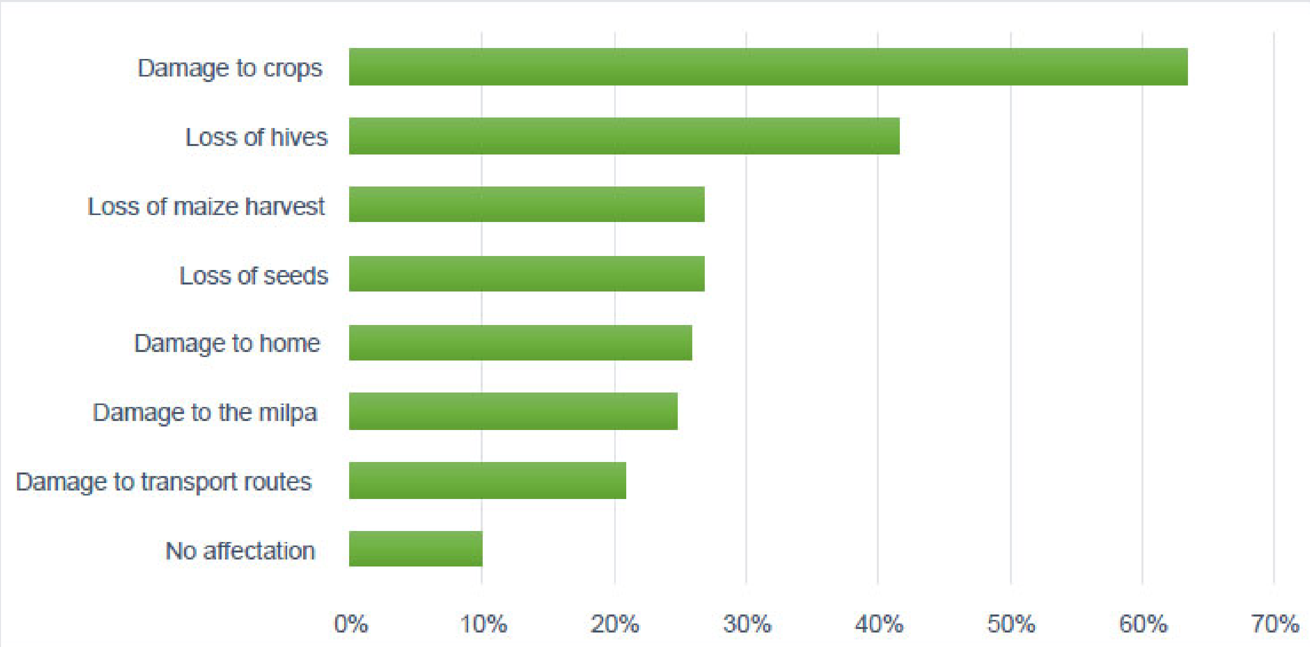

Figure 5. Distribution of affectations to productive systems and infrastructure experienced by peasant households in southern Yucatan as a result of tropical storms Amanda and Cristóbal. Source: Analysis from 101 peasant households.

(d) Strategies to confront the effects of COVID-19 and the tropical storms

Despite the recurrence of extreme hydro-meteorological phenomena in the south of Yucatan, neither small beekeeper-farmers, nor federal, state or municipal governments, nor international development agencies with presence in the Peninsula, have really managed to establish progressive schemes to surmount vulnerabilities, nor introduce systems of accompaniment capable of producing recovery from crises and socio-environmental disasters [58]. Instead, we have seen immediate and short-term responses using local resources, combined with small palliatives made up of isolated and insufficient public policies that only contribute to accumulated vulnerabilities in the face of future impact situations [15,59].

In the same way as occurs in situations when a family member becomes ill, or when facing a bad harvest and prolonged seasonal food shortages [60], peasant households with savings resort to these as a primary strategy for confronting crises (Figure 6). In a similar manner a frequent response to irregular constraints in household economies is to increase the number of workdays worked for better off domestic groups, or resort to the sale of productive stocks stored for an opportune sale, as in the case for example of honey. It is significant that more than 20% of peasant households resorted to asking for money loans despite high interest rates and payment conditions imposed by rural money lenders [61]. There were no reports of household members migrating as a strategy due to the mobility restrictions in place caused by the health contingency (Figure 6). This contrasts with the fact that peasant households frequently seek first support from migrant family members [62,63].

In this situation of economic and social vulnerability, and despite files opened after the storms, The Fund for Attention due to Emergencies (FONDEN) of the National System for Civil Protection (*Sistema Nacional de Protección Civil*) was not activated to cover agricultural or beekeeping losses. Half of beekeeper-farmers interviewed had received no government help; whilst 41% declared having received something from Yucatan state programs (the distribution of maize and pumpkin seeds, fertilizers, food parcels, or minimal support for the loss of hives). The paperwork involved so many bureaucratic requirements that the most marginalized families were unable to access this support.

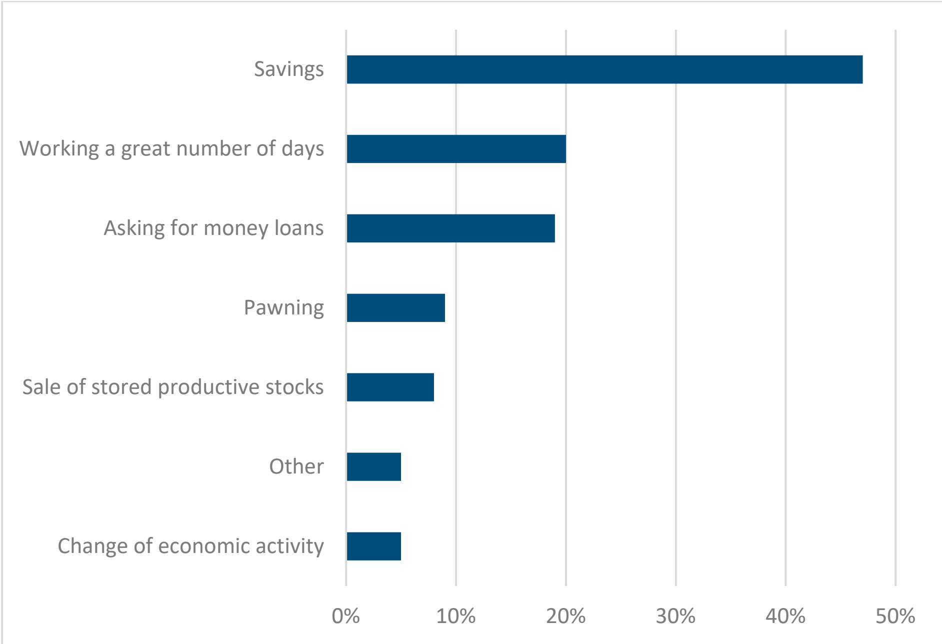

Figure 6. Strategies developed by peasant households to confront damage caused by the coupling of the COVID-19 health contingency with the tropical storms Amanda and Cristóbal in the south of Yucatan. Source: Analysis from 101 peasant households.

Despite the design of the Disaster Risk Management Unit of the UNDP (United Nations Development Programme) from 2002 in Yucatan for the accompaniment of actions and measures taken by government officials, the plans for disaster forecasting by federal and state government are practically inoperative. The UNDP project has the objective of forming local capacities for the prevention of disasters, designing and testing organization and training methodologies for multicultural rural communities with the intention of reducing vulnerability conditions in the face of future contingencies. However, the preventative measures recommended by the United Nations Disaster Risk Reduction Office (UNDRR) of the UNDP have not been carried out with real local participation either at state or national level. The need to build capacities in the face of structural vulnerabilities has become a tool for patronage in extreme tension, which prevents a truly operative political project for the actors involved [64]. Municipalities cannot resolve local needs created by a disaster, which ties them to authorities and decisions made at a state level, and these in turn are dependent on federal authorities [15].

4. Conclusions

Socioenvironmental crises occur as a result of a complex combination of natural threats such as hurricanes and droughts together with social inequalities that produce precarious economic situations, such as access only to marginal and rugged land, ambiguous or contradictory agricultural policies, limited control of commercialization, and reduced political participation [1]. Since the 1990s social scientists have pointed out that disasters and crises are not "natural" but are in fact constructed through accumulative and multidimensional vulnerabilities over the long term exacerbated by development models imposed by forms of economic growth and capital accumulation [1,4,5,11,65].

These kinds of accumulated vulnerabilities together with the arrival of extreme hydrometeorological events (storms or droughts) and other contingencies as the COVID-19 pandemic, express in differentiated ways become socio-environmental disasters for many peasant communities around the world. In some cases, recovery may be possible in the following agriculture cycles, whilst in other cases decapitalization may lead to the sale of fields, to indebtedness through rural loans, or even to migration dynamics of no return.

Faced with the limited capacity of governments for dealing with the effects of recursive and coupled crises on productive and commercial systems of the peasant sector, it is vitally important to orient future research to contribute to the construction of community strategies of mitigation. Following García-Acosta, Maskrey, and Audefroy & Cabrera [66–68], two fundamental directions are required: (i) the development of consciousness and social, cultural, and political organization at the local level; (ii) the design and implementation of specific, functional mitigation measures at the territorial level. The starting point for developing both directions should be the communities themselves and their immediate collaborators. From there, participatory processes can evolve in the form of spirals where different actors and accumulative levels of involvement and action can be added. From the perspective of community based hazard mitigation, the key is not to persuade local communities to participate in mitigation programs organized by governments, but on the contrary, to convince governments on all levels, multilateral development organizations, and universities to participate and join programs developed by communities and their local networks.

Based on our experience of working in different peasant communities around the world, we consider that at a minimum the following aspects should be considered in the design and implementation of community plans of prevention and mitigation of socio-environmental risks: (i) adaptive hydrological management, agroecological reordering of land use, and agricultural diversification in time and space; (ii) the recovery and conservation of native seeds, (in situ and ex situ) through local techniques of selection and improvement, the establishment of multiplication fields, community centers, programs of custody, fairs and exchange of seeds opportunities; (iii) the elaboration of schemes for fair trading in terms of added value, participatory certification, advance payments, local networks, and responsible intermediaries; (iv) savings funds; and finally (v) the demand for efficient and co-managed public policies, with an emphasis on opportune and transparent insurance for farmers, guaranteeing prices for production, and efficient systems of early warning for hydro-meteorological phenomena.

Particularly, we consider that in agri-food terms, public policy support for the development of mitigation capacities by peasant communities in the face of recursive and coupled crises should focus on promoting new agricultural production bases and marketing alternatives capable of better coping with risk. In the first place, agriculture reconstruction should be supported through governmental insurance schemes for small and medium production. It is recommended that such agriculture insurance could be focused on re-investment in the production of the main self-sufficiency and cash crops and be targeted to the neediest and most affected households. Agriculture insurance schemes themselves can also promote the transition to inputs and management practices that are less harmful to the environment and more resistant to disturbances, such as bio-manures and agro-ecological diversification [69–71]. The basis of a new organic agriculture and beekeeping production, capable of better coping with hydrometeorological risks, is the necessary platform to articulate commercial relations less subject to the impositions of the market and its intermediarism such as those aggravated during COVID-19. The medium-term path is to contribute to the construction of so-called nested alternative markets, that are based on the localization of agri-food systems and virtuous intermediaries to directly link farmers in transition and consumers [72,73]. Within these alternative food marketing logics, risk co-support schemes can also be consolidated, such as advance purchases by supportive consumers, or public procurement of agriculture and beekeeping production by government institutions [74,75].

These proposals for academic, community and political action are based on the fact that, throughout the paper, we have demonstrated the affirmation of our main research hypothesis which established that accumulated vulnerabilities and recursive and coupled crises impose historical limits on the prices of peasant production, cause the dismantling of many of the means of production, and even compromise the very capacity of rural households to continue agricultural activities. This has deepened even more their food dependency. In order to construct pathways for peasant-just livelihoods, it is necessary to reduce structural vulnerabilities and to fracture recursive and coupled crises by strengthening the productive and commercial peasant organization.

During our research, we faced some considerable difficulties and limitations. The first and most significant was the low participation of women. In this sense, the study was inherently biased towards male farmers, as women chose to remain sheltered in their homes during the peak periods of the pandemic. Inquiring into the vulnerabilities and affectations experienced by peasant households practically during the heart of the recursive crisis also represented an important challenge in achieving research space in the midst of family and community difficulties. Finally, it was extremely difficult to approach the different governmental authorities who showed a certain reluctance to be interviewed, as they felt that our research would reveal their lack of political action capacity to address the complex productive and commercial constraints caused by the coupled crises in peasant agriculture.

Finally, our research highlights the need for inter- and transdisciplinary research. Our understanding of this complexity of interrelationships requires historical, geographical, environmental, social, and cultural perspectives. We cannot be aware of all the vulnerabilities and uncertainties that farmers face every agricultural cycle without comprehending the historical processes that have driven them to those accumulated vulnerabilities and uncertainties. How territories reflect these vulnerabilities can be richly analyzed by geographers but the role of environmental vulnerabilities, mainly the ones related to droughts, hurricanes, and soil erosion, can be better explained by natural scientists. The trends for future research underline the need for interweaving of all these interdisciplinary perspectives, but also, for the knowledge, perceptions, interests, and emotions of the farmers' households, indigenous peoples, farmers' leaders, and local authorities. These interrelated viewpoints and perceptions can certainly guide a new way to have improved outcomes in order to acquire more just societies that can better face their vulnerabilities and uncertainties.

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