Afrocolombian Struggles for Food, Land, and Culture: The Case of El Tiple

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Abstract

El Tiple is one of many marginalized Afrodescendant communities confined within a green desert located in the southwest region of Colombia. This green desert is most widely known as the second-largest sugarcane monoculture field in the Americas. Herein, we describe a transdisciplinary and participatory effort to understand agroindustrial expansion in the region through the lens of the El Tiple community. Using qualitative and quantitative methodologies, we characterized the socioenvironmental context of El Tiple in terms of ethnography, autoethnography, social cartography, and ethnobotany. We implemented a participatory approach to codevelop a technology-assisted strategy for strengthening the community’s small-scale farming activities. Our contextual analysis results show systemic food dispossession, which arises from several factors, including dramatic land transformation, rapid depletion and contamination of natural assets, and biodiversity loss. All these factors are associated with the presence of bordering sugarcane plantations. In collaboration with community members, we designed, constructed, and analyzed a greenhouse hydroponic cultivation system as an actionable means to gradually restore local production of food and medicinal plants for the community. Our transdisciplinary and participatory approach demonstrates how academics can partner with vulnerable communities in the coproduction of knowledge and solutions to pressing social needs.

Keywords: environmental conflict, marginalized community, ethnobotany, food dispossession, glyphosate, hydroponics, participatory action research, sugarcane monoculture

Introduction

On a global scale, Colombia is among the top 10 sugarcane producing countries, occupying the seventh position with an average annual production of 34,900 metric ton. Nearly 85% of the sugarcane grown in Colombia is cultivated in the upper basin of the Cauca River, within the region known as Valle del Cauca (Procaña, 2017). Economic sectors directly linked to the sugarcane monoculture include industrial production of biofuels, food ingredients for domestic and export supply, and paper and textiles from bagasse (Solomon, 2011; Moncada et al., 2013). However, the systematic expansion of the sugarcane plantations in the Valle del Cauca region has turned this territory into a green desert.

While in 1960, the sugarcane plantations occupied 61,600 h.a., to date, the total planted area has reached 243,000 h.a. The region’s agroindustrial growth has brought about the monopolization of precious land. Concretely, this is the ecologically wealthier and geographically best-located land in the flat valley of the Cauca River (Vélez-Torres et al., 2019a). Ironically, the local rural communities have suffered an increasing shortage of water and food, directly proportional to the monoculture expansion (Arias, 2017). Thus, restrictions on collective access to land and water by poor rural inhabitants have generated major social conflicts in the last 50 years (Pérez et al., 2011).

For example, a recent analysis of land-use change based on satellite images showed that 98% (4,569 h.a.) of the geographic area of a rural village located in the upper basin of the Cauca River known as El Tiple had been permanently occupied by sugarcane plantations since 1989 (Correa-García et al., 2018). In El Tiple, land and water grabbing have
intensified together with the environmental contamination from the continued usage of synthetic pesticides and fertilizers in the sugarcane fields since the 1980s.

Some of the most detrimental impacts of the sugarcane agroindustry on the local rural communities are connected to the usage of synthetic herbicides. Glyphosate herbicides are regularly sprayed on the sugarcane plantations via airplanes. The industry adopted practice about three decades ago with the purpose of (i) preventing the growth of weeds and other competing flora and (ii) to manipulate the metabolic and physiological processes of the sugarcane plant, which increases sugar yields by 25% (Hurtado and Vélez-Torres, 2020).

According to a recent report, glyphosate is sprayed on sugarcane fields at concentration levels between 0.7 and 1.6 L/ha (Asocaña, 2018); this is ~0.77 kg/ha, based on a concentration of active ingredient of 0.48 kg/L (Hurtado et al., 2020). Such glyphosate application rates are within the allowable doses for agriculture in Colombia (Colombian Ministry of Environment, 2007). However, it is important to note that glyphosate manufacturers do not recommend application of their product via airplanes.

Some studies show that glyphosate residues can disperse beyond the plantations and contaminate nontargeted environments by the effect of weather conditions, during airplane fumigations, and also via the drift or runoff transport of herbicide residues (Pauker, 2003; Lee et al., 2011). Thus, nontargeted flora located in the areas neighboring the sugarcane fields (including food crops and other plant species of importance to the local communities) may be severely affected by the glyphosate fumigations (Nivia, 2000).

The previously described conditions feed into a progressive form of territorial dispossession that oppresses the local inhabitants, specifically, through the systematic disappearance of natural ecosystems such as wetlands and forests (Bremer and Farley, 2010). The term “toxic dispossession” was recently defined by Hurtado and Vélez-Torres (2020) to capture the particular mechanisms that trigger radical disruptions in the cultural-ecological-geographical nexus of rural communities located near these plantations.

Processes of toxic dispossession function to deprive communities of access and control over natural resources essential for their subsistence. These processes occur slowly and subtly through indirect and structural violence (Ojeda et al., 2015). For example, by implementing tactics such as (i) airplane fumigations with synthetic herbicides that may spread beyond the limits of the sugarcane plantations and into family orchards, (ii) extensive irrigation schemes that deplete precious freshwater sources used by communities, (iii) recurrent application of chemical fertilizers that may leach out of the soil and contaminate water sources, and (iv) open-field burnings that increase the levels of air pollution and make people more vulnerable to respiratory conditions (França et al., 2012; Precioado-Vargas et al., 2020).

In the case of El Tiple, the sustained combination of toxic agricultural practices by the sugarcane agroindustry has been forcing the town’s dwellers to choose between confinement or displacement (Hurtado and Vélez-Torres, 2020).

The research project described in this article started with the interest of the Black Community Council (BCC) of El Tiple in finding key allies to support their resistance efforts against the agroindustry. The BCC had identified the need for restoring family farming and local food production as one of the most important issues for the community. In early 2015, a college student, who is also a member of El Tiple’s BCC, sought support from the faculty at his home institution (Universidad del Valle). In response, a group of academics joined efforts to conduct a study in El Tiple.

The main objectives of our study were (i) to enhance the understanding of the impacts of sugarcane monocultures on small-scale food production systems of rural Afrocolombian communities and (ii) to empower the residents of El Tiple with tools and knowledge to counteract their loss of land and cultural assets.

We implemented a transdisciplinary and participatory research approach that integrates concepts from social sciences, botanical sciences, and engineering. Specifically, we conducted methodologies that include cogenerative dialogues, social cartography, autoethnography, ethnobotany, environmental assessments, agricultural systems design, and educational activities. While the scope of this study was delimited by a local context, this kind of socioenvironmental struggle is not unique to the region. In that sense, the participatory approach used in this project can serve as a model for other researchers interested in partnering with vulnerable populations facing similar problems.

Research Methods

Study Site and research model

El Tiple has an area of 46.09 km²; it is located at an altitude of 984 m.a.s.l. (Fig. 1). The town has a population of 1,800 people and 77% of its inhabitants self-identify as Afro-descendant (Vélez-Torres et al., 2019b).

Considering the complexity of the research problem, and the desire of the community to get involved as active participants in the study, we decided to implement a transdisciplinary research model that allowed us to integrate the community’s empirical knowledge with formal scientific expertise on areas such as ethnobotany, human geography, and biosystem engineering (Fig. 2). This iterative approach entails similar principles as other participatory action research models that have been previously applied in community-based studies in public health and social sciences (Lewin, 1997; O’Fallon and Deary, 2002; Wallerstein and Duran, 2008; Briscoe et al., 2009; Ross, 2010; Hacker, 2013; Delgado-Algarra, 2015; Hickey et al., 2018; Vélez-Torres et al., 2018).

However, a rare aspect of our approach was the integration of an engineering discipline to support coproduction of technology-assisted solutions. The participatory research described below took place in El Tiple between 2016 and 2019.

Recruitment of community participants

Community members participated in different stages of the project’s development, and recruiting strategies varied according to the aim and scope of participation at each stage. While ethnography was pursued by social researchers at all stages, autoethnography was a constant exercise by one young community member who, being a college student at Universidad del Valle, not only joint the project from the

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1BCCs are the main organizational form of Afrodescendant communities according to Law 70 of 1993 of the Colombia constitution.

2Desafíos en El Tiple. Available at: https://vimeo.com/436986522
FIG. 1. Map of El Tiple, Candelaria, Colombia.
beginning but also it was his interest and understanding of local environmental conflicts, which became a core guide to interpret local socioecological dynamics by the academic team.

Community participation was broader in the early stages of research, while the pilot testing of technology brought together fewer participants. The most difficult population to recruit in all stages of the project were working-age men and women (between 18 and 50 years old). This subset of the population was unable to participate mainly due to conflicts with work schedule. In the case of men, we also considered that some may have felt uncomfortable participating because they are employed as laborers in the sugarcane plantations, which may be perceived as a conflict of interests.

Recruitment of up to 50 adult participants (>17 years old) was convened through a local organization of peasant women and El Tiple’s BCC. Participation in the cogenerative dialogues and social cartography activities was restricted to adults. The educational program included 16 teenage participants, summoned through the local public school of El Tiple, and 12 elder adults, summoned through the organization of peasant women.

Daily monitoring of the pilot system for food production was at the charge of 6 elder women who met three criteria: (i) being participants of the educational program, (ii) having the available time required to conduct daily monitoring activities in the community greenhouse, and (iii) expressing specific interest in food production in confined spaces.

All research activities in El Tiple were conducted with the informed consent of the community participants. Research methods involving human subjects were first reviewed and approved by the Ethics Board of Universidad del Valle (IRB # 112–015).

Cogenerative dialogues

The cogenerative dialogues provided an opportunity for the academic team to establish trust relationships with the community, empower communication among community members, and simultaneously, for introducing different technological concepts that could potentially be applied for gradually reenabling small-scale farming in El Tiple.

Between February and May of 2016, we conducted a total of 4 meetings, with 26 community members (88% female, 11% male), some of whom have social leadership roles for several years. During these meetings, all relevant decisions for the project were discussed with, and approved by, the community participants. Four community volunteers were chosen to assist the academic team with logistic duties related to in-field work.

The community members that could actively engage in the development of technology-assisted strategies to strengthen local food production were organized into two groups: the wisdom team (10 females and 2 males of >50 years of age) and the future growers (8 female and 8 male high school students, 14–16 years old). Both groups participated in a series of 14 educational workshops as well as in the design, construction, and commissioning of the community farming pilot project.

Social cartography

In May 2016, we carried out a social cartography workshop to capture an articulated vision of the territory, particularly concerning the impacts of the sugarcane industry. The social mapping technique provides an opportunity to investigate the community representations of space, but at the same time, the execution of this technique is in itself an exercise of empowerment (Moore and Garzón, 2010). Therefore, we applied social cartography with a dual purpose: (i) to understand the distribution and spatial segregation of the communities that inhabit the towns embedded within the sugarcane plantation in relationship with their access to water and food and (ii) to create a collective reflection on the territorial transformations that came with the expansion of the sugarcane agribusiness since the late 1970s (Vélez-Torres et al., 2019a).

The social cartography workshop was developed with 10 adult community members (three males and seven females). Participants were recruited based on two criteria: (i) extensive knowledge of the territory and (ii) having resided in the municipality for at least 30 years. We provided drawing supplies and single blank paper (100×70 cm) for everyone to work on. Then, we asked the participants to represent their territory, including the different water sources, the sugarcane fields, the family farms, and the houses. After about 4 h, the social map was finished, and we spent another half-an-hour discussing the details of the image with the creators. At the end of the exercise, the social map was displayed in the Black Community Council headquarters.

(Auto) Ethnographic characterization

This technique was applied from both the outsider and insider perspectives. On the one hand, the ethnography work was conducted as an attempt to understand the community from the epistemic dimension of empathy rather than attempting to become an insider (Marker, 1998; Hammersley,
2015; Restrepo, 2018); it encompassed the process of contextualizing complex relationships between social practices and cultural meanings through close interactions with human groups (Restrepo, 2018). On the other hand, autoethnography is understood as a method to connect processes and meanings of broader political, cultural, and social issues, with the researcher’s personal experiences (Chang, 2016); this approach was particularly appropriate to guide the researcher role embodied by our undergraduate student who is also original from El Tiple.

Our ethnographic analysis was divided into two components. The first component followed the internal debates and public demands by the local community; this was done through the participation of a social scientist in 10 community meetings held by the BCC over the course of 2016 and 2018. The second component provides insights into all the practices built around the traditional food culture, from the ingredients to the methods of preparation and consumption (Contreras and Garcia, 2005). The second component was conducted by a social scientist who lived in El Tiple for 2 months separated in different periods between November of 2018 and March of 2019. Besides the time spent in the kitchen with the women and the observation process, nine semistructured interviews were conducted, with both young and older women, as well as two workshops.

The autoethnography was conducted in the summer of 2017 by a geography student who is also a community member. For this, the student spent time in cooking and talking with the family and neighbors. In addition, a semistructured format was used for one-on-one interviews with eight elder members of the local association of peasant women.

**Ethnobotany study**

To document the traditional knowledge about the use of plants in El Tiple community, we conducted an ethnobotany study during May–July 2017. In brief, 50 community members (16–70 years old) were randomly selected to participate in a structured survey. The objective of this survey was to identify the types and sources of plants used by the community (Fig. 3). Information gathered through the survey included gender, age, occupation, common name of the plants traditionally used, useful parts of the plant (e.g., root, leaf, fruit), and specific uses of the plant (Lucena et al., 2013; Kaur and Vashistha, 2018). Interviews were recorded in notebooks and digital recorders.

In addition, we gathered samples from five family orchards, and took them to the laboratory for taxonomic identification. These samples were included in the permanent

![FIG. 3. Social map collectively designed in 2016 during Social Cartography Workshop with community members of El Tiple.](image-url)
collection of the Herbarium at Universidad del Valle (Cali, Colombia). The plants were classified according to the particular use (e.g., human food, food additive, fuel, materials, medicinal, environmental) (Cook, 1995). Next, the “total uses” (UT) were determined for each plant species by adding all its reported uses, and the “use-value” (UV) was calculated by dividing UT by the total number of interviewees (Phillips et al., 1994). We used the UV parameter to quantify the relative cultural importance of the plants.

**Environmental assessment**

Together with three community volunteers who facilitated logistics for site visits, the engineering team performed a preliminary survey of spaces available for community farming in June of 2017. Criteria used for the selection of an experimental food production system included easy access to water for irrigation, water quality parameters, and physical distance to the sugarcane plantations. This last consideration was highly relevant because the sugarcane plantations are putative point sources of agrochemical pollution (Nivia, 2000).

During a single sampling campaign, we took samples of 7 natural water sources used for irrigation of family orchards in El Tiple. These samples were analyzed for pH, electrical conductivity, and concentration of glyphosate and amino-methylphosphonic acid (AMPA). The levels of glyphosate and AMPA in water were estimated via high-performance liquid chromatography on an ion exclusion column and identified/quantified through targeted tandem mass spectrometry (EPA method 547.0).

**Technology selection, construction, and commissioning**

Based on the results of the environmental assessment, we prepared a conceptual portfolio of small-scale agricultural production schemes that could withstand the environmental conditions of El Tiple. A meeting with the community participants was held on November of 2017 to discuss the general principles, advantages, and disadvantages, and foreseeable risks associated with each option. Next, community participants voted on their preferred production approach.

The design of a community greenhouse was done by a transdisciplinary team, including an industrial designer, a horticulturist, a mechanical engineer, an agricultural engineer, and two community members, which has some experience working in the construction sector. All materials used for building the greenhouse were locally sourced. The total built-up area was 15 m² and major construction materials included bamboo (Guadua angustifolia), standard clay bricks, concrete, translucent polyethylene covering, shading mesh, and clear polycarbonate roofing panels.

An Integrated Definition for Function Modeling approach (IDeFO) was used for the design of hydroponic systems based on the recirculating Nutrient Film Technique (NFT) (Sambo et al., 2019). Materials for the construction of the NFT systems were also low-cost and locally sourced. Main materials included PVC pipes (2” and 4”) and fittings, galvanized steel wires, threaded rods, polyethylene tanks, flexible black tubing (3/8”), and submersible pumps. Figure 4 depicts the schematic of the NFT units along with photographs of the hydroponic greenhouse setup.

Each NFT system is composed of eight interconnected growth channels. The reservoir tank was conveniently located under the support frame. A submersible pump located inside the reservoir tank was used to recirculate the nutrient solution from the reservoir to the top of the system. Each growth channel is 1.5 m long and has a 0.02 rad tilt angle to allow the downward flow of the nutrient solution by gravity. Each NFT system has a height of 1.56 m and occupies a surface area of 1 m².

The cultivation density was 64 plants per NFT system. A total of 5 NFT systems with the same characteristics were installed inside the community greenhouse in November 2018. For preliminary cultivation experiments, seeds of lettuce (Lactuca sativa var. longifolia) and cherry tomato (Solanum lycopersicum var. cerasiforme) were planted in plastic baskets (3”) filled with expanded clay pebbles. The plastic baskets were inserted in the growth channels of the NFT systems. Separate NFT systems were designated to each type of crop. A complete nutrient mix (FloraGro, FloraBloom, and FloraMicro) was used to prepare the nutrient solution based on the manufacturer’s instructions (General Hydroponics). Operational variables such as reservoir lever, pH, and electrical conductivity of the nutrient solution were monitored on a daily basis and compensated as needed by trained community participants.

**Education and training**

As part of the participatory model, we incorporated a series of educational modules specifically designed for two group sets (wisdom team and future growers). Biweekly workshops were led by a team of agricultural engineering and education specialists between August of 2018 and March 2019 (a total of 17 meetings was held with each group).

To increase the chances for a successful continuation of the project in the absence of the academic team, we developed a pedagogical strategy for social appropriation knowledge and technology. The goal was to enable the community to operate, maintain, adapt, and even integrate the hydroponic systems with other community enterprises. Topics covered in the workshops included (i) basics of plant biology, (ii) soilless agriculture, (iii) hydroponic cultivation requirements, (iv) monitoring tools and criteria for corrective actions, (v) local history of the ancestors and the land, (vi) food sovereignty and territoriality, and (vii) dreams (prospective life), perspectives on food, ecosystems, and livelihoods.

In April 2019, we held a meeting with all the education and training participants (16 teenagers and 12 elder adults) to learn about their perceptions regarding their experiences with the hydroponic cultivation systems. Perception assessment was conducted through an open dialogue session followed by a multiple-choice questionnaire with a box for comments. Questionnaires were designed according to age group (Fontella-Santiago and Fonseca-Fakembach, 2010).

**Results and Discussion**

**Interactions among academics and community members**

Our epistemological approach allowed us to integrate and give equal value to both academic and community knowledge. By rejecting the conventionally assumed hierarchies of knowledge, we created a radically different learning experience for everyone involved. The bilateral cooperation
FIG. 4. Schematic of NFT hydroponic systems built-in El Tiple, Colombia, and photographs of the arrangements inside the community greenhouse (top right image), and a functioning system (bottom right image).
between the community and the academic team enabled a more comprehensive understanding of the dispossession processes and the ideation of possible avenues to restore the local food culture. From the community’s perspective, having direct and continued communication with the technical team was paramount to maintaining a trust relationship.

“We want to be involved because previous interventions in the territory -including education, research, and extension projects brought by different academic institutions- have not produced any benefits for our community.”


For the academic team, the context immersion provided detailed information from both direct and anecdotal observations. That information helped us elucidate the community’s most pressing problems and how those problems relate to a history of complex interactions between economic, social, and environmental factors. It is worth noting that in our case, having the participation of an individual (also author of this article) who routinely navigates both worlds, as a community leader, and as a college student, was crucial for successfully bridging academia with the local space (Hall, 2009).

While the different types of knowledge were equally valued, application and relevance varied depending on the specific research activity. For example, from the communities’ territorial knowledge shown in the social cartography, it was possible to identify the locations where it would make sense to carry out water quality analyses. On the contrary, the engineering knowledge about environmental fate and transport of glyphosate, guided the community’s decisions to protect their family orchards.

Despite our efforts to discourage power relationships between academics and community participants, there were at least two hierarchies that were difficult to overcome. Specifically, elder participants were perceived as authority figures and had a decisive influence over younger community members. Similarly, university professors received a differential treatment by both students and community participants. These relatively benign power dynamics reflect how knowledge, in general, and experience, in particular, are recognized as highly valuable assets in rural contexts.

From confinement to food dispossession

On multiple occasions, community participants expressed deep concerns about the environmental degradation, agrochemical pollution, and water grabbing by the sugarcane agroindustry. From the community’s perspective, the monoculture expansion had significantly diminished their ability to practice family farming.

“When I was young, farming our land was our primary livelihood. Our farms provided sufficient resources for a dignifying life. It was central to our cultural identity and autonomy as Afrocommunity.”

-Elder resident of El Tiple, 2019

A sense of collective claustrophobia was also expressed in the workshops and represented in the social cartography drawings. Rather than an image, the socially constructed map was conceived as an act of language with creative agency (Butler, 1997; Green and Reid, 2014). From the geographical imagination, social cartography allowed participants to name their realities, (re)create identities, and make changes (Fig. 3).

Based on the cogenerative dialogues, social cartography, and autoethnography studies, we were able to characterize three processes of progressive marginalization:

(i) Spatial confinement: as reflected in the socially crafted map, the spatial confinement caused by the expansion of sugarcane plantations has reduced the physical access to parts of the territory that provided biodiversity and other common goods such as water (Borras and Franco, 2012; Correa-García et al., 2018). Water overuse by the agroindustry is facilitated by the State, which grants surface and underground water extraction permits for irrigation (Pérez, Peña and Alvarez, 2011). Furthermore, many residents of the town’s periphery have no choice but to purchase bottled water for human consumption because there is no aqueduct service to their homes. The lack of access to safe food and water has created additional barriers for upward mobility (Jaramillo et al., 2015).

Between ambivalent feelings of pride and nostalgia, the community recalled practices such as hunting and fishing in the wetlands, recreational activities with families in the Cauca River, and having plentiful access to food and medicinal plants collected in the area. All these cultural traditions have dramatically subsided over the past few decades. According to the elder women, this situation has forced the emigration of many community members to nearby urban centers, as well as the breakdown of generational relationships that are keys for passing on ancestral knowledge.

Despite the evident losses, the guided exercises allowed the participants to reflect on the past and recognize a shared identity (Rose, 2007). Furthermore, by reconstructing traditions connected with the local environment, the idea of a shared Afrodescendant culture and its intrinsic link to the struggles for keeping their territory was reinforced (Moore and Garzón, 2010).

(ii) Construction of class-identity: next to ethnic and cultural identity, the inhabitants of El Tiple have developed and internalized a notion of their position in society based on the oppression and dispossession that have taken place in the past few decades. In the collective mind, the oppressor/oppressed dichotomy is now present in almost every aspect of life. Thus, the community self-represent as “the poor”, while the agroindustrial businessmen are seen as “the rich”. The current geographical imagination of El Tiple community is strongly defined by socioeconomic inequality (Green and Reid, 2014).

The methodic impoverishment of the local community has only served the interests of a corporate elite. Thus, the alterity of identity includes ethnic and class dimensions associated with spatial confinement and other forms of dispossession. The reflection on ethnicity and class emerged from the social cartography exercise, which allowed individual experiences of marginalization and oppression to be shared, reinterpreted, and transformed into positions of enunciation for collective struggle.

(iii) Food dispossession: we use the term “food dispossession” to describe the drastic changes in food culture and food security that can be associated with two
confounding factors. On the one hand, the decrease in effective community control over means of production, nutritional quality, and diversity of the foods consumed locally and, on the other hand, over the crumbling relationship between the community and its ancestral territory as cultural, emotional, and material sustenance base.

In the old tradition, men were in charge of the most labor-intensive farming tasks, including preparing the soil, planting, nursing, and harvesting crops such as plantain, corn, cassava, pawpaw fruit, mango, breadfruit, and soursop. Women were in charge of growing vegetables and herbs such as achioti (Bixa orellana), which gave color to the meals, or spirit weed (Eryngium foetidum), which was an essential flavoring ingredient of the traditional “sancocho” soup. Back then, the plant diversity present in the family farms and other common areas of El Tiple allowed for a rich and varied culinary tradition.

Furthermore, the local wealth of food helped reinforce community values and bonds of solidarity. It was common practice for neighboring households to share their resources. In that way, those who did not have an orchard, or lacked a specific food ingredient, had the chance to obtain what they needed directly from a neighbor. Thus, lacking money was never a limiting factor for accessing culturally relevant foods (Altieri, 2009). With the violent transformation of socioecological relationships and cultural practices in the territory, in conjunction with the deprivation of the land and its natural resources, a particular form of dispossession has arisen in El Tiple (Bernal-Galeano, 2019). Moreover, these transformations are alienating the younger generations from experiencing cultural practices associated with food. The decrease in family farming spaces also coincides with the uprooting of the youth, who are decreasingly linked to traditional farming and cooking.

**Biological diversity and multiple uses of local species**

Plant diversity is a primary resource used by low-income rural communities to feed themselves and build their homes (Heywood and Watson, 1995). Peasant and indigenous communities rely on plant-based remedies to alleviate various ailments, and even treat fatal diseases such as malaria, hepatitis, and blood cancer (Alburqueque, 2009; Beck and Samal, 2012; Camara-Leret et al., 2014; Hussain et al., 2018). Our ethnobotany surveys show that the community of El Tiple knows the uses of 179 plant species. Plants with high cultural relevance have a UV value between 0.5 and 0.92. The total number of uses reported for each plant species varied between 1 and 5. The primary use of plants is food, followed by medicine. Besides, fruits and leaves are the most valued parts of the plants (Table 1).

Crops such as avocado, soursop, mango, lemon, orange, and pawpaw showed the highest UV. The ability to grow these crops locally would represent significant economic savings since the commercial value of tropical fruits is relatively high. Unfortunately, the gradual loss of suitable farming space in El Tiple provoked an ever-increasing dependence on food purchases from external suppliers. A recent survey revealed a dramatic prevalence of food insecurity that affects 70% of El Tiple households; that is 30 points above the average food insecurity rate reported in Colombian rural households (ICBF et al., 2015). This situation can be partly attributed to the low purchasing power of the population. Most families are unable to afford costly (healthier) diets, which also results in high levels of obesity, particularly in women of all ages (Hurtado et al., 2020).

Despite the ecological decline, there is still a significant knowledge of culturally relevant plants. The culinary and medicinal uses of fruit trees described in El Tiple are similar to the ones reported by other ethnobotanical studies in the neotropics (Suárez, 2008, Estupiñán-González, and Jiménez-Escobar, 2010). Moreover, the species listed in Table 1 are among the most frequently documented in ethnobotanical studies in Colombia (Bernal et al., 2011).

The number and diversity of plants used for food and medicine in El Tiple are similar to those found in other Afrocolombian communities (Crepaldi and Peixoto, 2010; Ortega and Torres, 2013; Conde et al., 2017; Rosero-Toro et al., 2018). The fact that most of the plants have two or more categories of use, reflect the community’s versatility to make the most out of their resources (Toledo et al., 2003). This cultural behavior has been documented in several rural communities of subtropical regions (Benítez and Valois, 2004; Aranguren, 2005; Estupiñán-González and Jiménez-Escobar, 2010; Whitney et al., 2018).

Regarding the interviewees’ current occupation, 82% of the women engage in household activities, family caregiving,

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Species</th>
<th>Use-value</th>
<th>Total uses</th>
<th>Main uses</th>
<th>Main parts of the plant used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avocado</td>
<td>Persea americana</td>
<td>0.92</td>
<td>4</td>
<td>Food, Medicinal</td>
<td>Leaves, Fruit</td>
</tr>
<tr>
<td>Soursop</td>
<td>Annona muricata</td>
<td>0.88</td>
<td>5</td>
<td>Food, Medicinal</td>
<td>Leaves, Fruit</td>
</tr>
<tr>
<td>Mango</td>
<td>Mangifera indica</td>
<td>0.80</td>
<td>5</td>
<td>Food, Medicinal</td>
<td>Leaves, Bud, Fruit</td>
</tr>
<tr>
<td>Lemon</td>
<td>Citrus x limon</td>
<td>0.76</td>
<td>3</td>
<td>Food, Medicinal</td>
<td>Fruit</td>
</tr>
<tr>
<td>Orange</td>
<td>Citrus x sinensis</td>
<td>0.72</td>
<td>2</td>
<td>Food, Medicinal</td>
<td>Leaves, Stem, Fruit</td>
</tr>
<tr>
<td>Pawpaw</td>
<td>Carica papaya</td>
<td>0.70</td>
<td>5</td>
<td>Food, Medicinal</td>
<td>Leaves, Stem, Flowers, Fruit, Seeds</td>
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<tr>
<td>Lemongrass</td>
<td>Cymbopogon citratus</td>
<td>0.58</td>
<td>4</td>
<td>Medicinal</td>
<td>Leaves, Roots</td>
</tr>
<tr>
<td>Guava</td>
<td>Psidium guajava</td>
<td>0.58</td>
<td>4</td>
<td>Food, Medicinal</td>
<td>Leaves, Cortex, Fruit</td>
</tr>
<tr>
<td>Wonder plant</td>
<td>Aloe vera</td>
<td>0.54</td>
<td>1</td>
<td>Medicinal</td>
<td>Leaves</td>
</tr>
<tr>
<td>Peppermint</td>
<td>Mentha x piperita</td>
<td>0.54</td>
<td>3</td>
<td>Medicinal</td>
<td>Leaves, Stem</td>
</tr>
<tr>
<td>Spirit weed</td>
<td>Eryngium foetidum</td>
<td>0.52</td>
<td>3</td>
<td>Food, Medicinal</td>
<td>Leaves, Roots</td>
</tr>
<tr>
<td>Mandarin</td>
<td>Citrus reticulata</td>
<td>0.52</td>
<td>4</td>
<td>Food, Medicinal</td>
<td>Fruit, Fruit peel</td>
</tr>
<tr>
<td>Squash</td>
<td>Cucurbita maxima</td>
<td>0.50</td>
<td>4</td>
<td>Food, Medicinal</td>
<td>Fruit</td>
</tr>
</tbody>
</table>
chicken raising, and gardening in their family orchards; the remaining subset of females of productive age (17–60 years old) work in nearby cities as housekeepers and other informal activities. On the contrary, 100% of adult men (17–60 years old) are employed in the agroindustrial sector as proletarian workers.

Interestingly, traditional knowledge on the use of plants is associated with gender. Men know more about trees and large crops, while women know more about herbs, bushes, and medicinal properties of plants. Similar studies have shown that men of various ethnic groups in the Northwest of South America have more knowledge than women about the uses of palm trees (Paniagua-Zambrana et al., 2014). This gender-differentiation is consistent with another community dynamic, in which women are responsible for the family health. In El Tiple, women are the primary caregivers for small children and the elder. Thus, they spend a lot of time at home. In contrast, men tend to spend more time outside of the house engaging in paid labor (mostly in the sugarcane plantations) or recreational activities.

Technology-assisted solutions for reenabling community farming

The construction site of the community garden was chosen based on the relative abundance of native vegetation in the surrounding area, which provided some shade (ambient temperature oscillates between 19°C and 33°C year round), and also served as an indirect indication of the degree of vulnerability to the recurrent aerial fumigations in the nearby sugarcane plantations.

In agricultural systems, the chemical quality of irrigation water is a determinant factor for crop health. We did not find any published reports of glyphosate traces in El Tiple’s water. For that reason, we made a preliminary assessment of herbicide residues in the community’s water sources. Some of the visited households had access to tap water from an aqueduct of the nearby town of Candelaria. However, most families relied exclusively on groundwater from deep wells located on their property. Therefore, water for the experimental agricultural activities would also have to be obtained from the local deep wells.

Table 2 depicts glyphosate concentration levels and its breakdown product aminomethylphosphonic acid (AMPA) detected in natural water sources in El Tiple. Deep well samples had a pH of 6.00 ± 0.04 and electrical conductivity of 636.5 ± 38.5 μS/cm. From these preliminary assessments, we identified three locations with sufficient space, access to sunlight, and shallow groundwater with low levels of organophosphate pesticide residues, and easy access by all community members.

Based on this information and a literature review, the engineering team delivered three agricultural production alternatives that could conceptually withstand the local environmental conditions. We held a meeting with the community participants to discuss the following options: (i) open-field cultivation of genetically modified glyphosate-resistant crops; (ii) indoor cultivation assisted by artificial illumination; and (iii) greenhouse cultivation.

The concept of introducing genetically modified plants in the territory was firmly rejected by the participants, mainly due to conflicts with their cultural and political principles. The idea of indoor production was discarded mostly because of the comparatively high cost of construction, operation, and maintenance, together with the artificial illumination requirements for plant growth, considering the instability of the town’s electrical infrastructure. The idea of building a greenhouse had good acceptance and was selected by the participants because it allowed the use of sunlight for plant growth. This option also entailed more opportunities for community participation in design and construction activities.

The next collective decision was to choose from soil-based or hydroponic cultivation formats. The soil-based system would have been designed as an arrangement of raised beds filled with soil, and the hydroponic systems as an arrangement of NFT units. We explained principles of operation, advantages, and limitations of each option, and the community participants voted for their preferred approach. Although none of the participants was familiar with hydroponics, they chose it as the preferred methodology. Many people in El Tiple already had raised beds at home, so the idea of learning a new technology seemed more appealing.

NFT hydroponics have gained attention as farming technology in resource-constrained areas because of several advantages over soil-based agriculture, including (i) versatility in the use of vertical space, (ii) high yields of crop per unit of cultivated area, (iii) shorter cultivation cycles, (iv) higher yields of biomass per nutrient input, and (v) lower water consumption rates (Sambo et al., 2019).

Figure 5 depicts the construction drawings and an outside image of the finished structure. Up to this point in time, the greenhouse has been in operation for 16 months and has not yet required any maintenance or repairs. The total cost of construction, including materials and labor, was COP$ 12’000,000.00 (~ USD$3,000). The construction was completed in 1 month, and its cost was entirely covered with the financial support provided by the research funding agencies. The structure was built on private property owned by a family of the community. However, through internal agreements, it was decided that El Tiple community would collectively own the greenhouse.

Table 2. Assessment of Pesticide Residues in Natural Water Sources in El Tiple, Candelaria, Colombia

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Source type</th>
<th>WGS-84 coordinates (x,y)</th>
<th>Glyphosate residues(^{1}) (μg/L)</th>
<th>AMPA residues(^{2}) (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cauca river</td>
<td>Surface</td>
<td>−76.464, 3.344</td>
<td>2.47</td>
<td>4.39</td>
</tr>
<tr>
<td>Deep well 1</td>
<td>Ground</td>
<td>−76.435, 3.349</td>
<td>&lt;2.0</td>
<td>&lt;0.7</td>
</tr>
<tr>
<td>Deep well 2</td>
<td>Ground</td>
<td>−76.43, 3.348</td>
<td>&lt;2.0</td>
<td>&lt;0.7</td>
</tr>
<tr>
<td>Deep well 3</td>
<td>Ground</td>
<td>−76.44, 3.351</td>
<td>&lt;2.0</td>
<td>3.53</td>
</tr>
<tr>
<td>Deep well 4</td>
<td>Ground</td>
<td>−76.427, 3.351</td>
<td>2.49</td>
<td>3.30</td>
</tr>
<tr>
<td>Deep well 5</td>
<td>Ground</td>
<td>−76.415, 3.347</td>
<td>&lt;2.0</td>
<td>3.73</td>
</tr>
<tr>
<td>Deep well 6</td>
<td>Ground</td>
<td>−76.429, 3.349</td>
<td>&lt;2.0</td>
<td>&lt;0.7</td>
</tr>
</tbody>
</table>

\(^{1}\) The lower limit of detection for glyphosate was 2.0 μg/L.

\(^{2}\) The lower limit of detection for AMPA was 0.7 μg/L.
FIG. 5. Architecture drawings (top panel) and photographs of the design and construction of a community greenhouse in El Tiple, Candelaria, Colombia.
Pilot experiments in the hydroponic greenhouse were conducted between January and April of 2019. Cultivation cycles from seed-planting to harvest were 6 weeks for lettuce and 10 weeks for cherry tomato. The pH of the nutrient solution in all tanks stayed within the 5.5–6.5 range without adding any buffers. We instructed the participants to add fresh nutrient solution to the tanks whenever there was a level drop of more than 10% (marked with a red line in the tanks). The average water consumption rates were 40.3 L/week for lettuce systems and 34.7 L/week for tomato systems. The electrical conductivity of the solution varied between 1,200–2,000 μS/cm in the lettuce systems and 1,000–2,000 μS/cm in the tomato systems. These ranges are within the normal operating parameters for hydroponic cultivation (Benton, 2005).

Some challenges emerged from uncontrolled experimental variables, for instance, the incursion of fungal and insect pests. Also, the high heat gradient formation during direct sun hours (temperature and relative humidity inside the greenhouse oscillated between 25°C–37°C and 77%–97%, respectively. The nutrient solution’s temperature oscillated between 16°C–24°C. These problems need to be tackled in future experiments through low-cost approaches. Potential solutions may involve using natural insect repellents and fungicides; making sealable openings on the greenhouse walls to enhance air circulation, and so on.

Given the low rate of energy consumption in the greenhouse (since only the submersible pumps required electrical input) and the low price of electricity in rural areas in Colombia, the cost of running each NFT system 24 h per day was estimated as COP$ 1,450/month (USD$ 0.38/month). Operational costs for the pilot greenhouse experiments were also covered with research funding garnered by the academic team.

Educational program. At the earliest stage of the project, the BCC proposed to get young community members involved in the educational program. This idea emerged from their desire to strengthen the bond between the new generations and their ancestral land. A recurrent concern expressed by the adult participants was the lack of economic opportunities to maintain a dignifying life in El Tiple, which resulted in many of their young people migrating to nearby cities in search of better-paid jobs.

“Once the kids graduate from high school, they are gone. The ones that decide to stay here in El Tiple, have to find a job somewhere else and commute back and forth every day. That’s why this is town is so lonely during the day.”
-Elder resident of El Tiple

Articulation between formal and empirical knowledge was necessary to achieve a collective construction of the

FIG. 6. Photographic depictions of educational activities carried out with community members of El Tiple, Colombia, (top insets), and examples of illustrations created by the future growers during the workshop on hydroponic cultivation (bottom insets).
hydroponic technology as a suitable alternative for restoring family farming. Figure 6 shows images taken during some of the educational workshops, along with examples of drawings made by the students.

These workshops allowed the participants to reflect on the different drivers of local socioenvironmental change and the importance of creating culturally appropriate alternatives to the sugarcane monoculture. We conducted a perception questionnaire and open dialogue during the final workshop to gather a common understanding of the participants’ learning process based on their experience and subjectivity (Fontella-Santiago and Fonseca-Fakembach, 2010).

Regarding the introduction to hydroponic cultivation as an alternative for the production of food and medicinal plants in El Tiple, 100% of the participants in both groups indicated that they see promise in experimenting with this agricultural format. They also expressed interest in being part of future projects. Eighty-six percent of future growers declared an intent to build their own hydroponic systems at home using recycled materials. However, 67% of the wise team and 57% of future growers did not feel sufficiently comfortable with their mastery of the NFT technique.

Taking the community’s feedback into consideration, we prepared a new proposal to compete for the funding that allowed us to start a follow-up cycle of participatory research in El Tiple. Ongoing work includes the design and construction of small greenhouses for individual households, seed propagation studies, development of a hydroponic nutrient solution based on organic waste recovery, and more education/training workshops.

Conclusions

El Tiple is one of several rural settlements embedded within sugarcane plantations in the upper Cauca River basin. The spatial confinement in El Tiple entails restricted access to land and water, which creates barriers for access to food and weakens community traditions. The sustained usage of agrochemicals in the sugarcane plantations has brought about an abstruse process of toxic dispossession in the region. This form of toxic dispossession functions to further marginalize vulnerable Afrocolombian communities. The persisting notion among El Tiple inhabitants is that the agroindustry’s economic success has occurred at the expense of their community’s prosperity and well-being. Thus, race and class alterities are experienced as exclusion and oppression.

Despite these barriers, the community has managed to preserve a wealth of knowledge on plants’ production and uses. Plants of greater cultural importance are used for food or medicine. Although family orchards show significant deterioration, the community still relies on these spaces to reproduce traditional knowledge, intergenerational relationships, and gender relationships associated with culinary and medicinal practices.

Our participatory research experience may serve as an example of how marginalized communities’ resistance efforts can be supported through strategic partnerships with academic groups that have a missional commitment to the democratization of knowledge and technology.

However, it is worth recognizing that community-based participatory research takes a long time, as evidenced by this study that lasted over 3 years. It also involved several adaptations of the original plan, including multiple changes of fieldwork schedule, adjustments of our communication methods with the different age groups, and modification of research directions at different stages of the project. Thus, we believe that it is essential to keep the following considerations in mind when pursuing similar community-based projects:

- When crafting a research plan, researchers must be cautious about not making false assumptions about the community, leading to unrealistic expectations about what can be achieved through the collaboration. From our experience, it has been useful to work in cycles that allow to go back to the communities to evaluate results, learn from mistakes, and adjust the plans. Change and adaptation to the needs, aspiration, limitations, and cultural specificities of the local settings have demonstrated to be successful ways to respond to the research challenges. This recommendation is, however, difficult to follow considering the restrictions and pressures posed by academic institutions, contracts, and funding agencies.
- Communication between scientists and nonscientists can be exceptionally challenging, particularly in contexts of low literacy. Having an individual who can wear both hats, as an active community member and also a trained researcher, is the preferred mechanism. However, if this is not a possibility, social scientists are usually better prepared than other academics to establish meaningful dialogues between both worlds.
- It is imperative to acknowledge that the community’s priorities may not always align with the researchers’ priorities. Even after fieldwork arrangements have been agreed upon, sudden events such as the death of a community member can completely shift the whole dynamics of the project for days or even weeks. Thus, flexibility, empathy, and the ability to compromise are personality traits that researchers must have when attempting to do research with marginalized communities.

Finally, a critical aspect of our study was the deliberate objection to the conventional academic mindset, in which social groups are viewed as passive research subjects. Instead, we have chosen to see and treat our community partners as active participants, capable of interpreting information, establishing relationships, making projections in time and space, making data-informed decisions, and taking actions to address their problems. To promote constant dialogue with the elderly women was key to make research decisions coupled with community’s best interests.

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Author Disclosure Statement

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