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Planning for agriculture and sustainable food systems

Edited by
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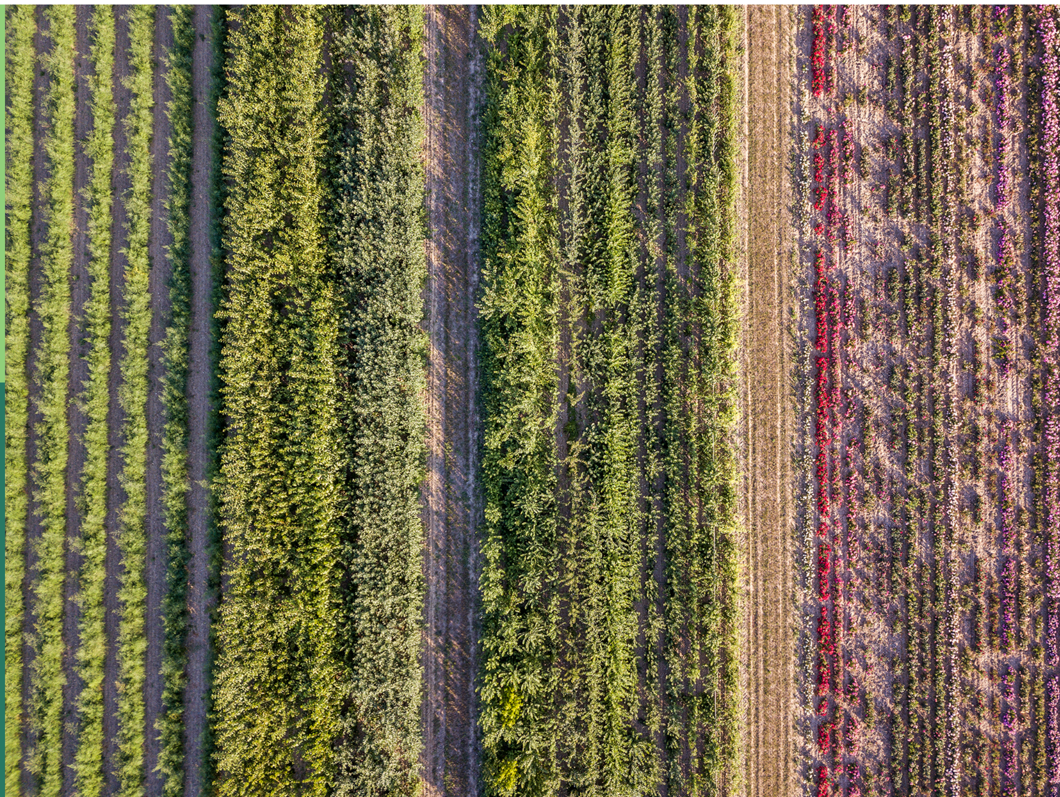
Published in
Frontiers in Sustainable Food Systems



ISSN 1664-8714
ISBN 978-2-8325-3126-6
DOI 10.3389/978-2-8325-3126-6

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Planning for agriculture and sustainable food systems

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Citation
Caldwell, W., Fullerton, C., Epp, S., eds. (2023). *Planning for agriculture and sustainable food systems*. Lausanne: Frontiers Media SA.
doi: 10.3389/978-2-8325-3126-6

This Research Topic has been developed in collaboration with Kaela Anderson — University of Guelph, Canada

Table of contents

TYPE Editorial
PUBLISHED 10 May 2023
DOI 10.3389/fsufs.2023.1194799

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
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RECEIVED 27 March 2023
ACCEPTED 14 April 2023
PUBLISHED 10 May 2023

CITATION
Caldwell W, Epp S and Fullerton C (2023)
Editorial: Planning for agriculture and sustainable food systems.
Front. Sustain. Food Syst. 7:1194799.
doi: 10.3389/fsufs.2023.1194799

Editorial: Planning for agriculture and sustainable food systems

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KEYWORDS

planning, agriculture, sustainable food systems, land use, farmland loss

Editorial on the Research Topic
Planning for agriculture and sustainable food systems

The future of agriculture, food security and sustainable food systems are fundamentally connected to how we treat the land base that supports agricultural production. Urban expansion, land degradation, access to water, threats to biodiversity, and climate change are having major impacts that threaten our ability to produce food and support the planet's growing population.

Community planning provides a framework to address many of these issues. Municipalities make decisions related to land use and senior levels of government establish policy and legislation with a goal of addressing the public interest. An agricultural lens can be brought to land use planning with a goal of protecting farmland, soil, water, air and natural heritage resources. Furthermore, we need to protect farmers and their livelihoods while simultaneously building a more sustainable form of agriculture.

In this Research Topic several authors highlight the importance of the land use planning process as a means to protect agricultural land from urban expansion. Population growth and related urban expansion require thoughtful planning strategies to intensify urban settlements and to direct growth away from the best farmlands. Dring et al. review strategies and approaches to agricultural planning in British Columbia, Canada. In British Columbia they have established an Agricultural Land Reserve where the best farmlands are protected for continued agricultural production. In this broader context municipalities embark upon agricultural planning consistent with "mandated obligations (conservation of farmland) and voluntary obligations (economic development, advocacy, public awareness)." They conclude by noting that "municipal governance systems could transition to improve agricultural outcomes, such as farmland protection, farmer economic viability, and integration with broader food systems." Caldwell et al. review the farmland preservation policy framework within Ontario, Canada. They do this by tracking planning decisions over nearly 20 years, providing insight into the relative success of local and provincial policy. Their findings bring specific focus to the role of upper levels of government in protecting agricultural land.

Akimowicz et al. take this a step further by noting the importance of periurban agriculture. Within Canada and France they found that it contributed to the resilience of metropolitan areas by providing local food and other multifunctional agricultural amenities. Within their article, they "tackle the beliefs that underlie farmers' decision-making" to identify the planning opportunities for supporting farm intergenerational transfers. In both countries the results highlight "the positive role of the institutional context" when farmers' beliefs and the beliefs shaping their institutional environment, including their family, their professional community, and the surrounding stakeholders, such as agricultural organizations, public agencies, and residents of the area, are well-aligned and result in a shared vision of the future.

Two examples from Ghana also demonstrate the competition for agricultural lands. Yiridomoh finds that illegal gold mining is lucrative and on the rise but with consequences for sustainable agriculture and resilient food systems. His work reveals that "agricultural practices such as terracing, crop rotation, use of domestic waste/manure, and irrigation of crops were affected adversely by illegal mining activities". He concludes by noting important roles for the Ghanaian government. In another example, Kuusaana et al. finds that urban agricultural zones are being compromised as many "urban land parcels are unsustainably converted to urban infrastructure" and residential uses. Using a local case study, the researchers found that, over 25 years, "agricultural lands decreased in terms of size and contiguity at the household level," compelling farmers to pursue compound farms or fenced urban gardens. They conclude that urbanization "will exacerbate the challenges of food production if relevant policy interventions are unavailable" to preserve urban agricultural space to sustain food supply.

Berge et al. investigated the effects of government agricultural planning on economic, environmental and social sustainability as implemented by individual and co-operative producers within the agricultural sector in Togo. For cooperative producers, "it was anticipated that a greater emphasis on social and environmental sustainability would be created through cohesive social action." This study found that the emphasis on economic development included in government planning built cohesion within cooperative membership focused on economic indicators rather than environmental or social development.

Local or traditional agri-food systems also contribute to sustainable food production and food security. Sarapura–Escobar and Hoddy offer perspectives on planning as a tool "to maintain the genetic pool of crops and landraces" in response to "disease, disasters, and climate change" in the Andes. Soil conservation, biodiversity, water management, and communal or cultural practices, are all shaped by peasants' intersecting identities. The authors emphasize the importance of local planning in Andean communities for managing resources in accord with Andean indigenous worldviews. Knowledge and Andean ways of adapting and innovating reflect innate capacities to maintain the land and their genetic resources. Of course, agriculture varies globally, and Mamun et al. demonstrate the importance of coastal areas and the connection to food production. Their study in south-west Bangladesh demonstrates the importance of livelihoods and wellbeing and the contributions that aquatic farming systems in SW Bangladesh can make to support household subsistence and local nutritional security.

Drescher and Warriner observe that intensive agriculture contributes to the loss of biodiversity and ecosystem services. Their study in Ontario, Canada, demonstrates that farm and non-farm attitudes toward land are embodied in the concept of environmental stewardship. They found that "participation in conservation programs was more pronounced for non-farming landowners." Their results point to opportunities "for reducing financial and knowledge barriers to pro-environmental land management behaviors."

The articles comprising this Research Topic help us to broaden our perception of the issues and the opportunities that exist to address these issues. While there is an overriding focus on "planning," the articles take us on a journey exploring not only land use planning, but also environmental stewardship, economic planning, cooperatives, urban infrastructure and agricultural development in coastal areas. Running through these ideas are a number of core concepts. They include the role of governance and community, the importance of agriculture and opportunities for planning, sustainability and stewardship. Collectively, they call for a coordinated strategy at the local, regional and national levels of government.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 22 November 2021
doi: 10.3389/fsufs.2021.713140

Export-Driven, Extensive Coastal Aquaculture Can Benefit Nutritionally Vulnerable People

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Export-orientated shrimp and prawn farming in coastal *ghers* has been associated with negative environmental, social, and nutritional impacts. This study challenges these perceptions based on field observations from four communities in South West Bangladesh. Most households observed (>60%) were either directly involved in seafood farming or engaged elsewhere in the seafood value chain. Our study set out to establish how the type and location of aquaculture impacted on access to and consumption of aquatic animals. Additionally, we assessed the effects of both household socioeconomic status and intra-household food allocation on individual diet and nutritional outcomes. We used a blended approach, including a 24-h consumption recall on two occasions, analysis of the proximate composition of aquatic animals and biomarkers from whole blood from a sample of the target population. The diverse polyculture systems generated broad social benefits, where "export-oriented" production actually supplied more food locally than to global markets. Key findings: (1) worse-off households achieved higher productivity of farmed aquatic animals on smaller landholding than better-off households with larger landholdings; (2) vegetable production on *gher* dikes was a significant source of nutrition and income in lower saline gradients; (3) more fish was eaten in lower saline gradients although fish consumption was highly variable within and between households; (4) intra-household allocation of specific foods within diets were similar across communities; (5) recommended nutrient intakes of protein and zinc exceeded daily requirements for adolescent females, but energy, calcium, and iron were below recommended intake levels; (6) n-3 LC-PUFA, expressed as percentage of total fatty acids, in whole blood samples of adolescent females declined with ambient salinity level regardless of household socioeconomic status; (7) analysis of aquatic animals consumed found that mangrove species and tilapia harvested from higher saline *ghers* contained high levels of desirable PUFAs. These findings suggest that export-driven, extensive coastal aquaculture can be nutrition sensitive when co-products are retained for local consumption.

Keywords: nutrition sensitive aquaculture, n-3 fatty acids, polyculture, export and local food, fishery-aquaculture continuum

OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to Land, Livelihoods and Food Security, a section of the journal Frontiers in Sustainable Food Systems

Received: *21 May 2021*
Accepted: *20 October 2021*
Published: *22 November 2021*

Citation:
Mamun A-A, Murray FJ, Sprague M, McAdam BJ, Roos N, de Roos B, Pounds A and Little DC (2021) Export-Driven, Extensive Coastal Aquaculture Can Benefit Nutritionally Vulnerable People. Front. Sustain. Food Syst. 5:713140. doi: 10.3389/fsufs.2021.713140

INTRODUCTION

Aquaculture production focused on supplying export and affluent urban markets has been criticized for diverting nutrients away from the poor and threatening their nutritional security (van Mulekom et al., 2006; Golden et al., 2016). Furthermore, the evidence base for aquaculture supporting nutritional security is poor (Béné et al., 2016). Aquaculture is typically framed as a dichotomy of intensive monocultures producing high-value seafood for the wealthy or low-input, smallholder systems producing food for the poor (Bush et al., 2019). In particular, coastal aquaculture focusing on high-value shrimp production has been criticized for a perceived range of negative social and environmental outcomes (Bailey, 1988). Coastal aquaculture in Bangladesh has now been tagged as maladaptation in terms societal response due to its vulnerability to the negative impacts of climate change through cyclones and sea level rise (Paprocki and Huq, 2018). Its export-oriented focus on high-value shrimp has been implicated in the Southwest coastal zone becoming a (food) "desert in the delta" (Swapan and Gavin, 2011) and that it represents a loss of food sovereignty (Paprocki and Cons, 2014). A major criticism of shrimp farming in Bangladesh is its association with negative impacts on local diets and public health (Rahman et al., 2011a). Nationally, rapid development of fish culture based on a limited range of stocked species has been explicitly linked to poorer livelihood and, specifically, nutritional outcomes (Roos et al., 2003b).

A better understanding of the mechanisms for aquaculture being "pro-poor" requires analysis of both direct and indirect pathways and the role of production and consumption to be understood (Toufique and Belton, 2014). Both community level and intra-household perspectives are required for a full understanding of the development impacts of aquaculture (Béné et al., 2016), both on vulnerable individuals and in terms of broader livelihoods (Chambers and Conway, 1992). Livelihoods frameworks have been found useful to capture the complexity and heterogeneity of rural coastal contexts elsewhere in Asia to inform policy (Pham et al., 2020).

Major progress has been made in addressing basic food security in Bangladesh and the severity of several micronutrient deficiencies has been reduced in the last two decades, but "hidden burdens" remain a key challenge for vulnerable groups. Preschool children remain susceptible to anemia and vitamin A and D and zinc deficiency, whilst more than half of non-pregnant, non-lactating women are zinc deficient, more than 40% lack iodine rich food. A significant proportion of the population (>20%) are anemic and dietary intake for vitamins A, D, and B12 is also low (Ahmed et al., 2012). Anthropometric data obtained in pre-school children in Bangladesh indicated that more than a third (36%) were stunted and underweight and about 14% suffered from wasting (Global Nutrition Report, 2020). Investment in ensuring adequate nutrition during the critical 1,000 days, pregnancy and the first 2 years of life, has been identified as critical for intergenerational welfare (Martorell, 2017). Bangladesh has high levels of pregnancy among female adolescents, and almost half have given birth by 18 (Blum et al., 2017). This carries particular risks (NIPORT, 2013) and makes adolescent females a highly vulnerable group to welfare-related issues. Increased research into the nutrition of young people (Akseer et al., 2017) and micronutrient deficiencies in female adolescents in particular are timely.

Strategies to improve nutrition and health outcomes of such vulnerable groups need to be culturally attuned and based on high accessibility and affordability (Jennings et al., 2016). Studies suggest that under-consumption of micronutrient dense food is common in both "worse-off" and "better-off" contexts (Keats et al., 2018; Mitsopoulou et al., 2020) which has been linked, at least partially, to fast food substitution (Li et al., 2020). The limited studies of adolescents in rural South Asia suggest that dietary patterns are strongly linked to socioeconomic status and gender in Bangladesh (Blum et al., 2017; Thorne-Lyman et al., 2020) and Eastern India (Unisa et al., 2020). The role of seafood as a source of micronutrients in the diets of vulnerable populations that are highly dependent on aquatic foods is critical (Coulthard et al., 2011).

The contribution of fish (fish is used interchangeably here for aquatic animals and seafood) to food and nutrition security is important in terms of contributing high-quality animal protein as well as important micronutrients and lipids. Inclusion of animal-source foods in diets improves growth, micronutrient status, and cognitive performance in children in low-income countries (Dror and Allen, 2011). The specific nutritional contribution of fish may be particularly important in populations with very limited general access to dairy and terrestrial livestock and where there is ready access to a rich aquatic diversity (Little et al., 2018). Both conditions exist in Bangladesh. Fish and seafood are well-documented for their contibution of a wide range of essential micronutrients, vitamins, and n-3 long-chain polyunsturated fatty acids (n-3 LC-PUFA) (Karapanagiotidis et al., 2006).

Export-driven shrimp and prawn farming in Bangladesh has expanded 10-fold, from an estimated 20,000 hectares in the early 1980's to more than 275,000 hectares (BFFEA, 2015). The rapid growth of shrimp and prawn farming is positively correlated with national economic growth (Ahmed et al., 2010; Ito, 2010). In parallel, rapid development, and commodification of farmed, mainly freshwater fish serving domestic markets has occurred (Hernandez et al., 2017). The replacement of small indigenous species (SIS) in peoples' diets by such conventional aquaculture species has been linked with poorer nutritional outcomes (Roos et al., 2003a). Due to this shift in fish species diversity in diets, iron and calcium intake through fish has dropped in spite of increased overall fish consumption (Bogard et al., 2017a).

However, the causal pathways to impacts on human health are often lacking as is a contextualized understanding of the nutritional role of fish in broader diets and resultant impacts on health (de Roos et al., 2019). Also, documentation of the distribution of fish within the household is often neglected, though important. Male head of households farming fish in Bangladesh were favored in the distribution of a fish meal among family members; females received on average 63% of the portion size of the household head, while other males in the household received portions amounting 84% of the head (Roos et al., 2003a). The inequities of intrahousehold food distribution disfavouring females was identified as a general pattern of concern in Bangladesh (D'Souza and Tandon, 2019).

Assessing health status, and how this relates to nutritional intake, remains a challenge. The use of biomarkers of intake, which for some nutrients are also recognized as biomarkers of efficacy, are starting to provide more powerful insights (de Roos et al., 2019). For example, n-3 LC-PUFA levels in blood are increasingly used as a health biomarker. In a well-designed study (Harris et al., 2020), the proportion of n-3 LC-PUFA (EPA+DHA) to total LC-PUFA, known as the Omega-3 Index, was linked to greater longevity and reduced cardiovascular disease risk. LC-PUFA are produced naturally by aquatic, predominantly marine micro algae and become concentrated through the food chain, particularly in some fish and other marine animals. As their importance to human health and that of farmed fish has become clearer, a supply gap has emerged as traditional sources of n-3 LC-PUFA (fish oils) are limited (Tocher et al., 2019). Distribution of these key products in the heterogeneous aquatic farming systems and species of Southwest (SW) Bangladesh have been little studied to date. Linking agroecosystem characteristics to the nutritional quality of food produced and resulting nutritional and health benefits among vulnerable people was a key objective of the study.

This field observational study aims to assess the importance of aquaculture in communities located across a salinity gradient in SW Bangladesh and, specifically, to determine its nutritional and health impacts on adolescent females. Production of, and access to, stocked and unstocked aquatic animals was hypothesized to be an important factor in the nutrient profiles of local diets. This paper, as a first step, describes the diversity of coastal floodplain aquaculture systems, food availability, and broader livelihoods (Chambers and Conway, 1992). We then assess differences in food consumption patterns in communities located along a saline gradient, and characterize intra-household food allocation of farmed aquatic animals and associations with the health status of vulnerable individuals.

This paper contributes a contextualized understanding of how land used for a commercial export-orientated aquaculture can contribute toward diversified food production and nutritional security locally.

METHODS

Communities characterizing aquaculture production in the Greater Khulna Area across four different salinity levels High Saline (HS), Medium Saline (MS), Low Saline (LS), and Freshwater (FW) were selected purposely based on the previous cluster analysis the EC FP7 funded Sustaining Ethical Aquaculture Trade (SEAT) (Murray et al., 2013). Qualitative and quantitative methods were coupled to explore household socioeconomic status, food consumption patterns and the health and nutritional outcomes of adolescent females. Key informant (KI) interviews led to identification of four indicative communities, in which Hindu households were a significant proportion (>20%). Participatory research activities (transect walks, village mapping, household socioeconomic ranking were conducted with KIs). A detailed understanding of the overall farming systems in each community was based on in depth interviews with 40 aquaculture producer households randomly sampled from each community.

A census ($n = 1,082$) of all households led to identification of 240 households with at least a single adolescent female from the same frame, again with randomized-stratified sampling based on socioeconomic categories for "intra-household" analysis. This resulted in sampling of 60 households per community consisting of 30 "better-off" and 30 "worse-off" households, following socioeconomic ranking of households by community leaders. Further analysis was conducted on livelihood options, intra-household food distribution and aquatic farming assets. Both the rich and medium household categories were combined into "better-off" and poor and ultra-poor into "worse-off" socioeconomic groups. A 24-h food recall method, food frequency questionnaire, food photography, and measuring cup sets were used to estimate food consumption for individual members from the sampled households. Anthropometric measures [stunting, wasting, Body Mass Index (BMI), Mid-Upper Arm Circumference (MUAC)] and levels of fatty acids [calculated n-3 LC-PUFA in RBC and n3:n6 ratio (n-3 LC-PUFA/n-6 LC-PUFA) in whole blood cell] were used to assess nutritional outcomes of adolescent female ($n = 200$ females). Samples of shrimp/prawn and fish polyculture species (57 species and 9 by-products, $n = 672$) were collected randomly from farmers' production systems across the major agroecologies (HS, MS, LS, and FW) and intensification level (extensive, semi-intensive, intensive). Macro and micronutrient content of the edible fraction of each sample were analyzed and formed the basis to assess distribution at the intra-household level.

Reference values for Body Mass Index (BMI), Mid-Upper Arm Circumference (MUAC) (NIH, 2016; WebMd, 2016), total n-3 LC-PUFA content in blood, ratio of n-3 LC-PUFA to total LC-PUFA (Lands, 2003; Harris, 2007), and recommendent nutrition intake (RNI) essential micronutrients, protein, and energy were obtained from standard sources (Islam et al., 2010; INFS, 2013; UNICEF, 2013). All analyzed data, graphical presentation of data have been customized from the statistical package program R (R Core Team, 2016). Detailed methods are supplied in the **Supplementary File 1**.

RESULTS

Coastal Floodplain Aquaculture Systems

Saline-impacted, coastal Bangladesh is an area of particular vulnerability. The livelihoods of an estimated 38.5 million people based on terrestrial farming and, increasingly, aquaculture are affected by salinization, which has been linked to climate change (Kabir et al., 2016). The pattern of farming systems are characterized both seasonally and spatially along a transect stretching from the coastline to more than 150 km inland in Greater Khulna and is complicated by polder construction and related water logging stretching back to the 1960's (Foxon, 2005). Low productivity of the single rice crop stimulated adaptation of rice fields through trenching and bund raising to shallow impoundments, locally known as *ghers* (Milstein et al., 2005) which, depending on salinity regime, may continue to be used for seasonal rice cropping. The area remains one of the most extensive systems of indigenous shrimp farming in the world (Tenison-Collins, 2016), supporting an estimated 80% of the national production of black tiger shrimp (shrimp; *Penaeus monodon*). This major concentration of coastal aquaculture is close to the relatively well-conserved Sundarbans mangrove forest that has largely resisted conversion to aquaculture (Hamilton, 2013). Traditionally, shrimp were raised together with finfish in a polyculture that complemented the seasonal social and ecological rhythm of rural life in Bangladesh (Pokrant, 2014). The majority of shrimp production remains low-input, and largely based on fertilization supplementing natural productivity through exchange of water. In contrast, giant freshwater prawn (prawn; *Macrobrachium rosenbergii*), the target export crop in freshwater systems further inland, are farmed in semi-intensive *ghers*, integrated with rice production, and reliant mainly on feed (Jahan et al., 2015).

Characteristics of aquaculture and broader farming systems are summarized in **Table 1**. In all communities, fish yields tended to be low (around 1 MT/ha), and produced for both export and local markets. Export crops, mainly shrimp, only dominated in the high saline (HS) gradient, approaching 50% of the total harvest. In other locations, export products ranged from 20 to 40% of the total harvest. Diverse aquaculture systems characterized the communities across the saline transect and aquatic animals are disaggregated (**Figure 1**) as crustaceans (i.e., shrimp and prawns), marine fish, freshwater fish and tilapias. There were significant differences in associated terrestrial cropping; production of rice and vegetables were inversely related to salinity levels.

In terms of overall harvested yield, shrimp dominated in HS, and prawn in LS and FW systems. Freshwater fish were harvested at all sites but mainly in LS and FW, where they contributed 78 and 58% of total yield, respectively (**Figure 1**). In contrast, mangrove fish were most important in HS (20% of total yield) and MS (16%), reflecting closer proximity to the Sundarbans mangrove forest. Tilapias were present across the saline transect, except for the FW environment; over 90% of *gher*s in higher saline gradients (HS, MS) had tilapia comprising 13 and 18% of total production volume in HS and MS areas, respectively (**Figure 1**). Household socioeconomic level (Morales, 2007) was associated with the types of fish and harvested yield. Across the four locations "worse-off" households on significantly smaller landholdings had higher fish productivity ($P < 0.05$) than "better-off" households on their larger landholdings (**Figure 1**). Apart from fish, vegetables, and rice were produced in the lower saline gradients (LS, FW). Most of the vegetables produced were destined for market sale whereas rice production was subsistence-orientated.

Coastal Zone Livelihoods

The majority of households (>60%) in the four communities had access (owned/leased-in) to an aquatic farming system (**Table 2**). The specific topography in the HS community, characterized by relatively high elevation, explains the lower participation in

TABLE 1 | Key characteristics of aquaculture-agriculture system by community.

Item	Variables	Area			
		High saline (HS)	**Medium saline (MS)**	**Low saline (LS)**	**Freshwater (FW)**
Number of farms		40	40	40	40
Location	Distance from mangrove (km)	<2	35	40	50
	Distance from Khulna town (km/hrs:mins)	130/3.40	85/2.20	25/1	66/2
Land holding	Gini co-eeficient	0.54	0.45	0.45	0.54
Income	Gini co-eeficient	0.28	0.26	0.29	0.27
Inputs	Water salinity (ppt)	>10	>5<10	<5	<0.5
	Juveniles* (stocked × 1,000; no. mean ± SD)	87.6 ± 29.9	61.6 ± 26.2	36.1 ± 25.7	16.6 ± 8.5
	Fertilizer for aqautic animal production (mt ha^{-1})	0.59 ± 0.6	0.42 ± 0.28	0.28 ± 0.22	0.07 ± 0.06
	Feed (mt ha^{-1})	0.077 ± 0.04	0.156 ± 0.17	0.75 ± 0.69	1.33 ± 0.58
Cost (rental, labor etc.)	Operational cost (US$ ha^{-1} yr^{-1})	703	610	1,230	1,948
Yield (t ha^{-1} yr^{-1})	Aquatic animal yield	0.91 ± 0.39	0.67 ± 0.26	1.14 ± 0.49	0.97 ± 0.49
	Rice	–	–	1.5	2.5
	Vegetable	–	–	2.7 ± 3.2	6.5 ± 4.4
Benefit	Gross margin for all crops (US$ ha^{-1} yr^{-1})	231.6	133.9	222.4	177.5
Market orientation of fish	Dedicated to export market and/or crustaceans to total fish volume (mt harvest) (%)	47.5	37.3	19.9	20.7

**Juveniles = for crustaceans PL (post-larvae) and for fin fish fry and fingerlings.*

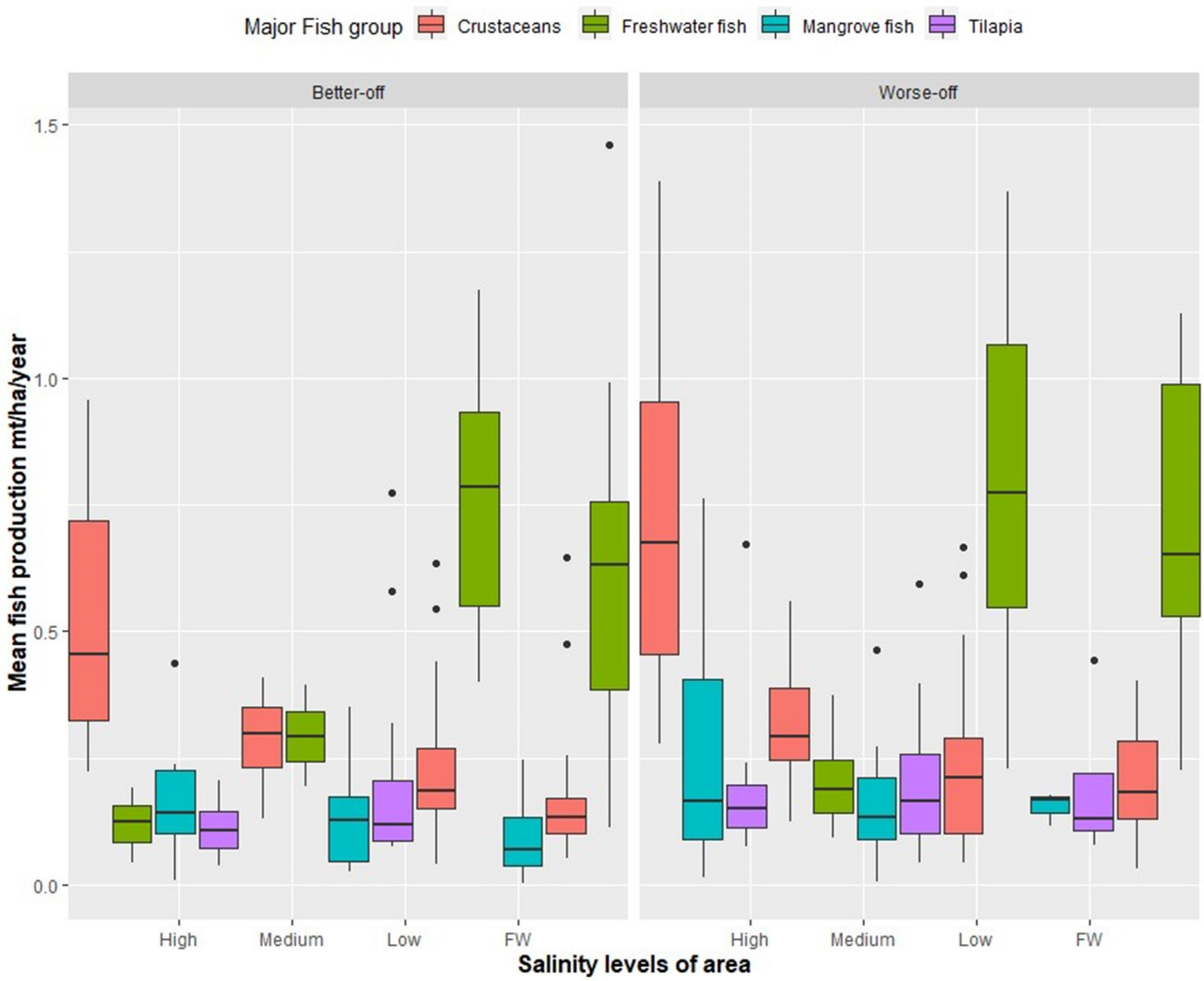

FIGURE 1 | Total aquatic animal harvested production (mt ha^{-1} yr^{-1}) in *gher* systems managed by (1) better off and (2) worse off households across the saline gradient in SW Bangladesh.

TABLE 2 | Share of households (%) with access to *gher* by salinity zone and socioeconomic grouping in south-west Bangladesh.

Household well-being	**Salinity level (no. of HH)**				**Mean total land holding in ha (min–max)***
	High saline (273)	**Medium saline (206)**	**Low saline (298)**	**Freshwater (305)**	
Rich	100% (22)	96% (25)	87.2% (39)	90% (41)	2.4 (1.05–3.7)
Medium	85.7% (91)	100% (47)	69.7% (114)	91.4% (70)	1.14 (0.7–1.4)
Poor	46% (137)	81.4% (86)	56.3% (119)	77% (122)	0.7 (0.4–1.1)
Ultra-poor	8.7% (23)	66.7% (48)	38.5% (26)	54.2% (72)	0.4 (0.16–0.7)
Geographical information	Arapangasia, Shaymnagar, Satkhira	Jaduardanga, Ashashuni, Satkhira, salinity	Shuvna, Dumuria, Khulna	Chor-Borobaria, Chitalmari, Bagerhat	
Water salinity	10 ppt	>5<10 ppt	<5>0.5 ppt	<0.5 ppt	

n, number of households. Total number of households assessed = 1,082.

**Land area based on post-hoc analysis (mean with max and min values) of land area of households. Both rich and medium households formed better-off segment whereas poor and ultra-poor households formed worse-off.*

fish production for which their land is less suitable. Ownership of, or leased-in access to, *ghers* was affected by household socioeconomic status. While "better-off" households had more access to *ghers*, even "worse-off" households had significant participation in aquaculture through leasing arrangements. The income Gini values (0.26–0.29) were also indicative to this lower disparity, compared to land holding Gini values (**Table 1**).

Agro-ecologies appeared to influence the types of household likely to be involved directly in aquaculture and mean area of land holding (**Table 2**). Limited off-farm livelihood opportunities in MS and FW areas pushed more ultra-low socioeconomic households into aquaculture; gross margins from aquaculture were also significantly lower in these two communities. This is mainly explained by limited off-farm livelihood options (**Supplementary Table 1**) related to their greater geographical isolation, and traveling times to mangroves (MS) and urban areas (FW) compared to HS and LS communities, respectively (**Table 1**).

Food Consumption Levels Across the Saline Gradient

The average levels of consumption of different food group's intra-household food allocation patterns were similar across the salinity gradient; however, overall fish consumption was higher in lower saline compared to higher saline locations (**Supplementary Table 2**).

Overall household consumption of some non-fish dietary components varied with position in the saline transect, e.g., less meat was eaten in HS, and more milk and eggs were consumed in MS than other locations. Daily intake of meat and fruit consumption was similar, although the food frequency study indicated the better-off tended to eat these nutritious food items more frequently than "worse-off" households (**Supplementary Figure 1**). There were no significant differences in consumption of any food group between household members, household socioeconomic status or location, except for cereals, where "better-off" households tended to consume significantly ($P < 0.05$) more cereals (1,670 g/capita/day) than "worse-off" (1,545 g/capita/day) (**Table 3**).

A higher proportion of individuals within households (>90%) consumed fish than any other food group except cereals and vegetables. In contrast <13.5, 13.0, and 18.0% consumed any meat, milk and eggs, respectively, during the two 24 h dietary recall periods (**Table 3**). Within households, fish consumption was highest for adult males; the mean daily fish consumption of adolescent and adult females was 20% lower ($P < 0.05$) than adult and adolescent males. Adolescent females consumed less fish than other household members (**Table 3**).

Levels of fish consumption were highly variable within and between households and were impacted by both geography and household socioeconomic status (**Supplementary Table 2**). Households in the LS consumed significantly less fish than in other areas; intake in the FW, MS, and HS areas was similar (**Supplementary Table 2**). Better-off households consumed over 20% more fish than worse-off households (122 vs. 100 g/day, $P < 0.05$; **Supplementary Table 2**).

Contribution of Fish Consumption to Nutrient Intake

Estimated macro and micro-nutrient consumption suggested that consumed total energy levels for adolescents were below the daily recommended nutrient intake (RNI) (NIH, 2016; WebMd, 2016) while those for adults slightly exceeded them (required energy for male 2,900 Kcal; female 2,300 Kcal). Overall individual protein intake was found to be well above the RNI for all household members with a major (about 25%) proportion of total protein derived from fish. Protein consumption by adolescent female was found to be 2-3 times higher (data not shown) than the RNI level (NIH, 2016; WebMd, 2016).

Estimated micronutrient intake compared to RNIs (FAO, 2001; NIH, 2016; WebMd, 2016) were variable (**Table 4**). Estimated zinc consumption of all household members was 20–50% higher than the RNI (**Table 4**). In contrast, calcium consumption was particularly low for all household members,

TABLE 3 | Summary of mean (±SD) daily intake of each food group by individual household members in four communities located across a saline gradient in SW Bangladesh based on two 24 h recall periods [the number in parenthesis is frequency of the individual that consumed the food item].

Food groups	Male adult (n = 219)	Female adult (n = 233)	Adolescent male (n = 130)	Adolescent female (n = 289)
Cereals	2,028 ± 624 (219)	1,684 ± 519 (233)	1,662 ± 673 (130)	1,168 ± 425 (289)
Fish	116 ± 91 (202)	98 ± 68 (219)	108 ± 89 (117)	94 ± 70 (268)
Vegetables	428 ± 2 (218)	380 ± 184 (230)	360 ± 305 (130)	321 ± 173 (288)
Meat	15 ± 39 (37)	9 ± 25 (36)	16 ± 39 (30)	9 ± 29 (39)
Pulses (ml)	92 ± 148 (89)	75 ± 119 (97)	67 ± 106 (52)	58 ± 102 (109)
Milk (ml)	22 ± 64 (36)	19 ± 49 (40)	17 ± 47 (17)	20 ± 48 (51)
Eggs	9 ± 21(53)	7 ± 16 (54)	9 ± 17 (36)	8 ± 18 (71)
Fruits	6 ± 25 (28)	7 ± 21 (34)	10 ± 25 (22)	8 ± 21 (55)
Beverage (ml)	18 ± 35 (63)	1 ± 9 (3)	3 ± 17 (10)	0.8 ± 8 (3)
Others*	3 ± 12 (24)	2 ± 9 (19)	3 ± 9 (15)	3 ± 14 (28)

Unit in g unless mentioned in parenthesis of first column.

**Others is a food group comprising ice-cream, chocolate, etc. In each site 60 households were chosen based on presence of at least one unmarried adolescent female. No significant differences found between locations and socio-economic groups except for cereals.*

TABLE 4 | Results showing factors affecting mean micronutrients consumption of household members in relation to the average reference value in the aquatic farming system in SW Bangladesh.

Minerals	Factor	Group	Mean residual	SD	% above (+) or below (–) the threshold level	Significance
Zinc	Salinity	High	3.6	5.1	36.0	ab
		Medium	3.5	5.9	35.6	b
		Low	2.3	4.7	23.0	ab
		Freshwater	3.9	5.8	39.0	a
	Socio-economic status	Better-off	3.9	5.4	39.4	a
		Worse-off	2.8	5.4	27.8	b
	Relation	Adult male	4.5	6.0	45.5	a
		Adult female	4.9	5.3	49.0	a
		Adolescent male	2.1	5.2	20.6	b
		Adolescent female	1.8	4.5	18.5	b
Calcium	Salinity	High	−586.2	328.7	−53.3	b
		Medium	−607.3	313.1	−55.2	bc
		Low	−707.5	250.6	−64.3	c
		Freshwater	−84.8	796.5	−7.71	a
	Socio-economic status	Better-off	−446.9	549.9	−40.6	a
		Worse-off	−533.7	492.7	−48.5	b
	Relation	Adult male	−340.4	602.9	−30.9	a
		Adult female	−515.9	475.4	−46.9	bc
		Adolescent male	−417.5	564.8	−37.9	ab
		Adolescent female	−609.4	445.6	−55.4	c
Iron	Salinity	High	4.06	10.4	33.8	a
		Medium	2.75	9.5	22.9	a
		Low	2.01	9.5	16.7	a
		Freshwater	4.49	10.3	37.4	a
	Socio-economic status	Better-off	4.3	10.1	36.4	a
		Worse-off	2.3	9.8	18.8	b
	Relation	Adult male	10.1	9.9	84.0	a
		Adult female	1.4	8.8	11.9	c
		Adolescent male	7.3	8.6	60.9	b
		Adolescent female	−1.9	7.8	−15.8	d

Different letters (last column) in rows under each factor row indicated significant differences ($P < 0.05$).

irrespective of sex and position, with intakes 30–55% below the RNI. Calcium intake was much lower among adolescent females compared to other household members (**Table 4**). The iron intake of males was 60–80% more than required and adult females consumed levels 10% above RNI but adolescent females were 15% lower compared to the RNI (**Table 4**).

The nutrient content of species consumed varied greatly. The level of n-3 LC-PUFA (EPA+DHA in mg.100g^{-1}) varied greatly across different species produced in *ghers* across the salinity gradient. Mangrove fish, such as mullet that mainly enter the *ghers* with tidal exchange, had relatively high n-3 LC-PUFA levels. The main edible fraction of farmed crustaceans had low levels of n-3 LC-PUFA, while tilapia had intermediate levels. Non-stocked species from freshwater areas had higher proportions of total lipids (on a mg per 100 g basis), and specifically n-3 LC-PUFA when compared to hatchery-derived larger freshwater fish, and different crustacean species (**Figure 2**). However, by-products such as the claws, heads, and specifically brains, of the giant prawn (*Macrobrachium rosenbergii*) were major sources of fatty acids and essential minerals. The energy content of samples from the current study were comparable with previously published data (INFS, 2013; Bogard et al., 2015).

The specific culture system and agroecology also impacted the nutritional status of aquatic animals produced. A decline in n-3 LC-PUFA content was correlated with ambient salinity level for several key euryhaline species (**Figure 2**). Of particular note was the trend for tilapias where peak levels of n-3 LC-PUFA were found in fish raised in the MS environment. In contrast, n-3 LC-PUFA (EPA+DHA in mg/100 g) levels in two species of shrimp *Penaeus monodon* and *Metapenaeus monoceros* were much lower across salinity levels (**Figure 2**).

The availability of high-quality nutritious fish does not necessarily translate to its accessibility and consumption by the most vulnerable groups. Adolescent females had both the lowest levels of fish and overall total food consumption and were identified as the most at-risk group for malnutrition, as evidenced biomarker outcomes (**Figure 3**).

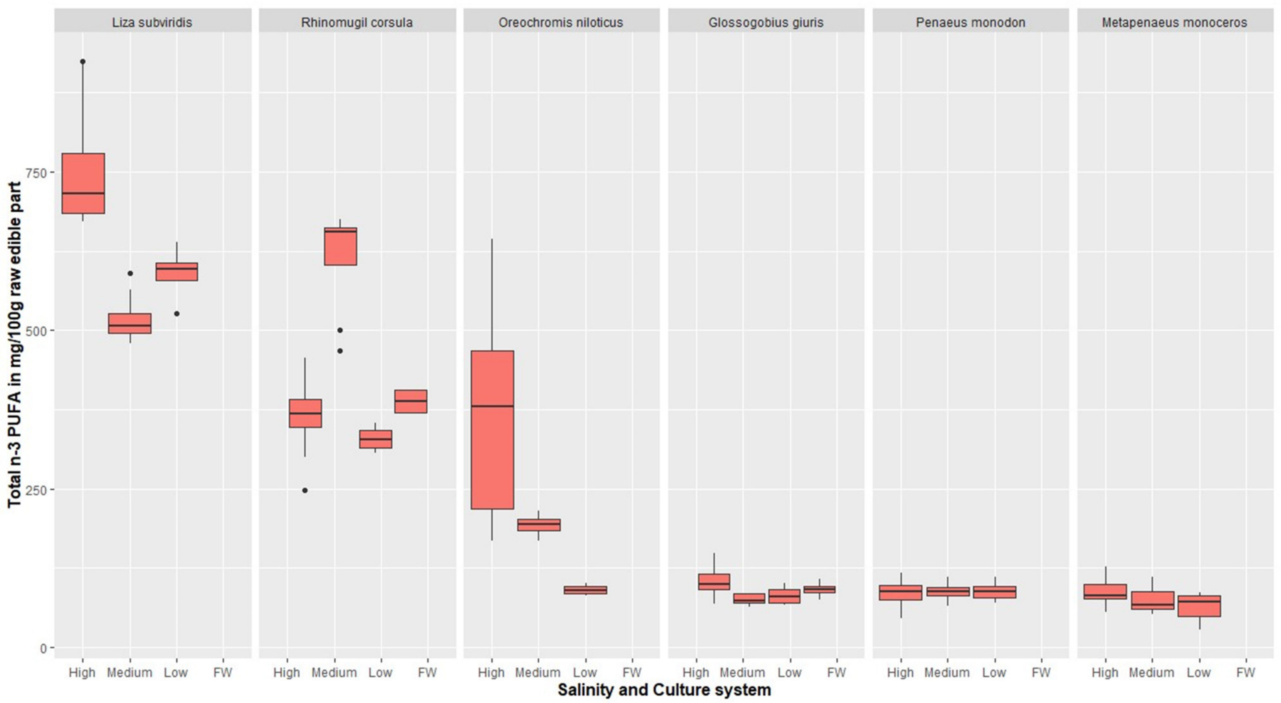

FIGURE 2 | Levels of total n-3 LC-PUFA (mg/100 g raw edible part, mena values; error bars show SD) measured in six fish species found across the range of culture systems and salinity regimes in SW Bangladesh.

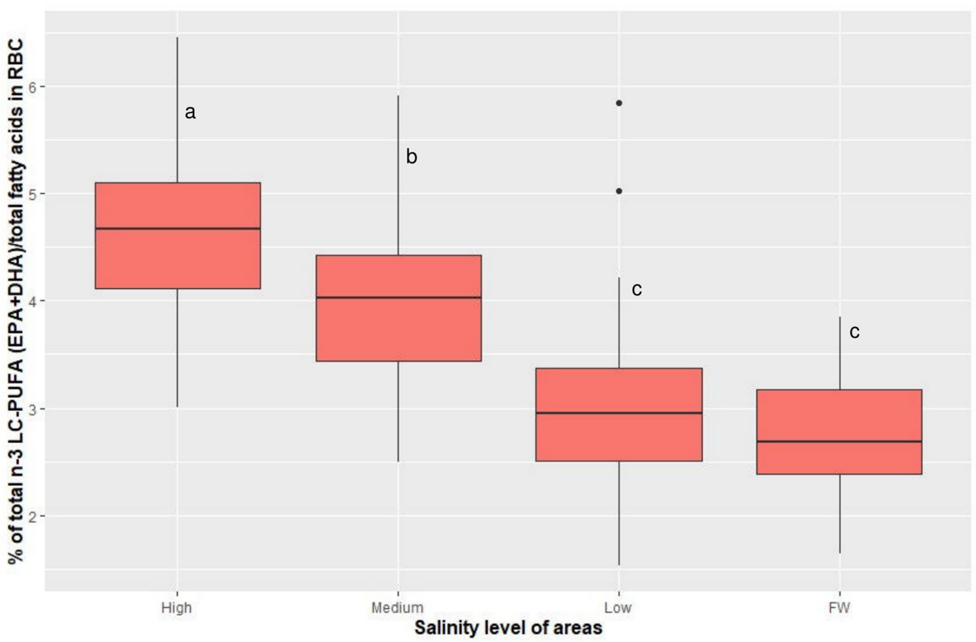

FIGURE 3 | Total n-3 LC-PUFA (EPA+DHA) as a percentage of total fatty acids (w/w) in RBC of adolescent females (10–19 years) across aquatic farming systems located across a saline gradient in SW Bangladesh [for in-depth household level study 60 households from each site with equal number from each social well-being group were considered, however for bloodspot collection we took 50 households from each site; different lettering above each whisker indicate significant differences ($P < 0.05$)].

Indicators of Adolescent Female Health

The comparison of n-3 LC-PUFA levels in red blood cells (where blood was taken whole and then transformed into RBC) of adolescent females living across the salinity gradient revealed a clear relationship (**Figure 3**). However, there was no relationship between n-3 LC-PUFA and household socioeconomic status.

Adolescent females from the HS and MS areas had significantly higher ($p < 0.05$) total n-3 LC-PUFA levels than those located in LS and FW areas (**Figure 3**). No significant differences in n-3 LC-PUFA index ($P < 0.05$) were found between adolescent females from the LS and FW sites. Higher salinity sites were significantly ($P < 0.05$) correlated with higher n-3 LC-PUFA outcomes. The average Omega-3 index was more than 4% in HS declining across the gradients to a low of 2.77% in FW (**Figure 3**). Location in the saline gradient and socioeconomic status did not impact on either body mass index (BMI) values that ranged from 17.48 to 20.8 (**Supplementary Figure 2**) or mid upper arm circumference (MUAC) values, which ranged from 22.1 to 24.11 cm (**Supplementary Figure 3**).

DISCUSSION

This study revealed strong associations between the characteristics of aquaculture and key livelihood impacts of households in the four coastal communities located across a surface water salinity gradient in SW Bangladesh. Aquaculture is practiced by the majority of households in these communities as polycultures, based on both stocked and unstocked species (Faruque et al., 2016), and has broader spillover benefits to the community as a whole through employment and nutrition. Typically characterized as export-focused, much of the production was found to contribute to local consumption. From 45% (HS) to 80% (FW) of the harvested yield was consumed locally, with the balance (mainly shrimp and prawns) entering the processing sector.

While a high level of inequality of access to aquaculture in HS communities adjacent to the Sundarbans area has previously been reported (Abdullah et al., 2017), our study suggests that this characterization was not representative across the saline zone. Our results indicate that apart from the most saline gradients, a significant proportion of "worse-off" households accessed both the means to, and benefits of, aquaculture production through ownership or leasing arrangements of land. Engagement of worse-off households in aquaculture increased household fish consumption (AFSPAN, 2015), although livelihood opportunities in addition to aquaculture, typically natural resource-based (HS) or urban-driven (LS), were still critical to ultra-poor households. Such pluriactivity was focused on exploitation of mangrove resources (fishing, etc.) in HS areas and around urban employment opportunities in LS areas (**Supplementary Table 1**). Greater disparities between rich and poor household incomes were observed in shrimp-prawn farming areas in Bangladesh (Environmental Justice Foundation, 2003; Ito, 2010; AFSPAN, 2015) than in the current study, which indicated a lower income disparity across seafood farming communities. The income Gini value (0.37) of all communities was within the range calculated for 62 countries (Carter, 2000). Furthermore, there was no correlation between area of land farmed and income levels, supporting the proposition that poverty has become increasingly detached from access to land and even from farming in much of Asia (Rigg, 2006).

Estimated net financial benefits of aquaculture systems across the saline gradient ranged from 134 to 230 USD ha^{-1} yr^{-1} (**Table 1**), which is within the range of average return reported in other studies (70–840) (Gammage et al., 2006; USAID, 2006; Abdullah et al., 2017). In the current study, productivity of "worse-off" households farming smaller *ghers* was higher than the "better-off" achieved in larger systems a common phenomenon in food production as a whole (Ramankutty et al., 2018). Coastal shrimp production within mangrove ecosystems have important roles in generating employment for the poor in both Central Vietnam (van Hue and Scott, 2008) and in East Kalimentan, Indonesia (Bosma et al., 2012). Adverse effects of shrimp farming on rice and vegetable production were revealed in a time series study in Bangladesh (Rahman et al., 2011b); however, in LS and FW communities, dyke vegetable and rice production were important parts of farmer livelihoods, a practice which has seen recent rapid expansion, especially by "worse-off" housheolds (Howson, 2014). Pond-dyke farming elsewhere in the country benefits both "better-off" and "worse-off" *gher* owners in rural and peri-urban settings through both cash sales and subsistence consumption (Karim et al., 2011).

Shrimp farming has been framed as an activity that disregards local people's needs (Paprocki and Huq, 2018), and was propelled initially through land grabs by wealthy outsiders, exacerbating disparities (Adnan, 2013). Earlier reports (Swapan and Gavin, 2011) of external investors gaining monetary benefits at the expense of local people were not observed in the current study, suggesting these might be more exceptional than normative outcomes. Indeed, Gini coefficients, high levels of engagement in production and similarity of consumption and health outcomes across social groups suggested that aquaculture was having broader societal benefits.

A reduction in biodiversity through salinization exacerbated by shrimp farming leading to "worse-off" dietary outcomes has been a key criticism of shrimp farming in Bangladesh (Rahman et al., 2011a). The "semi-saline" zone (Guimaraes, 1989) is subject to great dynamic salinity fluctuations across seasons, with individual locations being subject to both increases and declines in salinity over time related to saline intrusion and sedimentation, respectively (Faruque et al., 2016). "Industrial shrimp" systems have been characterized as part of a "blue future" with no rice, livestock, vegetables or freshwater fish, and limiting opportunitites for self-provisioning of food (Paprocki and Cons, 2014). A key concern is that intensification of aquaculture systems could reduce access to affordable low-value finfish (Little et al., 2018). Our analysis points to these HS floodplain systems being very low-input, nutrient sinks, indeed the opposite of "industrial" food production, and an important source of highly nutritious local food.

Ongoing reliance on the Sundarbans by "worse-off" households in the HS community remained high in contrast to a previous study (Abdullah et al., 2017), that found dependence on collection of natural resources by the poorest in this area improved resilience to environmental shocks (such as Cyclone Aila) compared to those engaged in aquaculture (Abdullah et al., 2017). Mangrove-derived fish in all HS and MS *ghers* comprised a significant proportion of total yield, demonstrating the importance of the Sundarbans as a source of biodiverse, self-recruiting species. The importance of porous boundaries and close interaction with natural stocks to maintain productivity and biodiversity has been demonstrated as a common characteristic of freshwater systems throughout Asia (Amilhat et al., 2009). It also points to the strong interrelationship between biodiversity and nutritional outcomes of localized, landscape food systems.

The more obvious agricultural diversity of LS and FW communities has been associated with enhanced food and nutrition security (Faruque et al., 2016) but both consumption patterns and health outcome data in the current study contradicted these conclusions. Although the diversity of local terrestrial cropping systems and intensity (Faruque et al., 2016) were lower in HS and MS gradients, consumption levels of vegetables, fruit and milk were constant across saline zones. This contrasts with earlier observations (Rahman et al., 2011b) of a decline in their consumption following the adoption of shrimp farming. Markets may now be increasing access to all foods due to improvements in market linkages and greater market inclusion (Belton, 2016; Faruque et al., 2016).

Overall, fish consumption was highest at the lower salinity sites, but there were not major differences across the saline gradient. Worse-off households consumed 60–80% of the levels reported by richer households in the same community, except for MS areas where "worse-off" males consumed 20% more fish than the "better-off"; females from "better-off" and "worse-off" households consumed similar amounts. In contrast, a nationwide study reported that "better-off" households, representative of rural Bangladesh in general, tended to consume twice as much fish as worse-off households (average 60 g/person/day) though much lower aggregate levels of total fish consumption overall. Also, dried fish, a concentrated nutrient source, was a significant proportion of total fish consumption nationally, and high levels (80%) of fish were purchased from the market. The current study found relatively high levels of fresh fish consumed in the producer communities studied and a lack of dried fish consumption, suggesting that retention of fresh fish for local use was prioritized.

This work confirmed that Bangladesh females, especially in "worse-off" socioeconomic groups, tended to consume less fresh fish than men (Bogard et al., 2017b). The current study demonstrated significantly lower consumption of cereals, fish, vegetables, and pulses by female adolescents compared to other household members irrespective of socioeconomic status or agroecology. Our study suggests that very low levels of rice consumption by adolescents might restrict energy intake below the RNI; another study found that 25% of adolescent females (and boys) had inadequate energy but, as in the current study, dietary protein was adequate (Leroy et al., 2018). These results contradict other studies that have found animal protein intake to be extremely low in Bangladesh (Ahmed et al., 1998; Khan and Ahmed, 2005; NIPORT, 2013). The high level of dietary protein consumption in the current study may also have reflected the timing i.e., during the peak dry-season harvesting season, when mobility and fish consumption is typically higher (Morales, 2007). The importance of disaggregating consumption by both gender and age is now more widely accepted, but the distinctive and crucial adolescent phase has often been missed (Haberland et al., 2018). The necessity for understanding the nutritional vulnerability of adolescent females in Bangladesh is further underlined by the enduring high rate of pregnancy in this group and the poorer outcomes for themselves and their children than adults (Nguyen et al., 2018). Recent research has confirmed the high burden of undernutrition in adolescent females in early pregnancy (Mridha et al., 2018).

A dietary pattern approach to assessing diets of adolescents in Northwest Bangladesh found fish to be by far the most important animal food source consumed but identified consistent and important differences in intake and dietary diversity among socioeconomic groups (Thorne-Lyman et al., 2020). Adolescents in the poorest households had the least diverse diets, but access to a fish pond was much lower in this part of Bangladesh (around 25%) than in any of the communities in the current study that were sampled from a known concentration of commercial aquaculture. Affordability was found to be the major factor in determining adolescent's access to nutritious food. The importance of fish in rice-based diets has been strongly linked to their high levels of micronutrients particularly zinc, iron, calcium, and n-3 LC-PUFA.

Zinc deficiency remains a critical issue among non-pregnant and non-lactating women in Bangladesh (UNICEF, 2013) but our findings concurred with the sufficiency reported elsewhere (Combs et al., 2008) that was linked to high levels and bioavailability in fish-rich diets. Although estimated iron intake was below RNIs, the prevalence of iron deficiency is low because of high levels in the ground water (Rahman, 2016). In contrast, the low dietary calcium intake observed in our study was related to both low dairy consumption and reduced consumption of small indigenous fish species (SIS) in SE Bangladesh (Combs and Hassan, 2005). Both livestock and milk production are believed to have declined significantly in shrimp farming areas, in line with limited land available for grazing (Rahman et al., 2002). However, milk consumption in the current study was not correlated with saline gradients or socioeconomic status. Small fish eaten whole including the (soft) bones are a particularly valuable source of calcium (Roos et al., 2003a), however, a large range in calcium content among small indigenous species (60–1,480 mg Ca/100 g edible portion) has been reported (NIH, 2016) in Bangladesh. The relative decline in their consumption has been linked to the increased production of a limited range of farmed fish (Belton et al., 2014). However, no monoculture was observed in the study area and the diversity of aquatic animals produced and consumed was high.

Differential access to and consumption of fish are likely to explain the variable n-3 LC-PUFA levels among adolescent females in the current study. Higher n-3 LC-PUFA levels are a result of higher consumption levels of n-3 LC-PUFA rich aquatic animals in HS/MS sites, compared with LS/FW sites. The strong link between the n-3 LC-PUFA content in aquatic animals and in females' whole blood levels demonstrated that local food production could influence the omega-3 index status of dependent communities as a whole rather than being limited to those who, as farmers, had direct access to the means of production. Consumption of small, unstocked, self-recruiting tilapias and indigenous species was particularly high in HS/MS communities, where the highest n-3 LC-PUFA blood levels were observed. Tilapia, globally most widely commonly raised in freshwater environments, has been criticized as a farmed species choice on the basis of a comparably low n-3 LC-PUFA content, and increasing levels has become a focus for contemporary diet formulation (Stoneham et al., 2018). This is in spite of an otherwise high nutrient content, including total lipid, protein, and micronutrients, like zinc (Karapanagiotidis et al., 2010). More favorable ratios of n-3:n-6 PUFA were found in less intensively farmed tilapia (Karapanagiotidis et al., 2006); however, the higher levels of EPA+DHA ($g.100g^{-1}$) found in saline-raised tilapia in the current study are unique and have impacted positively on human nutritional outcomes. The dietary contribution of micronutrients from small indigenous species is well-established for freshwater systems (Larsen et al., 2000; Gibson and Hotz, 2001; Roos et al., 2007). Relative connectivity of culture ponds to tidal water channels and availability of SIS originating from the Sundarbans mangrove forest probably explain their variable but greater importance in diets in the higher saline gradients: While the MS area was also close to the mangroves, it had limited SIS (just above half of HS area) due to poor connectivity of *ghers* to tidal water channels. This limitation appears to explain this area's reliance on introduced tilapias as a response to limited availability of mangrove-derived SIS. Tilapia accounted for 75–80% of the fish eaten by households in the HS community in another study in the same area (Faruque et al., 2016).

The importance of the "hidden harvest" of micronutrient-rich fish harvested from aquaculture, albeit that considered commercial, export-focused shrimp systems, parallels the term used for the under-reporting of yield, and nutritional significance, of freshwater fisheries (Fluet-Chouinard et al., 2018). The lack of any difference in n-3 LC-PUFA biomarker status between better-off and worse-off adolescent females also challenges the assumption that commercial aquaculture necessarily benefits the better-off at the expense of the poor (Belton et al., 2017; Nguyen et al., 2018). The impact of commercialization on the nutrition of smallholder farmers is, in general, under-researched (Ogutu et al., 2019), and nutrition-sensitive food production requires support, even in cash cropping contexts (Rukmani et al., 2018). Our study demonstrates undocumented complexity and diversity in commercial, export-driven aquaculture systems in Bangladesh and highlights their potential nutritional benefits for vulnerable adolescent females.

CONCLUSION

This work has quantified and described the heterogeneity of consumed seafood at an intra-household level, identifying continued inequalities and highlighting the need for targeted measures to improve consumption of nutritious food by vulnerable adolescent females across the socioeconomic spectrum. The finding that individuals located in freshwater areas maybe at greater risk of nutrition insecurity than those in more saline locations is novel; the diversity of integrated pond-dyke cropping in less saline and freshwater gradients has been correlated with increased dietary diversity but our results challenge this orthodoxy and have implications for targeting of interventions. Policy that supports less intensive polycultures that are both compatible with high quality export-orientated shrimp and production of affordable, nutritionally high-quality seafood for local people should be developed. The nutritional and broader livelihoods outcomes of extensive polycultures are underappreciated and are vulnerable to trends in global trade. Among its critics, a common perception of the Bangladesh shrimp sector is that it operates on an "industrial scale" with external investors being the main producers on consolidated land holdings. However, though commercial in orientation, the aquatic farming systems in SW Bangladesh remain smallholder-managed and clearly support household subsistence needs and local nutritional security. Furthermore, the diversity of the systems, highly influenced by prevailing salinity, has broader impacts on local food systems. Although increasing salinity may restrict production of rice and other terrestrial crops, *gher* dykes have given rise to significant production of high-value vegetables where the salinity of water remains low. This study also provides evidence for the linked value of conservation of the Sundarbans in sustaining proximate extensive aquaculture. Wild juveniles deriving from these enduring resources form a key part of the environemental services they provide.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://dspace.stir.ac.uk/handle/1893/25012#.YILTzKFDY2w.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Bangladesh Medical Research Council (BMRC). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. The animal study was reviewed and approved by Bangladesh Medical Research Council and University of Stirling, UK.

AUTHOR CONTRIBUTIONS

A-AM, DL, and FM designed the research. A-AM, BM, and DL analyzed the data. All authors wrote the paper.

FUNDING

This piece of research was funded by Commonwealth Scholarship Council, UK and Sustaining Ethical Aquaculture Trade (SEAT) research project funded by EU.

ACKNOWLEDGMENTS

The authors would like to thank the fish farmers and participants of the research work from the southwest coastal area of Bangladesh. Additionally, we would like to thank the staff at the Nutritional Analytical Service (NAS), Institute of Aquaculture, University of Stirling, UK for their kind cooperation and excellent supports. We acknowledge the support of Commonwealth Scholarship Commission in the UK. We also got financial support for the field work from the Sustaining Ethical Aquaculture Trade (SEAT) research project funded by EU. The work was also supported with the Competitive Research Grants to Develop Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA). IMMANA is funded with UK Aid from the UK government.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2021.713140/full#supplementary-material

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frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 30 November 2021
doi: 10.3389/fsufs.2021.758363

Cooperative Development: Sustainability Agricultural Planning Viewed Through Cooperative Equilibrium Management Theory in Togo, Africa

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Cooperative economics looks at market failures as areas for development. The cooperative development process, however, requires member engagement or cohesion in the process according to the Cooperative Management Equilibrium Theory. This cohesion requires an awareness and understanding by the cooperative members of the market failure to develop the capacity to address the failure. This article looks at the effects of government agricultural programs on economic, environmental and social sustainability. The questions we ask is how does a focus on economic development push against social and environmental sustainability within the agricultural sector in Togo? Does member cohesion within a cooperative represent a form of Polanyian double movement through social and environmental cohesion? The current development models utilize what Sen refers to as an austere mode of development which forgoes social or environmental considering them luxuries. Does the focus of economic development build capacity only for economic performance within the Togo agricultural sector at the expense of social and environmental sustainability? Utilizing Deep Participatory Indicator Approach (DPIB) approach this paper examines the economic, environmental and social indicators within two prefectures in the Plateaux Region of Togo. Indicators were separated to show the differences between individual or cooperative producers. As cooperatives it was anticipated that a greater emphasis on social and environmental sustainability would be created through cohesive social action. This study found that the emphasis on economic development included in government programs built development capacity within cooperatives emphasizing their cooperative market cohesion.

Keywords: cooperatives, agriculture, Equilibrium Management Theory, market failure, economic growth

OPEN ACCESS

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Specialty section:
This article was submitted to Land, Livelihoods and Food Security, a section of the journal Frontiers in Sustainable Food Systems

Received: *13 August 2021*
Accepted: *28 October 2021*
Published: *30 November 2021*

Citation:
Berge ST, Bokoumbo K, Johnson KA, Yabi JA and Yegbemey RN (2021) Cooperative Development: Sustainability Agricultural Planning Viewed Through Cooperative Equilibrium Management Theory in Togo, Africa. Front. Sustain. Food Syst. 5:758363. doi: 10.3389/fsufs.2021.758363

INTRODUCTION

Development economics has been focused on neoliberal approaches to community development emphasizing income growth and consumption for many years. For example, Rostow (1990) put forward the notion of stages of economic growth focused on consumption. Nobel laureate Kuznets' (1955) presented the inverted U hypothesis suggesting poor countries can outgrow inequality through re-distributed income created by increased economic growth. Development economics continues to examine development through the lens of increased economic activity in an attempt to "raise all boats" via a larger economic tide. Kuznets' Inverted U hypothesis shows that poor counties maintain a poor redistribution of income leading to greater inequality yet income remains a key focus of economic development practice.

Developing countries that follow this economic development paradigm fall prey to the same economic issues as developed countries, e.g., income inequality, food insecurity, the wealth gap. Greater inequality due to poor wealth re-distribution can be seen in developed countries like modern day China even as it becomes a powerhouse of economic growth. Authors such as Piketty and Goldhammer (2014) have discussed wealth distribution in-depth. These authors show that there is a greater wealth to income ratio in developed countries suggesting that growing larger economies does not improve wealth distribution or decrease inequality, nor will it in the future as inheritance takes a large role in wealth re-distribution (Piketty and Goldhammer, 2014). What is missing from the development approach is the multi-disciplinary nature of community development. Development is not simply increased wealth within a community leading to greater income distribution. Community development is increase interaction, shared direction, community safety, social assistance and so much more (Sen, 2000; Harwood et al., 2016; Taylor and Lybbert, 2020).

Even with the understanding that development is a multi-disciplinary issue touching on topics as complex as poverty, inequality, and human development the predominant development approaches are still influenced by neoliberal market beliefs. Since the 1980s a trust in market forces to correct developmental inequalities remains the major driver of development approaches. Many governments focus on export-oriented economic growth in an attempt to entice greater amounts of foreign capital into their county's economies. This export-oriented approach seeks to grow the size of the economic pie within the country with the hope that the larger pie will improve wealth distribution. According to Sen (2000) the export-oriented or market based approach to development is a type of austere attitudinal mode of development where things such as social safety nets, social services and even democracy are luxuries that must give way to the development process. This austere attitudinal mode fits the laissez-faire market approach utilized by the World Bank and the International Monetary Fund. The World Bank and the IMF direct developing governments to implement austerity measures as a means to focus on economic growth forgoing the multi-disciplinary nature of development. Abouharb and Cingranelli (2006) went so far to suggest that World Bank Structural Adjustment Agreements (SAAs), meant to improve economic performance in developing countries, actually worsens government respect for physical integrity rights such as health, education and human welfare.

In contrast to this austere attitudinal mode of development Sen (2000) suggested there is a "friendly" process for development that relies on mutually beneficial exchanges or working with social safety nets, improving political liberties and social development. This friendly approach to development is a component of Sen's Capability Approach that focuses on the moral significance of individuals' capability of achieving the kind of life they value rather than a universally accepted market based developed life. The market based approach to development simply assumes each community has similar needs and wants which is a disservice to the unique nature of communities. Assuming that an active, growing economy will provide for every individual within the community as well as all the community's needs is naïve.

The question this paper seeks to address is whether cooperative development is a form of push back, or Polanyian double movement, against the austere development approach that is prominent in current economic development practice. By examining the development approach utilized by the Togo Government for the agricultural sector in Togo's Plateaux Region this paper will assess if cooperatives represents an environmental or social push back against a strict economic development paradigm. The outcomes will be examined through the lens of Cooperative Equilibrium Management Theory as a framework to better understand the cooperative organizational form as it relates to Polanyian countermovement and Sen's Capability Approach to development.

Equilibrium Management Theory as outlined by Côté (2019) presents cooperatives as dualities separated into membership and the market. Three cohesions must be in place to ensure a functioning cooperative that addresses both the members' needs and the business needs of the cooperative. Cohesion among members represents the expression of members' needs within the cooperative including social and environmental concerns. A cooperative with a unified membership that has the capability to clearly express their needs within the cooperative would be considered to have strong member cohesion. On the other side of the duality is the need for Cooperative Market Cohesion. A cooperative that does not consider its business competencies, strengths and weaknesses or other economic success factors within the market would have minimal Cooperative Market Cohesion. The final cohesion that must exist within the cooperative is the combination of the first two cohesions in a balanced approach to the cooperative's operations known as the Cohesion between Members' Needs and the Economic Activities of the Cooperative (See **Figure 1**).

This balancing between Member Cohesion and Cooperative Market Cohesion is reminiscent of Polanyi's (1957) double movement. The membership (society) through Member Cohesion pushing back against market forces through Cooperative Market Cohesion. The social and environmental mission of the cooperative as defined by the cooperative membership which Polanyi would identify as the social

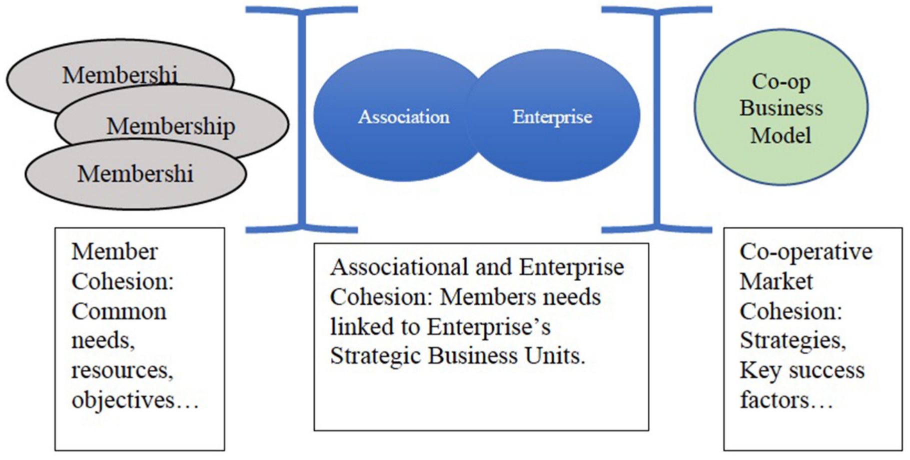

FIGURE 1 | Co-operative duality reprinted (adapted) from Côté (2019). Cooperative management: an effective model adapted to future challenges. Montréal (Québec): Éditions JFD.

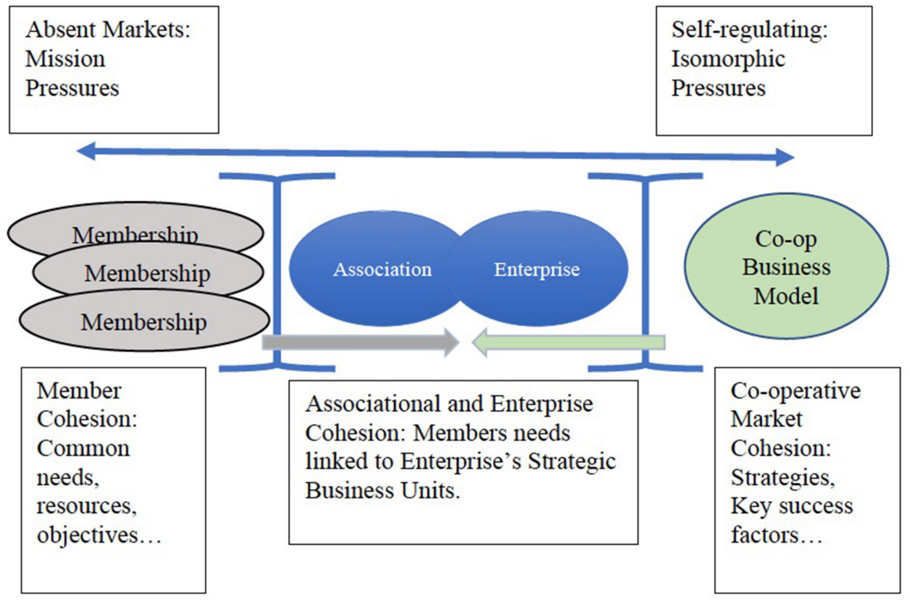

FIGURE 2 | Co-operative duality and market duality.

protection against marketization. The social protection moves production and resources within the cooperative toward social rather than economic needs. Polanyi's would see Cooperative Market Cohesion as the liassez-faire movement to expand the scope of the market as the cooperative seeks a strategic fit within the market to ensure economic viability of the organization (See **Figure 2**). A final balance between Member Cohesion and Cooperative Market Cohesion would result in Cohesion between Members' Needs and the Economic Activities of the Cooperative to form an organization that balances all three social, environmental and economic sustainability indicators within the cooperative. This ability to balance the three sustainability areas assumes the cooperative has the capability to manage these divergent needs. However, the approach to cooperative development, as will be shown in this study, emphasizes economic outcomes rather than social or environmental indicators.

The capacity to balance all three sustainability indicators in the development process speaks to Sen's Capability Approach. Sen speaks of the freedom individuals have to achieve outcomes that they value. Individuals, however, can only achieve freedom to accomplish what they value if they obtain an understanding of the processes of development to achieve these goals. Being inundated with claims of prosperity for all upon achieving a stable and growing economy focuses individuals to enhance their economic capabilities at the expense of social or environmental interests. Consider Sen's example of the bicycle. The bike has characteristics of transportation but only if the individual using the bike can ride it. The same can be said for development. Development can create a balance between economic, social and environmental interests, but only if the individual engaged in the development process is made aware of the inter-related nature of all three sustainability indicators.

As we will see in the next sections of this paper the economic sustainability of agricultural producers in the Plateaux Region of Togo is higher than average if the producer is a member of a cooperative. However, this economic sustainability is linked to the below average social and environmental sustainability scores of cooperatives as measure by the Deep Participatory Indicator-Based approach (DPIB). The next section of the paper will outline the background environment in which the co-operatives operate and will be followed by the methods section to clearly outline the DPIB approach used. The results section will outline the details of the environmental, economic and social sustainability scores calculated using the DPIB approach. The discussion and conclusion section will show that the approach to agricultural development used by the Togo Government was based on traditional economic development concepts. The Togo Government focused on building economic capabilities within cooperatives that resulted in a push back against the environmental and social sustainability of Togolese agricultural maize producers.

BACKGROUND

In 2018 the Togolese Government put forward its National Development Plan (NDP) 2018–2022 (Togolese Government, 2018). The NDP focuses development on networks of small producers supporting Agropoles (Agricultural Transformation Poles) throughout the country. Agropoles are derived from the growth pole concept suggesting a center, or foci, for development within a community linked to other centers via corridors of land (Perroux, 1950). These geographically focused agropoles agglomerate activities that produce outputs meant to enhance performance within the community, particularly economic performance (Sibbons and Boudeville, 1967; Ivarah, 2003). Brebbia et al. (2012) suggest that the function of Agropoles is to maximize the economic attributes of a particular center, emphasizing some special feature of place to encourage the growth-inducing nature of the geographic context. For example, in Brebbia et al.'s (2012) study the regional agropole emphasized agricultural production similar to our study. In our study the producers focused on maize while Brebbia, Basorun and Fasakin's study examined rice producers. Omuta and Onokerhoraye (1986) suggest that a major factor in the creation of structural differentiation through agropoles is to utilize a propulsive industry that interacts with the agropole centers and peripheral industries. The Togolese Government's NDP chose to focus on cooperatives as a propulsive industry. As a propulsive industry the cooperatives should be characterized by: (i) high interaction with other firms, (ii) high degree of dominance, and (iii) relatively great size (Darwent, 1975).

The Agropoles that the Togolese Government sought to create were to focus on accelerating growth, reducing poverty, develop food self-sufficiency, balance the agricultural trade, and massive agricultural job creation. These goals were meant to be achieved through the modernization of agriculture focusing on productivity, promotion of trade leading to improve export and improved food security along with job creation. With support from the private sector and development partners the Togolese Government sought to allocate resources to the agricultural sector through innovative financing tools. The additional resources were meant to improve yield through mechanization, control water use and strengthen cooperatives related to the processing sector. The Togolese Government also focused on upgrading research and agricultural training centers in the country to achieve its economic targets through increased economic capabilities within the sector (Togolese Government, 2018).

> The Togolese Government outlined the following targets: (i) improvement in agricultural productivity of about 10% per year; (ii) significant improvement in the agricultural trade balance from CFA F-44 billion in 2016 to CFA F-5.65 billion by 2022; (iii) a reduction in the poverty rate in rural areas to <50% by 2022; (iv) a reduction in the proportion of children under five suffering from acute malnutrition to 3% by 2022 (Togolese Government, 2018, p. 86).

These economic targets fit well with Sen's austere approach to development as they focus on economic outcomes within minimal reference to social safety nets that would be found in the Capability Approach to development.

The use of large-scale processing cooperatives as propulsive industries was meant to enhance this organization form within the agriculture sector in Togo. As a result cooperatives within the sector focused on the economic goals. Large scale cooperative development was meant to organize farmers in Togo as an economic force as only 8% of all Togolese farmers have grouped together in 2,500 small scale cooperatives across the Togolese Republic. This patchwork of cooperative development created a landscape of small scale cooperative producers that the government does not see as a potent economic force (Togolese Government, 2018).

The questions we ask in this paper is does this focus on developing economic capability within the Togolese agricultural cooperatives stifle the Member Cohesion's push back for social and environmental sustainability? How does Côté's (2019) Equilibrium Management Theory inform us on the development of the large scale producer cooperatives in Togo as propulsive industries? Is the Togolese NDP an example of traditional economic development or a subversion of Sen's Capability Approach through a focus on economic capabilities at the expense of social and environmental sustainability?

METHODS

With a focus on large scale, processor cooperatives in the Plateaux Region of Togo there needed to be a directed method for analyzing the sustainable outcomes. Recent literature into

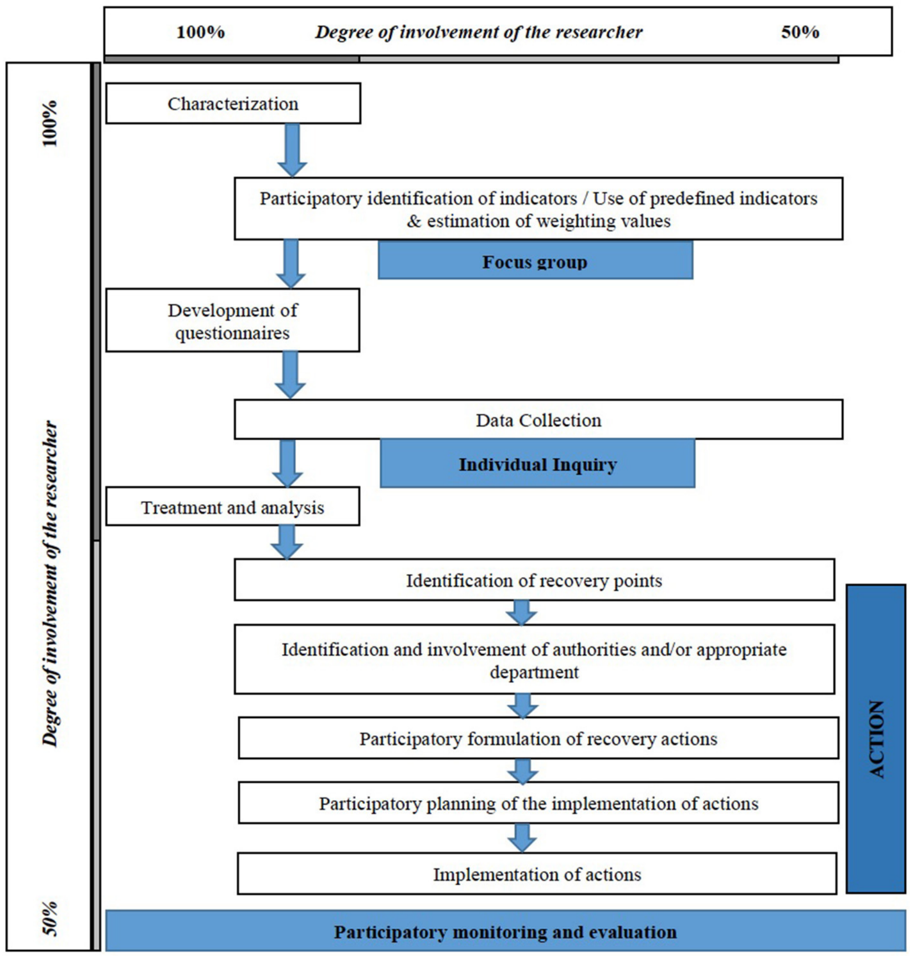

FIGURE 3 | Deep Participatory Indicator-Based (DPIB) approach. As one moves to the right and downwards, the degree of involvement of the researcher decreases.

sustainability measurement offered nearly sixty methods for assessing sustainability utilizing various indicators (Schader et al., 2014; Lairez et al., 2015; de Olde et al., 2016; Zahm et al., 2019). If we consider the sustainability problem within each of the agropoles in Togo as a universal problem, then the use of broad-based indicator methods would have been perfectly adequate. However, these indicator methods show a certain amount of discrepancy in the methodological approach as a result of their universal nature. This universal view of development does not take into account the regional or village level variances that are critical the agropole's development of local resources in a place-based approach. Nor does a universal view provide a means to measure the differences effectively. Therefore, to effectively assess sustainability approaches should be place-based resulting in a plan for monitoring the implementation of sustainability plans for each agropole at the village level. The measurement tool must not only show the positioning of the evaluated indicators in relation to sustainability universally, but also inform sustainability planning at the local level in order to enhance development at the local level via the agropole's development potential.

A directed indicator analysis approach was utilized by the IDEA-Run project initiated by Lobietti et al. (2018) and can be transposed into practice at the local level as shown by Roesch et al. (2016). The IDEA-Run conceptual framework for the development of a sustainability assessment tool was based on the IDEA method which outlines indicators of the sustainability of agricultural operations which fit this project's participants. The IDEA indicators aim to characterize the key concepts taken from the definition of sustainable agriculture:

1. *Viability* involves, in economic terms, the efficiency of the production system and securing the sources of income of the farming production system in the face of market swings and uncertainties surrounding direct payments.
2. *Livability* focuses on analyzing whether the farming activity provides a decent professional and personal life for the farmers and their families.
3. *The environmental reproducibility* of the ecosystems linked with the farms can be analyzed using agri-environmental indicators in particular, which characterize the impacts of farming practices on the environment (Landais, 1998, pp. 14–16).

IDEA method was developed to provide agricultural education programs with a tool for assessing the sustainability of agricultural holdings that are relevant, sensitive and reliable while being accessible to the greatest number of producers. Utilizing the IDEA method, the IDEA-Run project set about building a tool to assess the sustainability of agricultural production systems that is:

1. Systemic, complete, generalizable,
2. A dynamic decision support tool,
3. Educational, fast, and accessible,
4. Designed in a simple and original way (Lobietti et al., 2018).

IDEA method's focus on generalizability, however, does not address some aspects of the Togo cultural environment which could be lost or even hamper the implementation of actions meant to develop sustainable agricultural practices. As a result, an innovative approach to measuring and initiating sustainable activities at the local level was utilized in this project based on the IDEA method. The Deep Participatory Indicator-Based (DPIB) approach focused away from a generalizable approach to a localized, facilitated approach to ensure effective examination of the local nature of the agropoles and cooperative propulsive industries. The DPIB is a participatory, non-rigid approach to the choice of indicators (See **Figure 3**).

The DPIB approach initially engaged the researchers in the characterization of the research questions, the development of research tools including questionaries, surveys and focus group agendas followed by the analysis of the collected data. The engagement of participants in focus groups and individual interviews saw the engagement of the research lessen allowing for participants to manage the input into the DPIB process.

Focus groups were organized with producers and extension agents to collect data on current economic, social and environmental situations as well as to formulate the local actions to be carried out in view of the results. Each focus group consisted of, on average, seven people per group. In total, six focus groups were conducted, two for each of the three villages within the two prefectures (see **Table 1**). Research at the prefectural level made it possible to better define the research area, i.e., the sample size, and to better specify the data to be collected as well as refine the questionnaire used for the survey tool of this project.

Key informant interviews were conducted with self-identified maize producers and community leaders. Utilization of key informants allowed for more in-depth discussions on the current status of maize production in the villages along with future expectations. The key informant interviews were conducted individually with the researcher keeping detailed notes of the discussion. The interviews were conducted in an informal setting allowing the interviewee to freely express their views on the three dimensions of sustainability; economic, environmental and social.

Utilizing the DPIB approach this research completed a comparative study of the sustainability of farms in the Plateaux Region of Togo isolating whether producers are organized in cooperatives or were individual producers to determine if cooperative organizational form affects the definition and uptake of sustainable activities in all three areas of sustainability.

TABLE 1 | Breakdown of respondents by village.

Prefectures	Villages	Number of producers Surveyed		Percentage (%)	
Haho		**88**		**50.0**	
	Kloegname		33		18.8
	Tsrouvita		30		17.0
	Latho		25		14.2
Ogou		**88**		**50.0**	
	Itchiri		76		43.2
	Madjamakou		12		6.8
Total		**176**		**100.0**	

Source: Survey results, November 2019. Bolded values are # of participants surveyed and % of population the # of participants/population.

Case Environment–Togo

The Republique of Togo has a population base of 7.8 million people (The World Bank Group, 2020) representing over 21 different ethnic groups (McGill University, 2002). The population while growing at a 2.5% rate remains in relative poverty (The World Bank Group, 2020). In 2006 the poverty rate was 61.7% falling to 53.3% in 2017, but the inequality rate remained extremely high in rural areas reaching 69% of households living below the poverty line in 2015 (The World Bank Group, 2020).

The Plateaux Region of Togo is subdivided into 12 prefectures and is bordered to the North by the Central Region, to the South by the Maritime Region, to the East by the Republic of Benin and to the West by the Republic of Ghana. The overall population of the Plateaux Region is just over 1.375 million with an even split of 50.7% women and 49.3% men. The majority, 80.3%, of the Plateaux Region's population resides in rural areas leaving only 19.7% in urban centers such as Atakpame (85,000 pop.), Kpalime (75,000 pop.) and Badou (24,000 pop.). The age distribution for the Plateaux Region's population sees the largest age group in the 0–9 years old group followed closely by 10–19 year olds and then 20–29 year olds indicating a young population (City Population, 2010c).

The study environment, as shown in **Figure 4**, covered the prefectures of Haho and Ogou both located in the Plateaux Region of Togo.

Haho maintains a population of 248,160 based on 2010 Census (Togo. Direction générale de la statistique et de la comptabilité national. Direction des échanges et de la, 2013). Much like the Plateaux Region, Haho's population is evenly split between male and female with only a slightly higher male population percentage, 51.2 and 48.8%, respectively (City Population, 2010a). The population of Haho is predominantly rural with 85.9% residing in rural areas (City Population, 2010a). The age distribution of Haho does skew toward a younger population demographic much like the Plateaux Region with the largest population age groups being 0–9, 10–19, and 20–29 listed in order of magnitude (City Population, 2010a).

The Ogou prefecture's population base of 196,470 is split between males and females at 51.1 and 48.9%, respectively. The

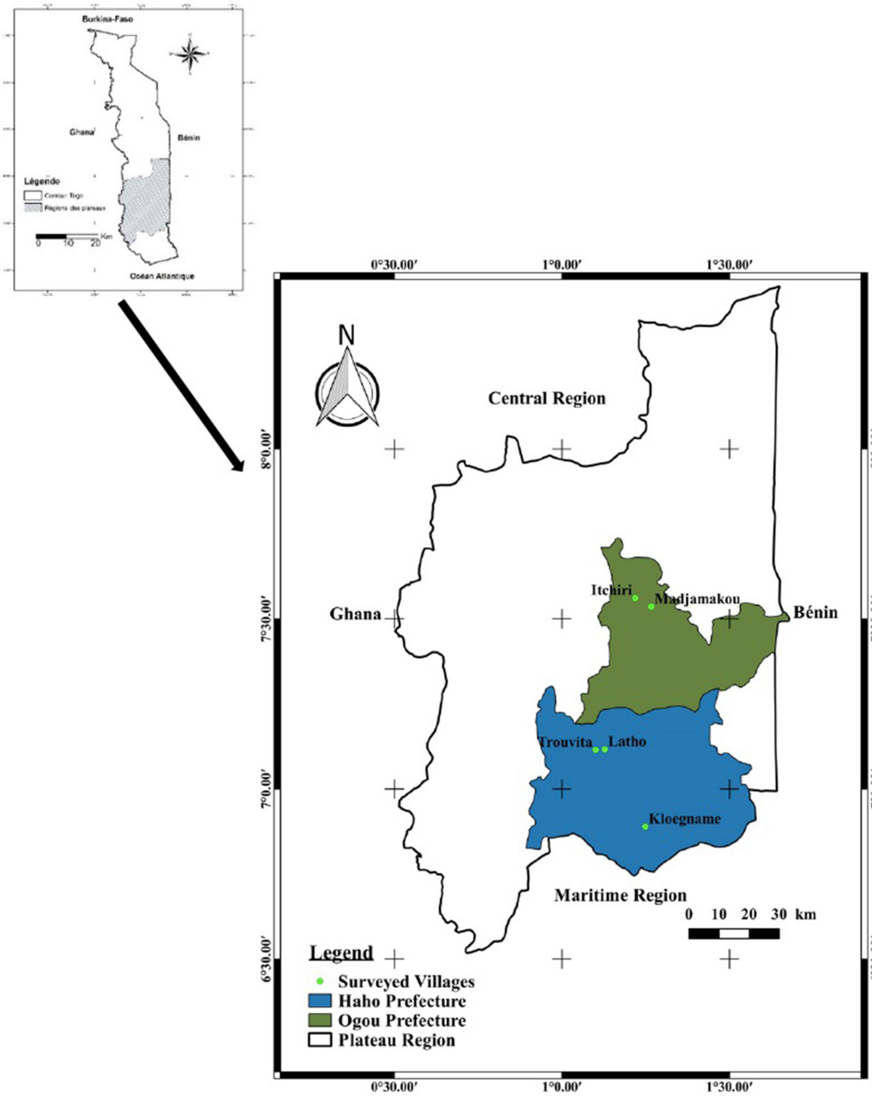

FIGURE 4 | Map of the study area. Source: Developed as part of this study.

Ogou population, unlike Haho's, is not as rural with 64.7% residing in rural areas. The major urban center of Atakpame maintains the 35.3% of Ogou's population that resides in an urban area. The age demographics of Ogou, like the overall Plateaux Region, skew young with the larges age group being 0–9 year olds followed closely by 10–19 and 20–29 year olds (City Population, 2010b).

The Haho and Ogou prefectures were chosen randomly from out of the 12 prefectures in Togo as representative sample sites for the Plateaux Region. Data Collection.

Data Collection

The sample size selected for this research is based on the following sample calculation formula, with 95% confidence and 50% maximum variability:

$$n = \frac{N}{1 + N \times e^2}$$

Where N is the size of the target population (all maize producers in the Plateaux Region of Togo), n is the sample size and e is the level of precision (Fellegi, 2003).

In view of the similarity, or high degree of homogeneity, of the maize producers in the Plateaux Region of Togo on the basis of their common characteristics with nearly 65% of Togo's active population engaged in agricultural production (Invest in Togo, 2020), the level of precision used to calculate the sample was determined to be ±8%. Having determined the level of precision to be used at ±8% and the size of the total population equal to 164,766 maize producers according to the 2012 National

Agricultural Census (Republic of Togo, 2012) the calculation formula gives the following minimum sample size (n):

$$n = 164\,766/(1 + 164\,766 \times (0.08 \times 0.08)) = 156 \text{ maize producers.}$$

The sample size (n) of 176 maize producers used within this study represents 13% of the total maize producers in the Plateaux Region of Togo. To connect with the 176 maize producers, researchers engaged with two partner organizations, Gebana and the Institut de Couseil et D'appui Technique (ICAT) Plateaux. Gebana is a private global farmers' market that focuses on developing supply chains for primary producers (Gebana, 2020). ICAT-Plateaux is a Technical Support Consulting Institute which is part of the Republique of Togo's Ministry of the Economy and Finance (Ministree de l'Econoimie et des Finances, 2021). On the basis of the documentation provided by these two partner organizations a random selection of villages was made from within the two prefectures of Haho and Ogou.

In the Ogou prefecture, two villages were randomly selected, namely: Itchiri and Madjamakou. In the Haho prefecture three villages, namely: Tsrouvita, Latho and Kloegname. Within each village an interviewer conducted semi-structured surveys and focus groups with self-identified maize producers along with key informant interviews. The **Table 1** shows the participation numbers and rates of surveys for each village.

The semi-structured surveys and focus group discussions were divided into components that focused on the three dimensions of sustainability; economic, environmental and social. The economic component queried producers on duration of operations, available capital, net income, financial autonomy, maize productivity, profitability and efficiency. The environmental component sought responses for soil fertility, soil erosion, land degradation, seed quality and yearly crop rotation cycle. For the social component quality of life, social involvement, household contribution to community, income sharing, classroom educational prosperity and revenue distributed for social causes.

Secondary data was also utilized in this study concerning the area and distribution of maize producer in the Haho and Ogou prefectures. Secondary data collection in the form of government reports were collected from the Agricultural Extension Service which is part of ICAT from the Republic of Togo's Ministry of Economics and Finance.

Data Analysis

The selected sustainability indicators for this study were organized as follows:

Economic dimensions:

- Available capital per hectare (Gafsi and Favreau, 2010; Yegbemey et al., 2014),
- Yield (Rasul and Thapa, 2003; Yegbemey et al., 2014)
- The number of hectares of land available for agriculture (Gafsi and Favreau, 2010; Yegbemey et al., 2014),
- Net income (Rasul and Thapa, 2004; Gafsi et al., 2006; Yegbemey et al., 2014), and
- Technical efficiency (Van Cauwenbergh et al., 2007; Van Passel et al., 2007; Yegbemey et al., 2014).

A slight change was highlighted in the net result reported for the economic indicators due to the difference in wage rates for Togo compared to other jurisdictions. Indeed, the minimum guaranteed inter-occupational wage (SMIG) in Togo is 35,000 FCFA as opposed to the basis of the work of Yegbemey et al. (2014) which took into account a SMIG equal to 30,000 FCFA.

Environmental dimensions:

- Duration of exploitation, fertilizer dose, herbicide dose (Rasul and Thapa, 2004; Yegbemey et al., 2014),
- The level of soil erosion (Rasul and Thapa, 2003; Gafsi et al., 2006; Van Cauwenbergh et al., 2007; Yegbemey et al., 2014)
- Trees density, seed renewal cycle, crop diversity (Rasul and Thapa, 2003; Gafsi and Favreau, 2010; Yegbemey et al., 2014)
- Rotation cycle (Yegbemey et al., 2014).

Social dimension:

- The rate of self-consumption
- Share of expenditures
- Level of prosperity*,
- Diversity of social organizations (Van Cauwenbergh et al., 2007; Gafsi and Favreau, 2010; Yegbemey et al., 2014)
- The share of revenues distributed for social causes (Yegbemey et al., 2014)

  *It should be noted that it was decided during the focus groups that the measurement of the level of prosperity in the classroom would be carried out in two stages: first by self-rating and then a secondary rating by the interviewer based on the high-value assets owned by the respondent. High-value assets include livestock, vast arable land, buildings on the assets side and other luxuries. The average of the two scores therefore gives the final prosperity score.

After identifying indicators with producers, these indicators were weighted in a participatory manner (Yegbemey et al., 2014). Indeed, the selected indicators were grouped into homogeneous components, namely preparation, sowing, fertilization, maintenance, harvesting and post-harvest. Then, the importance of each modality of each criterion was assessed by the producers on a five-point scale (1-very weak, 2-weak, 3-medium, 4-strong, 5-very strong)

It should be noted that there were no significant differences between the focus groups when defining indicators for sustainability. A farm is said to be sustainable if, and only if, its level of measured sustainability is greater than or equal to the threshold score, which is a score of 3-medium, which is the borderline between the two low levels (1 and 2) and the two high levels (4 and 5).

Estimation of Values of Indicators, Components, and Dimensions

The scores for each indicator, component and dimension of sustainability will be calculated (aggregated) using the linear aggregation technique of the participatory method (Yegbemey et al., 2014). Note, however, that the aggregation method used in this study is based on equal weighting due to the lack of information on the weight of each indicator and component defined.

This method provides insight into how a farm can likely be sustainable. The indicators identified and retained are presented in the **Table 2**.

The indicators presented are by components and the scores based on the raw data collected. The value of each indicator is equal to its sustainability score (1, 2, 3, 4, and 5). To simplify the calculations, an identical weighting method was used for each dimension and component, involving a simple linear aggregation technique. Thus, the value of a given component is equal to the average of the scores of the related indicators. Considering component *C* with *i* indicators (*I*), its value (*Vc)* is given by:

$$V_{\mathrm{C}} = N^{-1}.\sum_{\mathrm{i}} V_{\mathrm{Ii}} \tag{1}$$

Where N is the number of indicators in component C, V_{Ii} is the value (score) of the i-th indicator. Thus, the maximum value of each component is 5 and the minimum value is 1. The value of each dimension (V_D) is the sum of the values of its components. In addition, the maximum value of each dimension is set at 100 and the minimum at 20. The V_D of a given dimension with *j* component results in:

$$V_{\mathrm{D}} = 20.J^{-1}.\sum_{\mathrm{j}} V_{\mathrm{Cj}} \tag{2}$$

The **Table 2** shows the rating scales applied to each indicator.

RESULTS

Assessment of Economic Sustainability

Descriptive Statistics on Economic Sustainability

Table 3 shows that maize cultivation in the Plateaux Region of Togo was economically sustainable (Deco = 71.90 ± 16.07).

This economic sustainability score of 71.90, which is much higher than the average score 50, is supported, in order of importance:

1) By the technical efficiency of producers (score = 4.39),
2) Maize productivity (score = 3.72) and
3) The financial autonomy acquired (score = 3.51).

The graphical representation (**Figure 5**) shows these three components that form the basis of the economic sustainability of these producers.

Effects of Organizational Form on Economic Sustainability

As **Table 4** shows, the way in which the maize producers are organized has no effect on economic sustainability. However, the difference in the economic sustainability score concerning the available capital is significant depending on the individual or cooperative form of organization chosen by the producer ($P < 0.05$).

Assessment of Environmental Sustainability

Descriptive Statistics on Environmental Sustainability

According to the **Table 5**, maize cultivation in the Plateaux Region of Togo was environmentally sustainable (DurEnv = 62.47 ± 8.74).

This environmental sustainability evaluation of 62.47, which is well above 50, is supported by:

1) Respect for the environment by maize producers through the use of quality seeds (score = 3.31 ± 1.77)
2) Taking into account crop rotation (score = 3.81 ± 1.3) and
3) Crop rotation cycle which takes the highest score of all the indicators of the dimension (score = 4.03 ± 1.56).

The graphical representation (**Figure 6**) shows the radar's attraction to the crop rotation and seed quality.

Effects of Organizational Form on Environmental Sustainability

The form of organization of maize producers in the Plateaux Region of Togo, as shown in **Table 6** has a significant effect on environmental sustainability ($p < 0.05$).

The score for environmental sustainability was lower in cooperatives than when producers organized themselves into individual organizational forms. Significant differences were observed in indicators such as:

1) Farm duration, which scored better at the level of individual producers ($p < 0.01$),
2) The pesticide dose and the level of soil erosion, which scored higher at the level of non-cooperators ($p < 0.05$ and $p < 0.01$).
3) Only the seed renewal cycle showed a better score for cooperative producers (3.776 vs. 2.960 with $p < 0.01$).

Assessment of Social Sustainability

Descriptive Statistics on Social Sustainability

According to **Table 7**, maize cultivation in the Plateaux Region of Togo was generally socially unsustainable with a below 50 score (DurSoc = 40.66 ± 9.49).

Two components showed very low social sustainability scores for this region. These are:

1) Social involvement (score = 1.05) and
2) Food security (score = 1.9).

The graphical representation (**Figure 7**) shows that the radar is centripetal at the level of these two components and slightly supported by the contribution to household expenditures (score = 3.15) and quality of life (score = 3.00).

Effects of the Organizational Form on Social Sustainability

The way maize producers are organized has no significant effect on social sustainability (**Table 8**).

Nevertheless, depending on whether producers organized themselves individually or in cooperative organizational forms has a very significant effect ($P < 0.01$) on their levels of prosperity. Producers organized in cooperatives have a higher prosperity

TABLE 2 | Score scales used.

Economic dimension						
Financial autonomy	Available capital (FCFA/ha)	≤20,000	]20,000–80,000]	]80,000–150,000]	]150,000–300,000]	>300,000
Corn productivity	Yield (kg/ha)	≤1,000	]1,000–2,000]	]2,000–3,000]	]3,000–4,000]	>4,000
Profitability	Net income (FCFA)	≤100,000	]100,00–300,000]	]300,000–400,000]	]400,000–600,00]	>600,000
Efficiency	Technical efficiency in %.	≤10	]10–30]	]30–50]	]50–70]	>70
Environmental dimension						
Soil fertility	Duration of activity in years	≥16	[12–16[	[8–12[	[4–8[	<4
	Fertilizer dose in Kg/ha	≥400	[300–400[	[200–300[	[100–200[	<100
	Pesticide rate in l/ha	≥5	[4–5[	[3–4[	[2–3[	<2
Land degradation	Level of soil erosion in %.	≥20	[15–20[	[10–15[	[5–10[	<5
	Trees density in trees/ha	≤4	]4–8]	]8–12]	]12–16]	>16
Seed quality	Yearly seed renewal cycle	≥4	[3–4[	[2–3[	[1–2[	<1
Crop rotation	Diversity of Cultures in Culture	≤2	]2–3]	]3–4]	]4–5]	>5
	Rotation cycle in year	≤1	]1–2]	]2–3]	]3–4]	>4
Social dimension						
Food safety	Level of self-consumption in Kg/member of the household	≤200	]200–400]	]400–600]	]600–800]	>800
Contribution to household expenses	The share of income spent in %	≤10	]10–30]	]30–50]	]50–70]	>70
Quality of life	Level of prosperity in the classroom	1	2	3	4	5
Social Involvement	Diversity of organizations (%)	≤10	]10–20]	]20–30]	]30–40]	>40
	Share of revenue distributed for social causes in %.	≤5	]5–10]	]10–15]	]15–20]	>20

Source: Field data, 2019.

level score (score = 3.41) than those not belonging to any cooperative (score = 2.7).

The duration that a maize producer engaged in farming was found to be correlated with their choice of organizational form. **Table 9** shows that with more years as a maize producer leads to a greater probability that the producer will choose to engage in the cooperative organizational form. Similarly, a greater time out of school indicated a greater probability that the producer would favor a cooperative organizational membership.

DISCUSSION

The results show a high indicator score for economic sustainability for maize producers in the Plateaux Region of Togo. This is far from surprising given the government's focus on increasing yield, modernization, efficiency improvements through the development of processor focused cooperatives and other economic indicators of success. The subversion of Sen's Capability Approach to development through a focus only on economic capability development led cooperatives in the region to engage in Western style agricultural practices focused on high yields for greatest revenue generation. Without an educational programing that includes social and environmental capability development within the cooperative membership to enhance these indicators through Member Cohesion the cooperative can only be focused on economic indicators of success.

The emphasis of Togolese Government programs (both educational and developmental) were on traditional monocultural production to increase yields and increase producer income. Both are traditional economic development approaches focused on increasing economic growth and export. This approach has pushed, or guided, the cooperative membership toward a common purpose that emphasizes Côté's Cooperative Market Cohesion. This economic focus, or Cooperative Market Cohesion, is at the expense of social and environmental, or Membership Cohesion. Cooperative members are trained in the economic performance of their agricultural organization enhancing their income capabilities, but their

TABLE 3 | Descriptive statistics on the economic sustainability of maize producers in the Plateaux Region of Togo.

Components (C)	Indicators (I)	Average score	Std. Dev.
Financial autonomy (C1 = 3.511364)	Disposable capital (Fcfa/ha)	3.51	0.83
Corn productivity (C2 = 3.715909)	Yield (t/ha)	3.72	1.19
Profitability (C3 = 2.767045)	Net revenue (Fcfa)	2.77	1.46
Efficiency (C4 = 4.386364)	Technical efficiency %	4.39	0.60
Dimension			
Economic sustainability (Deco)		Deco = 71.90	16.07

With: $\mathbf{V_C} = \mathbf{N^{-1}}.\sum_i \mathbf{V_{Ii}}$ *and* $\mathbf{V_D} = \mathbf{20.J^{-1}}.\sum_j \mathbf{V_{Cj}}$

Source: Result of analysis of survey data, 2020.

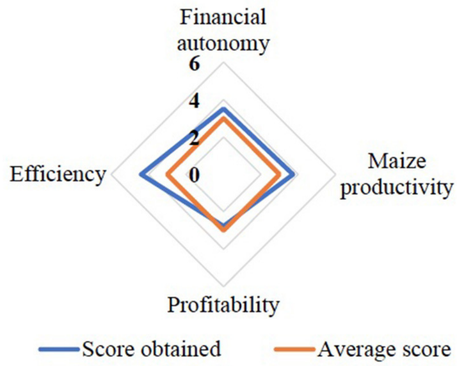

FIGURE 5 | Scores of the components of the economic sustainability of maize producers in the Plateaux Region of Togo. Source: Result of analysis of survey data, 2020.

TABLE 4 | Results of the estimation of the effect of the organization form of the maize producer in the Plateaux Region of Togo on economic sustainability.

Indicators	No cooperators	Cooperators	Pr (|T|>|t|)
Available capital (Fcfa/Ha)	3.39	3.67	**0.0265****
Yield (Kg/ha)	3.71	3.72	0.9403
Net income (FCFA)	2.65	2.92	0.2237
Technical efficiency In %.	4.37	4.41	0.6811
Dimension			
Economic sustainability	70.6	73.62	0.2183

$^{*}P < 0.1$, $^{**}P < 0.005$, and $^{***}P < 0.001$.
Source: Result of analysis of survey data, 2020.

TABLE 5 | Descriptive statistics on the environmental sustainability of maize producers in the Plateaux Region in Togo.

Components (C)	Indicators (I)	Average score	Std. Dev.
Soil fertility (C1 = 2,890152)	Duration of operation in years	3.02	1.46
	Fertilizer dose in Kg/ha	2.90	0.88
	Pesticide rate in l/ha	2.73	1.62
Land degradation (C2 = 2,6960225)	Level of soil erosion in %.	3.13	0.66
	Tree density in trees/ha	2.27	1.22
Seed quality (C3 = 3.3125)	Yearly seed renewal cycle	3.31	1.77
Rotation (C4 = 3,806818)	Diversity of cultures in Culture	3.58	1.03
	Rotation cycle in year	4.03	1.56
Dimension			
Environmental sustainability (DurEnv)		DurEnv = 62.47	8.74

With: $V_C = N^{-1}.\sum_i V_{Ii}$ *and* $V_D = 20.J^{-1}.\sum_j V_{Cj}$

Source: Result of analysis of survey data, 2020.

capabilities to understand the ramifications of Western style agricultural practices on social and environmental indicators are not developed. As a result, cooperative membership does represent a cohesive group with improved capabilities, but these capabilities are singularly focused on traditional measures of development focused on economic growth. Essentially, the bike has one gear and it is focused on growing the economy.

For example, the separation between economic and environmental sustainable development capabilities can be seen in the increased access to credit afforded to those engaged in the cooperative organizational form. Acting as a group cooperatives focused on Cooperative Market Cohesion purchasing greater volumes of chemical inputs through credit purchases. The chemical inputs, such as fertilizer and pesticides, allow for the successful achievement of the goal of increased income through monoculture production and modernization within the sector. Furthermore, the use of conventional farming practices, e.g., monoculture production, assists the Togolese Government in its export-oriented development process. The development process taken up by the sector and government fits Sen's austere attitudinal mode of development as the economic outcomes push aside luxuries such as environmental sustainability. The cooperative's Member Cohesion that should emphasize friendlier modes of development through a Capability Approach that includes a focus on quality of life is de-emphasized in favor of traditional economic success indicators. The use of cooperatives as propulsive industries in the economic development process moves communities away from environmentally sustainable production practices including biodiversity which would emphasize community resiliency. Instead, the cooperative acts as a credit worthy entity for farmers in Togo allowing them to gain access to chemical inputs and monoculture seeds at the beginning of the season which they never had before in an attempt to increase their incomes.

The study's data also suggests that individual farmers appeared to have more sustainable environmental production practices as seen in their slightly higher environmental sustainability score when compared to cooperatives. This could be due to lack of access to capital for chemical input purchases. Individual farmers could also have a stronger connection to their land as a result of land ownership and a focus on individual consumption

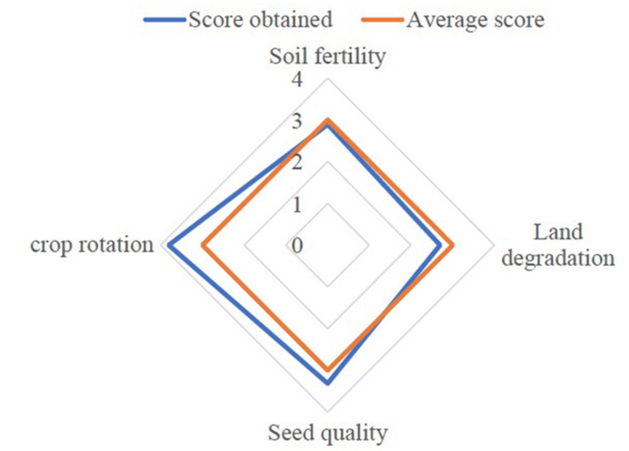

FIGURE 6 | Scores of the components of environmental sustainability of maize producers in the Plateaux Region of Togo. Source: Result of analysis of survey data, 2020.

TABLE 6 | Results of the estimation of the effect of the organization form of the maize producer in the Plateaux region of Togo on environmental sustainability.

Indicators	Non-cooperators	Cooperators	Pr (|T|>|t|)
Duration of operation in years	3.360	2.592	0.0005***
Fertilizer dose in Kg/ha	2.970	2.829	0.2918
Pesticide rate in l/ha	2.960	2.434	0.0324**
Level of soil erosion in %.	3.350	2.829	0.0000***
Tree density in trees/ha	2.210	2.342	0.4783
Yearly seed renewal cycle	2.960	3.776	0.0022***
Diversity of cultures in culture	3.540	3.632	0.5618
Rotation cycle in year	4.170	3.855	0.1846
Dimension			
Environmental sustainability	63.8	60.72	0.0203**

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.
Source: Result of analysis of survey data, 2020.

TABLE 7 | Descriptive statistics on the social sustainability of maize producers in the Plateaux Region of Togo.

Components	Indicators	Average score	Std. Dev.
Food safety (C1 = 1.903409)	Level of self-consumption in Kg/Household Member	1.90	1.06
Contribution to household expenses (C2 = 3.153409)	Share of income spent In %	3.15	1.46
Quality of life (C3 = 3.005682)	Classroom prosperity level	3.01	1.54
Social involvement (C4 = 1,051136)	Diversity of organizations (%)	1	0
	Percentage of revenue distributed for social causes	1.10	0.48
Dimension			
	Social sustainability	DurSoc = 40.66	9.49

With: $V_c = N^{-1} \cdot \sum_{ij} V_{Ii}$ *and* $V_D = 20 \cdot j^{-1} \cdot \sum_j V_{Cj}$

Source: Result of analysis of survey data, 2020.

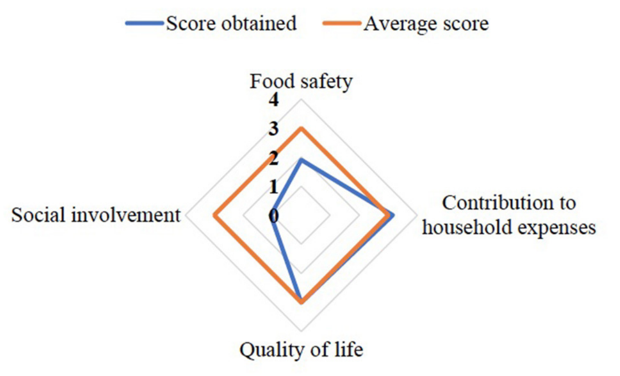

FIGURE 7 | Scores of the components of social sustainability of maize producers in the Plateaux Region of Togo. Source: Result of analysis of survey data, 2020.

rather than export. The focus on individual consumption, or improved quality of life, points to Sen's Capability Approach to development at the individual level. The capabilities of individual farmers to produce a variety of crops to feed their households indicates a greater capability to develop a quality of life that staves off food insecurity and improves social and environmental sustainability.

The export-oriented production approach promoted by Togo's Extension Agents, in order to meet the government's development goals, meant a stronger focus on modern agricultural practices that involve chemical inputs, monocultures and mechanization that are not environmentally sustainable. Extension Agents focused on building capabilities for modern agricultural practices emphasizing the export economy along with agricultural modernization as outlined in the government's NDP which was based on neoliberal development approaches. What was missing is an educational strategy to build capabilities for social and environmental sustainability. The improved social and environmental capabilities would aid Member Cohesion and focus development on Sen's Capability Approach focused on quality of life. Without building the capabilities to understand social and environmental indicators it is difficult to stimulate Member Cohesion around development that includes social safety nets, biodiversity, democracy and other social and environmental measures of success.

The push via government programming for agricultural production guides producers toward economic development emphasizing increases in monoculture yields, i.e., toward austere attitudinal mode of development. This mode of development de-emphasizes social safety nets, social services and even democracy as they are considered luxuries that must give way to the development process. Our study shows that Cooperative Market Cohesion has overpowered Member Cohesion giving up luxuries such as social and environmental sustainability practices. For example, food security and social involvement are components

TABLE 8 | Results of the estimation of the effect of the organization form of the maize producer in the Plateaux Region of Togo on social sustainability.

Indicators	No cooperators	Cooperators	Pr (|T|>|t|)
Level of self-consumption In Kg/Household Member	1.94	1.86	0.6015
Share of income spent In %	3.21	3.08	0.5567
Diversity of organizations (%)	1.00	1.00	.
Classroom prosperity Level	2.70	3.41	**0.0024*** **
Percentage of revenue distributed for social causes	1.10	1.11	0.9427
Dimension Social sustainability	39.8	41.78	0.1693

***$P < 0.01$; **$P < 0.05$; *$P < 0.1$.
Source: Result of analysis of survey data, 2020. The bolded values indicate a statistically significant deviation from the population mean as estimated by T values.

TABLE 9 | Estimated form for identifying the determinants of cooperative membership in the Plateaux region of Togo.

		Probit (OR) (1)	Marginal effect (dF/dx) (2)
VARIABLES		**MEMCOOP**	**MEMCOOP**
AGE	Years	0.00112	0.000412
		(0.0122)	(0.00451)
SEXE	0, Female	−0.273	−0.102
	1, Male	(0.303)	(0.112)
NIVSCO	1, Out of school	**0.302****	**0.111****
	2, Primary	(0.142)	(0.0526)
	3, College		
	4, High School		
	5, Academic		
NPERCH	People	**−0.0574***	**−0.0212***
		(0.0327)	(0.0121)
ACTIP	0, Other	−0.607	−0.237
	1, Agriculture	(1.442)	(0.563)
ACTIS	0, Other	0.231	0.0830
	1, Breeding	(0.326)	(0.113)
EXPAM	Years	**0.0283****	**0.0104****
		(0.0141)	(0.00526)
SUPEMBM	Hectares	**0.0844*****	**0.0311*****
		(0.0253)	(0.00897)
Yield (Kg/ha)		**0.636****	**0.235****
		(0.286)	(0.104)
SVUL	0, No	**2.463*****	**0.721*****
	1, Yes	(0.328)	(0.0545)
Constant		−2.688*	
		(1.573)	
Observations		176	176
Pseudo R^2		0.485	
Wald chi2		77.83	
Prob > chi2		0.00000	
Equation (A binomial probit estimated to explain the maize farmer's membership in a cooperative in the plateau region of Togo.) Area under ROC curve = 0.9179		$Yi = b_0 + b_1 AGEi + b_2 SEXEi + b_4 NIVSCOi + b_5 NPERCHi + b_6 ACTIPi + b_7 ACTISi + b_8 ExpAi + b_9 SUPEMBi + b_{10} Ri + b_{11} SVULi + ei$	

AGE, age; SEX, sex; NIVSCO, educational level; NPERCH, household size; ACTIP, main activity according to the importance of income; ACTIS, secondary activities according to the importance of income; EXPAM, number of years of experience in maize production; SUPEMBM, the area of land used for maize; R, the yield of maize; SVUL, the contact with technical extension services.
Using a law of $\chi 2$ with 17 degrees of freedom, we obtain chi2 (10) = 77.83 with a p-value of 0.0000. At a 1% risk, we can reject the hypothesis of the simultaneous nullity of the coefficients. The forml is globally significant.
Source: Result of analysis of survey data, 2020. The bolded values indicate a statistically significant deviation from the population mean as estimated by T values. *$P < 0.1$, **$P < 0.005$, and ***$P < 0.001$.

of the social sustainability indicators that have not improved as a result of the increased capabilities within Togo's cooperatives. These two components have driven the social sustainability indicator of producers in the Togo Plateaux Region down. Food security was outlined as a goal of the Togolese Government's NDP, but food security was meant to be address by increased production ignoring the fact that monoculture production produces food for export not community consumption. Indeed, the scores of these two components have remained very low in both organizational forms, individual producers and cooperatives, as Togo emphasizes export development rather than agricultural capabilities to improve quality of life of individual producers.

The cooperative's seventh principle of concern for community should have been a mechanism to enhance Member Cohesion around a social mission such as food security. The cooperative's focus on community development should have produced an above average social sustainability score. In this study cooperatives in the Plateaux Region did not have an above average social sustainability score as they were focused on higher monoculture yields for higher income as emphasized by the Togo government and its use of cooperatives as propulsive industries. This economic focus appears to have developed capabilities within the membership to focus on economic outcomes rather than social or environmental. Member Cohesion has moved cooperative performance toward Cooperative Market Cohesion that emphasizes strategic market fit and de-emphasizes social development goals such as food security and social involvement.

As a result, whether a producer works individually or through the cooperative organizational form does not appear to positively effect to the social sustainability indicators. The lack of Member Cohesiveness in the area of social sustainability within Togolese agricultural sector is as a result of treating the cooperative organizational form solely as a means of economic production. With education and government extension services focused on building economic capabilities to meet their development goals there is very little chance for farmers build capabilities on environmental or social sustainability indicators. In addition, the emphasis on Cooperative Market Cohesion within the agropole as cooperatives act as propulsive industries is meant to ensure economic sustainability not environmental or social sustainability. There does not appear to be a push back from Member Cohesion around their social and environmental needs partly due to the promise that improved economic performance will provide environmental and social sustainability as well as the lack of capability to engage the cooperative as a social and environmentally focused organization.

What Côté's Management Equilibrium Theory tells us is that Cohesive Membership only works to promote econoimc, social and evironmental sustainaiblity if the membership develops the capabilities within all three areas of sustainability. With social and environmental indicators for sustainablity being far more complex and difficult to communicate it is difficult to build a Cohesive Membership around these socail and environmental indicators compared to economic indicators.

Interestingly, the educational level and scope for the agricultural producer has been found to be conducive to good information management around the functions of supply, production and disposal, but not social or environmental sustainability. The curriculum being taught within the schools and development programs are not focused toward the social or environmental indicators. Agricultural schools teaching production practices are focused on high yield, monoculture production or other environmentally unsustainable production practices that produce higher yields. Given that export oriented production focuses on higher yields per hectare the utilization of chemical inputs at the expense of environmental and social sustainability it is not surprising. Togo's producers are taking this production approach based on their new found educational capabilities.

To enhance Cooperative Member Cohesion and move cooperatives away from a strict focus on Cooperative Market Cohesion, educational programming needs to include topics on social and environmental sustainability. Zeweld Nugusse et al. (2013), Hill and Kumar (2008), and Mojo et al. (2017) concluded that education provides positive incentives for people in rural areas to join cooperatives as it increases awareness and understanding of agricultural production, but the agricultural production education must include a wider scope of capabilities that include social and environmental success factors.

CONCLUSION

This paper looked at the development approach utilized by Togolese maize producers in the Plateaux Region of Togo. The primary producers were divided into individual and cooperative producers. Each group was assessed for their standing on economic, environmental and social sustainability indicators. Would cooperative maize producers through Membership Cohesion push back against a strict economic focus to include environmental and social sustainability within their communities? Based on the findings in this study it would appear that Membership Cohesion, influenced by a lack capabilities on social and environmental indicators, gave way to Cooperative Market Cohesion. As a result, cooperative producers with new capabilities focused on economic outcomes as promoted by the Togolese Government's export-oriented approach to development did not promote social or environmental sustainability indicators. This Togolese development approach fits the austere attitudinal mode of development as outlined by Amartya Sen and moves away from his Capability Approach focused on quality of life. In the austere attitudinal mode of development social and environmental indicators are seen as more of a luxury and as such are not the key focus of community development.

The question remains, if cooperative members enhanced their capabilities on social and environmental indicators would there be an effective Polanyian style push back against Cooperative Market Cohesion? Would Member Cohesion look to the seventh cooperative principle of concern for community that seeks to ensure sustainability includes social and environmental indicators as well as economic. In Togo the focus of the agricultural cooperatives is on the economic as cooperatives act as propulsive industries for an export focused development process and the Togolese Government encourages the development of capabilities to enhance economic outputs through extension and educational programs.

What Côté's Management Equilibrium Theory provides is some insight into cooperative development and a potential approach to moving cooperatives toward all three sustainability incidcators. What the theory relies on, however, is that members have the capability of directing their cooperative organization to successfully meet the sustainability goals. Building thes capabilities requires educational resources to inform membership of not only the economic, but the social and environmental outcomes of the cooperatives activities. With pressure and resources from the Togolese Government to enhance only the economic indicators of sustainability how can coooperatives engage in social or environmental sustainability. As long as the neoliberal production practices and the austere mode of development remains the dominant paradigm, social and environmental capabilities along with their associated indicators will decline. Cooperative members will only be educated on how increase production leads to economic growth which will somehow resolve the community's social and environmental problems. There needs to be a more balanced approach to developing capabilities within the maize production sector to include social and environmantal understanding within cooperative membership so that they can act as a cohesive group pushing back against neoliberal agricultural practices.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Parakou Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 08 December 2021
doi: 10.3389/fsufs.2021.745317

"Illegal" Gold Mining Operations in Ghana: Implication for Climate-Smart Agriculture in Northwestern Ghana

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Globally, climate-smart agriculture is highly recognized as an approach for sustainable agriculture and food systems. In Africa and other developing countries, climate-smart agriculture is observed to reposition and modify agricultural systems for improved food and nutritional security. Despite the relevance of the approach to sustainable agricultural planning, illegal gold mining in many parts of the society is placing constraints to its implementation and adoption through its contest with agricultural land for space and activities. Illegal gold mining is on the rise due to the lucrativeness of the non-regulated gold rush opportunities with hard consequences on sustainable agriculture and resilience food systems. As a result, this study seeks to investigate illegal gold mining and its environmental implication for climate-smart agriculture in Ghana. The study used a single case study using a mixed-methods approach to research. The study adopted purposive and systematic sampling techniques to select the study communities and respondents, respectively. Questionnaire and interviews were used to gather the primary data from respondents at the household level, as the unit of analysis. Descriptive statistics and thematic analysis reveal that known agricultural practices such as terracing, crop rotation, use of domestic waste/manure, and irrigation of crops were affected adversely by activities of illegal mining. The study recommends the need for conscious efforts from the Ministry of Lands and Natural Resources to sustain the ban on illegal mining with intensified monitoring and supervision while a systematic scheme involving relevant stakeholders is developed and implemented to ban illegal mining in Ghana completely. The Ministry of Food and Agriculture needs to develop an approach to support the adoption of climate-smart agricultural practices by smallholder farmers to meet the food demand of their households.

Keywords: illegal mining, environment management, environmental sustainability, climate-smart agriculture, food systems

OPEN ACCESS

Edited by:
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University of Guelph, Canada

Reviewed by:
Pius Siakwah,
University of Ghana, Ghana
Paul Kraehling,
University of Guelph, Canada

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Specialty section:
This article was submitted to Land, Livelihoods and Food Security, a section of the journal Frontiers in Sustainable Food Systems

Received: *21 July 2021*
Accepted: *08 November 2021*
Published: *08 December 2021*

Citation:
Yiridomoh GY (2021) "Illegal" Gold Mining Operations in Ghana: Implication for Climate-Smart Agriculture in Northwestern Ghana. Front. Sustain. Food Syst. 5:745317. doi: 10.3389/fsufs.2021.745317

INTRODUCTION

Mineral resources have become fundamental for economic development throughout the world. In several low- and middle-income countries that are rich in non-fuel mineral resources, mining contributes to national economic development (Addison and Roe, 2018; Ericsson and Löf, 2019). Studies have reported that 10 of the 20 countries where mining contributes most have moved up one or two steps of the World Bank's countries classification between 1996 and 2016 (Ericsson and Löf, 2017, 2019; Addison and Roe, 2018). In particular, African countries have benefitted. Thus, socio-economic development indicators show signs of progress for African mineral-rich countries. In Guinea, for instance, the Papua New Guinea Extractive Industries Transparency Initiative reported that, in 2020, the industries contributed 89% to exports, 29% to gross domestic product (GDP), and 10.1% to corporate tax, salary and wage tax, dividends, and royalties (Yamarak and Parton, 2021). In Kenya, Tanzania and other parts of developing economies where mining operates, whether on a large or small scale has contributed to per capita income through job creation, resulting in improved livelihood status of residents and communities (Apollo et al., 2017; Mwakesi et al., 2020). In Kenya and Cote d'Ivoire, for instance, mining has observed to be an off-farm livelihood activity for farmers and other agriculturalists (Apollo et al., 2017; Mwakesi et al., 2020). Notwithstanding the potential contributions of the mining industry to the economies of many developing countries, it has observed to be detrimental to sustainable development due to its hard implication on environmental sustainability and management (Christmann, 2021; Yamarak and Parton, 2021).

Ghana is home to a number of precious minerals. Over the past decades, the mineral sector has contributed to ∼37% of the exports of the country and accounted for ∼8.4% of the GDP of the country in 2011 from 6.1% the previous year (Ghana Statistical Service, 2010; Bach, 2014; Ofosu et al., 2020; Atta and Tholana, 2021). In recent years, gold production, for instance, has observed to increase substantially from <20,000 ounces in 1990 to 1.6 million ounces in 2016 (Ofosu et al., 2020). The increase in gold mining in Ghana has also seen some significant improvement in the livelihoods of communities where gold mining is in operation (Ofosu et al., 2020).

In Ghana, the people own the mineral resource with management power vested in the Government. The Ministry of Lands and Natural Resources, through the Geological Survey Department, the Minerals Commission, and Precious Minerals Marketing Cooperation Limited, oversees all aspects of the mineral sector of Ghana. The legislative framework for the mineral sector in Ghana is the minerals and mining act 703 of 2006. Under the provision of the law, no person has the authority to conduct reconnaissance, prospecting, exploration, or mining in Ghana unless the person has a mining license (Ofosu-Mensah, 2010; Benmudez-Lugo, 2016). However, illegal mining (both foreign and Ghanaian nationals) continues unabated in the country despite government efforts to curb these activities (Aryee, 2003; Darimani et al., 2013; Benmudez-Lugo, 2016). Illegal mining is defined locally (Ghanaian context) as mining operations in which miners without a license have no concessions of their own operate uncontrollably within concessions of large-scale mining companies or in areas prohibited for mining (Aryee, 2003; Hilson et al., 2013).

In recent years, with dwindling opportunities for employment in the formal sector and the lucrativeness of gold mining, there has been an upsurge of miners, majority of them operating illegally (Hilson, 2010; Hilson et al., 2013; Kwadwo et al., 2016; Obeng et al., 2019). Studies have already noted illegal gold mining as a way of livelihood diversification (Hilson et al., 2013; Kwadwo et al., 2016), which this paper cannot contest. However, the activities of illegal gold mining is best known for its disastrous effects on the environment particularly agricultural land, causing many to view the activity as dirty, unprofitable, and unsustainable (Ofosu-Mensah, 2010; Schueler et al., 2011; Ericsson and Löf, 2019; Atta and Tholana, 2021). Illegal mining over the years has been into serious competition for agricultural land for its operation (Ansah and Smardon, 2015; Danyo and Osei-Bonsu, 2016; Ndabi, 2017; Atta and Tholana, 2021). Empirical studies have focused on the impact of illegal mining on the environment (Amankwah, 2013; Ansah and Smardon, 2015; Prosper and Guan, 2015) with least attention paid to the environmental implications of the activity on climate-smart agriculture.

With agriculture being the mainstay of livelihood for the majority of people in Ghana (International Fund for Agricultural Development, 2011; Sugden, 2013; Andrieu et al., 2020), sustainable and productive agriculture should be given the necessary attention as its productivity is dependent on access to quality land and water. As estimated by the Environmental protection agency (2016), the quality of land for agricultural use (in mining operation communities) is fast diminishing largely due to the activities of illegal mining.

With illegal mining already diminishing the carrying capacity of the environment and climate change with it posing danger to the agricultural sector, Ghana is at a central point where it needs to pay attention to climate-smart agriculture. Climate-smart agriculture for this paper refers to agricultural practices that help smallholder farmers to sustainably manage systems of agriculture amidst climate change for improved productivity and income (Obeng et al., 2019; Andrieu et al., 2020). Climate change has intensified the challenges faced by rain-fed agricultural systems. This suggests the need to harmonize protection of the environment, invest in smallholder agriculture, and improve food production and productivity.

Nadowli-Kaleo district is one of the districts in the Upper West Region where small-scale mining is in operation. The emergence of the mining extraction in the area has serious impact on the environment to include loss of farmlands, destruction of crops and forest cover, and pollution of water bodies (Prosper and Guan, 2015). The Ghana News Agency (2018) report on "Galamsey activities is eating up Nadowli-Kaleo district" noted that artisanal miners have scarred the landscape with "excavated pits and trenches" particularly in Nanga, Vuuyiri, and Charikpong enclaves, which renders the land unsuitable for agricultural purposes. Literature has also indicated that over 2.5% of cultivable land has been destroyed in the district (Environmental protection agency, 2016; Ministry of Food Agriculture, 2016). Mineral Commission of Ghana (2017) observed that illegal mining has occupied about 3.5% of the land, which had been initially used for agricultural activities. As result, the study aims to investigate the activities of illegal gold mining for climate-smart agriculture in the Nadowli-Kaleo district in the Upper West Region, Ghana. This study is critically important to contribute to literature on sustainable agriculture, food systems, and climate change adaptation in Ghana, in particular, and in Africa, in general. The rest of the paper is organized as follows: the review of related literature to include climate-smart agriculture and illegal mining and environmental sustainability and climate-smart agriculture in Ghana. The other sections include the study method and materials, results and discussions, and the implication of the study for planning for agriculture and sustainable food systems.

REVIEW OF RELATED LITERATURE

This section presented existing literature on climate-smart agriculture and illegal mining. The section also presented literature on the need for environmental sustainability and climate-smart agriculture in Ghana.

Climate-Smart Agriculture and Illegal Mining

Climate change is already modifying production systems and exacerbating critical difficulties, including rising poverty and food insecurity [Intergovernmental Panel on Climate Change (IPCC), 2009; Yiridomoh et al., 2020; Owusu and Yiridomoh, 2021; Waaswa et al., 2021]. This prompted the Paris Climate Change Agreement jointly with the Sustainable Development Goals to set the premise for serious investments in climate change technologies for sustainable future [Food and Agriculture Organization Food and Agricultural Organization (FAO), 2013; Andrieu et al., 2020; Waaswa et al., 2021]. The joint decision recognized the fact that developing countries must develop, prioritize, and invest in climate change technologies for climate risk reduction and adaptation. One approach to respond to the changing climate system is the adoption of climate-smart agriculture (Asrat and Simane, 2017; Abegunde et al., 2019). Climate-smart agriculture is rooted in sustainable agriculture and rural development objectives, which, if reached, will contribute to achieving the sustainable development goals of reducing hunger and improved environmental management (El-Fattal, 2012; Andrieu et al., 2020; Waaswa et al., 2021).

Climate-smart agriculture is an approach that strives to meet the following criteria: (1) increase agricultural productivity in a sustainable manner, (2) improve the resilience of agricultural production and food systems to environmental change, or (3) reduce net greenhouse gas emissions associated with the agriculture and forestry sectors (Sugden, 2013; Angom et al., 2021; Waaswa et al., 2021). Rainforest Alliance (2016) added that climate-smart agriculture is not a defined set of practices or an entirely new type of agriculture, rather an approach that combines different methods under a climate change umbrella. Thus, it assesses the risks and needs of a specific farm or farming community through a climate impact lens and then addresses them using practices chosen for that particular situation. What that means is that climate-smart agriculture is not a universal approach but dependent on individual location. Appropriate practices will vary according to region, ecosystem, climate, and crop. For instance, common climate-smart practices such as planting diverse crops, composting and soil management for improved soil fertility, and water saving, harvesting, and retention systems, which improve water availability during times of drought, may be adopted depending on the climate and location (El-Fattal, 2012). The practice gives farmers tools and a pathway to make their operations and livelihoods more productive and resilient in the face of the changing climate (Angom et al., 2021). In other words, it creates the technical, policy, and investment conditions for achieving sustainable agriculture.

Although there is a growing interest in environmental sustainability for sustained agricultural productivity, unsustainable environmental practices are noted everywhere in the society. One particular antagonist to environmental management and sustainability is illegal mining. Illegal mining and the environment are linked inextricably with the former having disastrous implications on the later. The problem of illegal mining has been a matter of concern for a long time but it appears the challenges have been enormous and more visible in recent times (Amankwah, 2013; Obeng et al., 2019; Atta and Tholana, 2021). Thus, illegal mining results in extensive land cover changes leading to loss of forest and farmland (Prosper and Guan, 2015). The study of Schueler et al. (2011) on the impact of illegal mining on land use indicated that, apart from eroding the ecosystem services and placing constraints on conservation of natural resource base, illegal mining displaces farmers, thereby triggering increased deforestation, agricultural intensification, and land degradation. With the impact of illegal mining on the environment already observed, resilience and sustainable agricultural practices need to develop to enhance sustainable food systems for sustainable livelihoods of smallholder farmers [Intergovernmental Panel on Climate Change (IPCC), 2009; Sullo et al., 2020; Owusu and Yiridomoh, 2021].

Arguments for Environmental Sustainability and Climate-Smart Agriculture in Ghana

The environment plays a significant role in the existence of humankind. Thus, economic growth and development, which are at the heart of man's survival, are dependent on the suitability of the environment. Although impossible to define environment (Nasreen et al., 2006), it involves the aggregation of all the external conditions and influences affecting the life and development of a system or organism (Boon et al., 2008). The environment is a home to fundamental resources upon which people depend on for their livelihoods. This is the reason why Opschoor (2007) perceived environment as envelope for range of biotic and a-biotic processes operating in and between the ecosystems, which provides human beings with natural resources and ecosystem services.

The benefits derive from the environment are enormous and therefore call for environmental sustainability. According to Morelli (2011, p. 24), "environmental sustainability is defined as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity."

Achieving environmental sustainability means ensuring sound consistent development that increases the environmental asset base and productivity, reduces and manages environmental risks, and recognizes the long-term implication for the intra and inter-generational equity (Boon et al., 2008). The pains and wounds inflicted on the environment by humankind over the years are well-noted. These environmental concerns have double folded and dramatically expanded in recent years, and the effects on people livelihood are given more discussions at national and international deliberations (World Bank, 2008). To fight for sound environmental management and sustainability involves rethinking development that entails more socially and environmentally responsibility (Boon et al., 2008). With the interest in environmental sustainability increasing day in and out, more systems, individuals, communities, and nations are realizing the fundamentals of analyzing the impact of human activities on the environment and sustainable development [World Commission on Environment and Development (WCED), 1997].

Our environment is undergoing a cataclysm either by natural means or through anthropogenic forces [Intergovernmental Panel on Climate Change (IPCC), 2009; Yiridomoh et al., 2021]. This particularly places serious threat to the agricultural sector which must feed the world population projected to increase to 9.8 billion by 2050 (Food Agriculture Organization of the United Nations, 2013). This suggests pragmatic and innovative technologies and programs to ensuring that the world meets its food demand without placing much burden on the environment. Climate-smart agriculture is the right way to go to fight the magnitude, immediacy, and effect of climate and environmental change. The climate-smart agriculture approach is designed to identify and operationalize sustainable agricultural development for improved livelihoods and food security, especially among smallholder farmers, by improving the management and use of natural resources and adopting appropriate methods and technologies for production of agricultural goods (Food and Agricultural Organization (FAO), 2013; Andrieu et al., 2020; Waaswa et al., 2021). A key component of the climate-smart agriculture is the integrated landscape approach that follows the principles of ecosystem management and sustainable land and water use. Climate-smart agriculture seeks to support countries to put in place the necessary policy and the technical and financial means to mainstream climate change considerations into agricultural sectors and to provide a basis for operationalizing sustainable agricultural development under changing conditions (Food and Agricultural Organization (FAO), 2013).

METHODS AND MATERIALS

The method and material section of the paper presented issues on study setting, the study design, data collection instruments, and approaches to data analysis.

Study Setting

The Nadowli District is one of the districts along the Black Volta corridor in the Upper West Region (see **Figure 1**). In line with the decentralization policy of Ghana, which came into being in the 1988 (Ghana Statistical Service, 2010), Nadowli-Kaleo became a district in 2012 under Legislative Instrument 2101 with Nadowli as its capital. The Assembly is empowered as the highest political and administrative body in the district charged with the responsibility of facilitating the implementation of national policies. Under section 10 of the Local Government Act 1993 (Act 462), the Assembly exercises deliberative, legislative, and executive functions in the district. By this act, the Assembly is

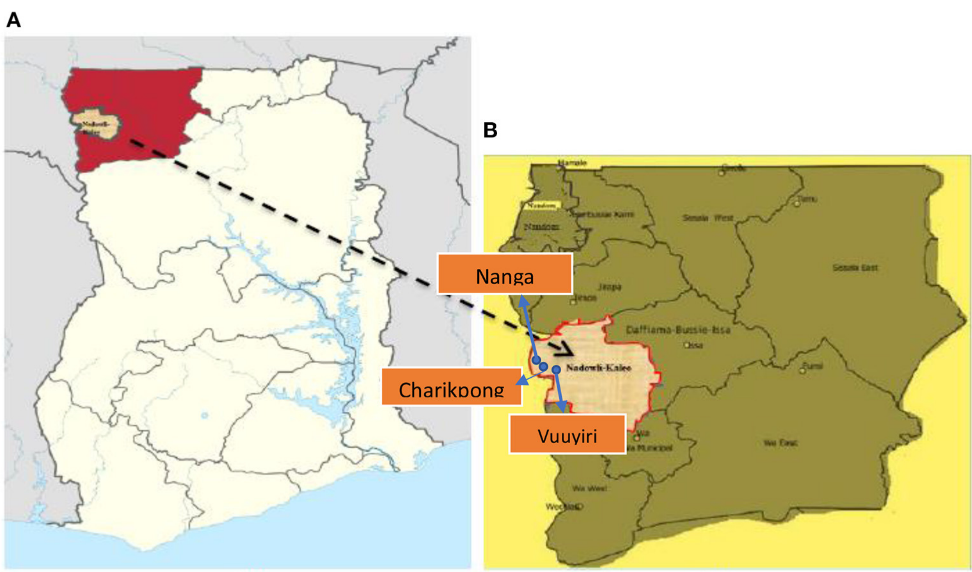

FIGURE 1 | Nadowli-Kaleo district in **(A)** national context **(B)** upper west reginal context.

responsible for the overall development of the district through the preparation of development plans and budgets and other development initiatives.

According to the Ghana Statistical Service (2010), the Nadwoli-Kaleo District has 61,561 residents. The northwestern enclave of the district, which constitutes Charikpong, Saan, Zukpiri, Nanga, and Vuuyiri, assumes 10% of the total population of the district. These communities are located along the Black Volta River of which about 85% of the total land area is covered by vegetation and underlain by hydrothermal gold deposition. The presence of the gold deposit in the area has seen some activities of mining in the area over the last decade. The concession was given to Azumah Resources Limited, a Perth-based ASX listed Company, headquartered in Australia (Prosper and Guan, 2015). Despite the official award of the concession to the mining company, illegal miners have forced their way into the area, depleting and devastating the whole environment due to poor mining practices. For regulating the activities of mining for environmental sustainability and management, the government of Ghana imposed ban on illegal mining with the popular phrase "operation vanguard." Operation Vanguard is a military police joint task force set up by the President of Ghana in 2017 to combat the operation of galamsey in Ghana. However, the purpose of the operation vanguard was defeated as many illegal mining activities still went on before, during, and after the launch of the "operation vanguard." Activities of illegal miners in the district have dreadful implication for activities of agriculture due to the majority of the dependents of the residents on agriculture for their livelihood. Mining as an economic activity is essential for the local economic development; however, it has severe environmental consequences and, if not properly managed, can conflict with existing community livelihood. For instance, surface mining with the support of mercury, which is non-degradable pollutant, is used by the illegal miners for the extraction of the gold, which has both short- and long-term implication for the communities and the district at large.

Study Design

The study adopted mixed-methods case study. According to Creswell (2007), mixed methods helps build on the synergies of the two approaches (qualitative and quantitative) to give relevant and comprehensive findings on the subject under investigation, which, in this case, the implication of activities of illegal mining on sustainable environment and climate-smart agriculture in a district that is already vulnerable to climate change. Again, given the complexity of illegal mining and climate change and their replicate effects on the environment and agriculture, mixed methods provided the best approach for the study as the method allowed for the generation of in-depth information and involving a relatively larger number of participants in the study. This particularly afforded the study the opportunity to explain vividly the viewpoints of the participants on illegal mining and its implication on climate-smart agriculture in the Nadowli-Kaleo district.

A criterion purposive sampling strategy (Patton, 2015) was used to select the study communities. Criterion sampling involves searching for cases that meet a certain criterion, which, in this case, communities hugely involve in activities of illegal mining in the Nadwoli Kaleo District. The reason for the adoption of the criterion sampling is to help make a sound decision about explanations most plausible to contribute to climate-smart agriculture amidst illegal mining and climate change in the study area. On the basis of the criterion purposive sampling, Nanga, Vuuyiri, and Charikpong communities were selected on the basis of their hugely involvement in illegal mining in the district. Again, in each of the three communities, systematic sampling (proportionate) was used to select household heads or their representatives for the study. On the basis of a reconnaissance survey conducted 21 January 2019, households with farming as their primary activity from each community were listed. The compiled register of households for each community was then arranged in alphabetical order, and one in three sampling ratio was applied to obtain the households. To ensure validity and accuracy of the process, a simple random sampling method was applied to determine the starting position for the selection of a household. On the basis of the systematic method of sampling, 111 (47 of 53 from Charikpong, 32 of 37 from Nanga, and 32 of 35 from Vuuyiri) smallholder food crop farmers were recruited for the study.

Questionnaire and interviews were conducted with the participants in all the three selected communities in May 2019. The questionnaires were granted to household heads who were involved in activities of farming, whereas the interviews were granted to the chiefs of the three communities: one officer at the Environmental Protection Management, one officer at the MOFA, one mineral commissioner, and four illegal miners as represented by **Table 1**. Maximum variation purposive sampling approach was adopted to recruit the respondents for the interviews. Maximum variation involves selecting highly qualified persons who cover the spectrum of position and perspectives in relation to a phenomenon (activities of illegal mining, environmental sustainability, and climate-smart agriculture). On the basis of the maximum variation purposive sampling principle, 10 key informant interviews were conducted. The study main objective guided the development of the questionnaires and the interviews. Particular areas covered by the questionnaires and interview were the effects of illegal mining on the environment and implication of the environmental impact on climate-smart agriculture. All the questionnaires and the interviews were held with participants at their homes with each questionnaire and interview lasting for 40 and 47 min, respectively. Questionnaire and interview guides developed were in English language but translated into Dagaare (local language of participant) during the interview for easy understanding and for appropriate responses.

Descriptive statistics were used to analyze the questionnaires. Thus, data collected from the field were well-sorted out and fed into statistical package for social sciences for analysis. Analyzed data were represented using charts and tables. For qualitative data, thematic analysis was used to analyze the interviews. Thus, field data collected were transcribed, and the transcriptions were read repeatedly to identify common themes about illegal mining and its implication on climate-smart agriculture. The first two

TABLE 1 | List of interviewees.

Interviewee	Sex	Role	Pseudo
Chief of Nanga	Male	Oversees the management of natural resources in his area	A1
Chief of Cherikpong	Male	Oversees the management of natural resources in his area	A2
Chief of Vuuyiri	Male	Oversees the management of natural resources in his area	A3
Field officer of environmental protection agency	Male	Provide environmental management support	A4
District field extension agent (MOFA)	Male	Support activities of agriculture in the district	A5
Field supervisor of mineral commission	Male	Supervises the activities of mining in the district/region	A6
Illegal miner 1	Male	Involves in activities of mining	B1
Illegal miner 2	Female	Involves in the activities of mining	B2
Illegal miner 3	Male	Involves in the activities of mining	B3
Illegal miner 4	Female	Involves in the activities of mining	B4

steps of thematic analysis outlined by Attride-Stirling (2001) and Braun and Clarke (2006) such as familiarization with transcript and themes identification guided the analysis.

RESULTS AND DISCUSSION

This section of the paper presented results on the demographic characteristics of respondents, the effects of illegal mining on the environment, climate-smart agriculture practices of the area, and the implication of illegal mining on climate-smart agriculture. This section also presented results on the relationship between climate-smart agricultural practices and the factors of sustainable agriculture and food systems (soil, land, and water management).

Demographic Characteristics of Respondents

The demographic assessment of the respondents revealed that 64% were male and 36% were female. For age, majority of the respondents, which represented 33%, were within the age category of 40–49, 29% of the respondents were within age category of 50–59, 23% of the respondents were within the age category of 30–39, and 14% were 60 years and above. On the level of education of the respondents, 61% had no formal education, which implies that they did not go to school, 25% had basic education, 8% had secondary education, and 5% had tertiary education.

Effects of Illegal Mining on the Environment in the Nadowli-Kaleo District

Table 2 presents the results on the effects of illegal mining on the environment. The study revealed that surface exploration and mining of the gold deposit in the Nadwoli-Kaleo district by the illegal miners have resulted in the loss of biodiversity, formation of sinkholes, contamination of soil and ground, and surface water pollution. Over the years, illegal mining has been a subject of discussion due to it perceived implications now and in the future with respect to environmental sustainability and agricultural land management (Kwadwo et al., 2016; Apollo et al., 2017; Mwakesi et al., 2020; Christmann, 2021). To determine the implication of illegal mining on the environment and its replicate effects on climate-smart agriculture, residents were asked to indicate the environmental effects of illegal mining on their environment. As represented by **Table 2**, 30% of the respondents reported that the activities of illegal mining have resulted in the formation of sinkholes, which initially were not present due to the absence of the mining activity. Again, 27% of the respondents revealed that illegal mining has led to the loss of the biodiversity around the study communities. Furthermore, 20% of the residents observed that the presence of illegal mining in the areas has led to the contamination of the soil, which previously was good for food crop production, and, lastly, 23% of the residents reported that illegal mining has led to ground and surface water pollution.

TABLE 2 | Effects of illegal mining on the environment in the Nadowli-Kaleo district.

Variable	Frequency	Percentage
Ground and surface water pollution	26	23
Contamination of soil	22	20
Loss of biodiversity	30	27
Formation of sinkholes	33	30
Total	111	100

The interview with the chiefs confirmed that illegal mining places serious threat to their environment and their agricultural land. The chiefs in all the three communities observed that, since the inception of the activities of illegal mining, it has led to the depletion of the forest cover. They added that illegal mining has resulted in loss of biodiversity around the area especially animal and mammal species that were predominant at the Black Volta river corridor, and the pollutants discharged by illegal miners destroyed microorganisms and cause loss of fauna and flora, as succinctly captured by A2:

> "*My son, some years back, if my memory can still set me right, our land was forested, especially along the Black Volta corridor. Today, due to the emergence of illegal mining, the community has lost that stretch of forested land to activities of illegal mining operators" (4 June 2020)*

Again, the chiefs referred to their streams and the Black Volta River where some years back served as sources of drinking water. The chiefs indicated that the high demand for water by miners in extraction, processing, and waste disposal pollutes water sources nearby and depletes freshwater supplies in the region surrounding the mine. The use of mercury for gold processing as confirmed by four of the miners during the interview indicated that the use of mercury has affected water quality. The miners reported that the use of the mercury is because it is cheap, dependable, and portable operation for concentrating and extracting gold from low-grade ores, as captured by B4.

> *"Mercury is the main chemical we in extracting the gold here. They are others chemicals but they are too expensive for us with limited financial capacity. We know the environmental consequences of the chemical (referring to mercury) but we cannot also stop using it because the alternative is not there" (4 June 2020).*

An interview with one of the officers at the EPA revealed that illegal mining in the areas has led to the formation of sinkholes as artisanal miners cleared the vegetation and dug for mineral-bearing ore. This accordingly has scarred the landscape with excavated pits and trenches, which, in turn, renders the land unsuitable for any other purpose. At the district agricultural office, one of the agricultural extension agents during the interview reported that illegal mining has caused a serious damage to the arable land with the possibility to affect food security of households who depend on farming. The officer indicated that every portion of the land of these three communities over decades were cultivable; however, over 9% of the land has been lost due to the activities of the illegal mining. In the officers own words, it was captured as follows:

> *"Before the emergence of the mining activities in these communities, every part of the land was cultivable, today as we speak, there are some portions of the land you cannot grow crops" (Interviewee A5, 4 June 2020).*

The results from the respondents agreed with the literature. Illegal mining, a low-technology and labor-intensive mining activity (Kwadwo et al., 2016) in Ghana, has come under serious scrutiny due to its implication on agricultural land and other livelihood sources (Amankwah, 2013; Okoh, 2014; Ofosu et al., 2020; Atta and Tholana, 2021). Studies have found that illegal mining has scarred the landscape with excavated pits and trenches in its operation areas, which, in turn, renders the land unsuitable for any other purpose (Ofosu et al., 2020; Atta and Tholana, 2021). Studies have also observed that the activities of illegal mining has contributed to water pollution due to the high demand for water by miners in extraction, processing, and waste disposal (Amankwah, 2013; Ndabi, 2017). From the study, the results indicated that the activities of mining in the study communities have resulted to environmental resources depletion. As reported by the residents of the three communities, the MOFA, and the EPA, illegal mining in the areas has resulted to unnecessary competition between agriculturalists and the miners for land. The activities of illegal mining will continue unabated because of its importance to the mining operators and communities (Hilson et al., 2013; Kwadwo et al., 2016; Obeng et al., 2019; Yamarak and Parton, 2021). In fact, the literature has observed illegal mining as livelihood diversification (Hilson et al., 2013; Kwadwo et al., 2016) and argued that the formalization of mining sector will do people good (Kwadwo et al., 2016). Although this study completely agreed with their proposal, it is also important that we do not create much room for activities of illegal gold mining such that sustainable agricultural activities have to compromise.

Illegal Mining and Its Environmental Implications for Climate-Smart Agriculture in Nadowli-Kaleo District

Climate-Smart Agricultural Practices Adopted by Respondents

As part of the assessment of the implication of illegal mining on climate-smart agriculture, **Figure 2** presents climate-smart agricultural practices that are engaged by the communities. From the assessment of the climate-smart practices, the study observed that smallholder farmers have specific climate-smart agricultural practices for soil, water, and land management.

For soil management, specifically, 66% of the respondents reported that application or use of domestic waste/manure for improved soil fertility for improved crop productivity was dominant, whereas 34% indicated that they do not use the practice. Again, 64% of the farmers also reported that they practice terracing, whereas 36% of them indicated that they do not practice terracing on the farmlands to maintain soil fertility. For crop rotation as climate-smart agriculture practice to soil management, 78% of them reported that they are involved in the practice, whereas 12% held a contrast view. Soil management has been observed to play a critical role in sustainable agriculture. Earlier studies have found that, to improve soil quality for improved food systems, application of manure, compositing, terracing, and crop rotation or fallowing are real ingredients to support the process (Maguza-Tembo et al., 2017; Nyasimi et al., 2017). Maguza-Tembo et al. (2017) on the determinants and impact of climate-smart agriculture technology adoption on the welfare of smallholder farmers in Malawi reported that the adoption of manure application, crop rotation, and terracing by the farmers has aided in sustaining the fertility of soil.

In addition, the assessment of water management practices in response to the changing climate revealed that 42% of the respondents revealed they irrigate their farms, whereas 58% indicated that they did not irrigate their farms. For terracing to ensure water percolation and retention, 64% of the respondents indicated that the practice is an old one among them. Lastly, for land management, the assessment revealed that 88% of the respondents indicated that planting of early resistant crop varieties was highest among them in response to the changing climate system, whereas 12% indicated that they did not adopt planting of drought resistant crop varieties. For terracing to ensure land management, 64% indicated that the practice has been with them for long, whereas 12% indicated that they did not adopt the practice. Farm level irrigation and adoption of

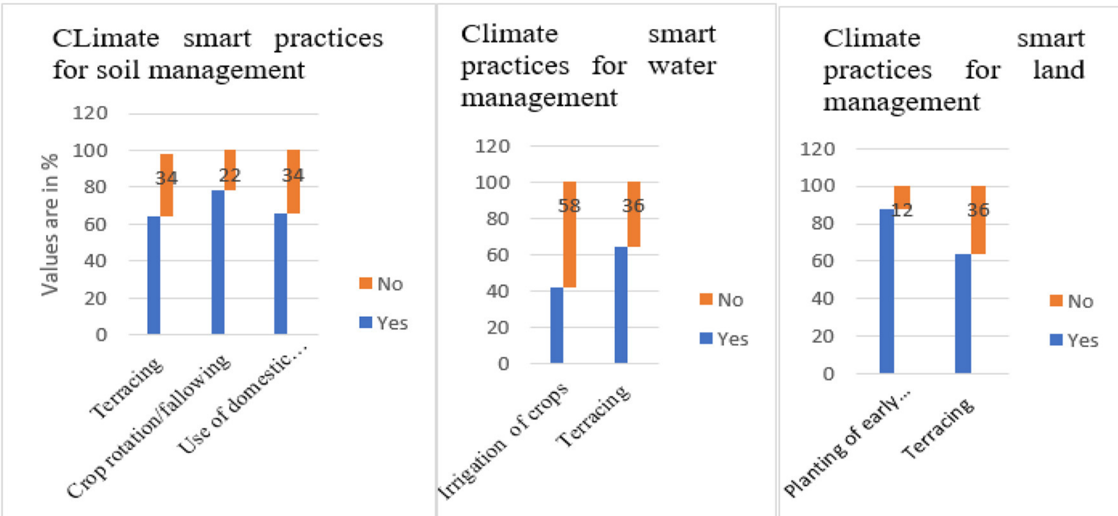

FIGURE 2 | Climate-smart practices adopted by residents of the study communities.

early maturing crop varieties are important strategies to support climate change adaptation (Yiridomoh et al., 2020; Angom et al., 2021). In a systematic review of climate-smart agricultural practices among smallholder farmers in Aravalli district, Gujarat, India, Angom et al. (2021) observed that farm level irrigation and planting of earlier maturing crop varieties have helped the farmers to put their land and water into good use for sustained agricultural activities. This implies that these climate-smart agricultural activities in Ghana must be promoted for sustainable environment and agriculture.

Relationship Between Climate-Smart Agricultural Practices and Soil, Water, and Land Management for Activities of Farming

To establish the relationship between climate-smart agricultural practices and soil, water, and land management, the results as represented by **Table 3** revealed that crop rotation/fallowing was strongly associated with soil management at 1% with ∗p-value 3.891. In addition, the use of domestic/manure and terracing as climate-smart agricultural practices was significant with soil management at 5% with p-values 4.218 and 2.197, respectively. Irrigation of crops and terracing of farm plots as climate-smart practices were significantly associated with water management at 5% with p-values 3.021 and 2.971, respectively. Finally, planting of earlier maturing crop varieties and terracing were significantly associated with land management at 1 and 5% with p-values 5.180 and 3.017, respectively. Earlier studies have found that the use of domestic waste, terracing, and crop rotation/fallowing have promising qualities to improve soil quality for activities of farming (Partey et al., 2018; Andrieu et al., 2020; Mensah et al., 2020). The study of Andrieu et al. (2020) on mapping favorable zones for uptake of climate-smart agricultural practices in West Africa reported that crop rotation as a climate-smart practice has the potential to support sustainable agriculture through improved soil fertility. Other studies have found that sustainable land management practices such as terracing could support sustainable food production and food systems (Issahaku and Abdulai, 2020; Mensah et al., 2020; Angom et al., 2021; Waaswa et al., 2021). The study of Waaswa et al. (2021) on climate-smart agriculture dissemination pathways among smallholder potato farmers in Kenya reported that crop rotation, compositing, terracing, and irrigation have helped improve the quality of soil, water, and land for agricultural activities. Climate-smart agricultural practices are known to contribute to achieving sustainable development through improved sustainable food systems. This implies that climate-smart agriculture need to be prioritized and promoted especially in developing economies to assist farmers meet their households food need.

Implication of Environmental Effects of Illegal Mining to Climate-Smart Agriculture

Soil, water, and land management are central to climate-smart agriculture in northern Ghana (Center for Scientiftic and Industrial Research, 2017; Issahaku and Abdulai, 2020). Traditional soil, water, and land management practices adopted by smallholder farmers (to improve soil fertility and water moisture content) such as use of domestic waste/manure on farm lands, terracing to ensure soil retention and water percolation, and crop rotation/land fallowing to maintain soil fertility and irrigation are under a serious threat. Application of organic domestic waste/manure has noted for their importance; improved soil fertility, structure, and soil moisture retention (Maguza-Tembo et al., 2017; Nyasimi et al., 2017; Partey et al., 2018; Waaswa et al., 2021). Terracing is noted for its water conservation and soil erosion reduction especially farmlands that are located on steep slopes (see **Figure 3**). Crop rotation/land fallowing helps reduce incidences of pests and diseases of crops and improve soil structure and soil fertility through nitrogen

TABLE 3 | Relationship between climate-smart agricultural practices and water, land, and soil management.

Component of environmental management	Climate-smart practices	Adoption	Non-adoption	Total	χ^2 value
Soil management	Use of domestic waste/manure	73(66)	38(34)	111 (100)	4.218***
	Terracing	71 (64)	40 (36)	111(100)	2.197**
	Crop rotation/fallowing	87 (78)	14 (12)	111 (100)	3.891***
Water management	Irrigation of crops	47 (42)	64 (58)	111 (100)	3.021**
	Terracing	71 (64)	40 (36)	111 (100)	2.971**
Land management	Planting of earlier maturing crop varieties	98 (88)	3 (12)	111 (100)	5.180***
	Terracing	71 (64)	40(36)	111 (100)	3.017**

****Denotes significant at 1% level, **denotes significant at 5% level, and *denote significant at 10% level.*
Values in parenthesis are percentages.

FIGURE 3 | Terracing as climate-smart agricultural practice identified in all the four study communities. Terracing is one of the oldest methods of managing soil and water—an agricultural practice, which involves collecting surface runoff water (thus increasing the infiltration and controlling water erosion known from ancient history) to transform landscape in hilly or mountainous regions or areas. Terracing is important for its considerable reduction in soil and water erosion, thus, if correctly planned, constructed, and properly maintained. However, terracing, if not properly maintained, could cause land degradation.

fixing crops (Maguza-Tembo et al., 2017; Nyasimi et al., 2017; Angom et al., 2021; Waaswa et al., 2021).

Although these practices are sound consistent to promote climate-smart agriculture, the results of the study suggest that the activities of illegal mining have had great implication on agriculture. Thus, illegal mining contests for agriculture space, and such contest affects the livelihood of people engage in agriculture. For instance, the formation of sinkholes as reported by the respondents due to illegal gold mining makes the land and soil unproductive and, therefore, affects agricultural food production. The scarcity of the land for agricultural activities due to competition from illegal mining will also affect traditional crop rotation and fallowing (Ndabi, 2017; Ofosu et al., 2020; Atta and Tholana, 2021). For instance, at Nanga, the chief reported the following:

"Our farming and food security is under serious threat due to activities of mining. For the past 10 years, it has become extremely difficult to practice farm rotation or fallowing which is one of our traditional farming practices to replenish our deteriorated soil fertility. This is due to competition for land by miners and food crop farmers. Two year ago, I got to my only farmland and saw it vandalize by these miners. As I speak with you, I have to beg for

land from other families every year to farm. How then do I practice climate smart agriculture like farm rotation or land fallowing?" (Interviewee A1, 4 June 2020)

Furthermore, the activities of illegal mining in the area have accounted for soil and water contamination and give rise to water turbidity as reported by the residents, the miners, the Mineral Commission, and the EPA and through the reconnaissance field survey of the researcher. What that means is that the high turbidity levels will affect primary productivity with consequence effect on the life of biodiversity (Millennium Ecosystem Assessment, 2005; Opschoor, 2007; Ndabi, 2017). Thus, if the biodiversity depletes due to activities of illegal mining, then it will affect the services of the ecosystem such as provisioning, regulatory, and supporting (Millennium Ecosystem Assessment, 2005). Again, water and soil contamination may constraint irrigation activities in the study communities, which is recognized as one of the most reliable and transformed ways of responding to the changing climate system. For instance, at Charikpong, the chief reported the following:

"Our few streams are completely contaminated with mercury and other chemicals. Our main river (The Black Volta River) is under serious threat of pollution. We cannot collect and drink water from the few streams around us nor use the water to irrigate our farms. This has made it very difficult for some of us who undertake dry season gardening to supplement our already diminishing farm produce" (Interviewee A2, 4 June 2020).

Agriculture must undergo a major transformation to meet the challenges of food security, reducing poverty while responding to the changing climate system. Water and land are likely to present the greatest challenges on the food supply side, given the diminishing carrying capacity of arable land and water resources (Amankwah, 2013; Adiyah, 2014; Poku, 2016). This is because many of the smallholder farmers and pastoralists that form the backbone of agriculture in northern Ghana are utilizing a degraded environment partly due to illegal mining. The ecosystems that provide healthy surface water and groundwater as well as food, fodder, and fiber are fast deteriorating in the Nadowli-Kaleo district due to illegal mining (Prosper and Guan, 2015; Environmental protection agency, 2016; Ghana News Agency, 2018). With these challenges, agriculture cannot proceed as a business-as-usual manner. Studies have reported on the devastating effect of activities of illegal mining on agricultural land to include conversion of agriculture lands for its operations (Schueler et al., 2011; Environmental protection agency, 2016). Agriculture and its activities need quality soil, water, and land resources to thrive well. Although these are prerequisite for sustainable agriculture, due to the emergence of illegal gold mining in the area, known agricultural practices in response to the already changing climate have been affected.

CONCLUSION

Agriculture remains the beacon of the economy of Ghana, and its development has serious implications for poverty reduction and food security in Northern Ghana. It is oblivious that mining do not contribute to the economy of Ghana. The argument here is its dreadful consequences on sustainable agriculture and food systems due to its detrimental effects on the environment that support climate-smart agriculture. The study aim was to investigate illegal gold mining and the environmental implication on climate-smart agriculture in the Upper West Region of Ghana. The study found that the activities of illegal mining have resulted in formation of sinkholes, contamination of soil, ground, and surface water pollution, and loss of biodiversity. The study further revealed that known agricultural practices such as use of domestic waste and manure, terracing, crop rotation/land fallowing, irrigation of crops, and planting of early resistant crop varieties have been affected by the activities of illegal gold mining in the area with the adoption of climate-smart agricultural practices remains extremely difficult. In Ghana and other developing countries, key issues threatening food security and sustainable agriculture are linked invariably to land use. Soil degradation, water quality, and biodiversity all have a land use components that affect activities of farmers, and land use planning with an agricultural lens will help protect farmland, farmers, and their livelihood and, at the same time, ensure environmental sustainability through improved soil fertility and water management. The author of this paper states that conscious efforts by the Ministry of Lands and Natural Resources and its subsidiary agencies and departments are needed to sustain the ban on illegal gold mining with intensified supervision and monitoring while a systematic scheme involving relevant stakeholders is developed and implemented to ban illegal mining in Ghana completely. Again, there is the need for the Mineral Commission of Ghana together with the district assemblies and traditional authorities to prepare short- to medium-term training programs to continuous to disseminate the impact of illegal gold mining activities on the environment and sustainable agriculture and food systems. The Ministry of Lands and Natural Resources and the Ministries of Food and Agriculture need to engage more with relevant stakeholders including academics, non-governmental organizations, researchers, the Parliament of Ghana, traditional authorities, and youth groups to work at better regulations of the mining activity to protect the environment and support sustainable climate-smart agricultural production in Ghana. Finally, The MOFA needs to develop an approach to support the adoption of climate-smart agricultural practices by smallholder farmers to meet the food demand of their households.

STRENGTHS AND LIMITATIONS OF THE STUDY

The study was a single case study using Nadowli-kaleo district. Including other districts, especially those in the southern Ghana, would have provided some more evidence on illegal gold mining and the implications of their activities on climate-smart agriculture in Ghana. Hence, policy decisions with respect to promoting climate-smart agriculture may be limited to the case study area. However, with limited studies of this caliber in the region and Ghana, the study would provide a perfect first-hand information on activities of illegal gold mining and climate-smart agriculture in a region known to have high indices of poverty and highly vulnerable to climate change. Going forward as a country, it will serve us better, if a more comprehensive study covering all the mining communities in Ghana is under similar investigation to help roll out policies, programs, and projects that are more detailed on climate-smart agriculture for sustainable food systems and production.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

Ethical review and approval was not required for this study with human participants, in accordance with the local legislation and institutional requirements.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

ACKNOWLEDGMENTS

The author wishes to acknowledge the respondents for the information. We also wish to thank all the field assistance for their good work during the fieldwork.

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frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 11 January 2022
doi: 10.3389/fsufs.2021.759638

Toward Agricultural Intersectionality? Farm Intergenerational Transfer at the Fringe. A Comparative Analysis of the Urban-Influenced Ontario's Greenbelt, Canada and Toulouse InterSCoT, France

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OPEN ACCESS

Edited by:
Christopher Fullerton, Brock University, Canada

Reviewed by:
Donald C. Cole, University of Toronto, Canada
Philip Walsh, Ryerson University, Canada

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Specialty section:
This article was submitted to Land, Livelihoods and Food Security, a section of the journal Frontiers in Sustainable Food Systems

Received: *16 August 2021*
Accepted: *06 December 2021*
Published: *11 January 2022*

Citation:
Akimowicz M, Landman K, Képhaliacos C and Cummings H (2022) Toward Agricultural Intersectionality? Farm Intergenerational Transfer at the Fringe. A Comparative Analysis of the Urban-Influenced Ontario's Greenbelt, Canada and Toulouse InterSCoT, France. Front. Sustain. Food Syst. 5:759638. doi: 10.3389/fsufs.2021.759638

Peri-urban agriculture can foster the resilience of metropolitan areas through the provision of local food and other multifunctional agricultural amenities and externalities. However, in peri-urban areas, farming is characterized by strong social uncertainties, which slow the intergenerational transfer of farm operations. In this article, we tackle the beliefs that underlie farmers' decision-making to identify planning opportunities that may support farm intergenerational transfers. The design of an institutionalist conceptual framework based on Keynesian uncertainty and Commonsian Futurity aims to analyze farmers' beliefs associated with farm intergenerational transfer dynamics. The dataset of this comparative analysis includes 41 interviews with farmers involved in animal, cash-crop, and horticulture farming in the urban-influenced Ontario's Greenbelt, Canada, and Toulouse InterSCoT, France, during which farmers designed a mental model of their investment decision-making. The results highlight the dominance of a capital-intensive farm model framed by a money-land-market nexus that slows farm structural change. The subsequent access inequalities, which are based on characteristics of farmers and their farm projects, support the idea of the existence of an agricultural intersectionality. The results also highlight the positive role of the institutional context; when farmers' beliefs are well-aligned with the beliefs that shape their institutional environment, the frictions that slow farm structural change in peri-urban areas are moderated by a shared vision of the future.

Keywords: farm transfer, peri-urban agriculture, farmers' beliefs, Keynesian uncertainty, Commonsian Futurity, agricultural intersectionality

INTRODUCTION

The current COVID-19 pandemic has highlighted the severe structural inequalities of the global food system. The exacerbation of the criticality of local food provision has resulted in renewed interests in food access issues and food chain resilience (Hobbs, 2020; Lioutas and Charatsari, 2021; Thilmany et al., 2021). In particular, the interest of city planners in peri-urban agriculture (Cadieux et al., 2013), as testified by the design of place-based/territorialized agricultural policies (Bonnefoy and Brand, 2014; Bissardon and Boulianne, 2016), the activity of municipal governments on land markets (Jarrige, 2018; Perrin and Nougarèdes, 2020), and the formation of networks to support urban-influenced agriculture (e.g., Cities for Agroecology Network, Eurocities, Organic Cities), has been strengthened: peri-urban agriculture is commonly perceived as a lever for designing more sustainable metropolitan areas (Sroka et al., 2021). In a context where the proximity to urban markets results in new opportunities and constraints for peri-urban farmers, who have developed original peri-urban farming systems that are quite specific from a production point of view (Duvernoy et al., 2018; Akimowicz et al., 2020), planning activities may substantially influence farming activities (Butt and Taylor, 2018; Buchan et al., 2019).

In the medium term, food provisioning for metropolitan areas is threatened by farm exit. While the number of farms currently tends to increase in the Global South, the situation is quite different in the Global North where the number of farms has been almost continuously decreasing since the end of World War II (Lowder et al., 2021). In Canada and France, two Global North countries, farm exit was confirmed between the last farm censuses, with a number of farms down by 6% between 2011 and 2016 in Canada (Ministry of Industry, 2017) and by 2% between 2010 and 2016 in France (Agreste, 2020). Paralleling farm exit, one can also note a consolidation of farm size with an average increase of +16 ha in Canada and +7 ha in France during the same time periods. In these two countries, the loss of farm operators, −7% in both cases, and their aging, 55% of farmers were 55 years old or older in Canada while 25% were 60 years old or older in France both in 2016, raises the issue of farm intergenerational transfer.

Farm transfer is indeed a key step for farm trajectories. For instance, the likelihood of transferring farms to identified successors contributes to maintaining farm-investment dynamics that foster the viability of agricultural systems (Akimowicz et al., 2013; Gasselin et al., 2014; Valliant et al., 2019). Interestingly, peri-urban agriculture also demonstrates specificities during the turning point of farm succession and take-over. Inwood and Sharp (2012) showed that, in an environment where farmland access is conflictual and rather constrained, farmers' adaptation strategies do not rely solely on land expansion but also on vertical growth that involves food processing and marketing. Bertoni and Cavicchioli (2016) further noted that a farm's proximity to urban labor markets in more densely populated areas fosters the transmission of horticultural farms due to better returns for farm work as well as the possibility to diversify income sources through off-farm work.

While farm takeover can be considered as an investment based on some rational mental computing (Jorgenson, 1967; Barry et al., 1995), it can also be interpreted as an intentional action based on reasons particular to the decision maker, such as their beliefs. Morais et al. (2017) identified three types of beliefs that influence farmers' decision-making when planning farm takeover: behavioral beliefs associated with farmers' attitudes, normative beliefs associated with farmers' perceived norms, and control beliefs associated with farmers' perceived behavioral control. Following Peirce's pragmatism, beliefs can be defined as "something that we are aware of; (...) appeases the irritation of doubt; (...) involves the establishment in our nature of a rule of action, or, say for short a habit" (Peirce, 1931–1958, p. 5397). This stance is a foundation for the field of institutional economics, which posits the social embeddedness of economic decisions. Interestingly, the overlap of Morais et al. (2017) three types of beliefs with Scott's (1995) three dimensions of institutions-i.e., cognitive, normative, and regulatory-supports the relevance of adopting an institutionalist stance for this research.

The indeterminacy of belief-based actions contributes to an updating of beliefs-i.e., confirmation or revision-once one experiences the outcomes of an action. However, the decision to take over a farm is a situation that is unlikely to be repeated; in most cases, this is a once-in-a-lifetime decision that implies a career-long commitment. From this perspective, the mechanism through which habits are forged has not taken place yet. In addition to the singularity of the decision to start farming, the peri-urban farming environment is highly uncertain (Bryant and Johnston, 1992; Darly and Torre, 2013). Yet, new farmers are not independent agents who permanently optimize their decisions. Their decisions are framed, instead, by beliefs resulting from their social embeddedness in place, which involves other territorial actors such as other farmers, collective organizations such as cooperatives, and public agencies (Akimowicz and Képhaliacos, 2018; Diendéré et al., 2018; Perrin and Nougarèdes, 2020). Therefore, understanding the beliefs that shape both new farmers' decisions to start farming and retiring farmers' decisions to transfer their farm can contribute to better policies supporting farm intergenerational transfers. In this article, we explore the beliefs associated with the event of farm transfer to elicit the articulation of farmers' beliefs.

The originality of this paper is fourfold. First, it relies on a comparative approach. The survey is conducted in two countries, in Ontario's Greenbelt in Canada and in the Toulouse InterSCoT in France; farm succession is currently a critical issue in both landscapes. Second, this research relies on a field investigation with farmers on their beliefs and habits. The data collection is based on mental modeling which framed a simultaneous semi-structured interview that elicited farmers' beliefs about farm transfer; this allowed for follow-up questions specific to each interviewee's farm trajectory. Third, the purposive sample includes farmers from a wide range of ages, which allows for differentiation between new farmers with a recent farm takeover experience and experienced farmers with a growing concern for transferring their farm. Last but not least, this work relies on a conceptual framework, centered on farmers' beliefs, that attempts to build on Keynesian social uncertainty and Commonsian Futurity, which both frame social actors' decisions; this is an attempt to explore the proximity of these two theoretical stances which may gain depth and consistency from the field of psychology. The following section explores the economic literature to theoretically ground this analysis of farm intergenerational transfer in the field of institutional economics, which emphasizes the social embeddedness of farmers' economic decision-making while allowing intentional decisions to depart from an internalized pre-existing belief system. The method and data presents the mental mapping method and the original data collected for this research. The results are detailed in the results section which highlights the singularity of peri-urban farming styles, which are framed, on the one hand, by farmers' intentional values and quality of life choices while being constrained, on the other hand, by the organization of both the food supply chain and the territory/place within which they are embedded. This double embeddedness frames an intersectional environment. The existence of a land-money-market nexus drives access constraints, which hinders farm transmission and slows farm structural change. In the discussion of this paper, a discussion of the results is provided before concluding the article.

LITERATURE REVIEW

This literature review aims to present the hypotheses of this research. We rely on a model of decision-making that is framed by Keynes' concept of uncertainty, which considers the psychological dimension of economic decision-makers, as well as Commons' concept of Futurity, which provides an adequate framework for discussing the rationality that animates farmers' decision-making. This tentative theoretical reconciliation, which aligns consistently with previous research based on the theory of planned behavior, is a first step toward further connections.

Navigating Uncertainty

In Patrick and Eisgruber's (1968) behavioral theory of the farm firm, farmers' behaviors are driven by the pursuit of personal goals; farmers specify alternatives to achieve goals and allocate resources according to selected alternatives. However, internal and external factors that are out of decision-makers' control may disrupt this planning. The economic literature often refers to these factors through the concepts of risk and uncertainty. Nowadays, several sources of stress can trigger risks and uncertainties for farmers, especially if they venture into more sustainable ways of farming, as they see it, as "a response to broader agribusiness trends" in line with "their beliefs about ecological health and valuing of resilience" (Bondy and Cole, 2019, p. 115). Indeed, Chavas et al. (2010) accentuated the need for better distinguishing these two concepts in economic analyses applied to agriculture. For Knight (1921, p. 20), risk characterizes a situation in which the outcome of future events can be calculated (measurable risk) whereas uncertainty characterizes a situation in which outcomes cannot be calculated (unmeasurable uncertainty). Additionally, for Keynes (1921), radical uncertainty results from the unpredictable behaviors of emotional agents: each anticipated outcome can be assimilated as a bet where uncertainty is reflected by the degree of credibility of the anticipated outcome.

Farming is, generally speaking, subject to multiple sources of uncertainty due to the unpredictability of adverse climatic events, price variations on the global market, and unforeseeable biological processes, which are all complex phenomena. For instance, Chavas (1994, 2008) analyzed farm production decisions under uncertainty with the introduction of temporal price uncertainty and climatic events. In peri-urban areas, additional sources of uncertainty complicate farmers' decision-making. Temporary land tenure with short leases are commonly implemented due to urbanization (Léger-Bosch, 2019). Agricultural practices may be regulated to solve potential conflicts with non-farming nearby residents (Owen et al., 2000). Land use zoning may be revised to allow for the development of farmland (Jongeneel et al., 2008). As a result, the uncertainty characterizing the decision to start farming in peri-urban areas is significantly different from other uncertainties in rural areas; in addition to biological, climate, and agricultural price uncertainties, peri-urban farmers also face land access and political uncertainties. These additional sources of social uncertainty may widen the gap between researchers' theoretical deductions (e.g., economic models of farmers' decisions, economic forecasts, normative prescriptions) and field observations of farmers' planning decisions due to an inappropriate conceptualization of time, which does not consider fully farmers' anticipations on which investment decisions rely (Viaggi et al., 2011). In particular, a set of external constraints resulting from the institutional environment within which farmers are embedded appears to inhibit their capacity to engage proactively in transformative decision-making (Del Corso et al., 2015; Akimowicz et al., 2020).

Hypothesis 1: The high level of uncertainty surrounding the decision to start farming slows the intergenerational transfer of farm operations in peri-urban areas.

Making Intentional Decisions

For farmers, navigating the uncertainties of peri-urban environments implies, therefore, that decision-making is based on anticipation of the future outcomes of decisions made in the present-a.k.a, planning. In the field of economics, J.R. Commons' (1934) concept of Futurity grasps the intentionality of farmers' decisions well. As Commons' (1934: 84) puts it, "man lives in the future and acts in the present," which implies that farmers' decision-making is based on anticipations and forecasting while being fallible. Commons coined the concept of Futurity to characterize this proactive behavior that considers "the future time of waiting, risking, purpose, and planning" (ibid. 389). For Commons, decisions are the result of the tension between two forces: a first force that drives farmers to shape their future through exploration and innovation and a second force that makes farmers conform to socially constructed and internalized frameworks (Atkinson, 2009). The latter force results from a socialization process that provides farmers with a form of background knowledge that enables them to navigate the uncertainties of the world (Berger and Luckmann, 1966). As such, farmers' interactions with peer farmers, extension services personnel, other agricultural stakeholders such as representatives of cooperatives and agricultural suppliers, or even with consumers and local residents, all contribute to the formation of farmers' beliefs and attitudes (Morgan, 2011; Labarthe and Laurent, 2013; Darnhofer et al., 2016).

In uncertain environments, farmers rely on imperfect models that help them navigate the complexities of their environment (Billaudot, 2009; Gislain, 2017). These models, which result from both inherited tacit knowledge internalized during early life stages as well as knowledge accumulated with past experiences that contribute to critical learning, are the foundations for decisions that consider decision-makers' emotions (Padua, 2015). Although often imperfect, these models provide farmers with critical information that can be used as such or transposed to new encountered situations that require creative solutions (Bromley, 2008). These imperfect models help decision-makers to make sense of their environment. In our case, they empower farmers to make decisions even though they may be inaccurate. This critical knowledge refers to Peirce's (1931–1958) beliefs that overcome the doubt triggered by uncertainty when making decisions. In summary, farmers' investment decisions are intentional, prone to trial and error, and socially constructed.

Hypothesis 2: Farmers rely on beliefs that enable them to anticipate the future outcomes of present decisions to decide to take over or transfer farm operations.

The Supporting Role of Territorial Organizations

In Keynes' decision-making process under uncertainty, decisions are influenced by the amount of information collected, agents' cognitive capacities, agents' experience with the issue at stake, and, last but not least, agents' social embeddedness (Postel, 2008). More specifically, in urban-influenced areas, farmers interact with other farmers, traditional farming organizations, and urban actors such as non-farming residents and urban planners. The diversity of worldviews is, unsurprisingly, a potential source of conflicts, which can be solved through the formulation of common projects framed by shared visions of the future (Akimowicz et al., 2020). Therefore, a mesoeconomic approach, which takes into account the integration of farmers' activities into both their territory-understood as place, where coordination is mostly achieved in the political sphere-and the food supply chain-understood as market organizations, where coordination is mostly achieved in the market sphere (Théret, 1994; Rastoin and Ghersi, 2010; Rocamora-Montiel et al., 2014), provides the right scale for such an investigation. For new farmers, the challenge of being situated in such interpretive communities is to solve the tensions that arise from the diverging goals that drive the actions of different stakeholders (Bromley, 2008).

The process of planning can either foster or hinder such an alignment, and therefore underlies either synergies or conflicts among local farmland stakeholders (e.g., farmers, environmentalists, developers, decision-makers, local residents). Although a multifunctional peri-urban agriculture can contribute to the sustainability of metropolitan areas (Torres-Lima et al., 2010), Marsden and Sonnino (2008) noted that ambiguous formal governance structures have hindered the development of a multifunctional farming sector; Benis and Ferrão (2018) observed that urban planning strategies and policies have long missed the integration of peri-urban agriculture. The definition of what is acceptable may "accommodate alternatives to hegemonic systems" (Butt and Taylor, 2018, p. 11), which may, in turn, facilitate the inclusion of alternative place-based peri-urban farming styles which are significantly different from traditional farms that are typical of the dominant extractive farming model (Allaire and Boyer, 1995; Ngo and Brklacich, 2014). Indeed, following Taylor et al. (2017), planning aims to define a balance between agricultural, environmental, and amenity values. The high technicality of planning often results in the perception that planning is a neutral process (Buchan et al., 2019) whereas Butt and Taylor (2018, p. 2) argue against the perception that planning is a "de-politicized managerial and technical project."

Hypothesis 3: Due to farmers' embeddedness in an institutional environment, the alignment of farmer's and territorial actors' visions of the future may contribute to smoothing farm transfer.

METHOD AND DATA

In this section, we detail the comparative method used to analyze farmers' beliefs about farm transfer, which relies on the interview of 41 farmers between 2015 and 2017 in two peri-urban areas in Canada and France, the design of the cognitive models of their investment decision-making, the transcription of the semi-structured interviews, and the responses to a questionnaire about their farm system.

Method

Dominant in the economic literature is the assumption that economic agents behave rationally through the optimization of utility (Stigler, 1950), even though the limitations of such a stance have long been highlighted (Veblen, 1909). Outside of economics, considering both one's fallible anticipation of outcomes as the root cause of one's decision-making as well as one's embeddedness in a social context is not unusual. In psychology, for instance, the theory of planned behavior stipulates that one's intentions are framed by three types of beliefs about behaviors, norms, and controls, thereby linking one's beliefs to one's behavior (Ajzen, 1991). This theory has since been used in economics; Howley et al. (2015) used this theory to demonstrate farmers' economically 'irrational' land use decision-making. In a similar manner, van Dijk et al. (2016) used the theory to highlight that non-subsidized environmental practices may nonetheless be implemented if in line with farmers' self-identity while being supported, for instance, by cooperatives. As mentioned earlier, the theory was also used by Morais et al. (2017) to analyze farm takeover in Brazil.

These results confirm our intention to frame our analysis with an institutionalist perspective that posits the idiosyncrasy of farmers' decision-making (Wilber and Harrison, 1978). The singularity of farmers' decision-making results from, on the one hand, internalized decision rules that structure farmers' thinking and, on the other hand, a capacity to deviate from these rules to respond to *ad hoc* situations and goals. In short, farmers act on their own volition, acting purposefully to meet particular ends (Bromley, 2008). This perspective, which mixes both micro and macro dynamics, refers to Commons' holindividualism (Chavance, 2012), which has been used for agricultural research on farm decisions (Léger-Bosch et al., 2020; Halewood et al., 2021). Consequently, the methodology relies on a flexible data collection tool-i.e., semi-structured interviews-that enables the capture of the singularity of farmers' beliefs.

The Sample

The embeddedness of farmers' decision-making in place drove the decision to conduct a comparative analysis, which enables the discussion of the respective roles of social and environmental contexts within which farmers navigate (Wolters and Steel, 2020). In this research, we compare two regions of a similar size that are under strong urban-influence: the Ontario's Greenbelt in Canada under the urban influence of Metropolitan Toronto and the Toulouse InterSCoT[1] in France under the influence of the city of Toulouse. Both areas are characterized by a variety of farming styles, including cash-crop farms, animal farms, and horticulture farms, while urbanization grows steadily due to demographic growth (Akimowicz et al., 2020). Furthermore, although Toronto is a far more populated metropolitan area than Toulouse, land consumption from which conflicts between farmers and non-farmers may arise remains comparable.

Within each research area, we selected a purposive sample of 21 farmers in Canada (C) and 20 in France (F) to cover the diversity of farming styles in each research area. More details about the characteristics of the farm operations can be found in Akimowicz et al. (2016) for the Canadian sample and in Akimowicz and Képhaliacos (2018) for the French sample. We focused on three main farm types-i.e., cash-crop (CC), animal (A), and horticulture (H) farms-which cover the issues commonly faced by peri-urban farmers. Approximately half of interviewed farmers operated under a sole proprietor legal status while the other half operated under a collective legal status, be it a partnership or a corporation. Cash-crop farmers tend to expand in size to generate scale economies while having both few opportunities to diversify on-farm income and difficulties when moving machinery. Conversely, horticulture farmers tend to have much smaller operations while having more opportunities to diversify on-farm income. On their end, animal farmers are usually confronted with recurrent conflicts due to animal nuisances, such as odors, while having some opportunities to diversify on-farm income. The sample, which reflects most issues encountered by peri-urban farmers, was, therefore, expected to reveal the diversity of beliefs associated with farm transfer.

Data

Beliefs are a tacit form of knowledge that is not directly observable (Del Corso et al., 2014). The data collection tool of mental mapping is commonly used to access tacit knowledge. With mental mapping, researchers can access interviewees' beliefs that frame their worldviews and, therefore, the reasons why interviewees behave the way they do (Carley and Palmquist, 1992; Isaac et al., 2009). Indirectly, the elicitation of these personal beliefs can also reveal the perceived dynamics of a system without necessarily knowing the details underlying its operation (Groumpos, 2010; Jones et al., 2011). Based on a literature review, we selected a set of 37 factors in Canada and 39 factors in France that potentially affect investment decision-making (**Appendix 1**). The factor labeled *Farm Transfer* was included in both sets and aimed to shed light on the impacts of the existence of an identified family member or non-family new farmer to take over the farm. Although the high-level impacts of this factor have already been discussed in previous publications, this article delves deeper in the dynamics of farm transfer in peri-urban areas.

For this study, investment was defined as a structural investment that is amortized over at least 15 years, such as investment in land, in a combined harvester, in a building such as a stable, or simply starting a farm operation. Although we focused on the structural characteristics of farm operations, the sample included a diversity of activities ranging from annual to perennial crop farming as well as diverse types of animal husbandry, from cattle to turkeys. Such investments affect farm financial status over a long period of time and can be considered as structural investments. In Canada, we further tailored the set of factors as well as their labeling during a focus group with agricultural experts. As a result, the set of indicators used in Canada and France is adapted to the local specificities of each agricultural environment.

Additionally, the mental modeling activity was used as a guide for semi-structured interviews; while farmers designed the mental model of their investment decision-making, interviewers followed-up with questions to understand the meaning associated with each causal relationship created by farmers. This way, the elicitation of farmers' knowledge was directed by farmers and framed by researchers. The constant interaction of both interviewees and interviewers resulted in rich data that included, for each farmer, the mental model of their investment decision-making, the transcription of the interview, and the responses to a questionnaire on the characteristics of the farm. This data was openly coded, which resulted in the identification of three themes: the mitigation of land expansion needs to generate income, the design of farm projects embedded in a family project, and the supportive role of well-aligned territorial organizations. **Figure 1** below showcases an example of a mental model collected during the interviews.

RESULTS

The results section explores, first, the fact that farm transfers may be considered as patrimonial transfers; next, attention is paid to the farmers' view that taking over a farm operation implies balancing quality of life with sacrifices. These two sub-sections support the idea that farmers' identities are connected to the activity of farming. The following sub-section confirms that peri-urban farmers constantly attempt to navigate the uncertainties of their productive environment with little flexibility; this constraint, as one can see in the last sub-section, may be lifted when the institutional environment is framed by a shared vision of the future among agricultural stakeholders.

[1] InterSCoT is a French planning policy enacted by a group of municipalities. It aims to increase the cohesiveness of planning at the intermunicipal scale through the definition of a shared strategy for waste management, biodiversity conservation, transportation, and land use planning, among other issues and responsibilities. SCoT stands for Scheme for Territorial Coherence.

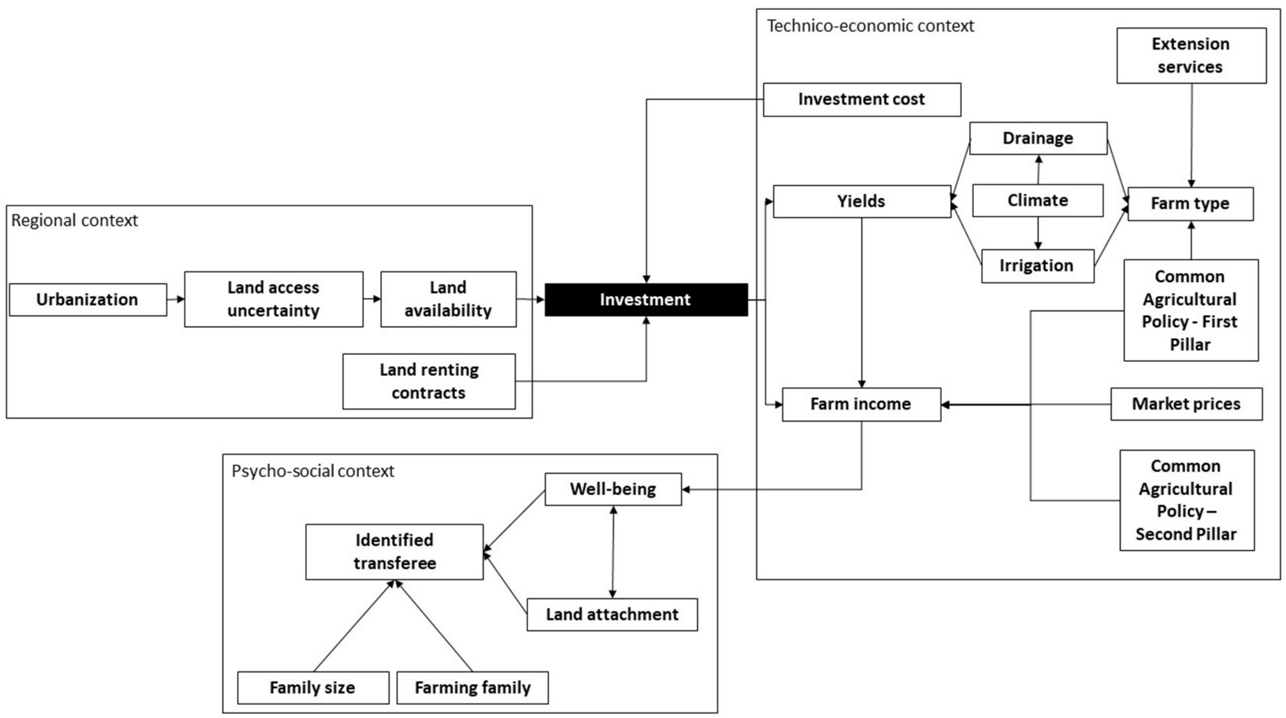

FIGURE 1 | The investment decision-making mental model of Interviewee F-CC3 (Source: adapted from Akimowicz et al., 2020).

Transferring a Familial Patrimony

For participating heirs, taking over the family farm is most often an obvious choice. Among the family farm heirs, more than 3/4 had taken over the family farm. There is a clear attachment to the farm and farmland, which constitutes a heritage to preserve and pass on. In this regard, farmers' families remain an active support system; while the older generation often maintains some sort of involvement on the farm, especially during work peaks, siblings entitled to inherit land may facilitate farmland access. Interestingly, with the lengthening of life expectancy and the difficulty to plan retirement pensions, one interviewee mentioned considering passing on the farm directly to the grandchildren. This perspective is supported by the frequent mention of absentee owners who rent farmland, a potential impediment for farmers who seek to acquire land and an opportunity for those who provide custom farm work.

> *"It's not a land attachment; it's an attachment to a family heritage. [. . .] There's a pond. We go to the pond shore and it feels like being in the middle of Gers. Have you seen the house as well? I'm 7th generation. Of course, there's a visceral attachment." F-CC1*

However, taking over the family farm is more than a commitment to preserve a family heritage. Growing up on a farm is also perceived by all interviewees as a unique experience that has led them to love farming and motivated them to start farming. Older farmers often explained that they let their children choose their own careers; while these farmers expect to contribute financially to the costs of higher education, they also favor the early on-farm involvement of their children. Only 1/10 interviewees openly shared their reluctance to pass on the family farm to their heirs due to the harshness of a farmer's life. In line with this perspective, 6 new farmers mentioned the desire to farm for the quality of life from which they and their family would benefit, while acknowledging the difficulties.

> *"They grew up with it, so it's part of their lives. [. . .] Neither of them is able to predict the future and say yes, I want to live in F. [. . .] We adopted a five-year-old, so he may be the most potential for the farm but he has to learn discipline first". C-CC2*

In addition to family heritage and the passion for agriculture, transferring the family farm to the next generation also includes passing on situated/place-based knowledge. While technical knowledge related to dealing with soil and climate conditions were most commonly cited, interviewees also mentioned some sort of social knowledge related to their embeddedness in a community. For instance, the ability to access land appears to be related to farmers' inclusion in local networks where opportunities to acquire farmland are shared. In France, SAFER, a private organization with a public mission to regulate farmland transfers, seems to contribute to the transparency of the farmland market; however, almost all the French farmers interviewed complained about the increased competition for land access among farmers resulting from SAFER action while 5 openly criticized SAFER's decisions in strongly urban-influenced areas when farmland is left to developers. Additionally, the importance of these networks is highlighted by the commitment of almost 1/4 of interviewees to political or farmers union responsibilities.

> *"I'm not a farmer's daughter [. . .]. I'm not a local [. . .] and one does not trust someone that just settled in. [. . .] On the other hand, the municipal council of B. helped me a lot [. . .] since they were looking for new farmers and a municipal councillor came to me." F-A2*

Balancing Quality of Life and Sacrifices

Although all the interviewees mentioned the difficulties of a farmer's life, most interviewees also shared that they enjoy their profession since they do something they choose to do and which they like doing. For those, there is nothing comparable to getting up early in the morning or coming home late at night for a job they have always wanted to do. However, all the interviewees also recognized their profession is a true commitment; work hours are more than regulated employees' working time, salary barely reaches minimum wages at least during the first years and most depend on their spouse's income, vacations are rare (only 1 to 2 weeks during off-peak work periods), and their work is commonly criticized by non-farmers. Regardless, for them, farming is a passion, a part of their identity. In this regard, farm intergenerational transfer is often a critical time for modifying farming systems and adapting it to the new farmers' perspectives.

> *"Like she [his daughter] has her bakery and J. [his son] is gonna do the goats, and he's actually gonna start bee keeping. So, one thing I see, if there is a business to be added to the farm without taking anymore land. . . You know what I mean?" C-A4*

They also recognized that they have to make permanent sacrifices to maintain the viability of their farm through continuous investment. Although the priority is to invest so as to improve economic results, 15 interviewees mentioned that investment can also simplify farm work (especially cash-croppers who seek a faster turnaround for their large holdings), which they will consider when they can afford it, given the positive impacts on health and family life. Inheriting the family farm is an additional constraint that requires the maintenance of the family property. Only F-H6, who converted to permaculture, openly opposed this perspective; she considers that her main task as a farmer is to maintain soil health through her own hand labor, rather than through the use of heavy machinery. To some extent, F-A2, who mentioned that soil health is a question of organic matter, had a relatively close perspective.

> *"It [quality of life] is important. Since I've been farming, I've seen that health is fragile. I've tried not to damage it too much. [. . .] Quality of life is important because if I'm sick, I cannot work. [. . .] I've changed; I've aged a little; I feel exhausted. Working outside, it damages health a bit." F-H5*

Farming constraints are exacerbated in peri-urban areas. The proximity to non-farming residents, who may complain about noise and odors, can complicate farm management activities. Consequently, most interviewees shared that they try to conduct mechanized tasks, such as tilling, harvesting, and spreading manure and pesticides, during times when this will not bother nearby non-farming residents. Traffic is another issue for interviewees who farm plots that must be accessed through municipal roads that are not designed for the movement of heavy machinery. A clear distinction exists among the three types of farmers interviewed: while the cash-croppers appeared to be the most affected by complaints about practices and the urban environment, the horticulture farmers where the only ones to complain about property trespassing. On their end, animal farmers stood somewhere in the middle; most of them rely on custom farm work for crop production, which both reduces their investment level and potential conflictual relationships.

> *"Farming last fall was bad. We were farming late at night. We are not looking to antagonize or looking at making the issue worse. But at the same time, we do what we have to do and we are always wondering if somebody is gonna call or say something." C-CC2*

Adapting to Uncertainties With Little Flexibility

For all interviewees (except F-V6 and her permaculture farming system that relies on less land), the initial investment is a financial burden that locks the farm on a path from which it is difficult to deviate. One can distinguish the case of farmers' heirs, who usually start with some land and farm equipment, from the case of new farmers, who have to invest in both land and equipment. This initial step is a major constraint for new farmers who commit most of their financial resources, which leaves them vulnerable to adverse events. In France, only cash-croppers sometimes invest in crop insurance (while crop insurance is commonly adopted in Canada) and, those who had, had criticized the damage evaluation criteria. New cash-croppers also rarely have the opportunity to store their first harvest due to cashflow constraints. For other farmers, the lack of insurance is barely compensated by fewer cashflow constraints due to less seasonal production.

> *"In any case, we have to invest regularly in order to renew the equipment at the end of its life. So, we don't have much choice. [. . .] Over these last few years, commodity prices have been really on the low end, and investments are all the more difficult." F-CC3*

Strong differences exist across farm types. On the one hand, cash-croppers invested with confidence seeking investment opportunities and still invest when necessary. They also invested without overly considering credit rates, especially when investment was land related. On the other hand, horticulture farmers are more cautious when investing and shared that they have more difficulties with banks in obtaining credit lines. However, horticulture farmers are also the most creative in accessing funding. For instance, C-V7 relied on community support via a sort of crowd funding to invest in a farm in exchange for opening the farm on the week-ends for community activities. F-A2 benefited from the support of the municipal council to access land next to her farm in exchange for maintenance. Last but not least, economic support from the rest of the family, especially partners, may also be key at this stage of the farm transfer for those with little equity.

> *"We've been married 26 years and he's always done that [working off the farm in winter]. And it's always given us the extras; like, it's given us our fifth wheel or bonus pool when we have one. If we needed a new washroom or dryer, the off-farm income would cover that, the extras." C-V1*

Institutional Lock-In

Overall, participants described a situation where new farmers, overall, face three difficulties when defining their agricultural projects: access to land, credit, and market. In peri-urban areas, access to land is conflictual due to strong competition among farmers and also with non-farming stakeholders. Participants who farm land in flood zones or in ecological reserves sounded more confident about the future viability of the farm. On the other hand, participants who farm land that is vulnerable to development are more cautious, especially those with smaller farms who rent land and can neither afford to lose plots nor buy any. On their end, larger landlords commonly shared that the sale of a piece of land for development may help overcome unforeseen adverse events or fund their retirement pension. While the mission of SAFER is well-recognized and solicited among participants, complaints were raised due to an increasing number of land-allocation decisions that did not meet their expectations as urban influences increase. Planning policies, such as Ontario's Greenbelt, are also raising concerns about potential changes.

> *"I've heard there's a lot of pressure from the development community on the [Provincial] Government to change [Ontario's Greenbelt border] and with the review I don't know if that's gonna … they say they are not gonna make it smaller but you never know." C-A1*

Access to credit is another issue for new farmers. Those farmers with capital-intensive farming systems appear more easily supported by banks and other economic stakeholders when investing. Both the experiences of F-H4, who grows tomatoes hydroponically in digitally-controlled greenhouses, had no major difficulty in accessing credit and land, and the experiences of F-CC4, who included intensive vegetable production on his farm as he had issues in accessing land because he had started cash-cropping on a smaller than average farm according to SAFER standards, tend to support this perspective. Despite sunk costs, access to credit seems more influenced by available collateral, especially land, than by the expected profitability of the farm operation. In this context, French cash-croppers seem to benefit from an additional advantage over smaller farmers due to the financial support of the Common Agricultural Policy, which, in this perspective, may be understood as a rent that pays for the investment.

> *"One has to fight. It is exhausting in the long run. One thinks of starting a business, a farm operation and they [bankers] are missing the point. They see figures, sit in their office. They never came to the farm. If there was a relationship, they would understand." F-V3*

Last but not least, market access also appears as a source of rigidity when starting a farm operation in peri-urban areas. All participants have developed activities that enable them to capture more added-value; while some explore niche markets (e.g., corn for popcorn, organic farming, seed farming), on-farm income diversification such as processing (e.g., ice-creams, soups) and agri-tourism (e.g., agricultural training, farm visits), others rely on off-farm incomes. One out of 10 shared that they are considering moving to less urban-influenced areas where investment and production costs are lower. Indeed, market prices are not sensitive to production conditions. While these *ad-hoc* solutions currently enable participants to cover their production costs, it is unclear whether the multiplication of similar farm projects and the integration of niche markets will guarantee that farmers can cover their production costs in the future.

> *"That's why we do farmers' markets. That's why I do my grass-fed beef […] All the things that we've added are for getting a better price for your product. So, like the grass-fed beef, you know, I can charge what a fancy butcher shop would charge, because it's very local." C-A3*

DISCUSSION

The results validate the three hypotheses that framed this research study. First, the high level of uncertainty surrounding the decision to start farming slows down the intergenerational transfer of farm operations in peri-urban areas. More specifically, the difficulty to generate a decent income, reimburse debts, and plan for retirement without selling farmland for development lengthens the career of current farmers and discourages new farmers to start farming. Moreover, a trend toward an assessment of farmers' solvability through the assessment of collateral rather than farm profitability seems to exacerbate this dynamic. In other words, the current unfair ability to access land, money, and market shape farmers' investment decisions. Second, farmers rely on beliefs that enable them to anticipate the future outcomes of present decisions in order to decide to take over or transfer farm operations. To begin farming is indeed a decision framed by past experiences and values that shape the entire life of new farmers. For them, farm projects are one part of a way of life that reflects their identity and impacts their mental health (Bondy and Cole, 2020); the restrictions that affect the implementation of farm projects may partly explain the shortage of agricultural vocations. Third, farmers are embedded in an institutional environment that may be more supportive of farm transfer through well-aligned regional and farmers' goals. More specifically, farm projects are framed by beliefs that tend to align, more or less, with the beliefs of organizations in charge of facilitating access to land, credit, and market: the better the alignment, the easier the process to take over a farm. A rigid institutional environment characterized by a poor alignment of farmers' and regional organizations' beliefs further slows the adaptation of food systems to changing territorial conditions.

There is thus a planning opportunity to design food systems that are more inclusive of new farmers' projects and agricultural systems (Macdonald et al., 2020; Hammelman et al., 2021).

These farm transmission dynamics appear to be slowed by an institutional framework where land access, credit access, and market access are tightly intertwined, and are prone to heterogeneous and unequal access given farm and farmers characteristics. In the French Toulouse InterSCoT, these three aspects of a farm project are controlled by a set of organizations that have long been involved in the governance of the farming sector-e.g., the SAFER, the Crédit Agricole, the supply chains, and the Agricultural Chamber (Akimowicz and Képhaliacos, 2018). Their proximity has resulted in the emergence of habits, materialized through, for instance, a farm viability evaluation tool that poorly grasps the complexity of farm systems based on non-agricultural income diversification strategies, which are contested nowadays. In Ontario's Greenbelt, the absence of any SAFER-like agency has been counter-balanced by zoning policies and regulations, which have sometimes also contributed to slowing farm structural adjustment (Akimowicz et al., 2016). The emergence of new public and collective stakeholders may contribute to unlocking this land-money-market nexus that currently contributes to maintaining the dominant model of capital-intensive agriculture described by Allaire and Boyer (1995). This dominant model, which has thrived under the above-mentioned nexus (**Figure 2** below), appears to foster unequal access to land, money, and market. These results align well, for instance, with Erwin's et al. (Erwin et al., 2021) findings that the utilization of the intersectionality framework helps to understand power relationships that frame the agricultural sector. In this perspective, results first confirm that traditional factors of intersectionality, such as gender and age, foster prejudice when assessing the credibility of new farmers' farm projects. Further, farmers tend to be discriminated against based on the characteristics of their farm project, such as the farm type of their agricultural project, available equity, land ownership, and worldviews framing agricultural practices, as well as social characteristics such as whether one has inherited a farm operation. These factors, which operate as exclusionary characteristics that prevent some farm projects to take shape, may be interpreted as factors of an agricultural intersectionality (Crenshaw, 1991). The intervention of community stakeholders-e.g., public agencies, collective organizations such as cooperatives, and associations-may contribute to alleviating farmers' access constraints to land, money, and market, and may foster the design of more inclusive food systems. Interestingly, farmers can play an active role in designing this supportive institutional environment (Ngo and Brklacich, 2014).

Finally, the theoretical framework, based on institutional economics, used in this research provides a relevant framework to analyze cognitive phenomena that frame economic decisions. In this research, we focused on the role of beliefs, which provide a background knowledge that farmers can use to navigate the uncertainties of their environment. This choice was adapted to the peri-urban farming context where land access issues resulting from landlords' decisions to rent out or sell farmland threatens farming, while political decision-making may result in regulation revisions that can impact farming practices. This social uncertainty, resulting from social actors' interactions, opens the door for a deeper investigation of psychological phenomena in economic analyses, such as Keynes' Animal Spirits (Dostaller and Maris, 2009), which may shed light on the rationality that underlies the practices implemented by the nexus stakeholders.

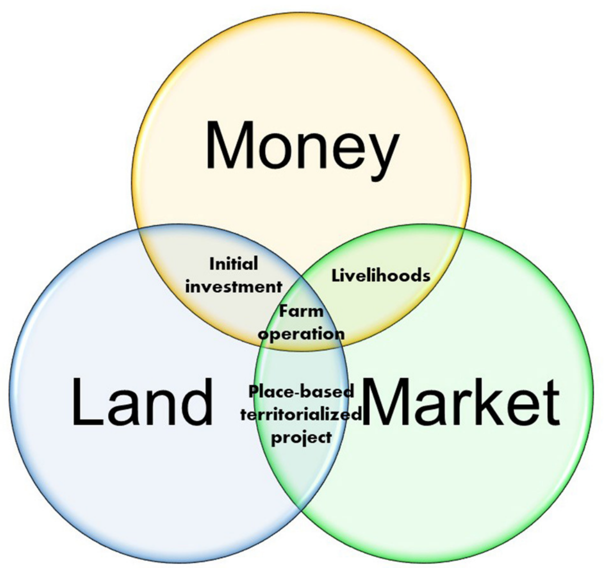

FIGURE 2 | The money-land-market nexus locking-in the agricultural sector.

This research is based on 41 interviews selected to represent the diversity of situations when making structural investments. Three types of farm operations were selected, namely cash-crop, animal, and horticulture farms. Future investigations could pay more attention to other farm types that tend to develop in peri-urban areas, such as horse farms and bee yards. These results could also be refined by the adoption of a more dynamic view that would better take into account innovation and its impact on profits (Menna and Walsh, 2020). The analysis of farm intergenerational transfers may also benefit from deeper attention to collective legal statuses, especially corporate statuses (Purseigle et al., 2017). Indeed, the consolidation of large individually-owned farm operations is problematic when passing on farm operations due to high initial investment costs for new farmers. In France, this often leads SAFER to dismantle large holdings and arbitrate between farmers who are interested in acquiring land, which, as we have seen, can lead to misunderstandings between stakeholders. On the other hand, collective legal statuses may be supportive of farm transfer processes through shared ownership of farm operations. However, these legal statuses may require additional regulations since farm share transactions are currently poorly regulated, which may result in land grabbing risks and a loss of sovereignty on land use issues. This also raises the issue of the involvement of other actors in land access and farm transmission, such as public agencies, collective organizations such as cooperatives, and associations. In this regard, Canadian land trusts (Bunce and Aslam, 2016) and the French association Terre de Liens (Lombard and Baysse-Lainé, 2019) are examples of initiatives that may rejuvenate farm transmission dynamics.

CONCLUSION

The results show that farmers rely on internalized beliefs to navigate the uncertainties of their production; these beliefs contribute to planning their investment decisions, especially when starting farming. The results highlight the positive role of the institutional context when farmers' beliefs and the beliefs shaping their institutional environment, including their family, their professional community, and the surrounding stakeholders such as agricultural organizations, public agencies, and residents of the area, are well-aligned and result in a shared vision of the future in line with Cadieux et al. (2013). The specialization of farm operations has led to the emergence of a variety of agricultural visions, where encounters may overlap to some extent and result in conflicts. While most farmers advocate for the coexistence of diverse agricultural visions, the existence of an institutional environment that regulates access to land, money, and market in favor of the dominant capital-intensive model of agriculture, described by Allaire and Boyer (1995), is detrimental for those new farmers who attempt to design farming systems that match their values. In this research, new farmers are generally driven by an ambition to design alternative, more sustainable farm projects, which do not align necessarily with the dominant capital-intensive farming model; these farmers share the feeling of being excluded. Meeting a certain quality of life requirement is a common issue for participants who highlighted the need for social relationships, be they with other farmers, or with consumers and tourists coming to the farm.

Farm intergenerational transfer and the lack of new farmers ready to take over farm operations are not only economic issues but also social issues. The inequalities framing the farm start process are detrimental to the renewal of farmers, especially those with more sustainable farm projects that can foster healthier societies (Duru and Le Bras, 2020). The intersectional barriers that have been highlighted in this research deserve more attention. In particular, the private ownership of farm assets restricts the farm start process and impacts, as well, collective organizations such as cooperatives where equipment is shared (e.g., French CUMA). There is a political space for the implementation of transformative solutions stemming from participatory processes (Cadieux et al., 2013; Calvário and Kallis, 2017; Anderson et al., 2020). The leadership of local stakeholders-public agencies, collective organizations such as cooperatives, and citizen associations-is key for the design of more flexible governance. Their initiatives to facilitate farmers' access to land, money, and markets can contribute to improving farmers' autonomous decision-making, increase their ability to embrace the future, and foster the transition toward more inclusive food systems respectful of the global health.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors according to the ethics requirements applicable to the MARSUPIA Project.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Guelph Research Ethics Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MA led the research and authored the manuscript. KL, CK, and HC supervised the research and co-authored the article. All authors contributed to the article and approved the submitted version.

FUNDING

The MARSUPIA project was funded by the European Commission' Research Executive Agency (Grant Marie Curie – IOF 622830). We are grateful for the financial support granted by IEP Toulouse.

ACKNOWLEDGMENTS

The authors like to thank all the participants, and especially the interviewees, for their time and commitment.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

APPENDIX

Appendix 1 | Classification of factors used for the mental modeling activities.

Category	Factors
Economic	Availability of labor, availability of land, commodity/produce prices, credit rating, custom farm work, farm income, farm size, food safety and traceability, input prices, interest rates, investment cost, land access uncertainty, land renting contracts, liquidity available, local planning documents, off-farm income, price volatility/uncertainty, share of rented land
Social	Family members in agriculture, family size, farm owner age, intergenerational transfer of the farm, land attachment, quality of life, support from local community
Environmental	Climate, perception of climate change, soil type, urbanization
Technical	Drainage, farm type, on-farm value adding (e.g., processing, value adding), technical support, yields
Ontario's Greenbelt specific	Greenbelt, subsidies and Ag programs
Toulouse InterSCoT specific	CAP–first pillar, CAP–second pillar, Green Crown, irrigation, SAFER

Source: *Akimowicz et al. (2020)*.

frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 11 February 2022
doi: 10.3389/fsufs.2022.797383

Challenges and Sustainability Dynamics of Urban Agriculture in the Savannah Ecological Zone of Ghana: A Study of Bolgatanga Municipality

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OPEN ACCESS

Edited by:
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Reviewed by:
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University of Ghana, Ghana
Andrew Butt,
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Specialty section:
This article was submitted to Land, Livelihoods and Food Security, a section of the journal Frontiers in Sustainable Food Systems

Received: 18 October 2021
Accepted: 05 January 2022
Published: 11 February 2022

Citation:
Kuusaana ED, Ayurienga I, Eledi Kuusaana JA, Kidido JK and Abdulai IA (2022) Challenges and Sustainability Dynamics of Urban Agriculture in the Savannah Ecological Zone of Ghana: A Study of Bolgatanga Municipality. Front. Sustain. Food Syst. 6:797383. doi: 10.3389/fsufs.2022.797383

Increasingly, urban land use planning is getting more complex as limited urban spaces are continuously allocated among diverse land uses. From previous urban food system studies in Ghana, it has become apparent that large portions of urban land parcels are unsustainably converted to urban infrastructure. Hence, the sustainability of the food system is significantly threatened by inefficient spatial and infrastructure planning mechanisms that fail to protect urban agricultural zones. Of critical concern is the fact that agricultural land use allocations on planning schemes are easily converted to residential uses under demand driven expropriations. In that respect, this study was undertaken in the Bolgatanga Township to understand how urban dwellers sustain urban agricultural practices within the city. Using field surveys, key informant interviews and GIS mapping, the study found that, the total sizes of agricultural lands have decreased significantly since 1996 as urban Bolgatanga began sprawling from the inner city through to the urban fringes. In the process, agricultural lands have decreased in terms of both size and contiguity at the household level, compelling farmers to create multiple segregated farmlands within residential neighborhoods in the form of compound farms or fenced urban gardens. Hence, some urban farmers continue to rely on undeveloped residential plots and open public spaces in the inner city for production, but they easily lose these as developments in residential neighborhoods intensifies. From the physical development pattern of the city, we conclude that urbanization in agrarian cities will exacerbate the challenges of food production if relevant policy interventions are unavailable to provide for and protect agricultural lands. The study recommends that, food-inclusive planning schemes should be the basis of future physical plans to guide land uses in the peri-urban and rural zones. This will require both political will and community consensus building on the necessity to preserve urban agricultural space to sustain food supply.

Keywords: urban agriculture, urban space, land scarcity, food systems, urban food systems, Bolgatanga

INTRODUCTION

Urban agriculture occupies a special economic niche and offers food and livelihood opportunities for a section of urban population especially urban poor. Importantly, it is critical to ensuring urban food security and attainment of the sustainable development goals; zero hunger (SDG 2) and sustainable cities and communities (SDG 11). However, the sustainability of this enterprise faces serious threat from rapid urbanization, spatial and regulatory lapses in urban planning and development process. According to Rakodi (1997:1) "it is almost a truism that the planet's future is an urban one, and that, the largest and fastest growing cities are primarily in developing countries." Already the effects of rapid urbanization in developing countries are manifesting in urban sprawl, socio-economic inequities, environmental degradation, and institutional challenges for urban residents and local authorities (Owusu and Lawrence, 2010; Anarfi et al., 2020). Even though governments have tried to tackle some of these emerging challenges through institutional and legislative reforms, very little has been achieved due to implementation bottlenecks. Coulibaly and Li (2020) and Aguilar and Ward (2003) indicated that rapid urban population growth has led not only to an increasing demand for urban land for residential purposes, but also for other urban uses.

In many parts of the world, there is spatial expansion, intensification and peripheralization of urban land (see Aberra and King, 2005; Kuusaana and Eledi, 2014, 2015a; Follmann et al., 2021). Urban areas in Africa have seen heterogeneous populations engaging in different land uses within its peri-urban enclaves (see Thuo, 2010). Urban areas have transformed greatly into non-agricultural uses due to urban population growth dynamics (see Chirisa, 2010; Coulibaly and Li, 2020). Food supply from the urban space faces potential collapse with attendant food security problems for urban households. For instance, Lyons et al. (2013), have noted that the growth in urban populations presents formidable challenges toward addressing potential food crisis that confront the world. They opined that in Australia for instance, there are growing concerns about sustainability of urban agricultural systems into the future and ability to continue to supply food to the growing population. They again noted that urban planners are strategically placed to contribute toward alleviating growing food security challenges through urban space creation for food production. Since there are concerns about environmental and socio-political limits to contemporary industrial food systems (Lyons et al., 2013), it is critical to project urban food production as a critical anchor to tackling global food security challenges.

Rapid urbanization has multiple impacts on urban land use as well as the livelihoods of peri-urban communities (Aberra and King, 2005; Mohammed et al., 2020). This is because it is inextricably intertwined with the rural fringes where urban growth encroaches on agricultural lands and the surrounding rural residents (Gantsho, 2008; Thuo, 2010; Coulibaly and Li, 2020; Mohammed et al., 2020). Thus, growth in urban population increases population densities within established urban and per-urban areas (Mandere et al., 2010). This means that urbanization transforms peri-urban settlements from simple patches of villages with rural lifestyles to a more complex, partly urban lifestyles (Edusah, 2008; Osumanu et al., 2018; Mohammed et al., 2020). A key challenge to the urbanization process is the rapid conversion of large amount of prime agricultural land in the urban periphery to urban housing, thereby creating a viable land market that escalates rural land prices (Owusu and Agyei, 2007; Gantsho, 2008; Osumanu et al., 2018; Akaateba, 2019; Czekajlo et al., 2021) and transforms them from hitherto gratuitous grants to highly commercialized transactions (see Kuusaana, 2016).

It is observed that the natural physical environment suffers greatly from peri-urban population growth (Chirisa, 2010; Mohammed et al., 2020). For instance, the extension of the urban corridors significantly reduces available productive land and encroaches upon important ecosystems (UNFPA, 2007). Peri-urbanization leads to farmland decline as rapid urban expansion consume peri-urban lands and creates productive land scarcity as non-farm activities increase land values (Abass et al., 2018). It breeds poverty among urban residents, triggers land fragmentation, creates unemployment and neighborhood conflicts, and disrupts traditional livelihoods (Abass et al., 2018; Abdulai et al., 2020). In the peri-urban area, the process of land use conversion from agricultural to residential, commercial, and industrial uses, goes hand in hand with transformations in the livelihoods of different groups—with the poorest often losing out (Tacoli, 2004). Whilst the wealthy can shed off rural attitudes in response to urban challenges, the poor in peri-urban areas are slow in doing so (CEDEP, 2005). It is worth noting that, urbanization does not only pose a constraint to urban poor living on urban fringes, but it may also create numerous opportunities as well. For instance, urbanization creates opportunities in wage employment, trade diversity, and provides them with improved access to urban services and infrastructure (Aberra and King, 2005; United Nations, 2019) if its dynamics are properly management. On the contrary, it can also result in unemployment, poor social amenities, escalation of crime, loss of social safety nets among others. As infrastructure and social amenities in urban areas improve, these areas are consequently transformed into complex monetised urban economies and integrated into the urban enclave (Aberra and King, 2005; Adu-Ampong et al., 2008). Consequently, urban land use changes from agricultural to non-agricultural uses can result in livelihood diversification across the different social classes.

In Ghana, Metropolitan, Municipal and District Assemblies (MMDAs) are tasked to spearhead urban development planning and to address urban challenges relating to urban and peri-urban livelihoods, governance, social service, infrastructure development, poverty alleviation, minimizing environmental degradation and urban security (see Annez et al., 2010; UN-Habitat, 2010). However, the lack of funding creates difficulties for the MMDAs in executing this mandate (Hackman et al., 2021). Though there have been numerous geographical studies on rural-urban linkages, particularly effects of urbanization on rural socio-economic and ecological systems (Aguilar and Ward, 2003; Tacoli, 2004; Aberra and King, 2005; Adu-Ampong et al., 2008; Kuusaana and Eledi, 2014, 2015a; Coulibaly and Li, 2020) few studies have examined the household level impacts of urbanization and how urban farmers sustain agricultural practices amid growing land scarcity. In addition, previous studies have laid emphases on uncontrolled urbanization and its livelihood implications (Aberra and King, 2005; Adu-Ampong et al., 2008; Appiah et al., 2014), its concerns for food systems (Kuusaana and Eledi, 2014) and food security (Bonye et al., 2021), determinants of peri-urbanization and land use change patterns in peri-urban Ghana (Appiah et al., 2014; Fuseini et al., 2017; Kleemann et al., 2017; Abdulai et al., 2021). However, few studies have explored the sustainability dynamics of urban agriculture in the wake of rapid urban expansions and population growth trajectories in the Bolgatanga area of the savannah ecological zone of Ghana. Even though Tacoli (2004) has emphasized that urbanization leads to the transformation of livelihoods among different groups, agricultural, residential, and commercial land uses continue to co-exist in many cities of developing countries. However, the dearth of holistic studies on how the peri-urban households cope with the growing land scarcity and underlining sustainability challenges impede sound appreciation of urban agriculture and food supply discourse, and the opportunities that urbanization presents.

As urbanization increases pressure on urban land, water, and labor supply systems (see Thebo et al., 2014; Zoomers et al., 2017), it is important to integrate urban and peri-urban agriculture into urban land use planning (Kleemann et al., 2017; Bonye et al., 2020; Nicholls et al., 2020). It is expected that to be able to keep urban and peri-urban agricultural lands consistently relevant, it is imperative to properly understand how to integrate them into urban land use planning (Bates et al., 2014; Cortinovis and Geneletti, 2018). This will prevent urban farmers from continuing to operate informally (Orsini et al., 2020) and on unauthorized public lands (see Kuusaana and Eledi, 2015a).

Agricultural activities in urban areas in Africa have been affected resulting in output reduction, reduction in farm size and farm output losses due to increasing land use changes emanating from city's outward expansion and the peripheralization of agriculture (see similar studies are Drechsel and Dongus, 2010 in Tanzania; Vermeiren et al., 2013 in Uganda). The Bolgatanga Municipality (in Ghana) is used as a case study because urban peasants have sustained urban agriculture within the Town notwithstanding the competition with non-agricultural land uses and the urban development complexities. Since such indigenous urban-poor peasants are recognized as a special category of vulnerable groups (Maxwell et al., 2000), it is imperative to empirically understand the urban characterization of Bolgatanga and how land use changes are affecting peri-urban peasants' access to land and identify sustainable options for urban agricultural activities. The study also addresses the question of how urban farmers respond to urban growth dynamics amidst existing spatial challenges (see Follmann et al., 2021). Hence, this study combines both the spatial dynamics and the multiple complexities and interlinkages of urban agriculture to understand the transformations and responses of urban and peri-urban farmers under urban growth. These discussions are relevant for both planning practice and policy formulation that are anchored on consultative approaches. Integrating urban agriculture into sustainable urban development framework is critical to the attainment of sustainable development goals especially considering the livelihood connections of the urban poor to urban agriculture economy (see Follmann et al., 2021).

The next section of the paper reviews literature on the nexus between urban farmer population dynamics and land use to establish the theoretical linkages of urbanization and its impacts on the urban population especially urban food systems, land use change and food production under customary land tenure settings. Section discusses the study area location, land tenure system and urban growth patterns. This is followed by the research methodology—materials and methods. Data presentation, analysis and discussions are contained in section five, while conclusion and recommendations constitute section six.

MULTIPLE IMPACTS OF PERI-URBANIZATION: FOOD SYSTEMS, FOOD PRODUCTION AND LAND USE CHANGE

For most of Africa, peri-urbanization is characterized as unprecedented informal urbanization of poverty (Kombe, 2005; Atu et al., 2013) through out-migration of urban inhabitants to escape from urban policies harassment (Lupala, 2002). Angel et al. (2005) indicates that peri-urbanization in Africa leads mainly to horizontal growth of towns and encroachment on farmlands and rural communities. While it is not accompanied by tangible economic growth and buoyant secondary activities as recorded in many African cities, peri-urbanization substitutes agricultural land uses (Spence et al., 2009). Global urban expansion revealed that cities in developing countries have three times the population density of cities in developed countries (see Angel et al., 2005; United Nations, 2019). Today, the largest and fastest-growing cities in the world are in southern countries i.e., Africa, Asia, Central and South America. Despite the general decline in population growth rates since the mid-1980s, Africa remains the world's fastest-growing region (Kaba, 2020) with expectation that its built-up area will triple, while the population doubles (see Angel et al., 2005; Kaba, 2020; Zimmer et al., 2020). Even in African cities with smaller densities, urban sprawl remains a major concern for urban residents and local governments (Otoo et al., 2006; Yankson, 2006) because of unique urban form, historical growth patterns and customary tenure systems of landholding (see Akaateba, 2019; Akaateba et al., 2021). For many smaller cities, migration remains a major source of population growth (Olima, 2003).

In Ghana, urban population growth rate of about 4.3% has outstripped the overall national population growth rate of about 2.1% (Ghana Statistical Service, 2002; 2021; UNFPA, 2007). This rapid rate of urbanization in Ghana represents a major redistribution of population, with significant implications for national development. The share of urban population is also higher in Ghana than in the West African region, where in 2010 about 42% of the West African population lived in urban areas (OECD, 2018).

Even though urban agriculture has not received significant policy attention in Ghana and in many developing countries, the practice flourishes in the developed countries where several conditions are favorable (Sroka and Pölling, 2015) as an employer and a source of food. De Bon et al. (2010) argue that urban agriculture could provide employment opportunities for the teaming unemployed youth in urban areas. Urban agriculture also has the potential to provide city markets with fresh fruits and vegetables, reduce the urban waste, as well as improve urban biodiversity (Orsini et al., 2020). Mariwah and Drangert (2011) have earlier argued that urban agriculture provides opportunity for the use of urban household waste such human excreta to improve crop yield and enhance food security among urban households and the larger city. The importance of urban agriculture therefore makes it imperative for planning authorities to consider it as a planning problem in urban planning schemes in Ghana and in similar contexts across the sub-region.

Peri-urban land is of capital importance in modern societies because it pivots all the dynamics of societal transformations (see Follmann et al., 2021). Urban expansion and the competition for land may also result in changes in land use, ownership, property rights regime, and land tenure (Wehrmann, 2008). Thus, peri-urban areas are the center of almost all formal and informal developments such as new urban expansion and decline of agricultural lands and rural employment opportunities (Payne, 1997; Allen, 2003; Lerise et al., 2004). Land use changes are foremost among changes occurring in the peripheral cities (Tacoli, 2004). Furthermore, Owusu (2008) observed that the process of peri-urbanization has successively changed the land use patterns in the peri-urban areas in Ghana. According to Appiah et al. (2014) the decision to convert land from agricultural uses to residential and commercial uses are driven by many [f]actors, including social and economic. Lambin et al. (2003) reported that land use changes are primarily influenced by changes in demography, policies, economic and political or at times a combination of these factors. Webster and Muller (2002) stresses on the economic rationality of peri-urban landowners as the key driver of peri-urbanization. Accordingly, higher economic gains from land conversion and transformation to other non-agricultural uses, motivate landowners to opt for the higher future returns on their land (Irwin and Geoghegan, 2001) and may speculate on the land (Satterthwaite et al., 2010). This incentive makes some customary landholders to alter the available land use plans to create non-existent "sellable" spaces for urban infrastructure (Adriana, 2003; Yeboah and Shaw, 2013). For instance, in the stool land areas in Ghana, the decision to convert agricultural land to non-agricultural uses in the peri-urban enclaves are influenced largely by economic incentives (see Kasanga et al., 1996; Kidido and Bugri, 2020; Kidido, 2021) and executed by chiefs and other traditional local actors. The changing land use patterns, to a large extent, have significant consequences on peri-urban land use decisions (Kombe, 2005; Dutta, 2012; Appiah et al., 2014), and deepens informal land tenure struggles (Haller, 2014; Cobbinah et al., 2015; Schmidt et al., 2015).

The need to produce adequate food to feed the rising regional populations makes the issue of food production within the urban space a crucial matter. Shields (2013: p. 6) cites two main forces which accompany the issue of urbanization: increase in the population on a concentrated space and the resultant decrease in the cultivable land available. This is inevitable to some extent, as civilisations have thrived in areas with high soil fertility as well as the availability of freshwater resources (Satterthwaite et al., 2010). The FAO (2011) believes that sustainable intensification is the best way to produce enough food to feed urban dwellers. For example, according to Robineau and Dugu (2018) farmers adapt farmland intensification practices to utilize diminished farmlands and to compensate for their losses. While the issue of boosting food production remains critical, there also appear to be some concerns about the environmental impact of agriculture resulting from intensification due to the usage of chemical fertilizers, pesticides as well as irrigation technologies (Shields, 2013: p. 6; Pinstrup-Andersen and Pandya-Lorch, 1994). However, the reverse is also problematic in which case urban industrial activities could pollute the soil and water, thus making urban agricultural produce unsafe for consumption. Also, urban flooding can pollute water sources and urban farmlands (McLees, 2011). The FAO (2011) advocates for a strong connection between rural and urban areas to ensure adequate food production by their combined agricultural practices (see also Bricas et al., 2003).

STUDY AREA DESCRIPTION—LOCATION, LAND TENURE SYSTEMS AND URBAN GROWTH

Location and Land Tenure System

The study was undertaken in the Bolgatanga Township within the Bolgatanga Municipality of the Upper East Region of Ghana. The Upper East Region is in the north-eastern corner of Ghana with a total landmass of approximately 8,842 square kilometers representing 3.7% of the total land mass of the country. Bolgatanga is the capital city of the Upper East Region, and it is located within the Bolgatanga Municipality. The Municipality was created in 2004 under the Legislative Instrument (L.I.) 1797 and is located at the heart of the Region. The Bolgatanga Municipality has a total landmass of about 444 square kilometers. The Bolgatanga Township is a fast-urbanizing city with increasing urban share of the Upper East Region's population in 1984 which stood at 32,495, the year 2000 was at 49162, 2010 was at 65,549, and the estimated population in 2016 was at 77,768 and to 156,678 in 2018 as projected (Ghana Statistical Service, 2010; 2014a). The 2010 Population and Housing Census subsequently recorded a population of 131,550 people in the Bolgatanga Municipality with a total of 65,549 representing 49.8% of the population living in urban areas (Ghana Statistical Service, 2012). This places the Municipal urbanized share at 49.8% above the regional urbanized share of 21% but slightly below the national average of 50.9%. The Bolgatanga Municipality has a population density of 302 persons per km^2, which is higher than the national average of 103 people/km^2 (Ghana Statistical Service, 2014a). One of the reasons for the high population density is the high fertility rate of 4.7 and immigration from deprived districts across the region. Apart from these, the peaceful environment characterizing the Bolgatanga Municipality coupled with its relatively endowed natural resources, especially at its periphery, as well as its commerce-oriented economy has acted as a trigger for migrants from Bawku because of the chieftaincy and related conflicts (Ampofo et al., 2015). **Figure 1** is used to indicate the geographical location of Bolgatanga as the study area and situated within the regional contextualization of the Upper East Region.

Like in many parts of Africa, land is controlled under the customary system which is governed by well-intentioned social and cultural rules, laws, and obligations meant to grant equal access to families within groups with common interest in land (Kasanga, 1995; Yaro, 2010). In Ghana, approximately 80% of the lands are controlled by chiefs, family heads, earth priests and individuals, while the rest are held in trust by the state through compulsory acquisition (Gyapong, 2021). It is, however, crucial to point out that the Tendamba (loosely translated as Landowners) control lands in northern Ghana, while lands in the south are largely controlled by stools and chiefs (Kasanga, 1995). Land owning groups in Upper East Region includes the Tendamba, Chiefs, families, individuals, and government (ISSER, 2007). In the Bolgatanga Municipality, the Tendamba are the highest authority as far as land is concerned. The Tendaana functions as the administrator of the land and the allodial interests over the land reside in him (Kasanga and Kotey, 2001). Besides the Tendamba, other allodial rights over land are vested in various families within the Municipality. Members of these families therefore enjoy the right to use the land indefinitely.

Chiefs enjoy greater public recognition because of their social and political responsibilities to the community, however, they have limited authority over land in the Municipality (Rattray, 1929). Natives of the area are said to possess customary freehold or usufructuary rights to land (ISSER, 2007). Although this may just be the right to use the land, the period could in fact be indefinite since there are no conditions attached to the holding of such land. Non-indigenes who possess this title are also not allowed to sell any part of the land in their possession. It is believed the Tendamba were given the land by God. However, like in other parts of the country, rapid

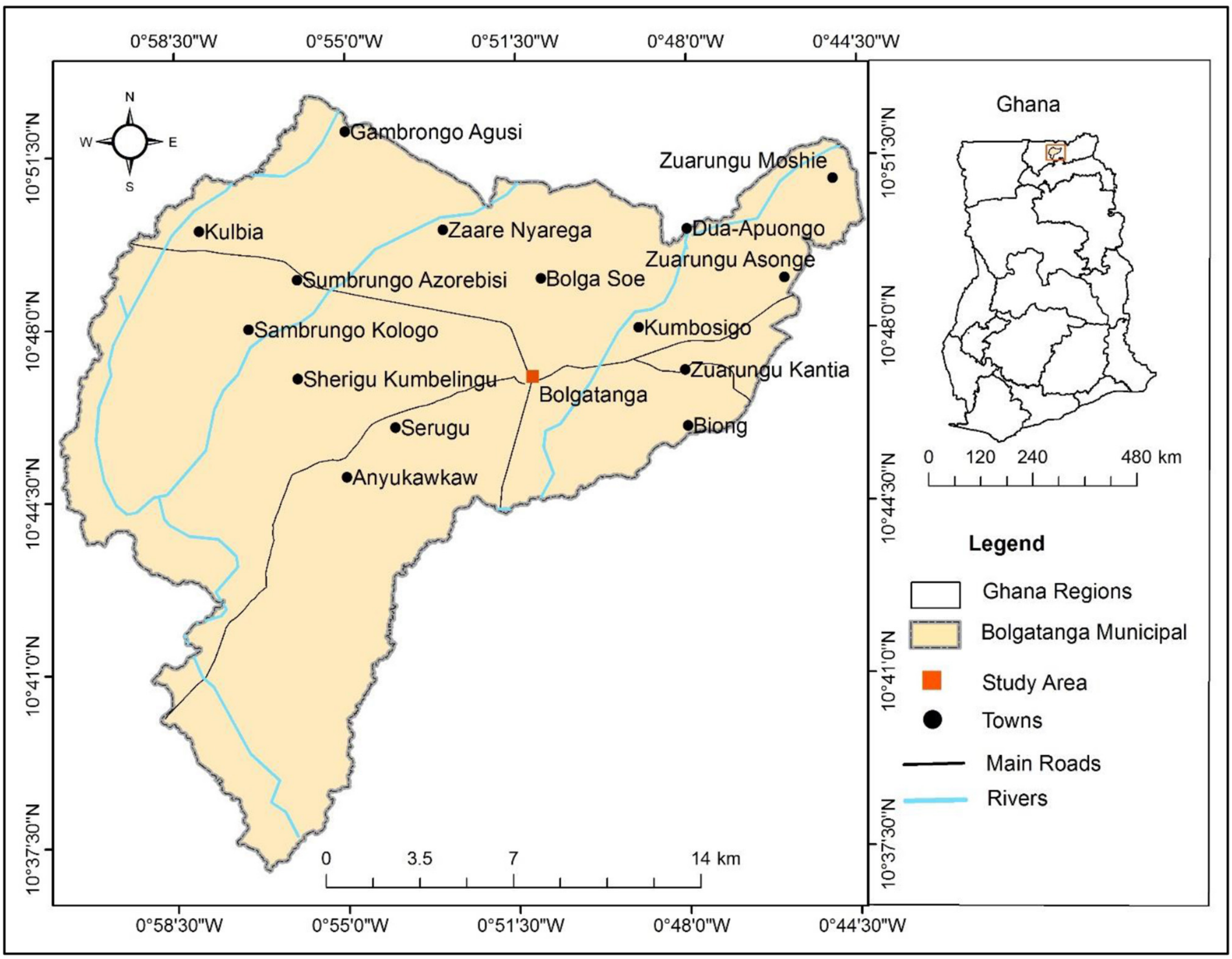

FIGURE 1 | Map of Bolgatanga municipality of the Upper East region of Ghana.

urbanization, land commoditisation and, competition between agriculture and residential uses are occasioning gradual changes in the customary land tenure arrangements and allocation dynamics. These emerging changes turn to promote haphazard developments in the peri-urban areas (Yaro, 2010) which undermine sound physical planning that delivers sustainability and resilience communities.

Urban Growth Pattern in Bolgatanga

Description

Urban growth in Bolgatanga has been quite slow but predominantly along major road infrastructure networks. The city has three major roads, which define the axis of growth and development. These roads connect to divide the city into three main quarters—the old residential area, government residential area and central built-up area. These roads have significantly contributed to the morphological structure of the city (see Briggs and Mwamfupe, 2000). The old residential quarters exhibit higher densities and compactness in comparison to the government residential areas. The government residential areas typically have low densities and less compactness because of the low level of developments. The central built-up area exhibits a very compact development of single-story multi-tenanted compound houses. The reason is that these areas house the first settlers and indigenous people who have culturally lived together to protect themselves against slavery which was a common practice during the period of the slave trade. The buildings in this area are predominantly constructed along or adjacent to the city's main roads and they serve mixed-use residential and commercial functions while those farther from the roads are dominated by residential developments. In the immediate periphery of the city, however, stretching over a large expanse of the Municipality, are dispersedly distributed local family compound houses. In these inner-city areas, urban agriculture exists in the form of fenced-backyard gardens. **Figure 2** is used to display the different compactness of residential developments from the Central Business District (CBD).

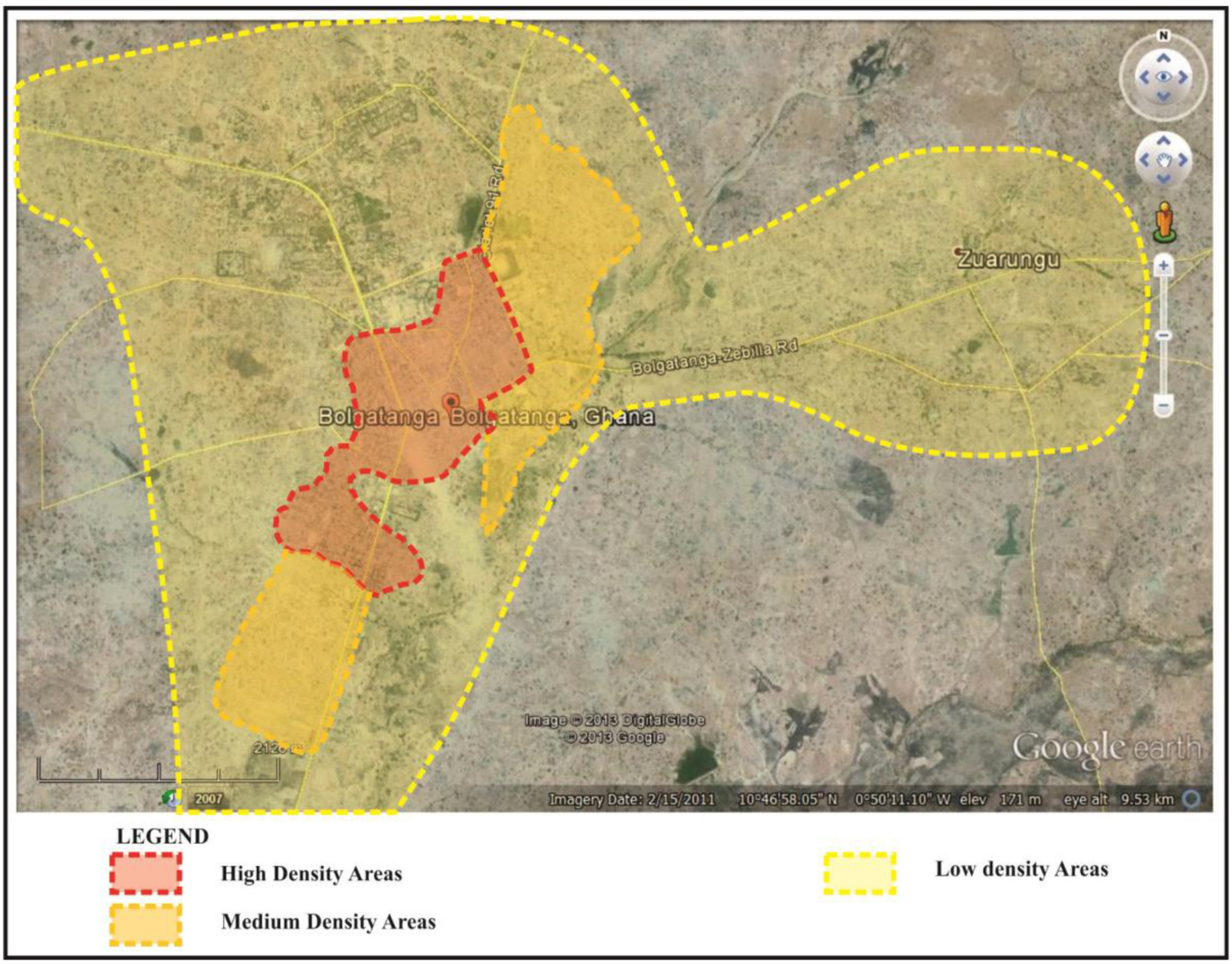

FIGURE 2 | General distribution of densities within Bolgatanga. Source: Google Earth image with illustrations.

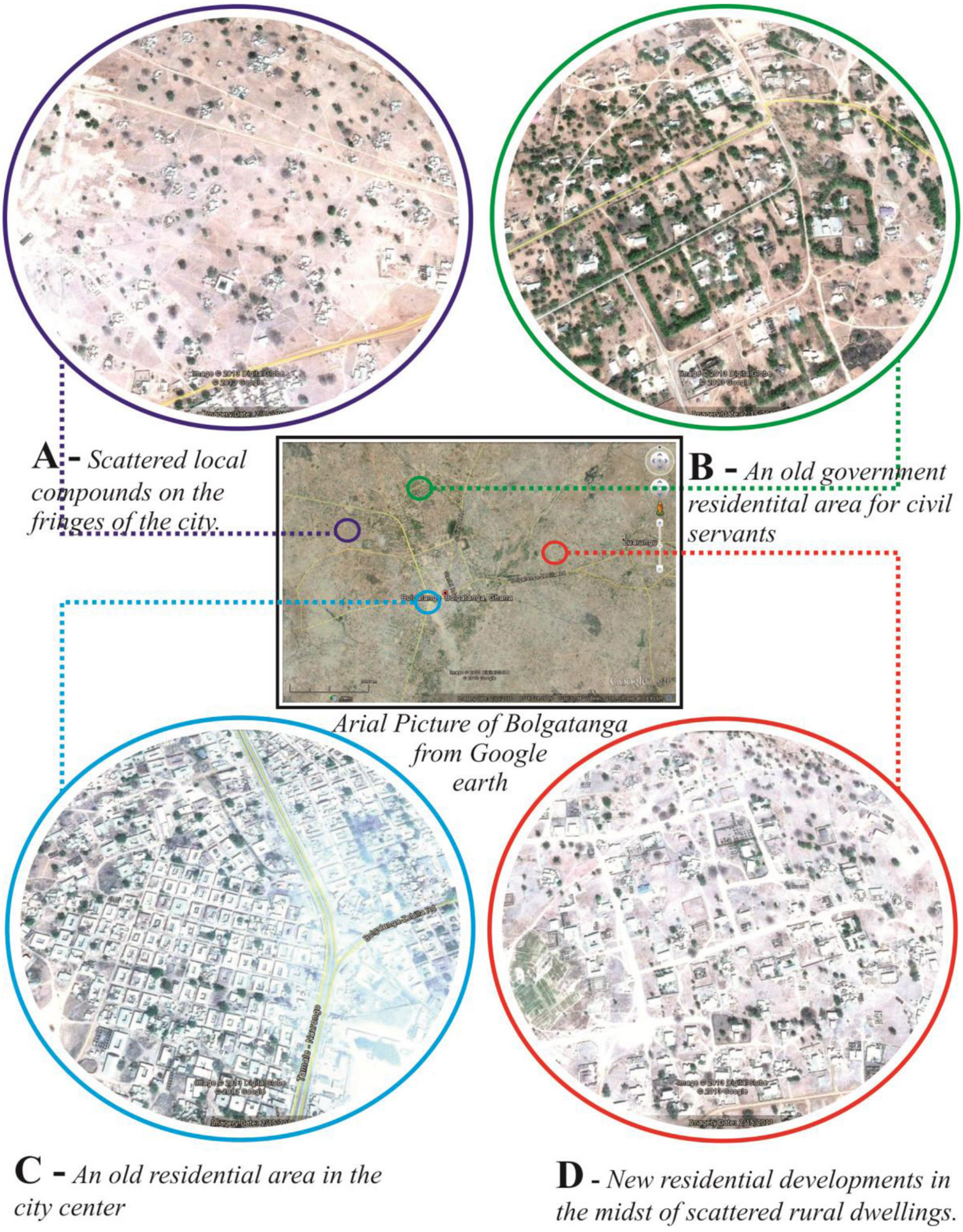

FIGURE 3 | Aerial view of Bolgatanga showing different levels of compactness of the city. **(A)** Scattered local compounds o the fringes of the city. **(B)** An old government residential area for civil servants. **(C)** An old residential area in the city center. **(D)** New residential development as in the midst of scattered rural dwellings. Source: Authors.

From the city center, running southward is the Bolgatanga-Tamale highway and eastward is the Bolgatanga-Bawku highway. These highways serve as growth poles which attract physical development activities of housing, social infrastructure, and commercial facilities. Growth of the city to the south and to the east of the city benefits from these highways as they are major entry points into the city. The Kumbosugu and Zuarungu communities have witnessed conspicuous infiltration of recent residential developments in a hitherto dispersed rural residential setting. Running from the city center northwest is the Bolgatanga-Navrongo-Paga highway, which connect beyond the national border to Ouagadougou (the capital city of Burkina-Faso). About 12 km along this road is the Sumbrungu community where the Bolgatanga Technical University is located. Even though the Bolgatanga Technical University is far from the city center, recent infrastructure developments in and around Sumbrungu has populated the area and has attracted several educational and recreational facilities in the area including the Akayet Hotel, the Millar Open University, and the Desert Pastures International School.

Bolgatanga has experienced new urban developments over the years, however, much of this development has been characterized by in-fill developments into the existing rural settlements. The growth trajectories of the city are markedly different from expansion patterns witnessed in other major towns in the northern Ghana like Tamale, Bawku, Wa and Yendi, where developments spread from the autochthonous inner cities toward the immediate hinterlands. It also appears that the city has not experienced as much influence from the pressure of non-natives coming into the area as compared to the other cities in northern Ghana. Unlike some other regional capitals located in the north of Ghana such as Tamale and Wa (see Kuusaana and Eledi, 2014, 2015a,b), where traditional settlements in the area appear to be compact and more distinct, typical villages in Bolgatanga have no distinct communal boundaries. They basically consist of scattered compounds widely interspersed over the vast landscape of the city. These growth patterns are depicted in **Figure 3**. Food production systems within the Bolgatanga growth pattern as elucidated above as well as the cropping seasons of the area are considered in the discussion section.

METHODOLOGY—MATERIALS AND METHODS

Qualitative Study Approach—Case Study, Interviews, and Descriptive Narratives

The study was conducted using the Bolgatanga Municipality (Upper East Region, Ghana) as a case study. Both explorative and descriptive narrative research approaches were used to address the research objectives. Qualitative data were collected through key stakeholder interviews at the Municipal level in two different periods. Initial fieldwork was undertaken from June 2013 to August 2013 and followed up with a second study from April 2017 to September 2017. Separate interviews were conducted with the Upper East regional and Bolgatanga Municipal planners, and the officers of the building inspectorate. The regional and municipal directors of the Ministry of Food and Agriculture (MoFA) were also interviewed. In addition, officials of the Public and Vested Land Management Division (PVMLD) and the Survey and Mapping Divisions (SMD) of the Lands Commission were interviewed. To understand how peri-urban peasant households continue to sustain agricultural land uses in residential areas, 40 household heads were surveyed. Some development plans (local plans) of the Bolgatanga Township were also studied as part of efforts to understand the spatial expansion dynamics using GIS mapping of the area. To vividly communicate some of the research findings, infographics were used. The summary of respondents for this study is put in **Table 1**.

Spatial Analyses Approach—Geographic Information Systems (GIS)

To understand the spatial dynamics and how agriculture has filtered through the spatial development trajectories, it was essential to carry out spatial temporal analysis. To obtain data for the GIS analyses, field data of the study areas were collected during various field visits to the study area. During these visits, a Garmin handheld GPS of accuracy between 0.3 and 3 m was used to record the GPS coordinates of the different Land Cover Land Use (LCLU) of the area. The dominant LCLU identified for the area are cultivated savannah, built area, closed trees, water, and bare land. **Table 2** shows the description of the different LCLU identified in the area. With this familiarity of the study area, Google Earth was further used to generate more LCLU of the area. The timeline tool in Google Earth helped to display previous images taken between 1986 and 2017. In all, 110 points were obtained.

Landsat satellite images covering the study area were downloaded from the USGS website Global Visualization Viewer

TABLE 1 | List of respondents for the study.

S/N	Designation of respondent	Frequency	Data required
1	Municipal directorate of agriculture	1	Data on agricultural productivity, practices, types of crops, and trends in land use changes.
2	Regional directorate of agriculture	1	Data on agricultural productivity, practices, types of crops, and trends in land use changes.
3	Municipal Physical Planning Unit	1	Planning practices, protection of agricultural lands, development plans, changes in land uses
4	Survey and mapping department	1	Boundaries, changes in land uses, preparation of cadastres
5	Public and vested land management division	1	Registration of lands, agriculture on public lands, nature of uses
6	Municipal building inspectorate	1	Enforcement of development controls, changes in land uses,
7	Household heads	40	Agricultural land use practices, yields, challenges, historical narratives
Total		46	

(http://glovis.usgs.gov/). All the images selected were acquired during the dry season with no clouds or less than 10% of clouds cover. Dry season images were used because they had no or less cloud cover compared to wet season images. However, it must be mentioned that the use of dry season images may lead to a misclassification between bare lands and farmlands as their spectral reflectance may look similar. Farmland delineation was undertaken by relying on visible characteristics of farming as defined by farm boundaries, crop residues and plowing/weeding activities. The characteristics of the images selected are shown in the **Table 2**. The Landsat 8 image was pre-processed by converting the raw DN values into radiance and from radiance to top-of-atmosphere reflectance using the relations:

$$\begin{aligned} &\text{TOA}_{\text{planetary reflectance}}\ \rho\lambda' \\ &\quad = \text{Band Specific Reflectance Multiplicative Band M}\rho \\ &\quad * \text{DN Values Qcal} \\ &\quad + \text{Band Specific Reflectance Additive Band}^{\cdot}\ A\rho \\ &\text{Correction factor for sun angle } \rho\lambda \\ &\quad = \frac{\text{TOA}_{\text{planetary reflectance}}\ \rho\lambda'}{\text{Cosine of local sun elevation angle}\ \cos(\theta)}\cdot \end{aligned}$$

The bands were then stacked, mosaicked, and clipped to the boundary of the Nasia watershed to obtain a complete coverage of the study area. The Landsat 7 ETM image was pre-processed using the Landsat 7 reflectance tool in Erdas Imagine. This converted the DN values of the image into reflectance. Using the haze reduction tool in Erdas Imagine we did atmospheric correction of the TM images. The images were then clipped to the boundary of the study area. The images were then clipped to the boundary of urban Bolgatanga, the study area. The boundary of urban Bolgatanga was obtained from the Bolgatanga Municipal Physical Planning Unit. The image classification was done using supervised image classification approach. To perform the supervised classification, the selected ground points were superimposed on the specific image. An Area of Interest (AOI) of 3 × 3-image pixel was then extracted to represent the LCLU at that point. For each LCLU, a minimum of 10 3 × 3-image samples was selected. A signature file was then created in ESRI ArcGIS. The MLC was then used with a parallelepiped decision rule to classify the images. Urban was determined by the human settlement with the high population (estimated population of 156,678 in 2018) and corresponding infrastructure (increase in the built-up area). Though with a low density as compared to other region capitals of Ghana, the population density of the Bolgatanga Township keeps increasing over the years. The peri-urban area was estimated at 15 km radius from the city center and considered communities that had a mix of both rural and urban characteristics with a direct functional interlinkage with the Bolgatanga Township. These GIS images will be used to show the growth patterns and extend of urban Bolgatanga. The characteristics of the images selected are indicated in **Table 3**.

TABLE 2 | Land cover classification.

Landcover	Description
Bare land/Settlement	Areas with no dominant vegetation cover on at least 90% of the area. They also include rural settlements with sparse rural buildings
Built up area	These are land areas with building and/or non-building structures. They also include peri-urban settlements
Canopy tress	These are canopy trees that usually occurs in a cluster of more than one tree
Cultivated savannah	These are savannah grasslands with isolated trees that are either frequently or occasionally cultivated for crop production
Farmland	These are cultivated areas that are solely rainfed and the land is burnt during the dry season to prepare for the next rainy season
Water	These are mainly artificially constructed dams. They also include rivers and Ponds

Source: Authors classifications.

TABLE 3 | The characteristics of the images selected.

Sensor	Path	Row	Year
Landsat TM 4	194	53	1984
Landsat TM 4	194	53	1988
Landsat TM 5	194	53	1992
Landsat TM 5	194	53	1998
Landsat TM 5	194	53	2002
Landsat 8	194	53	2016

RESULTS AND DISCUSSIONS

This section has been structured into 5 subsections in line with the study's focus to understand the sustainability dynamics of urban agriculture in the wake of rapid urban expansions and population growth trajectories in the Bolgatanga Township. Section Situating the Local Level Land Tenure at the Intersection of Urban Development of the paper discusses the changing land tenure system from customary to private ownership under urban change within the context of Bolgatanga. Food production systems within the Bolgatanga growth pattern as elucidated in section Trends and Extent of Peri-Urbanization as well as the cropping seasons of the area are considered in section Characteristics of the food System in the Bolgatanga Township. Section Implications of Urbanization on Agricultural Households: Employment, Income, and Land Access of the paper focuses on the trends and extent of peri-urbanization in the Bolgatanga from the year 2000 to 2018, while Section Phases of Agricultural Land Use Change in Bolgatanga Township looks at the phases of agricultural land use change in Bolgatanga.

Situating the Local Level Land Tenure at the Intersection of Urban Development

The customary land tenure system in the Bolgatanga Township invariably impacts on the urban development dynamics of the city. For instance, the parceling of land for urban uses, particularly those lands which emanate from the patriarchal inheritance practices, provides the entry point for urban development of the area. At the community level, land is owned by families, and this is passed on across generations as contiguous parcels or splintered parcels for nuclear family or even individual uses. The splintering of land into smaller parcels leads to land fragmentation, as the small parcels ends up unsuitable for agriculture and local planning (parcel by parcel planning) (Tonah, 2005). In previous research findings, Agana (2012) revealed that, customarily, land could be accessed, acquired, and owned among the Frafra communities by first settlement and by gift or grant from the landowning family. Land could also, however, be battered for cattle or pledged for cattle used for marriage dowry on promise by the pledgor to replace the cattle and redeem the land in future. However, due to urbanization and high population growth there is an existing commercialized exchange system, characterized by both informal and formalized land transaction, and this has promoted sale of land. Sale of family lands are meant to enable impoverished landowning families or individuals to raise money for critical social needs including funerals, sickness, travel expenses, educational supports, traditional marriage requirements, festivals and to support other essential livelihoods. In addition, chiefs and families are gradually interpreting common land as private ownership, which facilitates the selling of land for housing.

In addition, the public investment in improving road infrastructure for example, has significantly influenced peri-urban land marketisation. For instance, a household head explained,

> "improvement in accessibility through road construction has caused land values to appreciate making land a 'black gold' in the peri-urban communities" (Interview, male household head, Bolgatanga, 2017).

The Municipal Physical Planner also indicated that,

> "the main factors causing land use change in peri-urban areas are high demand for land by the increasing population from the city center, and to dispose lands for monetary gains by landowners" (Interview with Municipal Physical Planner, Bolgatanga, 2017).

The Municipal agriculture officer also noted that,

> "there has been a decrease in the average farm sizes between 2000 and 2010 from 3 to 0.36 ha under small-scale farming and 11 to 8 ha under large scale farming with residential land developments fast consuming agricultural lands, respectively" (Interview with Municipal Agriculture Officer, Bolgatanga, 2017).

These concerns represent the motivations, drivers and complications that may emanate from the operationalisation of urban plans and policies within cities in Ghana due to the dominance of customary tenure and multiple interests at both the community and family levels. Agricultural lands are mostly affected by rapid urban growth and its functional demands, such as land uses for residential, industrial, and commercial tend to dominate agricultural lands in the bid for space in the urban setup (Owusu and Lawrence, 2010). Naab et al. (2013) argue that a major problem of rapid urban growth is changing land-use patterns which affects agricultural land use, land sizes and crop yield. According to Appiah et al. (2014) the decision to convert land from agricultural uses to residential and commercial land uses are driven by both social and economic factors (see Kasanga et al., 1996; Kidido and Bugri, 2020; Kidido, 2021). Kuusaana and Eledi (2015a) opined that, efforts of governments to make cities self-sustaining in terms of producing their food locally will remain a mirage if there is no productive land available. Lyons et al. (2013) have also noted that, contemporary planning approaches are constrained by several factors including social, political, ecological, and economic boundaries that reduce options for growing food within the urban space. These factors appear to resonate in other jurisdictions as seen in our results in the Bolgatanga with the dissipation of urban agricultural land (see Akaateba, 2019; Akaateba et al., 2021).

Trends and Extent of Peri-Urbanization

This section of the paper focuses on the trends and extent of peri-urbanization in the Bolgatanga Township from the year 2000 to 2018. The population for Bolgatanga leapfrogged from 77,768 people in the year 2000 to 156,678 in 2018. This growth represents twice increase compared to the population figure recorded in 2000. The annual population growth rate was 5.64%. The implication of rapid population increase has a direct link to rapid expansion of residential land uses in these peri-urban settlements. The growing population of the Bolgatanga Township has spilt over surrounding areas, which constitute what can be called the peri-urban Bolgatanga. These areas, which include Tindomoligo, Yikene, Yarigabisi, and Tindonsobligo among others, offer cheaper land for housing development for the increasing urban population and for other complementary urban activity as well. The rapid urban growth is attributed to natural population growth and migration from rural areas due to poverty and land conflicts (Ampofo et al., 2015). The Bolgatanga Muncipality has experienced a rapid urban land expansion over the past 30 years; it increased by 6 times; from 499.49 hectares in 1984 to 1525.14 hectares in 2016 with an annual growth rate of 6.4%.

The field survey revealed that the pace of urban expansion in the Bolgatanga Muncipality between 1984 and 2002 was 2.8% per annum as against 8.6% per annum for the year 2002 to the year 2016. While the built up area in 1984 spanned to only 2 km from the city center, by 2016 the growth of the city had reached about 12 km. Clearly, the last two decades witnessed a drastic expansion of the Municipality. This is attributable to key developmental activities such as the redevelopment of the township and the upgrading of the city core after 2002. The expansion trajectory of the Bolgatanga Township is further explained by the establishment some critical social and commercial facilities which has served as growth poles and pull forces of development in the last two decades. For instance, there is a general concensus among the studied urban households that the establishment of Millar Institute for Transdisciplinary and Development Studies

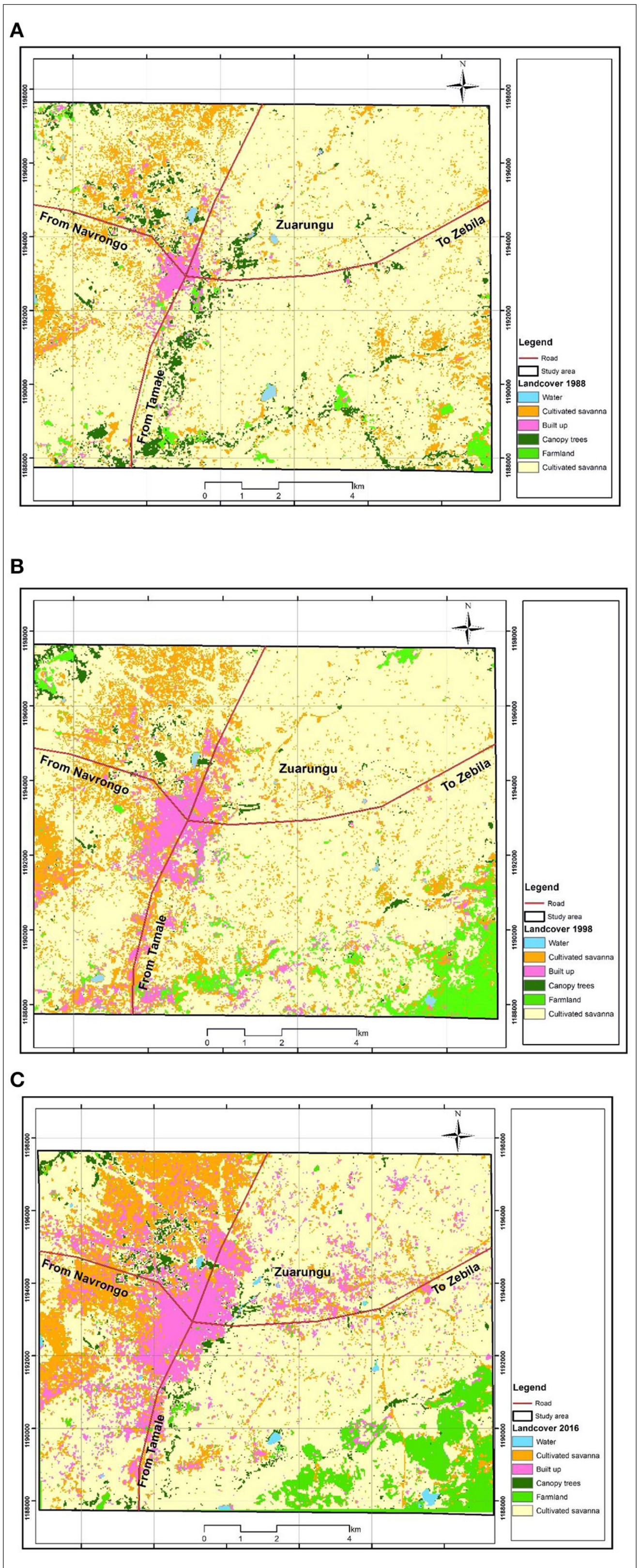

FIGURE 4 | (A–C) GIS maps showing urban development dynamics and loss of vegetation in Bolgatanga township.

(now known as the Millar Open University, Bolgatanga Technical University, Bolgatanga and Zuarungu Nursing Training Colleges, Zuarungu Meat Factory, Bolgatanga Rice Mill and many of such establishments have triggered the expansion of the social, economic, and educational sector with intense effect on the spatial transformations of the town.

The analysis of the 1984–2016 data indicated that there is an inverse relationship between built up area and farmland. Whiles the share of urban farmlands was decreased from 1299.60 hectares to 115.07 hectares, built up area was on an increase from 455.07 hectares to 1,525 hectares. From **Figure 4**, the period between 2002 and 2016 recorded the highest spatial expansion with built up (proportion of urban share) of the study area increased from 682.92 (30%) to 1525.14 hectares (70%), almost triple, while the extent of farmland decreased drastically from 652.05 hectares (85%) to 115.07 hectares (15%). The spatial analysis implies that about 567.85 hectares of peri-urban land initially previously used for agriculture and related activities were built-up between 2002 and 2016. The spatial expansion between 2002 and 2016 was attributed to the infrastructural development that occurred within that same period. Also housing development was more of infilling, completion of abandoned and uncompleted projects as well as redevelopment of old structures (especially at the inner cities) among others largely influenced the growth and expansion of Bolgatanga. This result corroborates the view that most cities in developing countries are characterized by unconsolidated lateral physical expansion and sprawl (Webster and Muller, 2002; Kombe, 2005; Cobbinah and Amoako, 2012). This is plausibly because of the increased urban share of the population in Bolgatanga from 32,495 in 1984 to 65,549 in 2010 (Ghana Statistical Service, 2014b). The Municipality recorded the largest growth in urban population in the region as of 2014. The expansion of the urban frontprint also increases rural spatial demand to accommodate the growing population and economic activities.

Further spatial analysis (as shown in **Table 4**) indicates that bare land which comprised of all vacant spaces, sands, rocky areas, cleared lands occupied 3,550.32 hectares in 1984. However, this subsequently decreased to 2,978.54 hectares in 2016 due to the supply of land for housing construction. Water bodies also increased from 32 hectares in 1984 to 52 hectares in 2016 comprising rivers and dams in the area. The increase is as a result of construction of new dams and expansion of existing dams such as the Vea dam and Gambibgo-Azuabisi dam expansion projects by the Government of Ghana. The rural water supply system consists of boreholes, hand-dug wells and other natural water sources such as rivers, dams, ponds and dugouts. The water supply system in the Municipality can be classified into rural and urban, based on the location of the facilities and the technology of delivery. The results also show that the farmland and canopy trees decreased over the years from 1,299.60 hectares to 115.07 hectares, 791.1 hectares to 259.65 hectares, respectively between 1984 and 2016 as a result of the increased conversion of farmland to housing and also due to the felling of trees for charcoal burning and farming.

With urbanization expansions occasioned by population growth, naturally, agricultural land was severely impacted as depicted in **Table 4**. The reduction in farmland sizes also presents some unintended consequences and implications on households within these frontiers. According to Steinhübel and von Cramon-Taubadel (2021) the diminishing prospect of urban agriculture reallocates labor to non-agrarian urban economies. These implications are largely manifested in the form of food supply challenges, land access, income, and livelihoods of people. These are discussed in the next section.

Characteristics of the Food System in the Bolgatanga Township

Across the households studied, the major food crops, maize, rice, millet, sorghum, groundnuts, cassava, and cowpea make up the main staple foods of the people in Bolgatanga. Farmers in the rural and peri-urban areas mainly produce food for subsistence and income. After harvesting, farmers put aside some of the foodstuff for the family subsistence while the rest is sold in the market. Farmers may sell farm produce in bulk or bits as and when the need arises to meet pressing expenses at the family or individual level. Rural farm produce is, however, distributed differently through organized transport systems or through private means to market centers. Urban consumers purchase their food from the local markets. In the urban centers, different neighborhoods have different localized market centers, where they access food supply on daily or weekly bases. Such a market center exits in the Bolgatanga Township and runs every 3 days.

TABLE 4 | Changes in the land size for the different uses in the study areas.

Land cover type	Area (ha)					
	1984	1988	1992	1998	2002	2016
Bare land	3,550.32	3,445.15	2,983.87	2,902.51	2,987.94	2,978.54
Built	455.07	499.49	588.96	651.78	682.92	1,525.14
Canopy tree	791.1	488.34	474.21	155.34	464.67	259.65
Crop and grassland mosaic	9,254.79	9,064.0	7,488.45	8,893.44	6,281.19	7,753.50
Farmland	1,299.60	903.51	749.7	729.63	652.05	115.07
Water	33.75	37.35	46.53	33.3	87.3	52.65

Source: Field Survey, 2017.

The cropping period is vastly dependent on the rainfall pattern and the crop under cultivation (see in **Figure 5**). Hence, the cropping calendar may vary slightly from year to year depending on when the rains commence. Land preparations usually commence after the first rains which is mostly around April. As such, when the rains delay, it tends to cause a delay in the preparation of the fields for planting and consequently, delays the entire cropping season. Farming in terms of crop production in the area like the rest of Ghana, is primarily seasonal rainfed. The earlier part of the dry season is used for processing and storage of the farm produce. Some farmers also engage in irrigation-based vegetable production in the dry season around their homes and in designated irrigated valleys across the city. In the Upper East Region irrigated tomatoes farming thrives during the dry season. In the rural areas, farmers farm around their compound where there is hardly a distinction between the compound and farms because farmlands extend from the very edge of the compound. However, urban, and peri-urban farmlands are dynamic with varying phases of the landscape as the seasons and the development priorities change. The settlements themselves, however, remain largely static. Some of these characteristics are displayed in **Figures 6**, **7**.

Implications of Urbanization on Agricultural Households: Employment, Income, and Land Access

Peri-urbanization is said to be double-edged sword because urban expansion is documented to present both limitations and opportunities to people living in the urban periphery (Aberra and King, 2005). In terms of opportunities urban areas provide many

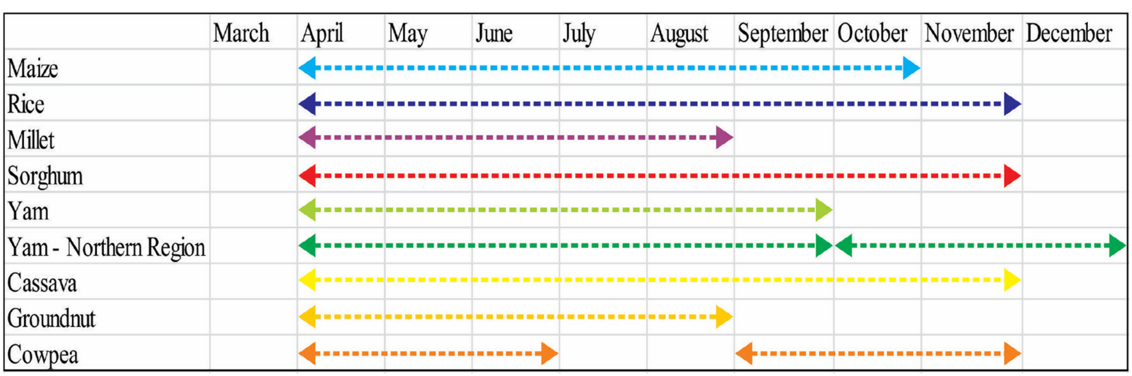

FIGURE 5 | Cropping calendar for major food crops in the wet season in the study area. Source: Author's illustration with information from Agricultural Extension Handbook (2006).

FIGURE 6 | A typical compound farm in Yikene in Bolgatanga Source: Field Survey, 2013.

FIGURE 7 | Land use change in peri-urban Yikene in Bolgatanga Source: Field Survey, 2017.

potentials for improving living conditions through economies of scale and proximity they provide for most forms of infrastructure and services (Satterthwaite et al., 2010). Improvement in urban-based employment and social amenities such as access to healthcare, improvement in access to quality education, and regular supply of potable water are also critical opportunities available to peri-urban households (see Mandere et al., 2010; Vermeiren et al., 2013). It was revealed through this study that the outward expansion of Bolgatanga has created multiple livelihood opportunities in the communities such as, construction work, welding, NGO's, electricians, craftsmanship and trading business because of their proximity to the city. Even though these new livelihood opportunities are peculiar to the urban populace, it creates agricultural labor shortages in the peri-urban fringes (see Hussain and Hanisch, 2014). The study further found that the proportion of men in these jobs were significantly higher than the females, especially in the construction industry (see Brook and Dávila, 2000; Tacoli and Satterthwaite, 2013).

It is argued that the process of peri-urbanization is characterized by changing local economic and employment structures, from agriculture to manufacturing (Bah et al., 2003; Narain and Nischal, 2007; Hudala et al., 2008; Mandere et al., 2010). Nevertheless, observation from the Bolgatanga Township reveals that the process of peri-urbanism is not characterized by growing industrialization. An elder in Yarigabisi commenting on the effects of peri-urbanization on their income noted as follows:

> "My son I hardly find money these days due to loss of farmlands, and I lack employable skills and requisite qualifications for available jobs in my community. Since I lost my farmland, my financial situation has worsened than before. My income has decreased significantly, I cannot afford three square meals in a

day less to talk of accessing health care. When we fall sick, we pray to God to heal us" (Interview, Elder, Yarigabis-Bolgatanga, 2017).

The cost of land acquisition is one of the main factors that determine the accessibility to land for agricultural purpose (Pavel et al., 2012). Peri-urbanization is accompanied by certain changes in agricultural practices as farm sizes reduce in the peri-urban areas. Farmers have adopted all forms of strategies to survive. During the field survey, respondents indicated that agricultural practices have undergone changes over the last decade in response to peri-urbanization. For instance, labor shortages have compelled urban farmers to choose less labor-intensive farming methods (see Nguyen and Kim, 2019) or concentrate on only high yielding or high value crops (see Hussain and Hanisch, 2014). Most farmers have shifted from the traditional extensive agriculture toward intensive agricultural practices where crops with shorter gestation period as well as high valued crops either as a survival strategy or accumulation strategy (Tacoli, 2004; Mandere et al., 2010; Thuo, 2010).

Peri-urbanization usually leads to declining landholdings at the household level, which possibly diminishes the economic significance of agriculture in the cities (Kuusaana and Eledi, 2015a; Haller, 2017; Pribadi et al., 2017). The negative effects of peri-urbanization are manifested in the greater loss of agricultural land and the growing integration into the urban monetised economy. Urban intrusion displaces traditional livelihoods in the urban and peri-urban areas (see Babo, 2010). This point is buttressed by Dávila (2002) that majority of the peri-urban poor who depend heavily on natural resources are worse affected by urban expansion. There is a gradual shift from full time farming to part farming or abandonment of farming (Lerner and Appendini, 2011; Mosha, 2015). Abandonment of farming is, however, widespread because of its informality, low level technological adaptation and its association with economically poor households (see Feola et al., 2020). How the overall urban expansion morphology mutates existing agrarian landholdings and agricultural structure of the local inhabitants is further elaborated in section 5.5.

Phases of Agricultural Land Use Change in Bolgatanga Township

Growing population and urban expansion goes with no concomitant growth in land supply because land is fixed in supply and does not in any way grow with increasing population growth (Ampofo et al., 2015). The pressure exerted by increasing population and rapid urban sprawl dispossess other sectors such as agriculture (Edusah, 2008). The analysis of the different levels of compactness in the urban built up area, in relation to the practice of urban agriculture (see **Figure 8**) reveals different phases of food production capacities in the Bolgatanga Municipal area. In the peri-urban interface, urban growth is driven by individual developments. Thus, the level of compactness in these areas increases gradually over several years, with most people developing their houses in piecemeal fashion (Adade et al., 2021). Farmers in these areas therefore lose their farms gradually, with infilling as individuals develop their separate parcels of land. The loss of production capacity therefore takes place gradually. **Figure 8** illustrates these dynamics in the form of an infograph.

The process of peri-urbanization poses serious threats to urban and peri-urban farmers because of the scarcity of agricultural land. The peri-urban interface in most cases is the agricultural hub of the urbanites and supplies its food requirements (Atu et al., 2013). At the plight of losing their farmlands to urbanization and urban growth, peri-urban and urban farmers have had to find adaptive measures to survive. Urban area growth does not wipe out the indigenous rural settlements that become urbanized. Hence, under the same circumstances, farmers lose their farms and not their homes through a slow land use conversion process. The scenario described supra is illustrated in **Figure 9**. Although farm sizes in the peri-urban interface are typically small as compared to rural farms in the hinterlands, they are generally bigger than the sizes of an average plots of land as defined in many local plans in Ghana. The situation therefore arises where a parcel of land which was previously cultivated by one farmer is subdivided into plots and allocated to several different residential developers. The decisions of these developers to develop their parcels piecemeal means that the farm sizes

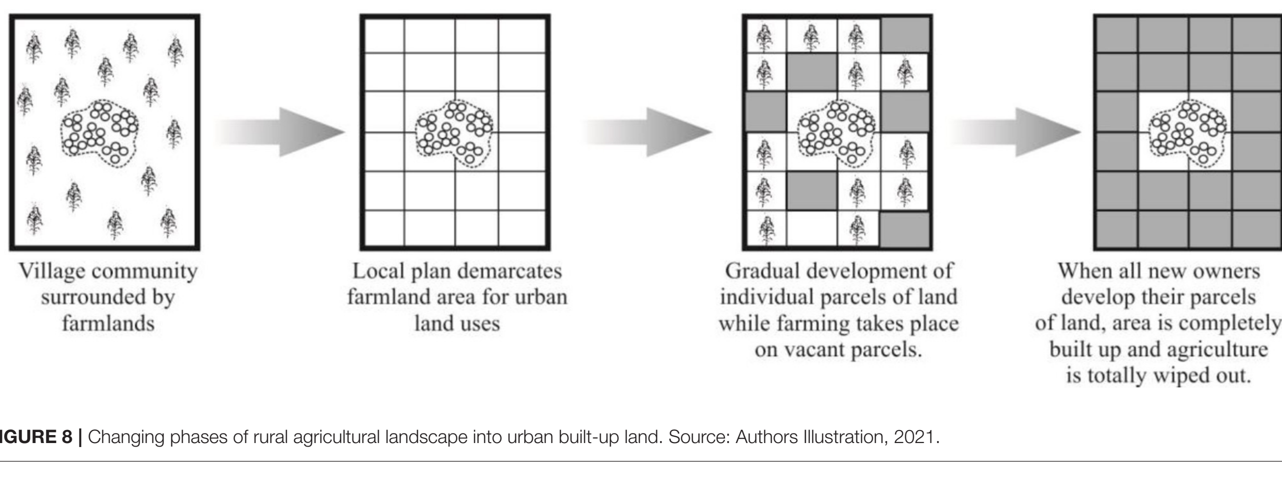

FIGURE 8 | Changing phases of rural agricultural landscape into urban built-up land. Source: Authors Illustration, 2021.

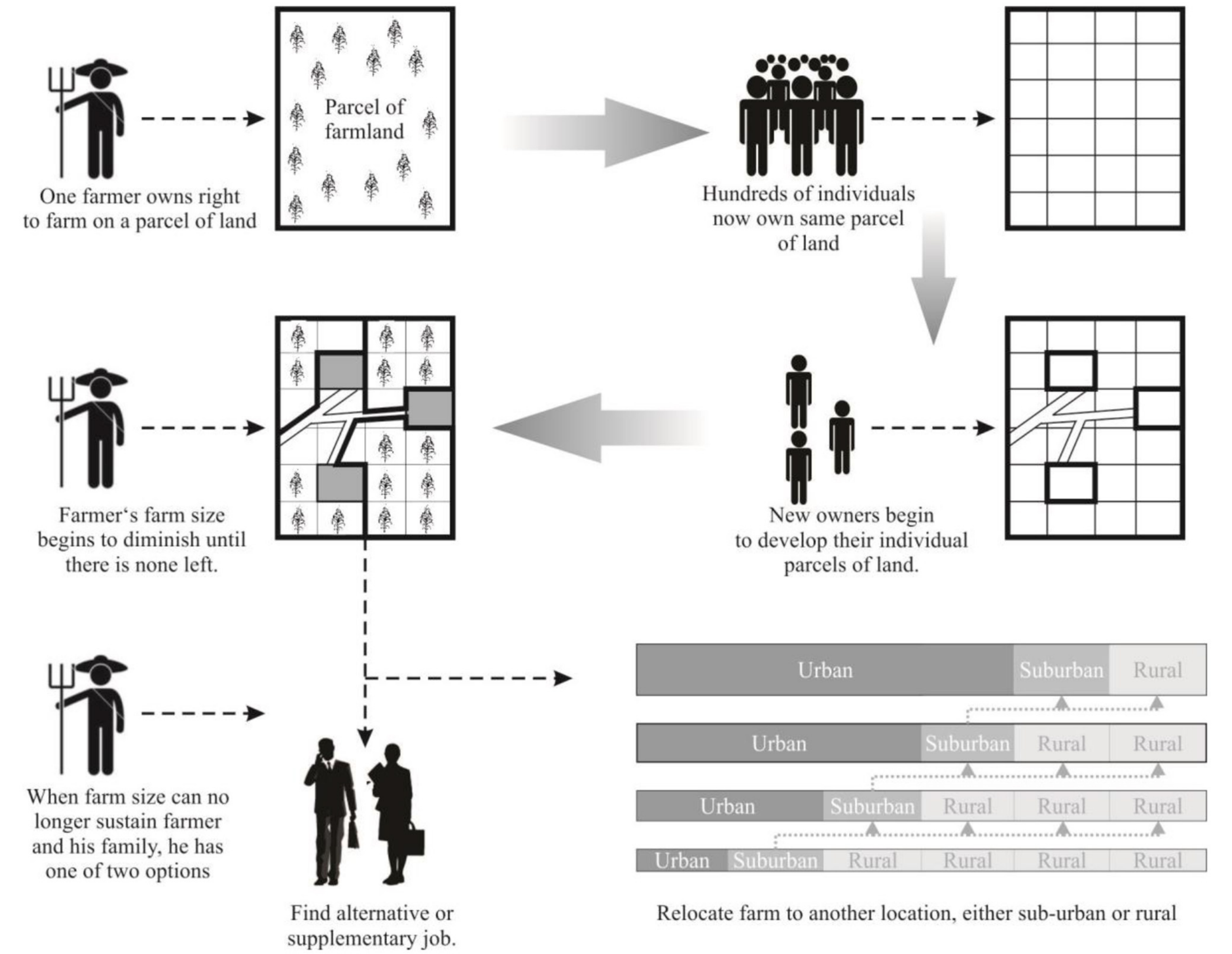

FIGURE 9 | Gradual disappearance of rural farmlands in the peri-urban interface. Source: Authors Illustrations, 2021.

gradually decreases until the farmer is compelled to relocate to the periphery or abandon farming. In the end, however, relocation of the farmlands is a sure option for many urban farmers due to diminishing farm sizes and poor accessibility to water resource (see Foeken and Owuor, 2008; Taiwo, 2014). Hence, the sustainability of urban agriculture is constructed on the farmers' abilities to identify alternative farmlands either in the immediate residential neighborhoods or in distant peripheries.

CONCLUSION AND RECOMMENDATION

Urban food supply remains critical for the functioning of the urban populace. Understanding the characterization of urban areas and how they sustain urban food production is relevant. The conversion of urban agricultural land to residential uses has multiple impacts on the urban food system and the sustainability of urban agriculture. These land use changes have led to rapid transformations and [re]structuring of agricultural production, spatial dynamics, social-economic [f]actors, land ownership and land markets. Encroachment on urban and peri-urban agricultural lands leads to changes in the customary processes and procedures of land tenure as land becomes commoditized rather than a communal property. The changes manifest in the emergence of formal and informal land transaction activities that have emerged as the local economy shifts from a batter economy to a monetised one through socio-economic induced land transactions. This is because of the disconnection and low-level participation of the planning authorities on one hand, and the customary landowners on the hand. The development of Bolgatanga is anchored on the morphology of the major road network in the city center. However, there is variation in level of compactness: higher housing density in the older inner-city settlements, and lower density in the government residential and peri-urban areas due to regulations and piecemeal development of residential housing. Notwithstanding rapid urbanization, local peasant farmers are still able to secure small patches of farmlands within the city to engage informally in agriculture with insecure tenure. Of critical notice is the fact that the rapid urban expansion into the peri-urban communities has created multiple livelihood opportunities in the communities even though these are skewedly male dominated.

In Bolgatanga, food production capacities are being shifted from one locality to another in the face of increasing urban growth. There is a deepening agro-ecological impact of urban expansion on urban food production and the supply of ecosystem goods and services within the urban core and peripheries. This is set to exacerbate in the coming decades due to increasing urban population. Since securing safe and sufficient food for the urban population is critical to sustainable development, this study recommends that, food-inclusive planning schemes are fundamental in future physical plans to guide land uses. These planning schemes can be developed and sustained through multiple sectoral/stakeholder planning processes. Key stakeholders including the traditional authorities, farmers, planning authorities and youth groups should see these food-inclusive planning schemes as a shared responsibility in ensuring strict adherence and implementation. This process can then be supported by the respective planning authorities through regulation and monitoring.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because data was used previously as MSc./M.Phil. thesis which the authors were involved. Requests to access the datasets should be directed to Elias D. Kuusaana, ekuusaana@yahoo.com.

AUTHOR CONTRIBUTIONS

EK worked the lead author and contributed to the conception and writing of the manuscript. IA helped in data collection and used same for his M.Phil. Thesis in 2017. JE also collected data in Bolgatanga in 2013 and used it for her MSc. Thesis. IA and JK both contributed to the review of critical literature and defining the focus of this manuscript. All authors contributed to the article and approved the submitted version.

FUNDING

This research was fully funded and operationalized by the authors using their personal resources.

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frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 18 February 2022
doi: 10.3389/fsufs.2022.777816

Farmland Preservation and Urban Expansion: Case Study of Southern Ontario, Canada

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Farmland is an essential resource for the sustainability and security of human food systems. Preserving an agricultural land base is critical, as it is significantly affected by local, national, and global urbanization. This research introduces a case of farmland preservation in southern Ontario. This area contains some of Canada's most finite and productive soils but has an agricultural system facing enormous pressure from urban expansion. This paper reviews the farmland preservation policy framework within Ontario and provides insight into the role of different levels of government in protecting this critical resource. It also provides data at a regional level that provides the basis to evaluate the success of provincial and local policies. By tracking agricultural land conversion through local Official Plan Amendments (OPAs), this study documents farmland loss across southern Ontario between 2000 and 2017. Implemented and approved by local government and designed with public input, municipal Official Plans outline and describe land-use planning policies on how municipalities should use lands to meet community needs and desires. OPAs are formal and legally binding administrative changes to a municipal Official Plan decided through an open public process, which are required to change local land-use designations that conform with the long-term vision for growth and physical development. These OPAs may include the conversion of farmlands for non-farm uses (or, in contrast, the protection of agricultural lands). Over time, they will reveal the loss of farmlands in each community for different uses (and reflect changing priorities). Using OPAs to track the conversion of prime agricultural land is an innovative and rigorous methodological contribution, given the lack of data documenting long-term changes to the availability of agricultural lands and the impacts of urbanization on farmland conversion. Measuring farmland loss with this approach can be transferred and applied to contexts where municipalities are the entities responsible for agricultural land-use planning, outside of Ontario and beyond. Data from 36 counties/regions shows that the provincial policies and local planning framework have worked in tandem to affect the agricultural land base in southern Ontario significantly. In Central Ontario, the most urbanized area of Canada, the Province's Greenbelt Plan has significantly reduced the rates of farmland loss since 2005, while the Growth Plan and other policies contributed to enhanced municipal control over agricultural land conversion. Specifically, the Inner Ring municipalities have played increasingly active roles in agricultural land protection

OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to Land, Livelihoods and Food Security, a section of the journal Frontiers in Sustainable Food Systems

***Received:** 15 September 2021*
***Accepted:** 27 January 2022*
***Published:** 18 February 2022*

Citation:
Caldwell W, Epp S, Wan X, Singer R, Drake E and Sousa EC (2022) Farmland Preservation and Urban Expansion: Case Study of Southern Ontario, Canada. Front. Sustain. Food Syst. 6:777816. doi: 10.3389/fsufs.2022.777816

with both planning approaches and local initiatives. Outer Ring municipalities have seen increasing urbanization pressure. Data on farmland loss for non-agricultural use showed large-scale municipal-led urban boundary expansions and small-scale individual applications on policy changes. In Western Ontario, over the past two decades, there has been no obvious upward or downward trend of farmland loss. Most of the farmland conversion cases in this region were small-scale applications to create small lots on existing agricultural land to allow non-agricultural uses such as commercial, recreational, residential, and agricultural-related facilities. Since 2000, Southeastern Ontario, which has the smallest provincial share of prime agricultural land, has experienced limited farmland loss, consisting primarily of small-scale, individual applications on land-use re-designations (partially reflecting reduced acreages of prime agricultural land). The provincial policy impact on farmland preservation is not as evident in this region. The findings and methodology of this study contribute to the groundwork on farmland availability and land-use planning policy development and research by providing a baseline enumeration of farmland availability and the effect of farmland protection policies at provincial and municipal levels within Ontario's land use planning regime.

Keywords: farmland loss, preservation, urban expansion, Greenbelt, land use policy, Ontario

INTRODUCTION

Farmland is an essential resource for the sustainability and security of human food systems, environments, agricultural industries, and livelihoods. Beyond the provisioning value and services of farmland, such as with food and fiber, sustainably managed farmland provides several other invaluable ecosystem services, such as pollinator and wildlife habitat, carbon sequestration, nutrient cycling, water regulation, as well as amenity value (Power, 2010). However, the capacity of farmland and agricultural industries to provide these services beneficial to collective wellbeing depends on the availability and quality of farmland available (Barral et al., 2015; Hu et al., 2018; Benton et al., 2021).

Due to global urbanization, farmland availability has been increasingly under threat from social, physical, and climate factors (Hertel, 2011; Vinge, 2018). Preserving agricultural land for current and future generations is a worldwide topic that must be addressed urgently (Hertel, 2011; Caldwell et al., 2017; FAO, 2021). Research on the threats of urbanization on farmland resources specifically is of global priority and is evident in Canada (Qiu et al., 2015; Epp and Caldwell, 2018; Connell, 2020; Cameron and Connell, 2021), the United States (Moroney and Castellano, 2018; Narducci et al., 2019), Europe (Tan et al., 2009; Perrin, 2013; Skog and Steinnes, 2016), and China (Chien, 2015; Zhang et al., 2016; Hu et al., 2018; Duan et al., 2021; Miao et al., 2021). There is a need to address complex drivers contributing to farmland loss as well as diminishing physical capacity of lands to support climate change mitigation and adaptation measures (Masson-Delmotte et al., 2021). Agricultural and urban anthropogenic land uses have already partially converted an estimated 43% of global land area (Barnosky et al., 2011), having significant implications for the land base fragmentation, biodiversity loss, ecological health, and climate resilience (Laurance et al., 2014; Capmourteres et al., 2018). Additionally, once farmland is lost to urban development, its productive capability is lost forever (Moroney and Castellano, 2018). Thus, preserving and protecting existing agricultural land resources is critical for the future resilience and sustainability of food systems, communities, and agricultural economies.

Canada has a robust agricultural sector with over $100 billion annual GDP and 2.3 million jobs in agriculture and agri-food (Agriculture and Agri-Food Canada, 2019). Nevertheless, farmland is a limited resource in Canada, and only occupies 7.3% of the land area due to soil quality, climate, and terrain restrictions (Statistics Canada, 2014). Much of the most productive agricultural soils are located within Ontario, both the most populated part of Canada and where most farmland loss occurs nationally (Statistics Canada, 2016). Census data shows that total farmland in Ontario has fallen by 50% since 1941. Additionally, over 1.5 million acres of farmland were lost between 1996 and 2016 (Ontario Ministry of Agriculture, 2017). Like many fast-developing regions worldwide, urban sprawl has consumed large tracts of agricultural soils in Ontario during the past few decades. Urbanization is unlikely to slow down: the population in Ontario is projected to grow to over 20 million by 2046, representing a 35.8% increase from 2020 (Government of Ontario, 2022). Moreover, the fragmentation of the agricultural land base and the imposition of low-density urban sprawl into agricultural communities often poses challenges for agricultural viability and compatibility for farmers and non-farmers alike (Qiu et al., 2015; Epp and Caldwell, 2018).

Relative to the rest of the province, southern Ontario contains some of Canada's most finite and productive soils (Agriculture and Agri-Food Canada, 2019). The Canada Land Inventory (CLI) is used to designate land based on soil type, giving the land a numerical designation based on agricultural suitability (in terms of crop production). The CLI consists of seven distinct classes of agricultural land based on its productive potential, with classes 1, 2, and 3 soils considered to be "prime agricultural land." By contrast, categories above soil classification 3 are deemed limited in their productive capability. Only 0.5% of Canada's total land base comprises Class 1 land (which is the highest quality in soil classification), and most of this soil is in southern Ontario (Walton, 2003; Caldwell et al., 2017). Since most of the future urban development is expected to occur in this region, farmland protection is vital for southern Ontario (Office of the Auditor General of Ontario, 2021).

While movements, programs, and policies to protect farmland from urbanization across North America have been implemented since the 1950s (Bunce, 1998), there is much to learn about the effectiveness of farmland protection policies (Liu and Lynch, 2011; Connell, 2020). For example, since 2005, the Ontario provincial government has established a series of policies to regulate urban sprawl and strengthen farmland protection, including the Provincial Policy Statement (MMAH, 2005c, 2014), the Greenbelt Plan (MMAH, 2005b), and the Growth Plan (MMAH, 2005a). Collectively, these plans establish a provincial land-use planning framework to identify policies for where urbanization should *not* occur to protect ecological features such as farmland, and guide transit-oriented development, intensification, and densification to already urbanized communities. These provincial plans are then interpreted and implemented at the municipal level, leaving room for variability in their interpretation and application of policies amongst local communities. Since establishing these policies, little research has evaluated farmland loss in southern Ontario to test their effectiveness in preserving farmland. This absence of evaluation is despite Ontario's farmland protection policies being internationally recognized for its success (see Government of Ontario, 2007) and establishing one of the most extensive greenbelts in the world (Carter-Whitney, 2008). This article attempts to provide a comprehensive provincial-wide assessment of one of the world's largest geographically protected farmland areas (Carter-Whitney, 2008), building off a study exploring farmland loss in two Ontario municipalities from Epp and Caldwell (2018). This study also contributes to the larger body of literature evaluating the effectiveness of farmland protection policies around the globe (Connell, 2020).

While the Canadian Census of Agriculture quantifies the amount of agricultural land in production, it lacks documentation of land-use planning decisions (i.e., non-farm and urban development), compromising the preservation of prime agricultural lands. This research fills this gap from a land-use planning perspective, for which the methodological framework can be applied in other municipal jurisdictions responsible for agricultural planning but have yet to officially account for the preventative loss of this vital resource (Robert and Mullinix, 2018; Connell, 2020; Cameron and Connell, 2021). An innovative approach to measuring farmland loss is introduced by tracking agricultural land conversion in municipal Official Plan Amendments across southern Ontario municipalities. OPAs are legally binding municipally-led administrative decisions to change a municipal Official Plan, which are required to redesignate lands to different uses so that new proposed uses may conform with the municipality's long-term vision for growth and physical development. In turn, OPAs reflect the potential loss of farmland and change in community development priorities over time. This approach provides a more comprehensive, accurate, and reliable picture of the state of farmland loss in Ontario by measuring the amount of converted farmland to non-agricultural uses when the land-use planning decision was made (Epp and Caldwell, 2018). The reliability of this method is relative to what could be inferred from the Canadian Census of Agriculture, or other methods of measuring farmland loss, such as land cover map comparisons (Chen et al., 2016; Song and Liu, 2017), plan quality evaluation (Connell, 2020; Cameron and Connell, 2021), GIS analysis and remote sensing (Qiu et al., 2015; Skog and Steinnes, 2016; Hu et al., 2018; Duan et al., 2021), propensity score matching (Liu and Lynch, 2011), econometric modeling (Qiu et al., 2015; Xu et al., 2019; Miao et al., 2021), statistical analysis of census data (Epp and Caldwell, 2018; Moroney and Castellano, 2018), and qualitative analysis of archival records and anecdotal accounts (Perrin, 2013; Cameron and Connell, 2021). The analysis of OPAs thus reveals how provincial policies shaped farmland loss at a regional scale between 2000 and 2017. Tracking the decisions made during this time frame reflects how municipalities may vary in their interpretation and implementation of the provincial land-use planning framework, inclusive of plans such as the Provincial Policy Statement, Growth Plan for the Greater Golden Horseshoe, and the Greenbelt Plan.

BACKGROUND AND CONTEXT

This next section will review the context for the research, providing some background into the legislative and policy-setting justifying land-use planning and farmland preservation in Ontario. This section will then provide an overview of the study area, including geography, development characteristics of various regions, and land area.

Agricultural Land-Use Planning and Legislative Basis for Farmland Protection in Ontario

A hierarchical planning system regulates agricultural land in Ontario. This means that the provincial government sets up the overall policy framework, which applies to various regions across the province. Municipal policies must meet the requirements of consistency and abide by provincial and regional regulations, plans, and policies in their local planning decisions. However, local-level interpretation and implementation of provincial planning policies will vary by municipality. This system promotes a coordinated planning system that achieves "good planning" that recognizes specific provincial interests (e.g., growth management and farmland protection) while allowing local governments to translate policies and make decisions to fit their local needs, desires, and contexts. As a result, decisions around agricultural land uses will vary at municipal levels despite provincially implemented farmland protection policies.

The Provincial Policy Statement (PPS) establishes the provincial interest in planning across the province, and municipal planning decisions must be consistent with this document. It lays out the vision for Ontario's long-term agricultural land protection and specifies conditions under which agricultural land can be converted to non-agricultural uses. Municipalities have the authority to create their own Official Plans. In doing so, municipalities can establish their local agricultural land designation system, specify local agricultural land-use policies, and map out the designated agricultural land under the authority of the provincial Planning Act (1990). Official Plans serve as a guiding document that outlines the community's vision and designates land for a variety of uses. Any change in agricultural land designations must go through the municipal government's approval and be finalized *via* Official Plan Amendments (OPAs).

The Greater Golden Horseshoe (GGH) is Canada's and Ontario's most urbanized region. The GGH is currently home to an estimated 10.2 million residents in just 3% of Ontario's land area (Office of the Auditor General of Ontario, 2021). Regarding economic significance to Ontario, the GGH alone contributes two-thirds of provincial gross domestic product (GDP) and one-quarter of Canada's annual GDP (Allen et al., 2015). Concurrently, some of Canada's finite, most productive agricultural lands and ecologically sensitive features, such as the Greenbelt, Oak Ridges Moraine, and Niagara Escarpment, are found in this part of southern Ontario. As a result, the GGH is an economic powerhouse and asset for agriculture and agri-food industries in Ontario. For example, 40% of GGH land area is quality productive farmland, and the regional agriculture industry contributes supports 38,000 jobs and one-third of Ontario's agri-food industry area (Office of the Auditor General of Ontario, 2021). Despite the value of these finite agricultural resources and agri-food networks, this provincial resource base has historically been threatened by "scattered" low-density development and urbanization. This growth pattern has led to farmland loss and the subsequent loss of ecosystem services that the agricultural resources and ecological features provide (MMAH, 2005a). For instance, from 1996 to 2021, the GGH's population increased by 57%, with the provincial government forecasting an additional 45% increase (to 14.8 million residents) by 2051 (Office of the Auditor General of Ontario, 2021). This unprecedented rapid growth and urbanization in southern Ontario have emphasized the need for effective land-use planning policies and measures to prevent adverse outcomes from unchecked growth in the region and prevent sprawling development from spilling outwards of the highly-desirable GGH to the rest of southern Ontario's prime agricultural areas.

In 2005, the provincial government undertook several initiatives to strengthen their response to urban sprawl across Ontario (Macdonald and Keil, 2012). Legislation and policies were issued in tandem to guide urban intensification and agricultural resource protection in southern Ontario. Agricultural lands were given a greater level of protection with a more comprehensive regional governance approach. The 2005 version of the PPS directed those prime agricultural areas be protected for long-term agriculture with certain exceptions for settlement boundary expansions, mineral and petroleum resource extraction, and limited non-residential uses given there are no suitable alternative locations. The 2005 version of the PPS also included the concept of specialty crop areas, mandating planning authorities to designate these areas and giving them the highest priority for protection. In 2014, the Government of Ontario updated the PPS to provide further guidelines for identifying, designating, and protecting prime agricultural land within Official Plans. The province also introduced stricter policies for settlement area expansions into prime agricultural areas. These updates mandated that in addition to the policies outlined in earlier PPS documents, identification and expansion of settlement areas may only occur at the time of a Municipal Comprehensive Review (MCR).

In addition to the changes to the PPS, the *Greenbelt Act*, established in 2005, provided a legislative foundation to create a 7,200 km^2 permanently protected "greenbelt area" in the Greater Golden Horseshoe and gave agricultural land further protection. The Greenbelt Act established a *Greenbelt Plan* in June 2005, which the provincial government subsequently updated in 2017. This continuous and permanent land base secured by the Greenbelt intends to support long-term agricultural production in the Greater Golden Horseshoe area. According to the Greenbelt Act, the Greenbelt Plan prevails, and local Official Plans and zoning by-laws within the protected countryside must be amended to conform with the Greenbelt Plan. Prime agricultural lands were given the following protection by the Greenbelt Plan (MMAH, 2017b):

> *"Prime agricultural land in the 'protected countryside' will be protected 'by preventing further fragmentation and loss of the agricultural land base caused by lot creation and the re-designation of prime agricultural areas; (section 1 (c))."*

Any municipality with land designated "protected countryside" by the Greenbelt Plan was required to identify such areas within their Official Plan. Agricultural land outside of the jurisdiction of the Greenbelt Plan would be designated as agricultural, but land-use protections would vary (reflecting the PPS or other provincial plans). An exception was provided through Policy 3.4.4. for settlement area expansion proposals that had been initiated prior to the implementation of the Greenbelt Plan. In these cases, settlement area expansions may be permitted into prime agricultural areas (MMAH, 2005a).

Two other provincial plans should be noted as they may have overlapping boundaries within the Greenbelt Plan area: the Oak Ridges Moraine Conservation Plan (ORMCP) (MMAH, 2017a) and the Niagara Escarpment Plan (NEP) (Ontario Ministry of Northern Development, Mines and Natural Resources and Forestry, 2017). The ORMCP and NEP tend to be focused on significant ecological and environmental features. In this context, the differing plans need to be interpreted for consistency where they overlap, as natural heritage protection can potentially conflict with agricultural viability.

Apart from the conservation plans noted above, the Places to Grow Act (2005a) and the Growth Plan for the Greater Golden Horseshoe (established in 2006 and updated in 2017;

TABLE 1 | Policies relevant to agricultural land protection in Ontario.

Plan/policy	Priority
Provincial Policy Statement	Protect agricultural resource for long-term use
Oak Ridge Moraine Plan	Protect the ecological integrity and continuity of Oak Ridge Moraine
Niagara Escarpment Plan	Protect the ecological integrity and continuity of Niagara Escarpment
Greenbelt Plan	Protect farmland, communities, forests, wetlands, watersheds, preserves cultural heritage
Growth Plan	Growth management in the GGH area

hereby referred to as the "Growth Plan") also indirectly support agricultural land protection by regulating urban boundary expansion, setting urban intensification targets, and encouraging more compact and mixed-use development (**Table 1**).

Study Area

This research covers 36 municipalities across southern Ontario (**Figure 1**) and the following analysis divides them into three geographic regions, including Central Ontario, Southwestern Ontario, and Southeastern Ontario.

The Central Ontario boundaries were selected in accordance with the Greater Golden Horseshoe. There were 15 municipalities in this area, including Dufferin, Durham, Niagara, Haldimand, Brant, Hamilton, Halton, Waterloo, Wellington, Peel, York, Simcoe, Kawartha Lakes, Peterborough, and Northumberland.[1]. This Central region reported 1,472,687 hectares of census farmland in 2016, 29.5% of the provincial total. Municipalities in this region are further divided into two groups, an "Inner Ring" and "Outer Ring," according to where they are located around the Greenbelt; a provincially protected area comprised of prime agricultural land and environmentally sensitive landscapes.

The "Inner Ring" area covers the municipalities closest to the City of Toronto, including the Regions of Durham, York, Peel, Halton, Niagara, and the City of Hamilton. This area is the most populated metropolitan area in southern Ontario and is under the greatest pressure from urban expansion. It contains 28.8% of the total census farmland in Central Ontario. The "Outer Ring" area refers to municipalities further removed from Toronto, including the Counties/Cities of Dufferin, Haldimand, Brant, Waterloo, Wellington, Simcoe, Kawartha Lakes, Peterborough, and Northumberland. This area includes 72.2% of the census farmland area in Central Ontario.

Most of the municipalities in this region are rural areas with a varied landscape of small and mid-sized cities, towns, villages, and hamlets. Southwestern Ontario comprises 11 municipalities, including Grey, Bruce, Huron, Perth, Oxford, Norfolk, Middlesex, Elgin, Lambton, Chatham-Kent, and Essex. The 2016 Canadian Census of Agriculture reported 2,135,538 hectares of census farmland in this region, 42.7% of the province's total census farm area. The Southeastern Ontario area covers ten municipalities, including Hastings, Prince Edward, Lennox and Addington, Frontenac, Renfrew, Lanark, Leeds and Grenville, Ottawa, Stormont, Dundas and Glengarry, and Prescott and Russell. The total census farm area was 1,014,968 hectares in 2016, which is 20.3% of the provincial census area of farms.

[1]The City of Toronto is excluded from this project because no significant undeveloped prime agricultural land is in its jurisdictional boundary.

METHODOLOGY

This next section will outline, in detail, the methodological framework undertaken inclusive of secondary data collection and analysis procedures, as well as the approach of the methodology adopted and its contributions to the fields of agricultural land-use planning (and preservation) and more specifically, plan evaluation.

The Canadian Census of Agriculture is the primary data source for measuring farmland availability in this research context. The Canadian Census of Agriculture, facilitated at the federal level by Statistics Canada, is conducted every 5 years to collect data related to physical, economic, social, and environmental characteristics of Canadian agricultural industries, farm operators, and farm operations (Statistics Canada, 2021). While the census provides an enumeration of agricultural land in production at different geographic levels, it does not reflect local land-use planning decisions compromising the long-term preservation of these lands, nor does it distinguish between other classes of agricultural land productivity (i.e., prime vs. non-prime). When farmland is redesignated to non-agricultural land uses, on-site farming activities may continue, but these lands are eventually destined for conversion to non-farm uses (Epp and Caldwell, 2018). The census only tracks changes to land production; farms that have been redesignated for urban development but continue agricultural production would be counted in the census regardless of the land-use designation. The census would not capture farmland availability and, potentially, farmland under threat of development. As a result, the use of OPAs would provide a more accurate and valid measure of farmland availability.

This article tracks land-use planning decisions that convert agricultural land to other uses. Municipal OPAs were used as the primary data source to track farmland conversions. These amendments reflect a marked decision to permit the land to be used for an alternative, often development-driven purpose. This methodology responds to the gaps in quality data (specifically the census), documenting the change in farmland availability and the current impacts of non-farm and urban development contributing to long-term trends of farmland conversion. The resulting data provides insight into land-use changes as they occur before development and ultimately assesses the effectiveness of existing policy planning tools in their ability to preserve agricultural lands for the long term in Ontario. Overall, the method is valuable for evaluating policy effectiveness in real-time, in contrast to waiting for census results accounting for the loss of farmland after it has already occurred.

FIGURE 1 | Map of the Southern Ontario.

OPAs provide a consistent, valid, reliable, and publicly available source of data that can be used to track the conversion of prime agricultural land in Ontario reliably and at individual municipal levels, given as they are required by all municipalities when altering land-use designations [Drake, 2019; MMAH, 2021]. In adopting the following methodological process, this article quantifies the Greenbelt Plan's (MMAH, 2005b) effect and measures farmland loss in individual municipal plans in a given timeframe (2000–2017). This methodology has value applied to contexts in Canada and elsewhere, particularly municipal governments responsible for land-use planning, policy implementation, and decision-making. Measuring approvals at this level can help describe prominent regional trends, successes, and failures in managing growth.

The methodological process includes location analysis, boundary identification, and data collection. The first step was to determine where prime agricultural land existed in Ontario to determine the focus areas for the study. Information was drawn from various sources including the Ontario Ministry of Agriculture, Food and Rural Affairs' Agricultural Information Atlas soil capability for agricultural mapping layer.[2] Thirty-six counties and regions with prime agricultural land were identified. The Official Plans of these selected municipalities were reviewed to determine what designations applied to prime agricultural land and any distinction between prime and non-prime agricultural land areas. Researchers collected the data in partnership with municipalities or independently through online databases. As a governance mechanism that mandates reporting, OPAs exist and are publicly available as prescribed by ministerial regulation under the Planning Act (1990), which outlines legislative requirements for the land-use planning process and decision-making in Ontario. As a result, OPAs are a mechanism and application required when a proposed use or development conflicts with a municipal Official Plan and requires an amendment to ensure plan conformity, which is subject to a public hearing process and is approved at the discretion of the municipal council. The primary data collected for this study is taken directly from OPAs approved at the upper-tier (i.e., region or county) level during the study's timeframe. Where available, secondary data including information from the accompanying planner's report, initial OPA application forms, archived municipal council minutes, and Ontario Municipal Board (OMB) case decisions were also used. Additional information collected included: application date, adoption date, OPA purpose, previous land-use designation, new land-use designation, special policy (if applicable), impacted area

[2] http://www.omafra.gov.on.ca/english/landuse/gis/portal.htm

TABLE 2 | Categorization of OPAs in the research study.

No.	Category type	Examples of converted uses
1	Prime agricultural areas redesignated to a development designation.	To permit residential, commercial, industrial, and infrastructural uses. This includes OPAs connected to Municipal Comprehensive Reviews and urban boundary adjustments.
2	Prime agricultural areas redesignated to a rural designation.	Rural designations to permit non-agricultural uses (e.g., village or hamlet).
3	Land designated as a prime agricultural area with a site-specific policy amendment to allow for additional, non-agricultural uses.	Site-specific policies permitting non-agricultural uses on either a portion of the land or the entire parcel, with some of the land remaining in agricultural production (such as on-farm diversified uses).

in hectares, lot and concession plan, other location identifiers and, if applicable, OMB appeals.

Applicable OPAs were categorized into three themes to illustrate and quantify the scales and community development patterns contributing to farmland loss. These categories represent the nature of the amendment. Redesignations to development tended to lead to direct urban expansion (often large-scale farmland conversion); redesignations to rural tended to occur on areas of lesser quality farmland, and the uses tended to be more "rural" (relating to villages and or hamlets). Lastly, site-specific policy amendments tended to be used where the land was still designated as "agriculture." Still, the actual uses, while extensive, were not agricultural (e.g., an automotive speedway on an agricultural parcel). Applicable OPAs were organized into three categories:

1) Prime agricultural areas redesignated to a development designation;
2) Prime agricultural areas redesignated to a rural designation; and
3) Land designated as a prime agricultural area with a site-specific policy amendment to allow additional uses.[3]

These categories and examples of their respective development designations converted from prime agricultural areas are described in further detail in **Table 2**.

FARMLAND LOSS BETWEEN 2000 AND 2017

This next section will outline research results, including various trends relative to farmland loss from 2000 to 2017. First, it will outline trends of farmland loss at a provincial level, followed by region-specific trends related to Central Ontario, Southwestern Ontario, and Southeastern Ontario.

Trends of Farmland Loss at the Provincial Level

Between 2000 and 2017, 545 OPAs were approved to convert prime agricultural land to non-agricultural designations or to permit non-agricultural uses in southern Ontario. In total, these amendments affected 29,217 hectares of designated prime agricultural land. The most prime agricultural land loss occurred in Central Ontario, representing 83.5% of the provincial total (24,404 ha). Comparatively, Central Ontario also experienced the highest population growth[4]. during the past two decades. Southwestern Ontario, which has the greatest farmland area among the three regions, captured 12.1% of the total prime agricultural land loss (3,541 ha). Southeastern Ontario saw the smallest amount of farmland loss among the three areas, with 4.4% of the total captured amount (1,272 ha).

Most prime agricultural land loss identified in this research is captured in the category of "prime agricultural areas redesignated to a development designation," (76%) resulting from large-scale urban boundary expansions, followed by redesignation to rural uses (14%), and site-specific policies allowing for non-agricultural uses (12%) (see **Chart 1**).

The years of 2006, 2013 and 2015 saw the highest amount of prime agricultural land loss due to urban boundary expansion OPAs in the GGH area (**Chart 2**). The most increased annual occurrence of prime agricultural land loss transpired in 2006, with 5,325 hectares of designated prime agricultural land converted. This loss was mainly accounted for by York Region (1,696 ha) and Peel Region (2,428 ha). Another peak of farmland loss was in 2013, which lost 4,388 hectares of prime agricultural land, mainly in Halton Region (2,656 ha) Durham Region (1,562 ha). Similarly, 2015 had the third-highest annual loss of prime agricultural lands, consisting of 1,966 hectares, mainly in York Region (1,000 ha) and Peterborough (688 ha). Most of these large-scale OPAs were part of local MCRs.

In a 5-year incremental timeline (**Figure 2**), the period between 2000 and 2004 (before the establishment of provincial policies) saw a total of 6,172 hectares of prime agricultural land lost, including that in Central Ontario (5,573 ha), Southwestern Ontario (522 ha), and Southeastern Ontario (77 ha).

The period between 2005 and 2009 experienced the greatest amount (11,651 ha) of prime agricultural land loss in all three regions: Central Ontario (8,980 ha), Southwestern Ontario (1,696 ha), and Southeastern Ontario (975 ha). It is important to note that this increase of farmland loss is not "caused" by the 2005 provincial policies, but rather that the extent of farmland loss in this phase is a consequence of applications approved before the Provincial Policy Statement and the Greenbelt Plan came into effect.

The period between 2010 and 2014 better reflects the effect of the 2005 provincial policies, as most of the OPAs

[3]Some types of OPAs were not included in this study. Certain classes of "housekeeping amendments" were excluded, as were OPAs relating to wind turbines and aggregate operations, as they were not considered a permanent land-use conversion in the existing planning system. The timeframe for this study covers 2000–2017. Much of the data pivots around 2005 when revised provincial policy and new legislation were adopted. It, therefore, provides comparative data to assess the strength of these policies.

[4]https://www150.statcan.gc.ca/n1/daily-quotidien/200213/dq200213a-eng.htm

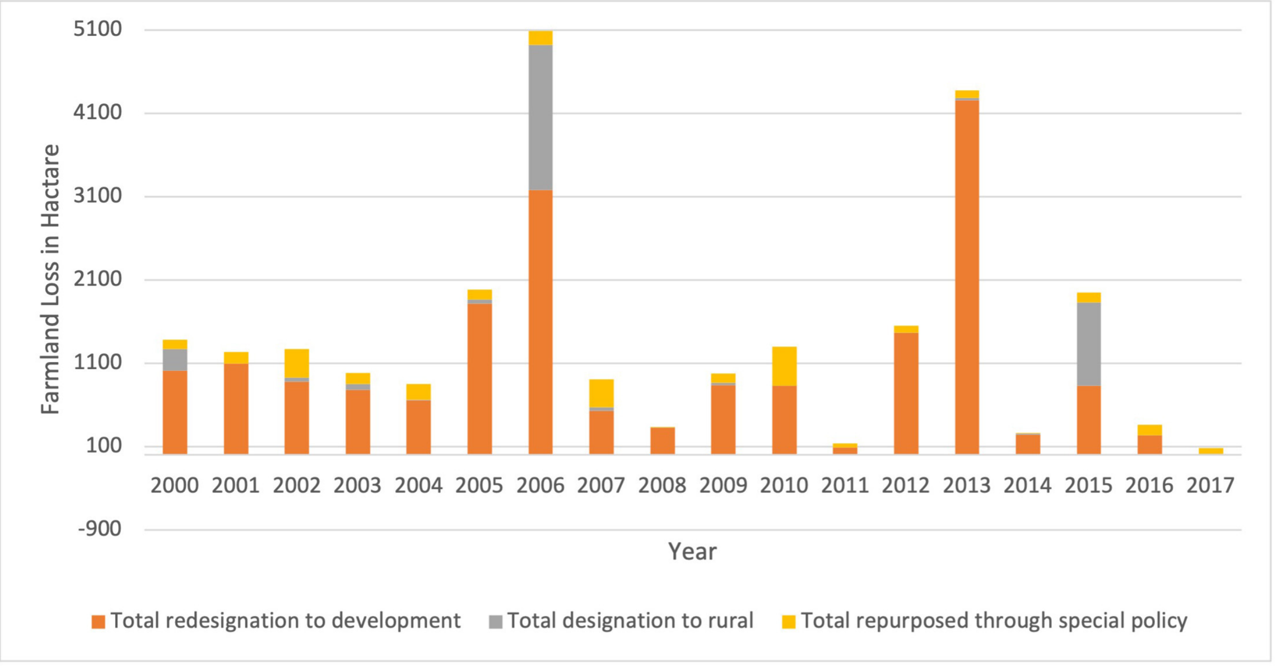

Chart 1 | Yearly prime agricultural land loss divided by category in Southern Ontario, 2000–2017.

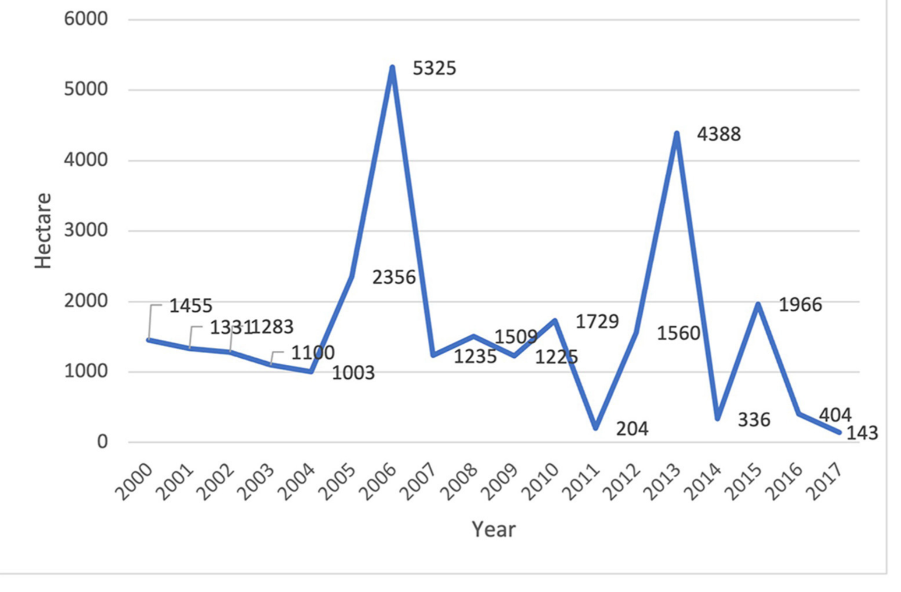

Chart 2 | Agricultural land loss across Southern Ontario by year, 2000–2017.

approved in this phase were subjected to provincial policies' regulation after 2005. All three regions experienced an apparent decline in prime agricultural land loss from 2010 to 2014 (total of 8,216 ha) relative to the farmland lost from 2005 to 2009.

Central Ontario

The Central Ontario region, or the Greater Golden Horseshoe area, is the most urbanized and fastest-developing area. Currently, Central Ontario is under the directive regulation of the Growth Plan and the Greenbelt Plan, with over 90% of the

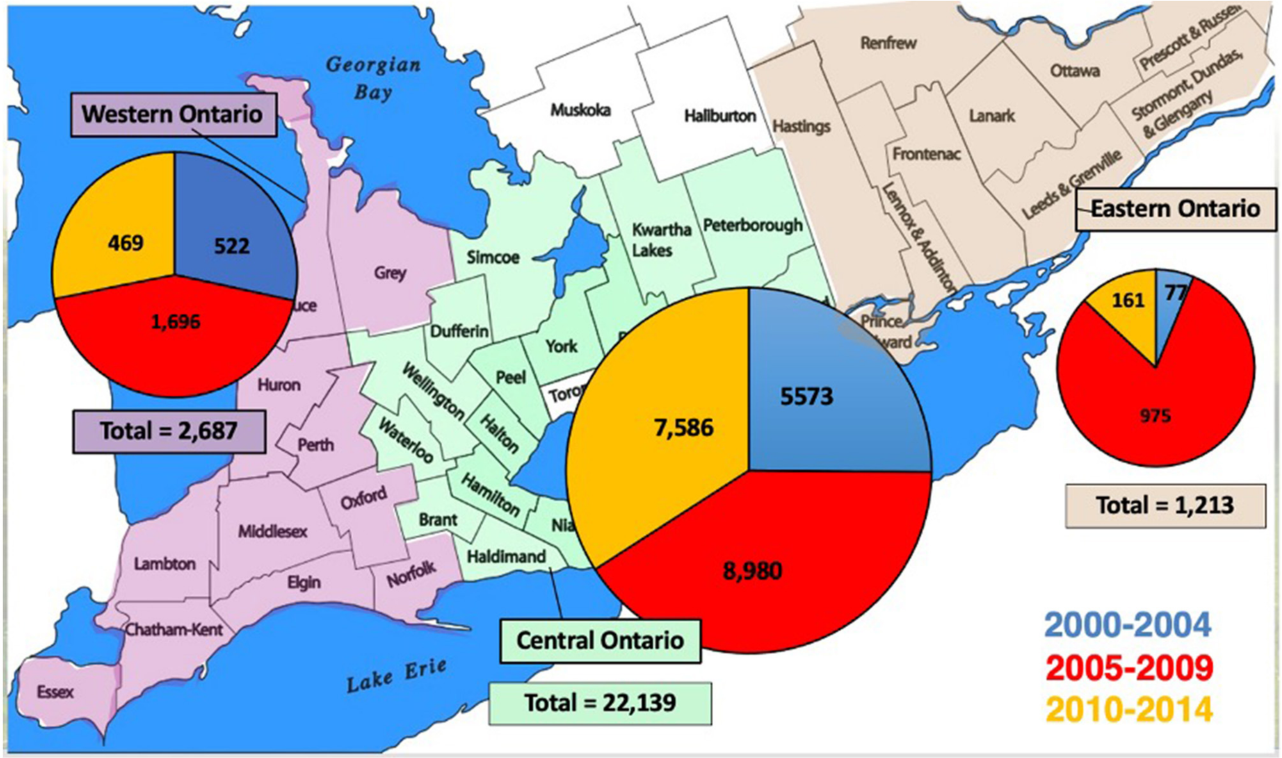

FIGURE 2 | Regional total prime agricultural land loss in 5-year increments in Southern Ontario, 2000–2014.

Greenbelt Plan area and 25 urban growth centers identified in the Growth Plan located within its boundary.

Between 2000 and 2017, Central Ontario captured 83.5% of the total prime agricultural land loss identified in this article and 1.7% of the census farmland area. The three counties/regions which have experienced the highest percentage of prime agricultural land loss are all in the Greater Toronto Area (GTA), including York, Peel, and Halton (**Table 3**).

This article found an overall downward trend in the number of approved OPAs relevant to prime agricultural land loss in Central Ontario from 2000 to 2017 (**Chart 3**). The number of OPAs and their average size demonstrate three different patterns of farmland loss in this region. First is that the most populated GTA municipalities have comparatively fewer OPA numbers and larger average sizes (>200 ha). The fast-developing Outer Ring population centers have comparatively medium OPA numbers and average OPA size (30–60 ha). The other rural Outer Ring counties have a relatively small average OPA size, and they vary in the total number of OPAs.

Most OPAs redesignating prime agricultural land to non-agricultural land uses resulted from MCRs (72%), namely to expand urban boundaries or redesignate farmland for comprehensive urban uses (**Table 4**). Additional purposes for OPAs resulting in farmland loss (**Table 4**) include redesignations to employment lands (10%), recreational, residential, and municipal infrastructural (4%), and other uses, including industrial, commercial, and institutional (5–6%).

Between 2000 and 2017, most of the farmland loss occurred in the Inner Ring area (337 ha lost), accounting for 75% of the total lost farmland in Central Ontario (**Table 5**). Land redesignated for development totaled 13,860 hectares within the Inner Ring (3,052 ha for rural purposes and 1,426 for site-specific non-agricultural uses). During this period, the Outer Ring lost 6,072 hectares. The number of OPAs in the Outer Ring is 50% higher than the Inner Ring; however, the average OPA size is distinctly less (38.9 ha) than the Inner Ring (176.3 ha). **Table 5** illustrates these trends in further detail.

Southwestern Ontario

Southwestern Ontario is a traditionally agricultural region with the greatest provincial share of farmland. The Growth Plan does not apply here, and only a small part of Grey and Bruce Counties falls under the protection of the Greenbelt Plan. There are three major population centers in this region (London, Windsor, and Sarnia); however, urban development in this region has been relatively limited over the past decade. Between 2000 and 2017, this region saw 3,541 hectares of prime agricultural land converted to non-farm uses, representing 12% of the total farmland loss in this research (**Table 6**). The total number of relevant OPAs captured in Southwestern Ontario is 246 and accounts for 45% of the total number of captured OPAs in this project. This makes the average OPA size 14.9 hectares, 27.8% of the provincial average—the smallest among the three regions.

TABLE 3 | Prime agricultural land loss in central Ontario.

County	Census farmland (ha) 2001	Prime agricultural land loss (ha) 2000–2017	Percentage loss (%)	OPA number	Average OPA size
York	71,211	7,989	11.22	17	469.9
Peel	42,263	3,442	8.15	6	573.7
Halton	39,966	2,938	7.12	11	267
Niagara	94,218	2,087	2.22	45	46.4
Durham	133,662	1,693	1.27	5	338.6
Simcoe	218,882	2,426	1.11	45	53.9
Waterloo	91,378	1,019	1.12	7	145.6
Peterborough	104,669	796	0.76	12	66.3
Wellington	190,764	935	0.47	28	33.4
Hamilton*	56,202	186	0.33	21	8.9
Haldimand	86,590	284	0.33	21	13.5
Dufferin	78,170	247	0.32	8	30.9
Kawartha Lakes	145,966	236	0.16	23	10.3
Northumberland	102,654	63	0.06	6	10.5
Brant	64,221	64	0.1	5	12.8
Total	1,520,816	24,404	1.6	260	93.9

**The City of Hamilton's results are not directly comparable to other regions in this Table as the dataset is not considered to be complete or verified.*

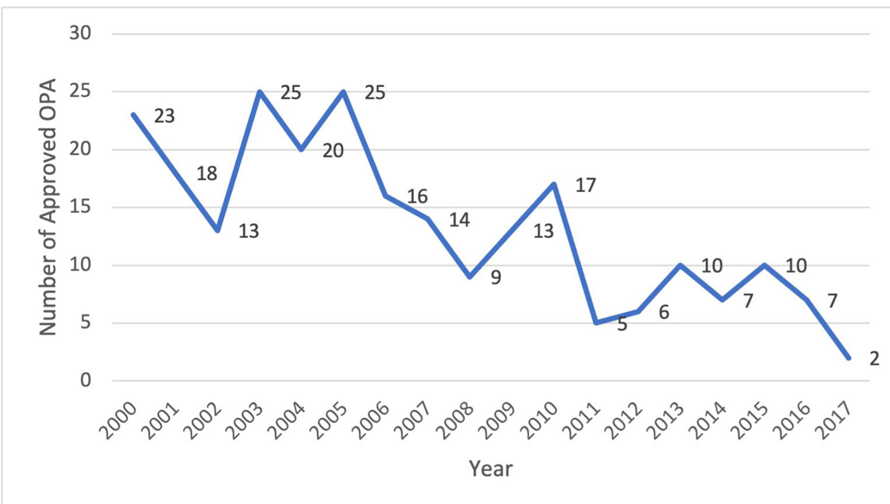

Chart 3 | Number of yearly approved OPAs in Central Ontario.

Most cases for farmland conversion in Southwestern Ontario were small-scale applications intended to create small lots on existing agricultural land, allowing for non-agricultural uses, such as commercial, recreational, residential, and agricultural-related facilities. The "rural" designation does not exist in most local municipalities' Official Plans within Southwestern Ontario. As a result, most of the farmland losses were captured under the categories of "redesignation for development use" or "non-farm use through site-specific policies" (**Table 6**).

In Southwestern Ontario, there was no obvious upward or downward trend regarding the annual loss of prime agricultural lands and approved numbers of OPAs (**Charts 4A,B**). The years 2008 and 2017 saw the most approved OPAs with 20 each and most farmland loss occurring in 2008. Relative to the rest of the province, particularly Central Ontario, the rates of urban development have been more limited within Southwestern Ontario. This finding is unsurprising given that Southwestern Ontario has the highest provincial share of productive farmland and a competitive and

TABLE 4 | Area of official plan amendments categorized by purpose and proportion of total OPAs (%).

Purpose of OPA for redesignated use	Proportion of total OPAs (%)
Comprehensive official plan update (MCR)	72
Employment	10
Recreational	4
Municipal infrastructure	4
Residential	4
Industrial	2
Mineral extraction	2
Commercial	1
Institutional	1

prosperous regional agricultural industry. Given these regional characteristics, these trends may illustrate the lesser development pressures contributing to farmland loss relative to the more rapidly urbanizing and populated Central Ontario.

Southeastern Ontario

The Southeastern region of Ontario has the lowest proportion of census farms and prime agricultural land (**Table 7**). Bedrock geology characterizes a large proportion of this area. Consequently, this area has the lowest capability of agricultural soils and, in turn, the lowest amount of prime agricultural land loss. Between 2000 and 2017, 1,272 hectares of prime agricultural land were redesignated to non-farm uses, representing ∼5% of the total captured prime agricultural land loss in this project. The average OPA size in this region is 32.6 hectares, 60.8% of the provincial average.

The Southeastern region had the lowest number of relevant OPAs among the three areas within the study period, with each county reporting <10 relevant OPAs (**Chart 5A**). Like Southwestern Ontario, there is no obvious upward or downward trend regarding annual prime agricultural land loss. The most OPAs approved, and the highest amount of primary agricultural land loss were in 2008 when 8 OPAs converted 394 hectares of prime agricultural lands (**Chart 5B**). Proportions of OPAs contributing to this total land loss include development redesignations (54.7%), rural redesignations (30.4%) and site-specific policies (14.9%) primarily (see **Table 7**).

DISCUSSION: THE STRENGTH OF PROVINCIAL FARMLAND PROTECTION POLICIES

In tracking agricultural land conversion through regional and local OPA decisions, this article indicates patterns of future farmland loss in Ontario and the effectiveness of agricultural land preservation policies in real-time. Our analysis presents that 545 OPAs were approved, converting 29,217 hectares of prime agricultural land in southern Ontario from 2000 to 2017. While rates and nature of farmland loss vary regionally across the study area, large-scale farmland conversion caused by urban boundary expansion dominated Central Ontario, the region with the most significant population growth. Also, it accounted for the highest amount of farmland loss. In terms of the area lost, Southwestern and Southeastern Ontario accounted for the following highest levels of farmland loss during this period, respectively, due to an accumulation of permissions for site-specific uses. The highest peaks of farmland loss were accounted for in 2006, 2013, and 2015 as part of local MCRs and large-scale urban boundary expansions, reiterating the threats urban sprawl imposes on farmland loss. However, while most farmland loss results from large-scale urban boundary expansions, the cumulative effects of farmland loss resulting from rural designations and site-specific policy amendments on individual parcels should not be underestimated. Results in this study evidence a general decline in farmland loss in 2010–2014 relative to the 2000–2004 and 2005–2009 periods, before the establishment of provincial farmland preservation policies in 2005.

Overall, this article (**Table 8**) demonstrates that the establishment of several provincial policy initiatives in 2005, including the revised Provincial Policy Statement, the Growth Plan, and the Greenbelt Plan, has successfully minimized the rates of farmland loss and protected prime agricultural lands. For example, the Growth Plan establishes density and intensity requirements that several urban centers and regions outside of the Greenbelt (not subjected to Greenbelt Plan policies) need to adopt and implement into their Official Plans. While not prohibiting development in prime agricultural areas directly, these growth management policies facilitate the densification and intensification of urban areas and the mitigation of urban sprawl—highlighting the "other side of the coin" to farmland protection in land-use planning. Overall, these policies establish a framework that consistently contributes to enhanced municipal control over agricultural land conversion in southern Ontario.

The Inner Ring municipalities have played increasingly active roles in agricultural land protection with both planning approaches and local initiatives. The Outer Ring municipalities have seen increasing urbanization pressure. Data on farmland loss showed a mixed landscape of large-scale municipality-led urban boundary expansions and small-scale individual applications on policy changes to allow for non-agricultural uses. Southwestern Ontario has experienced limited urbanization during the past two decades, and this research did not detect an obvious upward or downward trend of farmland loss in these areas. Most of the farmland conversion cases in this area were small-scale applications to create small lots on existing agricultural land to allow non-agricultural uses such as commercial, recreational, residential, and agricultural-related facilities. Southeastern Ontario has the smallest provincial share of prime agricultural land and has seen minimal farmland loss

TABLE 5 | Redesignations in the inner ring of the Greenbelt, 2000–2017.

County/region	Number of approved OPAs related to the loss of prime agricultural land	Prime agriculture redesignated to:		
		Development (ha)	Rural (ha)	Non-farm uses through site-specific policies (ha)
Durham	5	1,619	56	18
Halton	11	2,656	0	282
Niagara	45	1,001	240	847
Peel	6	3,316	0	127
York	17	5,233	2,756	0
Hamilton	20	34.5	0	152
Inner ring total	104	13,860	3,052	1,426
Brant	5	0	0	63.5
Simcoe	45	2,034.2	82	310
Waterloo	7	1,019	0	0
Wellington	29	817	32	88
Haldimand	21	71	0	213
Peterborough	12	746	15	34
Dufferin	8	59	0	188
Northumberland	6	2	60	2
Kawartha Lakes	23	129	50	57
Outer ring total	156	4,877.2	239	955.5

TABLE 6 | Redesignations in Southwestern Ontario, 2000–2017.

County/region	Number of approved OPAs related to the loss of prime agricultural land	Redesignations in Southwestern Ontario 2000–2017			
			Prime agriculture redesignated to:		
			Development (ha)	Rural (ha)	Non-farm uses through site-specific policies (ha)
Grey	15	136	0	107	29
Huron	2	25	25	0	0
Perth	72	756	254	0	502
Middlesex	15	175	78	0	97
Lambton	31	540	285	0	255
Chatham-Kent	16	132	74	0	58
Elgin	7	242	242	0	0
Bruce	35	136	43	0	93
Oxford	16	869	842	0	27
Norfolk	37	519	85	0	434
Essex	0	0	0	0	0
Total	246	3,541*	1,928	107	1,495

Totals may not add due to rounding.

since 2000. Most of which were small-scale individual application on land-use redesignations (partially reflecting reduced acreages of prime farmland). The provincial policy impact on farmland preservation is not as obvious in this geography.

The connection between minimized rates farmland loss and provincial farmland protection policies is particularly evident within Ontario's Greater Golden Horseshoe, particularly within the Inner Ring, also the Greenbelt Plan Area. During the initial

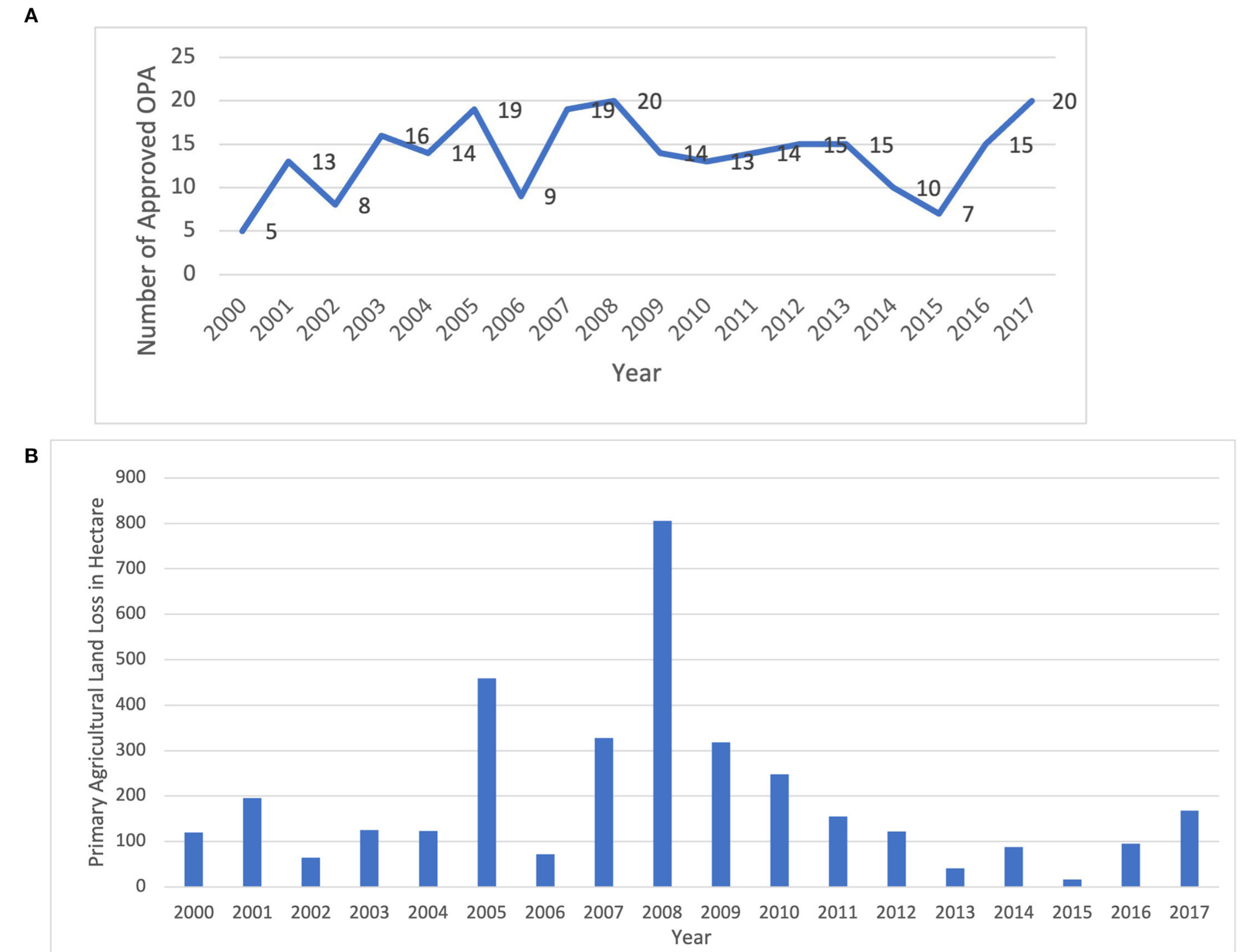

Chart 4 | (A) Number of yearly approved OPA in Southwestern Ontario. **(B)** Yearly primary agricultural land loss in Southwestern Ontario.

implementation of the Greenbelt Plan in 2005, there was much scrutiny (and doubt) within Ontario from several stakeholders over the perceived efficacy of the policy (Hume, 2010). For example, anecdotal accounts share how farms in the Greenbelt's "protected countryside" were subject to development after the initial onset of the Greenbelt in 2005—signaling a perceivable policy failure amongst Ontario communities (Epp and Caldwell, 2018). However, as noted in our article, quantifiable evidence illustrates this is not the case. These agricultural parcels were "lost" to development at the time of the planning decision, which would have occurred before the implementation of Greenbelt policies. For instance, before establishing the Greenbelt Plan, there were 1,427 hectares of prime agricultural land redesignated across the Greater Golden Horseshoe between 2000 and 2004 within the current Greenbelt boundary. Approximately 1,420 hectares of the converted farmland were located in the Inner Ring area, and only 7 hectares of farmland were converted in the Outer Ring area. The annual average farmland loss in the Inner Ring area was 284 hectares. Since the Province of Ontario enacted the Greenbelt Plan, the total farmland loss in the Inner Ring area within the Greenbelt boundary dropped to 13 hectares during 2005–2017, making the annual average loss only 1 hectare. There were only three OPAs approved since the establishment of the Greenbelt, which affected prime agricultural land within the Greenbelt boundary. This article shines a light on the success of the Greenbelt Plan, evidencing the effect of the Greenbelt policies on farmland protection when comparing communities with high development pressure to those outside of the protected countryside. Moreover, these findings reiterate the lessons from other Greenbelt policy areas in the world to illustrate the critical and pivotal role policy plays in mobilizing sustainability and farmland protection within policy-protected areas (Carter-Whitney, 2008).

Concerning the success of other farmland protection policies, our analysis suggests that for those areas outside of the Greenbelt and Growth Plan areas, the agriculture policies of the Provincial Policy Statement have performed reasonably well in protecting prime agricultural lands. For example,

TABLE 7 | Redesignations in Southeastern Ontario, 2000–2017.

County/region	Number of approved OPAs related to the loss of prime agricultural land	Prime agriculture redesignated to:		
		Development (ha)	Rural (ha)	Non-farm uses through site-specific policies (ha)
Ottawa	3	132	41	6
Prescott and Russell	5	51	137	29
Stormont, Dundas, and Glengarry	9	1.4	120	33
Leeds and Grenville	3	186	12	7
Renfrew	3	0	54	0
Hastings	7	40	179	0
Prince Edward	9	0	110	137
Frontenac	0	0	0	0
Lennox and Addington	0	0	0	0
Lanark	0	0	0	0
Total	**39**	**777**	**431**	**212**

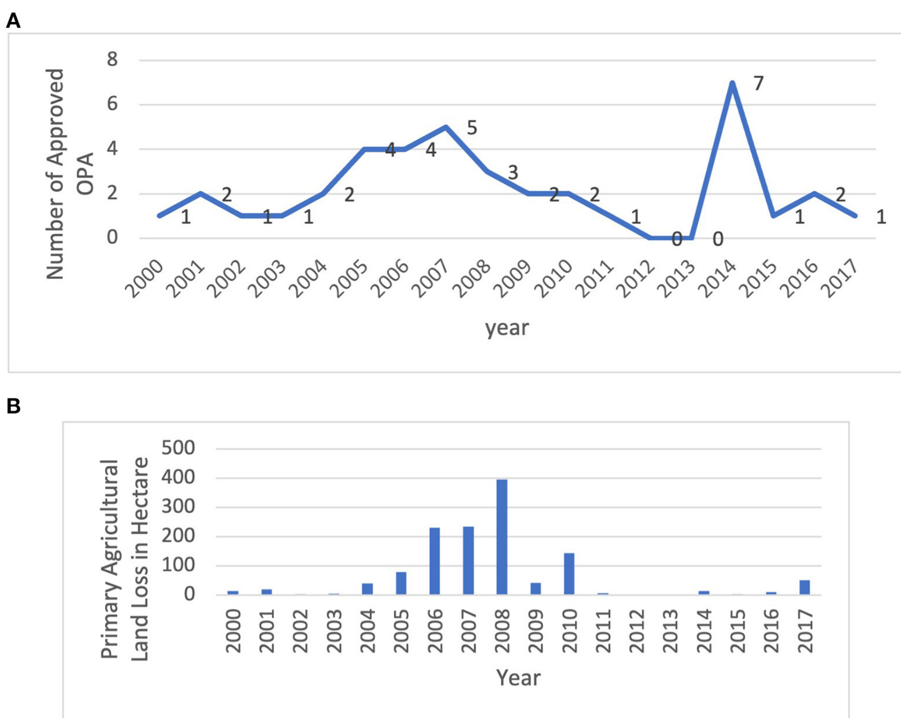

Chart 5 | (A) Number of yearly approved OPA in Southeastern Ontario. **(B)** Yearly primary agricultural land loss in Southeastern Ontario.

outside of the Greenbelt, there has been an overall declining rate of farmland loss across the Greater Golden Horseshoe since 2005. Annual farmland loss outside the Greenbelt has dropped by almost 50%. Both the Inner Ring area and the Outer Ring have seen a decline in yearly farmland loss. The average of the Inner Ring's annual farmland loss dropped by 40%, whereas the average of the Outer Ring's annual farmland loss dropped by 75%. This is evident in regions such as southwestern and Southeastern Ontario, where only one policy layer (the PPS) is applied and implemented to protect prime agricultural lands at the municipal level, and trends of farmland loss are relatively low or consistent throughout 2000–2017. This is relative to areas subject to multiple layers of farmland protection policy, however, such as Central Ontario,

TABLE 8 | Prime agricultural land conversion in GGH 2005–2017.

Region	Within the Greenbelt		Outside the Greenbelt	
	2000–2004	2005–2017	2000–2004	2005–2017
GGH PAL loss	1,427	31	10,061	12,433
GGH Annual PAL loss	285	2.4	2,012	956
Inner Ring PAL loss	1,420	13	6,540	10,178
Inner Ring Annual PAL loss	284	1	1,308	783
Outer ring area Total PAL loss	7	18	3,521	2,255
Outer Ring Annual PAL loss	1.4	2.4	704	173

which is experiencing consistent development pressure (i.e., the highest amount of farmland loss, urbanization, and population growth) and why we bring focus to this policy area in our discussion. Overall, the provincial-wide analysis of farmland loss has provided a way to evaluate whether more robust policy instruments are needed elsewhere in the province beyond the Greenbelt area.

CONCLUSIONS

This article reviewed southern Ontario's farmland preservation and urban expansion policies and evaluated their effectiveness with quantitative data. By tracking the agricultural land conversion through local Official Plan Amendments, this study documented farmland loss across Ontario between 2000 and 2017. Provincial policies and local municipalities' role in preserving farmland in different geographic regions were analyzed.

At a provincial level, data from 36 counties/regions shows that the provincial policies and local planning framework have perceivably worked in tandem to affect the agricultural land base in southern Ontario significantly. At a regional level, however, this study reveals that the loss of prime agricultural lands and resulting policy implications are focused within Central, rather than Southwestern or Southeastern, Ontario. In Central Ontario, which is the most urbanized area in Ontario, the Province's Greenbelt Plan has significantly reduced the rates of farmland loss within this geographic range since 2005. Elsewhere within the province, the Provincial Policy Statement and the Growth Plan, for example, establish requirements that municipalities are expected to adopt and implement into local Official Plans, which protect farmland in different ways.

This research has introduced a planning-based methodology to track the availability of agricultural land and has documented the farmland conversion at regional and municipal levels. Measuring approvals at this level can help describe prominent regional trends, successes, and failures in helping to guide growth as it occurs in real-time. This methodology has potential broader applicability in Canada and elsewhere, where land-use decisions primarily involve municipal governments. Moreover, the data in this research has provided a baseline for future farmland availability research, and has created a framework for further policy, agricultural, economic, and planning research.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: http://www.waynecaldwell.ca/projects/.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

FUNDING

This research was made possible through funding support from the Ontario Ministry of Agriculture, Food and Rural Affairs.

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frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 21 February 2022
doi: 10.3389/fsufs.2022.758426

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Environmental Concerns and Stewardship Behaviors Among Rural Landowners: What Supports Farmers and Non-farmers in Being Good Stewards?

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Intensive agriculture is a main factor of biodiversity and ecosystem services loss globally. It is therefore of great importance to understand how rural landowners are managing their lands and how environmental stewardship behaviors could be strengthened. Farming and non-farming rural landowners are often considered a homogenous group. In reality, however, they vary by their histories, attitudes, interests, and resources. While many rural landowners manage their lands with environmental values in mind, others may struggle to do so. Ignoring this diversity poses the risk that planning and policy for sustainable agriculture are less effective than they could be. Hence, it is of interest to understand the variety of environmental perceptions and stewardship behaviors across these varied groups. To help addressing this knowledge gap, we conducted a survey of 1,200 farming and non-farming rural landowners, using Ontario as a case study. We specifically investigated whether farming landowners differed from non-farming landowners in expressed environmental concerns and stewardship behaviors, as well as what the roles are of participation in conservation incentive programs, demographic factors, and landholding characteristics. We analyzed survey answers with logistic regression and text analysis. Our results suggest that farming landowners are generally less environmentally concerned than non-farming landowners. However, it appears that this difference may be less driven by farm ownership than by contextual factors, such as landowner age and participation in conservation programs. Participation in conservation programs was more pronounced for non-farming landowners and was associated with higher likelihood of environmental concerns and engaging with stewardship behaviors. In contrast, higher age emerged as predictor of lower environmental concerns. In addition, we found that cost factors and knowledge needs were important barriers for stewardship behaviors across farming and non-farming rural landowners. Based on our results, we are making recommendations for increasing the effectiveness of agricultural sustainability planning and policy in Ontario, focusing on reducing financial and knowledge barriers to pro-environmental land management behaviors.

Keywords: agriculture, environmental concern, farm, land conservation, rural landowner, stewardship, Ontario

OPEN ACCESS

Edited by:
Christopher Fullerton, Brock University, Canada

Reviewed by:
Cheryl Wachenheim, North Dakota State University, United States
Viswanathan Pozhamkandath Karthiayani, Amrita Vishwa Vidyapeetham (Kochi Campus), India

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Specialty section:
This article was submitted to Land, Livelihoods and Food Security, a section of the journal Frontiers in Sustainable Food Systems

Received: *13 August 2021*
Accepted: *13 January 2022*
Published: *21 February 2022*

Citation:
Drescher M and Warriner GK (2022) Environmental Concerns and Stewardship Behaviors Among Rural Landowners: What Supports Farmers and Non-farmers in Being Good Stewards? Front. Sustain. Food Syst. 6:758426. doi: 10.3389/fsufs.2022.758426

INTRODUCTION

Intensive agriculture has been recognized as one of the main factors in loss of biodiversity (Dudley and Alexander, 2017; Sánchez-Bayo and Wyckhuys, 2019; Raven and Wagner, 2021) and ecosystem services (Gomiero et al., 2011) across the world. The Green Revolution has provided immense benefits for agricultural food production globally (Smil, 2004). However, as the world population continues to grow and globalization of trade expands, agricultural producers are under intensifying pressure to increase production and maximize profits, often at the expense of more conservation-friendly agricultural practices (Gomiero et al., 2011). Consequently, how to balance agricultural production and environmental conservation, and thus increase the sustainability of agricultural operations, remains an enduring problem without easy answers (Mamabolo et al., 2020).

Agriculture is located at the intersection of society and the environment (Fischer et al., 2017). Much past research has focused on the bio-physical and economic aspects of agriculture. However, a better integration of the social sciences is required in this research area to deliver deep understanding of the various actors in the environment-agri-food nexus and enhanced ability to design effective planning and policy in support of sustainable agriculture (de Snoo et al., 2013; Norton, 2016). Next to the rational economic decision-making required to run a successful agricultural business, farmers may also be affected in their land management activities by their perception of being good land stewards (Raymond et al., 2016; Bennett et al., 2018). Many farmers have strong ties to their place of residence, local communities and natural environments, and they care deeply about the lands they manage (Gosling and Williams, 2010; Baldwin et al., 2017). However, it has also been observed that many farmers can perceive environmental issues and stewardship actions differently than other rural landowners or urban dwellers (Berenguer et al., 2005; Huddart-Kennedy et al., 2009; Gottlieb et al., 2015). When designing effective planning and policies for conservation in agricultural landscapes, it is therefore important to differentiate between relevant population groups and understand their specific concerns, needs and opportunities (Raymond et al., 2016; Ujházy et al., 2020).

Several past studies have investigated the environmental impacts of agricultural operations in a variety of regions globally (Tilman et al., 2001) and have provided recommendations for the reduction of environmental impacts (Wezel et al., 2014). Farmers' land management activities can be beneficial to the natural environment, even though they will have to be balanced with agricultural uses (Lewis-Phillips et al., 2019, 2020; Swartz and Miller, 2019). However, various studies also have demonstrated that many farmers apply conservation-friendly management practices less often than they could, often owing to operational, financial and political factors (Lahmar, 2010; Dupraz and Guyomard, 2019). What is less well-researched is whether farming landowners in fact differ in their environmental perspectives and actual stewardship behaviors from non-farming, rural landowners (Greiner and Greg, 2011). Such an understanding is essential for land conservation planning and policies that connect meaningfully with the specific perspectives of farming landowners and the conditions under which they are operating.

Therefore, to help close these existing knowledge gaps, we pursued answers to the following research questions. First, do farming landowners differ in their concerns about environmental issues and in their stewardship behaviors from non-farming, rural landowners? Given farmers' strong ties to their land, we expected that farming landowners show higher levels of environmental concern and higher engagement with stewardship behaviors than non-farming landowners. Second, next to being a farmer, do other factors influence rural landowners' concerns about environmental issues and engagement with stewardship behaviors? We expected that participation in conservation programs, landowner characteristics, and characteristics of the landholding affect environmental concerns and engagement with stewardship behaviors.

MATERIALS AND METHODS

We used data collected with a large-scale survey to investigate rural landowners' environmental concerns and their stewardship behaviors. Using quantitative and qualitative methods, we compared environmental concerns and stewardship behaviors between farming landowners and non-farming landowners. In addition, we investigated the modifying effects of a range of landowner and property characteristics. Below, we first describe the study context, which is then followed by descriptions of the survey, questionnaire, and analyses.

Study Context

With ∼15 million inhabitants, Ontario is Canada's most populous province. The vast majority of this population is concentrated in the province's south-central region, which also is one of Canada's most important agricultural centers. In 2015, Ontario's agriculture and agri-food industries contributed $15 billion to the province's economy (Statistics Canada, 2019). In 2019, agriculture and agri-food industries employed close to 900,000 people, representing close to 12% of total provincial employment [OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs), 2020]. In the same year, direct employment in primary agriculture was 74,000 [OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs), 2020].

Next to its high population concentration and economic importance, south-central Ontario also is one of Canada's most biodiverse regions, especially for rare plant species (Argus and Pryer, 1990). However, due to species distribution patterns and intense land use pressures, south-central Ontario also is among the Canadian regions with the highest concentration of species-at-risk (Coristine et al., 2018). The most widespread and intense land use in south-central Ontario is agriculture. Of the total land area of south-central Ontario, 4.7 million hectares, or 37%, is classified as farmland [OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs), 2020]. Private lands, of which agricultural lands are the largest part, harbor a large proportion of rare and threatened species in Ontario and throughout Canada (Lovett-Doust et al., 2003; McCune and Morrison, 2020). Land and nutrient management on Ontario farms is correlated with surface water quality over a distance of several kilometers (Houlahan and Findlay, 2004). Consequently, land stewardship practices on Ontario farms can have pronounced biodiversity and other environmental effects across scales from the individual farm to the landscape level throughout south-central Ontario.

Land conservation is a recognized priority in Ontario. Several provincial programs exist that support and encourage private landowners to engage in land stewardship behaviors. These programs include the Conservation Lands Tax Incentive Program (CLTIP), which is focused on the conservation of environmental features of recognized provincial value (Ontario, 2019a), and the Managed Forest Tax Incentive Program (MFTIP), which is focused on the sustainable management of privately owned forests (Ontario, 2019b). Both of these programs are administered by the Ontario Ministry of Natural Resources and Forestry.

Survey

The data used for this study were acquired with a postal mail survey of 1,200 rural landowners. Since we were interested in the stewardship behaviors of rural landowners that owned conservation-relevant properties, the survey was addressed to landowners that owned properties of provincial conservation interest. All addressed landowners participated in one of two provincial conservation programs (CLTIP: $n = 400$; MFTIP: $n = 400$), or were eligible to participate in one of the programs (i.e., CLTIP), but did not participate ($n = 400$). Targeting our study on these landowners ensured that we would be working with participants who own land of importance to land conservation in Ontario.

The survey was designed following the total design method devised by Dillman (2000), including an initial information letter, repeated (three times) mail outs of the full survey package to non-responders, and a final thank you letter to responders. In addition, we offered participants the option of using an online version of the questionnaire and provided each participant a \$5 cash token of appreciation. To protect the privacy of all participating landowners, we used a sampling procedure that anonymized landowners and conducted the survey with the help of a third-party mail service.

Questionnaire

The questionnaire design followed best practices including a full color front cover, use of high-quality paper, consistent visual appearance, and proper ordering of questions (e.g., important questions at the beginning, sensitive questions toward the end). The full questionnaire contained ∼250 questions relating to several topics such as conservation program participation, landowner and landholding characteristics, environmental conservation activities, conservation activity history, condition of natural heritage features on the land, opinions regarding environmental issues, and consumer behaviors. For the purposes of the current study, only a small fraction of questions was utilized (see **Supplementary Material** for short forms of questions included in the current study).

We piloted the questionnaire with eight rural landowners. These landowners provided feedback regarding their understanding and relevance of the questions and we incorporated their feedback to improve the questionnaire.

Analyses

We investigated the effect of being a farming landowner, as opposed to being a non-farming landowner, on landowners' environmental concerns and stewardship behaviors using logistic regression analyses. We defined farming landowners as those who self-identified through the survey as owning a commercial farm that is operated by themselves (47%), or those owning a commercial farm that they leased or rented out to another operator (53%). We defined non-farming landowners as those who self-identified through the survey as owning a residential lot with surrounding lands (i.e., a property not used as a commercial farm).

We used information from CLTIP (Ontario, 2019a) and MFTIP (Ontario, 2019b) guide documents to identify eight potential environmental concerns and eight potential stewardship actions that landowners could reasonably undertake. We used this information because it provides a common basis for possible environmental concerns and stewardship behaviors that can be expected to be relevant to all participating landowners.

Environmental concerns and stewardship behaviors are treated as dependent variables in the logistic regression. Being a farming landowner (or non-farming) is the independent variable of main interest. We also included conservation program participation and several landowner and property characteristics as independent variables that could modify analyses results (see descriptions of the independent variables in the **Supplementary Material**). All regression analyses were conducted with the glm function in RStudio (Version 1.3.1093).

To add richness and depth to the statistical results, we conducted a text analysis of responses to open-ended questions inquiring about (i) suggestions for additional supports for promoting environmental protection and biodiversity conservation on private lands, (ii) possible improvements to the two provincial conservation programs, and (iii) general comments. Text coding was conducted with an iterative process drawing on several coding approaches: hypothesis coding was used to infer respondents' mention of key concepts (e.g., incentives, cost, and taxes); descriptive coding was used to understand respondents' emerging main areas of concern; magnitude coding was used to infer the frequency of topics mentioned (Saldaña, 2009). Coded text fragments were sorted by independent variables (farming identity and conservation program participation) to deduce differences in focus between landowner groups. All coding and text analysis was conducted in MAXQDA Analytics Pro 2020 (Release 20.4.1).

We applied the continuum of resistance model (Lin and Schaeffer, 1995) to investigate whether our data were affected by a non-response bias. For this purpose, we compared the survey responses of early (first half) to late (second half) responders and investigated these groups for differences in gender, age, education, household income, membership in an environmental group, and property size.

TABLE 1 | Summaries of participant and property characteristics for landowners owning a commercial farming property or a rural residential (non-farming) property.

	Farming		Non-farming	
	ha	%	ha	%
Conservation program participation				
CLTIP (participating)		48.6		47.0
MFTIP (participating)		21.5		51.1
Neither		34.6		11.0
Property characteristics				
Property size (median)	40.5		14.0	
Woodlands (present)		87.9		94.0
Grasslands (present)		53.3		51.1
Wetlands (present)		72.9		70.7
Participant characteristics				
Gender (male/female)		71.0/22.4		63.1/33.4
Age (younger/older)		48.6/41.1		58.4/34.1
Education (lower/higher)		49.5/40.2		46.1/49.2
Employment (working/not working)		40.2/54.2		40.7/56.2
Income (lower/higher)		43.0/38.3		43.8/42.3
Environmental group (member/not member)		21.5/71.0		24.6/70.3

RESULTS

Study Participants

We received 598 completed questionnaires from the entire survey. After excluding 110 landowners as they were unreachable, these completions resulted into a response rate of 55%. For the purposes of the current study, we removed from the sample all landowners that identified their property as primarily used as hobby farm, non-farm rural business, and for conservation purposes by a charitable organization or conservation authority. The remaining sample of 421 landowners consisted only of those who identified their property as primarily used for commercial farming by themselves, or by a lessee or renter (henceforth: farming landowners, $n = 107$), and those who identified their property as primarily used for residential purposes (henceforth: non-farming landowners, $n = 317$; **Table 1**).

The largest group of farming landowners participated in the CLTIP (48.6%), their median property size was 40.5 ha and the vast majority of them had woodlands (87.9%) and wetlands (72.9%) on their property. The majority of farming landowners identified as male (71.0%), were younger (<65 years −48.6%), had lower education (no university −49.5%), were not working (54.2%, including landowners owning a farm but not operating the farm themselves), had lower household income (<$100,000 annually −43.0%), and have never been a member of an environmental organization (71.0%).

The majority of non-farming landowners participated in the MFTIP (51.1%), their median property size was 14.0 ha and the vast majority of them had woodlands (94.0%) and wetlands (70.7%) on their property. The majority of non-farming landowners identified as male (63.1%), were younger (<65 years −58.4%), had higher education (at least some university −49.2%), were not working (56.2%), had lower household income (<$100,000 annually −43.8%), and have never been a member of an environmental organization (70.3%).

Early and late responders did not differ by property size ($t = -1.287$, df = 306.68, and $p = 0.199$), gender ($X^2 = 0.229$, df = 1, and $p = 0.632$), age ($X^2 = 1.218$, df = 1, and $p = 0.270$), education ($X^2 = 0.001$, df = 1, and $p = 0.978$), employment ($X^2 = 1.306$, df = 1, and $p = 0.253$), household income ($X^2 = 0.347$, df = 1, and $p = 0.556$), or membership in an environmental group ($X^2 = 2.080$, df = 1, and $p = 0.149$). These results suggest that a non-response bias may not be expected.

Environmental Concerns and Stewardship Behaviors

The survey results demonstrate generally widespread concerns about environmental issues among both farming and non-farming landowners. However, somewhat lower levels of environmental concerns were found among farming landowners than among non-farming landowners, except for threats to water quality and climate change (**Table 2**). For farming landowners, the highest level of concern was for threats to water quality with 84.1% stating this was a serious or slight problem. Farming landowners' lowest levels of concern were for damage to species and loss of species, with 72.0% stating this was a serious or slight problem for both issues. For non-farming landowners, the highest level of concern was for loss of woodlands (90.9%), closely followed by spread of invasive species (90.5%). Non-farming landowners' lowest levels of concern were found for climate change (80.8%).

The survey results for stewardship behaviors were more mixed than for environmental concerns (**Table 2**). Non-farming landowners tended to engage more in planting native species, removing unhealthy trees, improving wildlife habitat and allowing natural succession. However, farming landowners engaged more in controlling erosion. Farming landowners, engaged in or planned most often removing unhealthy trees (55.1%) and least often protecting groundwater and controlling erosion (both 29.0%). Non-farming landowners engaged in or planned most often allowing natural succession (70.0%) and least often controlling erosion (17.0%).

Predictors of Environmental Concerns

The model fit statistics show that most models of environmental concern were highly significant (**Table 3**). The Count R^2 results, which report the proportion of correctly assigned observations, were at least 82% for all models, with 90% as the highest Count R^2 value for loss of woodlands, spread of invasive species and threats to water quality.

The logistic regression analysis results suggest that being a farming landowner does not affect any of the eight environmental concerns (**Table 3**). However, participating in the MFTIP was

TABLE 2 | Summaries of environmental concerns and stewardship behaviors for landowners owning a commercial farming property or a rural residential (non-farming) property.

	Farming (%)	Non-farming (%)	p
Environmental concerns (serious or slight problem)			
Damage to species	72.0	85.8	<0.01
Loss of species	72.0	82.0	0.04
Threats to endangered species	72.9	82.0	0.05
Loss of woodlands	82.2	90.9	0.02
Loss of greenspaces	76.6	88.6	<0.01
Spread of invasive species	79.4	90.5	<0.01
Threats to water quality	84.1	89.6	0.16
Climate change	74.8	80.8	0.21
Stewardship behaviors (completed, underway or planned)			
Removing invasive species	29.9	28.1	0.71
Planting native species	30.8	45.7	0.01
Removing unhealthy trees	55.1	67.2	0.03
Leaving dead trees	37.4	34.1	0.56
Improving wildlife habitat	29.0	43.5	<0.01
Protecting groundwater	29.0	24.6	0.37
Controlling erosion	29.0	17.0	0.01
Allowing natural succession	48.6	70.0	<0.01

Shown are counts of landowners who consider the environmental concerns as problems instead of not problems, and who engage in stewardship behaviors instead of those who do not engage. Shown also is the probability of difference between farming and residential landowners using Fisher's Exact Test.

a positive predictor of five environmental concerns (loss of species, threats to endangered species, loss of woodlands, loss of greenspaces, and spread of invasive species: B $\geq$ 0.887, odds ratio $\geq$ 2.428, and $p \leq 0.04$). Participation in the CLTIP was a positive predictor of just two environmental concerns (loss of greenspaces and climate change: B $\geq$ 0.821, odds ratio $\geq$ 2.274, and $p \leq 0.03$).

Among landowner characteristics, age stood out as being most often a predictor of environmental concerns (**Table 3**). Age negatively predicted five environmental concerns (damage to species, loss of species, loss of woodlands, spread of invasive species, and climate change: B ≤ -0.773, odds ratio $\geq$ 0.353, and $p \leq 0.05$), and was a marginally significant, negative predictor of another two environmental concerns (threats to endangered species and loss of greenspaces: B ≤ -0.689, odds ratio $\geq$ 0.445, and $p \leq 0.08$).

Among property characteristics (**Table 3**), presence of woodlands was most often a predictor of environmental concerns. Presence of woodlands positively predicted three environmental concerns (damage to species, loss of species, and threats to endangered species: B $\geq$ 1.430, odds ratio $\geq$ 4.896, and $p \leq 0.01$).

Predictors of Stewardship Behaviors

The model fit statistics show that most models of stewardship behaviors were highly significant, with one other model being marginally significant (**Table 4**). The Count R^2 results were at least 68% for all models, with 79% as highest Count R^2 value for controlling erosion.

In contrast to environmental concerns, being a farming landowner is a predictor of four stewardship behaviors (**Table 4**). Being a farming landowner positively predicts two stewardship behaviors (removing invasive species and controlling erosion: B $\geq$ 0.825, odds ratio $\geq$ 2.390, and $p \leq 0.02$) and negatively predicts two other stewardship behaviors (planting native species and allowing natural succession: B ≤ -0.678, odds ratio $\geq$ 0.461, and $p \leq 0.05$). Participation in the MFTIP was a positive predictor of four stewardship behaviors (removing invasive species, planting native species, removing unhealthy trees and improving wildlife habitat: B $\geq$ 0.822, odds ratio $\geq$ 2.275, and $p \leq 0.02$). Participation in the CLTIP was a negative predictor of one environmental concern (controlling erosion: B $= -0.828$, odds ratio $=$ 0.437, and $p = 0.03$).

Most participant characteristics did not stand out as particularly influential on stewardship behaviors (**Table 4**). But among property characteristics, presence of grasslands was a positive predictor of four stewardship behaviors (removing invasive species, planting native species, improving wildlife habitat and allowing natural succession: B $\geq$ 0.586, odds ratio $\geq$ 1.796, and $p \leq 0.04$).

Main Land Conservation Concerns

The text analysis revealed topics of specific interest to farming and non-farming landowners as emerging from the open-ended survey answers. The text analysis results demonstrate that the five most frequently mentioned topics of interests were incentives (8.3% of coded segments), information needs (7.7%), taxes (7.1%), costs (5.7%), and conservation (5.0%).

Farming and non-farming landowners mentioned incentives with similar relative frequency. However, incentives were mentioned somewhat more often by CLTIP participants than by MFTIP participants (CLTIP: 8.9%, MFTIP: 7.8% of all coded segments). While participants generally appreciated the existing incentives, the general tenor of the comments was that financial incentives for land stewardship should be higher, including for specific stewardship behaviors, such as voiced by ID 2030, "*Incentives to promote removal of invasive species.*" An important element was that landowners often felt unable to engage in active stewardship behaviors instead of a general hands-off approach, such as expressed by ID 19003, "*If some authority decided something needed to be done to preserve the environmental features, then we would require compensation*."

Expressed information needs related both to stewardship behaviors and to conservation programs. Participants in either conservation program mentioned information needs with similar relative frequency. However, information needs were mentioned more frequently by non-farming landowners than by farming landowners (farming: 4.8%, non-farming: 8.7% of all coded segments). Many participants felt not very knowledgeable about land conservation and expressed a need for more information

TABLE 3 | Logistic regressions of eight environmental concerns on owning a commercial farm property, conservation incentive program participation, landowner, and property characteristics.

Independent variable	**Damage to species**			**Loss of species**			**Threats to endangered species**			**Loss of woodlands**		
	B	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***
Farming	−0.206	0.814	0.64	0.082	1.086	0.84	0.160	1.173	0.70	0.266	1.305	0.62
CLTIP	0.446	1.561	0.29	0.700	2.014	0.08	0.595	1.814	0.12	0.938	2.554	0.06
MFTIP	0.901	2.461	0.06	**0.932**	**2.540**	**0.03**	**0.887**	**2.428**	**0.04**	**1.874**	**6.511**	**<0.01**
Gender	0.370	1.447	0.33	0.154	1.167	0.66	−0.281	0.755	0.44	−0.214	0.807	0.67
Age	**−0.929**	**0.395**	**0.03**	**−0.992**	**0.371**	**0.01**	−0.689	0.502	0.07	**−1.002**	**0.367**	**0.05**
Education	0.305	1.356	0.40	0.515	1.673	0.12	0.391	1.478	0.23	−0.380	0.684	0.39
Employment	−0.362	0.696	0.39	−0.087	0.917	0.82	0.029	1.029	0.94	−0.271	0.762	0.59
Income	−0.250	0.779	0.51	−0.398	0.672	0.25	0.057	1.058	0.87	0.013	1.014	0.98
Environmental group	**1.029**	**2.799**	**0.05**	0.410	1.507	0.33	**0.886**	**2.424**	**0.05**	1.130	3.095	0.09
Property size	−0.206	0.814	0.18	−0.127	0.880	0.36	−0.172	0.842	0.21	**−0.360**	**0.698**	**0.05**
Woodlands	**1.430**	**4.180**	**<0.01**	**1.589**	**4.896**	**<0.01**	**1.439**	**4.218**	**<0.01**	0.848	2.336	0.15
Grasslands	0.531	1.700	0.14	**0.758**	**2.135**	**0.02**	0.413	1.511	0.19	0.630	1.877	0.14
Wetlands	0.703	2.019	0.06	0.558	1.747	0.11	0.607	1.835	**0.08**	**0.958**	**2.606**	**0.03**
Constant	−0.034	0.966	0.96	−0.874	0.417	0.18	−0.589	0.555	0.37	1.166	3.209	0.18
Log-likelihood	−122.904			−142.452			−144.895			−90.476		
Chi-squared	43.408			53.120			48.234			39.043		
p	<0.001			<0.001			<0.001			<0.001		
Count R^2	0.85			0.82			0.82			0.90		
Mean VIF	1.404											
Max VIF	1.972											

(Continued)

TABLE 3 | Continued

Independent variable	Loss of greenspaces			Spread of invasive species			Threats to water quality			Climate change		
	B	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***
Farming	−0.258	0.772	0.59	−0.706	0.494	0.16	0.021	1.021	0.97	0.090	1.094	0.82
CLTIP	**1.014**	**2.757**	**0.03**	0.702	2.018	0.13	0.682	1.978	0.17	**0.821**	**2.274**	**0.03**
MFTIP	**1.570**	**4.806**	**<0.01**	**1.218**	**3.381**	**0.03**	0.402	1.494	0.46	0.718	2.050	0.08
Gender	−0.629	0.533	0.20	0.521	1.683	0.24	0.157	1.170	0.73	−0.289	0.749	0.41
Age	−0.809	0.445	0.08	**−1.041**	**0.353**	**0.04**	−0.572	0.564	0.25	**−0.773**	**0.461**	**0.04**
Education	−0.248	0.780	0.54	0.072	1.075	0.86	−0.005	0.995	0.99	0.257	1.293	0.41
Employment	0.550	1.733	0.23	0.111	1.117	0.82	0.348	1.417	0.47	0.145	1.156	0.68
Income	−0.079	0.924	0.85	0.347	1.415	0.44	0.237	1.267	0.60	−0.070	0.933	0.83
Environmental group	1.119	3.061	0.06	1.212	3.361	0.07	0.747	2.111	0.20	0.548	1.730	0.17
Property size	−0.198	0.821	0.24	−0.024	0.976	0.89	−0.096	0.909	0.59	−0.028	0.973	0.84
Woodlands	0.790	2.204	0.15	0.270	1.310	0.64	0.671	1.957	0.26	0.138	1.148	0.79
Grasslands	**1.083**	**2.954**	**0.01**	0.363	1.438	0.38	0.777	2.174	0.07	0.444	1.559	0.14
Wetlands	0.591	1.805	0.16	−0.145	0.865	0.75	−0.064	0.938	0.89	0.065	1.067	0.85
Constant	0.502	1.652	0.53	1.048	2.853	0.20	0.902	2.464	0.28	0.672	1.958	0.32
Log-likelihood	−102.425			−97.007			−96.110			−152.960		
Chi-squared	55.734			34.575			18.918			26.559		
p	<0.001			<0.001			0.126			0.014		
Count R^2	0.88			0.90			0.90			0.82		
Mean VIF	1.404											
Max VIF	1.972											

Significant independent variables ($\alpha \leq 0.05$) are bolded.

TABLE 4 | Logistic regressions of eight stewardship behaviors on owning a commercial farm property, conservation incentive program participation, landowner, and property characteristics.

Independent variable	Removing invasive species			Planting native species			Removing unhealthy trees			Leaving dead trees		
	B	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***
Farming	**0.871**	**2.390**	**0.02**	**–0.678**	**0.507**	**0.05**	–0.455	0.635	0.18	0.363	1.438	0.26
CLTIP	0.228	1.257	0.52	0.292	1.339	0.38	–0.212	0.809	0.52	0.555	1.742	0.09
MFTIP	**1.537**	**4.652**	**<0.01**	**0.822**	**2.275**	**0.02**	**0.905**	**2.472**	**0.01**	0.191	1.210	0.57
Gender	–0.325	0.723	0.25	0.387	1.473	0.16	–0.216	0.806	0.45	0.501	1.651	0.08
Age	–0.402	0.669	0.24	–0.309	0.734	0.33	–0.366	0.694	0.26	–0.164	0.849	0.60
Education	0.130	1.139	0.63	0.171	1.187	0.50	–0.331	0.718	0.22	0.370	1.448	0.15
Employment	–0.076	0.927	0.82	–0.555	0.574	0.07	0.211	1.235	0.50	–0.387	0.679	0.19
Income	–0.536	0.585	0.06	0.214	1.238	0.42	0.114	1.121	0.68	–0.149	0.862	0.57
Environmental group	0.513	1.670	0.09	**0.783**	**2.187**	**<0.01**	–0.030	0.970	0.92	0.018	1.019	0.95
Property size	**–0.275**	**0.760**	**0.03**	0.055	1.057	0.62	0.066	1.068	0.57	0.030	1.031	0.79
Woodlands	0.001	1.001	1.00	–0.346	0.707	0.50	**1.157**	**3.180**	**0.01**	–0.754	0.470	0.10
Grasslands	**0.756**	**2.130**	**0.01**	**1.152**	**3.164**	**<0.01**	0.207	1.230	0.43	0.011	1.011	0.97
Wetlands	0.138	1.148	0.66	–0.088	0.916	0.77	–0.034	0.967	0.91	–0.359	0.698	0.22
Constant	**–1.261**	**0.283**	**0.05**	**–1.276**	**0.279**	**0.04**	–0.477	0.621	0.43	–0.508	0.602	0.38
Log-likelihood	–181.933			–200.577			–191.665			–203.058		
Chi-squared	39.306			56.062			44.959			16.875		
p	<0.001			<0.001			<0.001			0.205		
Count R^2	0.73			0.68			0.73			0.70		
Mean VIF	1.404											
Max VIF	1.972											

(Continued)

TABLE 4 | Continued

Independent variable	Improving wildlife habitat			Protecting groundwater			Controlling erosion			Allowing natural succession		
	B	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***	***B***	**Odds ratio**	***p***
Farming	−0.467	0.627	0.17	0.400	1.492	0.25	**0.825**	**2.282**	**0.02**	**−0.773**	**0.461**	**0.03**
CLTIP	0.289	1.335	0.39	−0.303	0.738	0.37	**−0.828**	**0.437**	**0.03**	0.090	1.094	0.79
MFTIP	**1.523**	**4.584**	**<0.01**	0.380	1.462	0.29	0.025	1.026	0.95	**1.517**	**4.556**	**<0.01**
Gender	−0.166	0.847	0.55	−0.441	0.644	0.12	**−0.666**	**0.514**	**0.04**	0.169	1.184	0.56
Age	−0.422	0.656	0.19	0.476	1.610	0.15	0.693	2.000	0.06	0.554	1.739	0.12
Education	−0.221	0.802	0.40	−0.001	0.999	1.00	0.157	1.170	0.60	0.153	1.166	0.58
Employment	−0.354	0.702	0.25	0.045	1.046	0.89	0.215	1.240	0.55	−0.365	0.694	0.27
Income	−0.294	0.745	0.28	0.464	1.590	0.10	0.350	1.419	0.27	0.006	1.006	0.98
Environmental group	0.270	1.310	0.36	−0.053	0.949	0.86	0.260	1.297	0.43	0.329	1.390	0.32
Property size	0.173	1.189	0.14	−0.039	0.961	0.75	0.152	1.164	0.28	−0.030	0.970	0.80
Woodlands	−0.190	0.827	0.71	0.116	1.123	0.83	0.712	2.038	0.31	0.382	1.465	0.41
Grasslands	**0.698**	**2.010**	**<0.01**	0.226	1.254	0.40	0.488	1.629	0.11	**0.586**	**1.796**	**0.04**
Wetlands	−0.160	0.852	0.60	**0.992**	**2.696**	**<0.01**	0.591	1.806	0.11	0.273	1.314	0.39
Constant	−0.958	0.384	0.12	**−2.162**	**0.115**	**<0.01**	**−3.348**	**0.035**	**<0.01**	−0.675	0.509	0.27
Log-likelihood	−197.763			−183.482			−152.900			−179.817		
Chi-squared	61.088			20.903			37.621			63.038		
p	<0.001			0.075			<0.001			<0.001		
Count R^2	0.68			0.73			0.79			0.73		
Mean VIF	1.404											
Max VIF	1.972											

Significant independent variables (α ≤ 0.05) are bolded.

on how to protect valuable environmental features, such ID 23213, "*As a new landowner I had zero information as to what is invasive species.*" Other landowners suggested that conservation education should be provided by government agencies, such as ID 9797 "*free seminars for landowners on land stewardship.*" In addition, several participants mentioned difficulty of obtaining information about conservation programs, such as ID 2146, "*Landowners would benefit from easier access to information and materials pertaining to these programs.*"

Dissatisfaction with the tax relief for conservation program participation was commonly expressed. Participants in both conservation programs mentioned taxation with similar relative frequency. However, taxes were mentioned more frequently by non-farming landowners than by farming landowners (farming: 5.3%, non-farming: 7.7% of all coded segments). Many landowners expressed that the height of the tax relief for conservation program participation was too low, such as mentioned by ID 12461, "*More compensation—higher tax relief.*" Several participants in the MFTIP specifically suggested providing tax supports to compensate for the cost of the required forest management plan, such as voiced by ID 17483, "*Provide tax rebates [or] subsidies to participants to offset the cost of Managed Forest Tax Incentive Program approved plans.*" Other landowners expressed that they did not participate in the conservation programs because the available tax incentive was too low, such as ID 6604 "*We get the farm tax rate, which is the same as the CLTIP or MFTIP, so we are not willing to go to the expense of plans to get the same tax rate.*"

Costs were mentioned by many landowners, referring to their own costs but also to the presumed costs of the conservation programs. Participants in MFTIP referred to costs with higher relative frequency than CLTIP participants (CLTIP: 4.3%, MFTIP: 7.0% of all coded segments). As well, non-farming landowners mentioned costs somewhat more often than farming landowners (farming: 4.8%, non-farming: 6.0% of all coded segments). However, many landowners, no matter whether they were participating in the CLTIP or MFTIP, expressed that they were engaging only in passive, hands-off land management because costs of stewardship behaviors were a barrier to more active land conservation, such as ID 27752 "*Free material like bat boxes, cages, etc.*," and ID 7964 "*Provide free [tree] saplings (native species).*" Several landowners suggested that especially the CLTIP was too burdensome administratively and costs could be reduced by streamlining the conservation program delivery, such as ID 2146 "*Offering the program in 3-year increments would reduce the administrative costs, including time, significantly.*"

Conservation was broadly supported by participants and many comments were provided on the performance of conservation programs and suggestions made for improved land stewardship. Participants in the CLTIP mentioned conservation with somewhat higher relative frequency than MFTIP participants (CLTIP: 5.8%, MFTIP: 4.3% of all coded segments). In addition, conservation was mentioned more frequently by non-farming landowners than by farming landowners (farming: 3.7%, non-farming: 5.5% of all coded segments). Broad support for land conservation and a desire for increased protection was expressed by several participants, such as stated by ID 10374, "*I would like to see you protect valuable land, example [area name] from pavement and strip malls with the same vengeance you protect poor land*" and by ID 27598, "*The [government agency] needs to raise the bar in terms of active forest management by MFTIP participants as most people enter the program only for tax savings.*" Other participants made more specific suggestions for measures to support increased land conservation, including stronger policies, such as ID 19906, "*Pass laws strengthening protection of streams and rivers running through private lands and farmings.*"

DISCUSSION

Often rural landowners are dealt with as if they were a homogenous group (Huddart-Kennedy et al., 2009). However, rural landowners are diverse; their histories, attitudes, interests, resources, and abilities differ among geographies and groups, causing a whole range of different motivations and behaviors. Ignoring this diversity poses the risk that conservation policies and programs aimed at these populations are not connected well to the conditions under which they are operating, potentially leaving these policies and programs less effective than they could be otherwise (Raymond et al., 2016). One of the key contributions of the current study is the explicit differentiation between farming and non-farming rural landowners. Our results provide insights into the similarities and differences in environmental concerns and stewardship behaviors between these populations.

We found that farming and non-farming, residential landowners generally share concerns about environmental issues. Supporting our findings that environmental concerns are widespread across rural landowners are the results by Wardropper et al. (2020) regarding effects of "farming identity" on appreciation of natural areas and processes in Wisconsin, USA. They found that appreciation of water quality and supply, or wildlife habitat did not differ between study participants who relied, or did not rely, on agriculture for their livelihood (Wardropper et al., 2020). However, our results suggest that farming landowners do tend to be somewhat less concerned about most environmental issues than non-farming landowners. Our findings also echo the work of Berenguer et al. (2005) who investigated conservation concerns among residents in central Spain. They found that concerns about environmental issues were not affected by residents' economic dependence on the natural environment (Berenguer et al., 2005).

Environmental attitudes and behaviors are linked with people's experiences with nature (Rosa and Collado, 2019). Therefore, differences between farming and non-farming landowners in the degree of environmental concern, as observed in our study, might be driven by differences in past experiences with specific environmental issues. Our results show that the properties of farming landowners harbored natural habitats (woodlands, grasslands, and wetlands) similarly or more often than the properties of non-farming landowners. However, through the very nature of farming lands, one can assume that natural habitats cover smaller areas of farming properties than of non-farming properties. This could mean that non-farming landowners are more exposed to natural habitats than farming landowners, which might lead to more positive environmental attitudes and higher levels of environmental concerns about habitat and species losses in non-farming than in farming landowners (Rosa and Collado, 2019). Interestingly, this logic might also provide an explanation for the lack of difference in concerns about water quality and climate change between farming and non-farming landowners in our results: Both landowner groups should be equally likely to experience climate change and water quality problems and therefore be similarly concerned about these environmental issues. Such a line of argument is supported by the results of Haden et al. (2012), who found that farmers' concern about climate change was related to their past experience with climate change impacts.

In addition, our results also suggest that differences in environmental concerns between farming and non-farming landowners may not primarily be driven by farming identity *per se*. Instead, it appears they might be influenced more by other landowner characteristics, such as participation in conservation programs and landowner's age. Specifically, we found that increasing age had a negative effect of environmental concerns. This finding parallels results from a study of Austrian farmers by Vogel (1996). His results suggest that the age of farmers was negatively correlated with general attitudes toward the environment (Vogel, 1996). It may be possible that in our study the negative impacts of age on environmental concerns are driven by a cohort-effect. In his review of demographic effects on farmers' environmental perceptions and behaviors, Burton (2014) suggested the existence of such an effect, where a person's attitudes and beliefs become fixed through the particular socio-historical context of their education and socialization. It is quite possible that the environmental attitudes of older farmers in our study were fixed by their past socio-historical context when environmental concerns were of lower prominence than at present. However, our results stand in contrast to the findings by some other studies, which did not find an effect of age on general environmental concerns (Berenguer et al., 2005) or appreciation of natural areas and processes (Wardropper et al., 2020). It is possible that the studies by Berenguer et al. (2005) and Wardropper et al. (2020) covered younger individuals or a smaller age range and therefore did not observe an age effect. Unfortunately, Berenguer et al. (2005) did not report the age of their study participants.

Interestingly, we did not find an effect of educational level on environmental concerns. This result parallels the findings by Vogel (1996) who did not find an effect of farmers' education on environmental concerns either. However, our results stand in contrast to Maas et al. (2021). In a study of farmers' perceptions of biodiversity and ecosystem services in Germany and Austria, they found that lower education level was correlated with lower importance attributed to biodiversity and ecosystem services (Maas et al., 2021). Conflicting results about the role of education in famers' environmental concerns might be explained by a lack of detail pertaining to farmers' education. In a study of Finnish students' attitudes toward environmental issues, Tikka et al. (2000) found that knowledge and attitude regarding environmental issues varied by students' major subject and not terminal degree. It is therefore possible that a farmers' educational orientation (e.g., Ecology vs. Business) would be of greater effect on environmental concerns than educational level itself.

Our results suggest that farming landowners engaged with half of all stewardship behaviors just as often or more often than non-farming landowners; for the remaining stewardship behaviors farming landowners engaged less than farming landowners. Differently from environmental concerns, ownership of a commercial farm property did appear to be a driver of differences between farming and non-farming landowners for several stewardship behaviors. Commercial farm ownership had a positive effect on engaging with removing invasive species and controlling erosion, and it had a negative effect on planting native species and allowing natural succession. Most of these effects might be explicable by farmers' concerns for the agricultural productivity of their land. Reimer et al. (2012) found that farmers in Indiana, USA, who viewed their farm mostly through a business lens, were least likely to adopt conservation practices. In contrast, farmers who were motivated by off-farm environmental benefits were more likely to adopt conservation practices (Reimer et al., 2012). Similarly, in a study of farmers in Illinois, USA, Thompson et al. (2015) did find a positive effect of stewardship views on farmers' willingness to adopt environmental best management practices. Invasive species can invade crops, erosion can reduce availability of high quality soil and natural succession, for example on fallow land, can make subsequent agricultural production more difficult. Therefore, these stewardship behaviors might be driven by a focus on agricultural production as well as by conservation concerns (Raymond et al., 2016). McGuire et al. (2013) found that even farmers who are focused on agricultural productivity can harbor conservationist views. However, these conservation views tend to be overshadowed by production interests and need to be specifically triggered to lead to more frequent stewardship behaviors (McGuire et al., 2013). On the other hand, the work by Marr and Howley (2019) supports the view that some farmers' stewardship behaviors might be driven by non-conservationist motives. In a comparison of farmers in England and Ontario, they found that farmers engaged in pro-environmental behaviors for other reasons, such as the health and well-being of their family (Marr and Howley, 2019).

In the current study, landowner characteristics were less frequently of importance for stewardship behaviors relative to for environmental concerns. Our results suggest an effect of gender, where male landowners were less likely to engage in controlling erosion than female landowners. Our results match several other studies who found that gender can have an effect on environmental perceptions and stewardship behaviors. Liu et al. (2014) found that female ranchers and farmers in Nevada, USA, were better informed about climate change and its impacts than males. In his review of demographic effects on famers' environmental perceptions and behaviors, Burton (2014) found that women farmers were generally more environmentally oriented and preferred more extensive production methods than men.

Similarly to environmental conerns, our results did not indicate any effect of education on stewardship behaviors. These findings coincide with the results of a study on farmers' environmental awareness and farming practices in Michigan, USA (McCann et al., 1997). McCann et al. (1997) found that level of education did not differ between farmers that practiced more eco-friendly than conventional agriculture. Similarly, in a study of Californian farmers' perceptions and behaviors toward several types of wildlife, Kross et al. (2018) did not find an effect of education. However, in their review of the literature, Ahnström et al. (2008) reported that education can have variable effects on farmers' conservation behaviors. They suggested that higher educated farmers might have higher readiness to apply new practices including conservation actions, but also to use pesticides (Ahnström et al., 2008). As is the case with environmental concerns, the driver of stewardship behaviors might not be educational level itself but rather educational orientation (Tikka et al., 2000). Educational orientation, i.e., the subject of somebody's education such as Ecology or Business, might be better at predicting their stewardship behaviors than their highest level of education, as it may indicate underlying interest and acquired knowledge base (Tikka et al., 2000).

In addition, our results indicate that participation in conservation programs influenced environmental concerns and several stewardship behaviors. We found that participation in the MFTIP frequently was associated with environmental concerns and with engagement in stewardship behaviors. The MFTIP requires landowners to create an approved forest management plan (Ontario, 2019b). Creation of such a plan and discussion of it with the forest management approver requires the landowner to be at least somewhat knowledgeable about environmental and ecological topics, at least as they pertain to forests. For landowners, creation of a forest management plan therefore is an opportunity to inform themselves and become aware of environmental and ecological topics. This learning effect might explain the positive effects of MFTIP participation on environmental concerns and on stewardship behaviors (Drescher et al., 2019). Unfortunately, the rate of MFTIP participation of farming landowners is less than half of non-farming landowners. The reason for this might be that most farming landowners will participate in the Ontario Farm Property Class Tax Rate Program. Participation in this program guarantees that the property class tax rate applied to the farmed land is not more than 25% of residential property tax (Agricorp, 2019). This, however, is the same tax incentive as provided by the MFTIP. Consequently, there is little reason for farming landowners to participate in the MFTIP for financial reasons, which often is a driver of farmers' stewardship behaviors (Mills et al., 2018). Further, the creation of a forest management plan is an additional cost factor and participation barrier for the MFTIP, which has been criticized by many of our study participants. The CLTIP provides tax relief of 100% of the residential property tax for the program eligible lands and may explain why the proportion of CLTIP participating farming and non-farming landowners is almost equal. Consequently, increasing the tax relief for the MFTIP might increase the participation by farming landowners and provide for more widespread land stewardship across the rural landscape.

Our qualitative results highlight the importance of financial factors (incentives, taxes, and costs) for engagement in stewardship behaviors for rural landowners. It might be surprising that conservation incentives were not mentioned more frequently by farmers than by non-farming landowners given that stewardship behaviors might impose a greater opportunity cost on farmers than on non-farmers. We speculate that this lack of a difference in attention to incentives might be due to high perceived conservation costs even among non-farming landowners, who emphasized this issue more frequently than farming landowners. High perceived conservation costs might stem from non-farming landowners not seeing themselves as active land managers. Our results suggest that non-farming landowners more frequently feel that they lack conservation knowledge than farming landowners. Lack of knowledge and lack of access to equipment, may lead to increased perceived and actual costs for stewardship behaviors.

Other studies have found that financial factors clearly are a major component in motivating, enabling, and constraining environmental actions. For example, Mills et al. (2018) found that overall farmers engaged more in subsidized environmental activities than in non-subsidized activities. They also found that farmers' motives for engaging in stewardship activities varied by whether they were subsidized or not. When activities were subsidized, the main motivation was financial, while for non-subsidized activities main motives varied between agronomic, environmental and tradition (Mills et al., 2018). It is possible that we did not find a stronger influence of financial factors on farming landowners' stewardship behaviors because several of these behaviors are in a farmer's self-interest, such as improving soil health and water quality, which were addressed by us through questions about controlling erosion and protecting groundwater. On the other hand, controlling erosion and protecting groundwater were among the stewardship behaviors that farmers least engaged with.

The qualitative results of our study also suggest that while land conservation was largely supported by rural landowners, many landowners wished for more help by government agencies and some landowners called for stronger conservation policies. Knowledge gaps about environmental issues and conservation programs were frequently mentioned by landowners, suggesting they might be a constraint for stewardship behaviors. However, farming landowners much less frequently expressed a need for more information than did non-farming landowners. This difference might be driven by farmers' strong local knowledge of the land they manage and the perception that they do not require access to additional information, especially not from outside experts that do not have the same intimate knowledge of their land. By necessity, farmers certainly should have good knowledge of their land, and many do. For example, farmers in Austria have been found to be knowledgeable about the threats of toxic plant species to grassland management (Winter et al., 2011; Šumane et al., 2018). However, there is also evidence to suggest that farmers' local environmental knowledge may be limited to more obvious phenomena and that at times they could benefit from additional advice from outside experts, especially regarding more technical applications (Wyckhuys and O'Neil, 2007; Ingram, 2008).

The stewardship behaviors that we assessed should be of general relevance to farming and non-farming rural landowners (e.g., protecting groundwater) and should be broadly accessible to them because they require only limited technical know-how and equipment (e.g., removing invasive species). However, the range of stewardship behaviors that we assessed was necessarily limited and it is possible that rural landowners might engage in stewardship behaviors that we did not cover (e.g., reducing pesticide use, limiting nutrient runoff, and planting windbreaks). The Canada-Ontario Environmental Farm Plan is a voluntary program in support of farmers' environmental education, awareness, and actions [OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs), 2016]. This program stresses farmers' self-assessment of the strengths and challenges of their individual agricultural operations and emphasizes that standardized lists of stewardship behaviors might not connect well with all farmers. Had we inquired about a much broader range of possible stewardship behaviors, we might have uncovered more stewardship behaviors that farmers engage in Robinson (2006). However, participation in the Canada-Ontario Environmental Farm Plan is confidential and therefore it is unknown how widespread farmers' participation is and what stewardship behaviors they engage in. Smithers and Furman (2003) conducted a study on participation in the Canada-Ontario Environmental Farm Plan. They found that about a third of farmers participating in the Canada-Ontario Environmental Farm Plan do not proceed to the implementation of any environmental actions (Smithers and Furman, 2003). The extent of farmers' active engagement in stewardship behaviors, whether as part of an environmental program or not, remains poorly understood.

CONCLUSIONS

Intensive agriculture is a main factor in biodiversity and ecosystem services loss globally. Increasing the sustainability of the agricultural sector is paramount to safeguard world food supplies and protect global society against widespread environmental collapse. Achieving this goal requires a multi-sectoral approach that involves all stakeholders from policy-makers to producers and consumers. To be effective, planning and policy for agricultural sustainability must be sensitive to local conditions and the varied needs, interests and opportunities of the various stakeholder groups. The key findings of the current study are its contributions to increasing understanding of the environmental concerns and stewardship behaviors of farming and non-farming rural landowners, as well as of drivers of similarities and differences between these groups. The results of this study from Ontario, Canada, highlight the importance of contextual factors for the expression of environmental concerns and stewardship behaviors in rural landowners. Farmers tended to be less concerned about addressed environmental issues than non-farmers. However, this difference was not primarily driven by being a farming landowner *per se*, but by factors such as participation in conservation programs that provide environmental learning opportunities, and landowner age, which might point toward fixing of environmental attitudes during past socio-historical contexts. Possible drivers of stewardship behaviors may be external to conservation concerns and more often be related to landowners' regard for agricultural productivity; if stewardship behaviors are also positive for agricultural operations, farmers are more likely to engage. Of clear relevance to rural landowners, farmers and non-farmers alike, are finances. Participants expressed a desire for decreased costs of stewardship actions and larger incentives. Knowledge needs were especially expressed by non-farmers, but they may also be present for farmers even though they might be unaware of these needs. Based on our results, we make several recommendations that should be useful for increasing the effectiveness of agricultural conservation planning and policy in Ontario:

1. Decrease the costs of stewardship behaviors. Rural landowners express concerns about the costs of stewardship actions and experience several constraints including time and money. In the context of the CLTIP, the provision of materials and equipment by (semi-)governmental agencies at no or shared cost would help many landowners who currently are confined to being passive stewards. Participation costs for the MFTIP could be reduced by subsidizing the costs for an approved forest management plan.
2. Increase the incentives for conservation program participation. When programs do not offer any financial incentive beyond the status quo, program participation is largely driven by conservation ethics, which are not shared by all. Increasing the incentives, such as through additional property tax relief, also will speak to landowners who are primarily driven by the business factors of agricultural operations. In the context of the MFTIP, this means that tax relief should be increased to a level that is higher than the tax relief provided by the Ontario Farm Property Class Tax Rate Program.
3. Increase knowledge transfer about possible stewardship behaviors. Being motivated to engage in stewardship behaviors is not enough when landowners lack knowledge about realistic and effective stewardship options. When a conservation incentive program lacks knowledge transfer mechanisms, government should re-design the program to include them, such as provision of information pamphlets and workshops. In the Ontario context, this is especially true for the CLTIP, which does not contain an active knowledge transfer mechanism. This stands in contrast to the MFTIP, which provides an active learning opportunity through the requirement for an approved forest management plan.
4. Clarify to landowners the co-benefits of environmental stewardship behaviors for agricultural operations. Some farmers may be unsure about managing their land differently and might worry about potential negative impacts of stewardship actions on the profitability of their agricultural business. However, many stewardship actions do not

only provide off-farm benefits but can also improve the economics of farm operations (e.g., windbreaks can decrease energy consumption). Government should reinvest into agricultural outreach programs that educate farmers about the simultaneous environmental and business benefits of a variety of stewardship behaviors.

Though the presented research is based on a case study from Ontario, we believe that the general results can be transferred to other regions with similar socio-economic contexts. Useful extensions of our analyses would be experimental, longitudinal studies that investigate the effects of conservation incentive programs designed to provide educational elements on environmental concerns and stewardship behaviors. While many rural landowners are at least partially motivated by conservation ethics to engage in stewardship behaviors, willingness-to-accept studies that explore farmers' engagement in stewardship behaviors at various incentive levels, would be of great interest. Together, these kinds of information would be useful for further strengthening planning and policy for sustainable agricultural operations.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Waterloo Office of Research Ethics. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

MD ideated the study, collected and analyzed the data, and wrote the draft manuscript. MD and GW designed the research. GW critically reviewed the data analysis and provided critical review of the draft. Both authors contributed to the article and approved the submitted version.

FUNDING

This research has been made possible financially through a grant from the Social Sciences and Humanities Research Council, file number 430-2012-458.

ACKNOWLEDGMENTS

We are thankful for the comments provided by two reviewers who helped us strengthening this manuscript. We gratefully acknowledge the landowners who participated in this study, who generously have given of their time, and who have shared their knowledge and opinions. We thank the Ministry of Natural Resources and Forestry for its support of this research.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.758426/full#supplementary-material

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TYPE Original Research
PUBLISHED 19 December 2022
DOI 10.3389/fsufs.2022.787600

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OPEN ACCESS

EDITED BY
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SPECIALTY SECTION
This article was submitted to Land, Livelihoods and Food Security, a section of the journal Frontiers in Sustainable Food Systems

RECEIVED 01 October 2021
ACCEPTED 18 November 2022
PUBLISHED 19 December 2022

CITATION
Sarapura–Escobar S and Hoddy ET (2022) Safeguarding the land to secure food in the highlands of Peru: The case of Andean peasant producers. *Front. Sustain. Food Syst.* 6:787600. doi: 10.3389/fsufs.2022.787600

Safeguarding the land to secure food in the highlands of Peru: The case of Andean peasant producers

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Local or traditional agri-food systems in the Andes depend on community land use planning to maintain the genetic pool of crops and landraces in the face of disease, disasters, and climate change. These systems are managed integrally and on the basis of traditional knowledge around soil conservation, water management and maintaining biodiversity. At the same time, agri-food system research, policy and programming exhibit a limited understanding of local or traditional systems planning and community and cultural contexts. In policy and programming, the treatment of communities as homogenous groups overlooks heterogeneity in local identities, which is reflected for example in different access and use of traditional knowledge among men and women and forms of community organization and customs. The purpose of this article is to respond to this gap by shedding light on the intersecting identities of Andean farmers–peasant women and men–that contribute to the sustainability and resilience of local agri-food systems. Our focus is on intersecting identities and planning processes in particular. We detail the nature and cultural components that make up local agri-food systems in the Andean region and identify policy gaps around identities. To do this, we draw on intersectional feminist thinking, socio-ecological systems and resilience thinking to apply an intersectional lens to the study of planning processes in several Andean communities. Findings identify contributions around soil conservation, biodiversity upkeep, water management, and communal or cultural practices that are shaped by peasant's intersecting identities and their interactions within social-ecological systems. Findings illustrate the importance of multiple social locations, relations, and structures of power, including but not limited to gender, but other categories such as age and ethnicity for the delivery of equitable resilience. We formulate some initial recommendations so that national approaches and interventions better reflect the diversity of Andean people's identities and the way these affect relationships with socio-ecological systems in national and public planning. In particular, we suggest there may be value in exploring further the potential of rights-based approaches for enhancing equitable resilience in Andean agri-food systems. This article should be of interest to academics and practitioners in planning working around local or traditional food systems.

KEYWORDS

resilient agri-food systems, social ecological resilience, intersectional analysis, discourse analysis, situated knowledge, land use planning

Introduction

The focus of agri-food system research for the most part has been on non-local and non-indigenous systems that are attuned to large scale cultivation and which support national development imperatives. Left out of the picture have been local, traditional and indigenous systems, such as found in the Andean highlands where communities have preserved and managed a vast diversity of crops and species and maintained sustainable and resilient agri-food systems over many millennia (Brush, 2004). In this setting, local practices are set apart from rational, technocratic perspectives on planning that undergird research, policy and practice. Rather, local planning practices are culturally-informed, set within wider Andean worldviews, or "cosmovisions", about nature, values and livelihoods, and rest on the principle that these resources should be maintained, preserved, and improved for securing food for present and future generations. They emphasize the interfacing of humans and nature and the importance of maintaining and valuing ecological systems as guiding principles for harmonizing these relationships and guiding social organization of communities (Helles, 1995; Zimmerer, 1996).

Lack of treatment of these systems in the planning literature reflects a dominant strand of thinking in the field that prioritizes intensification of the use of land, extensive use of external inputs and reliance on the technocentric paradigm of agricultural industrialization (Núñez Ramírez, 2005). Though there is a focus on climate and environmental change, analysis and planning for resilience and adaptation to diverse social and biophysical changes is lacking (Bennett et al., 2016). The influence of this on policy and programming in the Andean region is that these remain insensitive to local systems and practices. Top-down systems of control persist which are inefficient and take responsibility away from peasant people in the Andean region, who routinely find themselves excluded from decision-making processes (Grillo, 1998). Plans are drawn up by small groups of "experts" or by outsiders with little or no reference to community priorities or realities.[1] One particularly significant implication is that the role of community heterogeneity in planning is overlooked. Peasant farmers are treated as a homogenous group, as "*campesinos*", "*comuneros*", or as "beneficiaries", where local identities and their roles in local planning processes are overlooked. Peasant men and women's concerns and experiences, contributions, and opportunities are ignored. This is strongly evident at the macro level, as reflected in national policies and legal frameworks, while heterogeneity, expressed for example through social diversity and the intersection of socially and culturally defined identities such as gender, age and marital status, is ignored. When projects have included Andean communities, these are sector-oriented and overlook the importance of identities shaping who benefits and who is excluded from policies and resource allocation.

The aim of this article is to respond to these gaps. It does this seeking to shed light on the complex identities of Andean farmers–peasant women and men–that contribute to sustainability and resilience in local agri-food systems through traditional or local planning. We situate the article as a contribution to the indigenous planning literature, which treats planning in alternative agri-food systems such as indigenous, local, family and smallholding systems (Altieri and Nicholls, 2012; Pereira et al., 2018; Tittonell et al., 2021). The article responds to these gaps by (1) documenting local processes of land use planning for agri-food production; (2) identifying the contributions and positions of peasant people in the agri-food systems; and (3) identifying the impact of social identities on peasant people's relationships or interactions within social-ecological systems. By focusing on five Andean communities, our analytic treatment of intersectionality is on the meso- and micro levels where we are concerned to understand identities and social practices in terms of community institutions and processes of identity construction (McCall, 2005; Grünenfelder and Schurr, 2015). We treat the macro-level in terms of the discordance of policy and programming with the complex identities of Andean farmers. Further, the article draws on rights-based thinking to consider implications for policy and practice as a further set of contributions. We identify policy gaps and formulate some initial policy and practice recommendations so that national approaches and interventions might better reflect the diversity of Andean people's identities and the way these affect relationships with socio-ecological systems in national and public planning. In doing this, we lay out in some detail the nature, social and cultural components making up the local agri-food system. We note here that we use the term "Andean peasant producers" to differentiate this group from other Andean groups and communities, yet recognize that communities are heterogeneous, as reflected in our study approach.[2]

1 In Peru, the National Strategic Planning System (SINAPLAN) and its governing body, the National Center for Strategic Planning (CEPLAN) were created to articulate and integrate set of bodies, subsystems and functional relationships to coordinate and make viable the national strategic planning process for national development. The SIPLAN granted responsibility and function of provincial municipalities to comprehensively plan local development and land use planning at the provincial level. The provincial municipalities are responsible for the planning process for integral development in the scope of their province, gathering the priorities proposed in the local development planning processes of a district, where peasant communities are found. However, these gaps still exist and have become wider and more severe due to confrontation among peasant communities (Central Andes) and Amazon Indigenous groups (Amazons) with the different levels of government that is due to the misuse of natural resources and environmental problems.

2 "Andean Peasant Producers" are a distinct and heterogenous socio-cultural and economic group established in a specific geographic

Overall, we position the article within a wider literature that responds to the inattention to local or traditional systems and planning, and as a response to a gap in understanding how indigenous planning and its outcomes for resilience are shaped by local identities. Our choice of focus on Andean peasant producers highlights how impacts related to agriculture are integrated and addressed in local and traditional land use planning and how land use planning and planning for agriculture relate to local food security. We also suggest ways for connecting local and in particular indigenous planning with state policies and legal frameworks.

The paper is structured as follows. First, we introduce the context of the study before moving on to present the theoretical bodies of the literature on local resilient agri-food systems, social-ecological resilience, and feminist intersectional critical analysis. We then introduce the context, the Central Andes of Peru and the peasant communities. The research design section sets out the methodological approach and is followed by a presentation and discussion of results. The study is presented in two phases. The first concerns the first research objective and is a thematic and descriptive account of women's and men's contributions to planning for local agri-food systems sustainability and resilience. We have opted for a descriptive approach that outlines in some detail Andean specific processes of land use planning and planning for agriculture on the grounds that these processes are not well understood in the literature. The second, focused on remaining objectives, critically analyzes the discourses on the impacts of women's and men's identities in their relations within social-ecological systems.

Andean agri-food system context and its novelty

The Andean Region is considered one of the most globally significant centers of crop and animal species adaptation (De Haan, 2021). The region covers around 121 million hectares with an agricultural population of over seven million people in six countries from Venezuela and Colombia to Argentina (Mateo and Tapia, 1987). Socially and culturally, the figure of the *Pachamama* ("Mother Earth") presides over planting and harvesting, and connotes life, wholeness, unity, fertility, nourishing, and richness. A supernatural being, *Pachamama* is geographically, ecologically, and culturally linked to the mountains (Pease, 1982). At the center of the Andean cosmovision is the notion of nurturing life, which holistically integrates the local *pacha* (the living, natural collectivity of all beings–space/time), the *runa* (humans), *sallqa* (nature), and *Apus/wacas* (deities) (Tapia et al., 2012).

The Andean cosmovision, and the "harmonious relationship between humans and their environment" together with social and cultural practices in the Andean communities has persisted in the face of colonialism, oppression and exclusion (Ranta, 2018; Gonzales and Gonzalez, 2010). Colonial and mechanistic processes challenged notions and practices of sustainability that were rooted in indigenous places, yet the Andean ayllus or "cultural places" have continued "to be nurtured through the spiritual values of indigenous communities" (Gonzales and Gonzalez, 2010 p. 84). At this time, indigenous peoples and ayllus were reduced to small villages for the purpose of evangelization and their land and natural resources appropriated as the state sought to develop a more commercialized and individual society (Pease, 1989). In the twentieth century, legal change and reform would move in a different direction, for example in Peru where the 1933 Constitution recognized and granted legal status to indigenous communities (Revilla and Price, 1992) and where a comprehensive agrarian reform programme was initiated in 1969 (Figure 1). In recent decades, in agrarian settings characterized by neoliberalism and the reassertion of power by rural oligarchs, indigenous-based movements and organizations in the region have sought to reassert traditional practices and secure greater autonomy and protection. In Bolivia for example a movement of indigenous peoples has organized around the reconstitution of the ayllus, and in Peru movements and organizations have led a sustained struggle for the land and territorial rights of indigenous peoples.

Social practices and economic activities in many parts of the contemporary Andean region, and in our case study settings, continue to be shaped by the Andean agro-centric vision of agriculture as a system (Grillo and Rengifo, 1990). This vision integrates four sub-systems as recurring categories. The first is the use of land that provides soil and water. The second refers to the means of domestication of plants and animals. The third system is related to the construction of a microclimatic infrastructure. The fourth system embraces the techniques of conservation, storage and transportation of foods to ensure effectiveness and continuity of economic production (Grillo and Rengifo, 1990). A cultural principle of "complementarity" belonging to the Andean cosmovision refers to the control and use of ecologically distinct, spatially separated production zones by single ethnic groups. Murra (1975) articulated this idea as "verticality" as a totality of levels arranged "vertically", one on top of another, forming a macro-adaptation, a system of ecological relations purely Andean (Murra, 1975). Thomas (1973) discusses energy flows, demonstrating that multiple zones were better able to provide sufficient energy than single zones. Golte (1980) suggested that multiple zones are used to smooth out labor demand, thus making labor more efficient

space, the Andean Region. They are considered a group that has learned to manage diverse modes of production and communal organization outside western ideas and specific modes of reproduction and sustainability of life. They have great capacity to adapt to the new conditions that are generated by changes in their systems and their ability to cope and adapt to very different political-economic-social systems internally and externally.

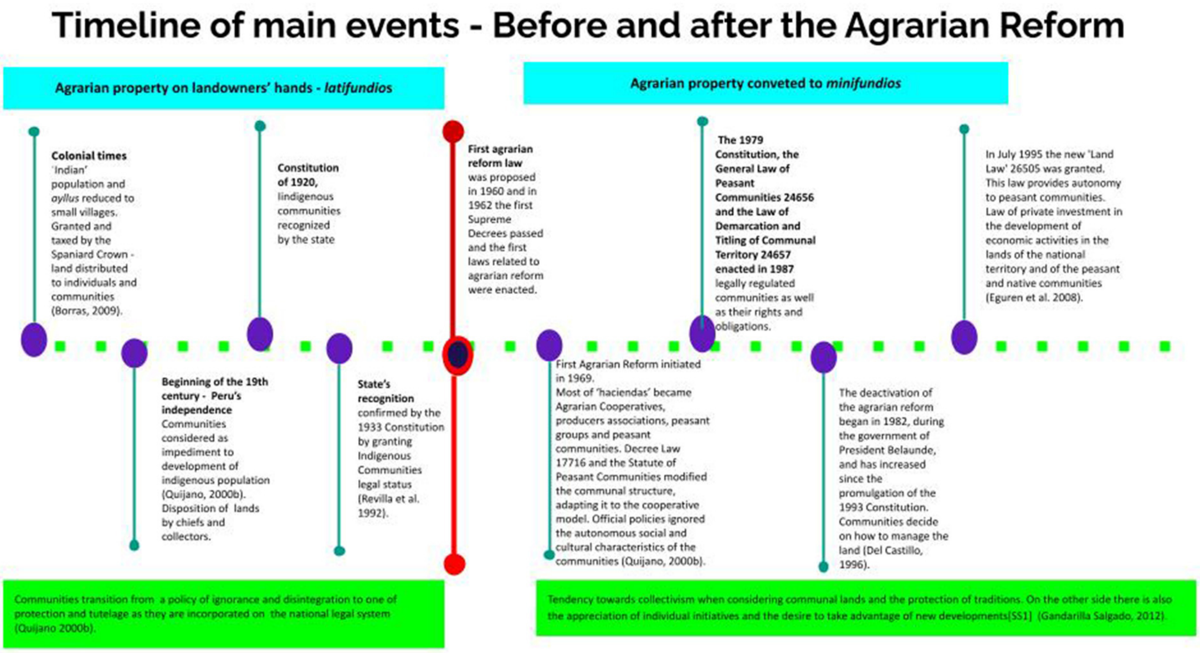

FIGURE 1
Timeline of events before and after agrarian reform.

and productive than is possible within a single zone (Brush, 1992). Another cultural principle, the notion of reciprocity, promotes cooperation among and within Andean communities. It determines the roles and activities in agricultural practices (Delgado and Ponce, 2003). One of the most common types of reciprocity is denominated *al partir:* a farming family owns the land and the other works on it in exchange of dividing the profits equally to both groups (Mayer, 1974). *Ayni* is another work exchange arrangement practiced at the family's level (Mayer, 1974). The exchange of labor inside this farming system allows Andean people to work for others without any exchange of money (Delgado and Ponce, 2003). These classifications of reciprocity depend on the climate, topography, and biodiversity of Andean ecosystems" variability (Mayer, 1974).

Theoretical components

Our intersectional analysis for understanding the complex identities of Andean farmers draws on three main theoretical components. First, intersectionality and intersectional analysis is centered on the idea that people do not have fixed, one-dimensional identities (Hankivsky, 2012) but rather experience multiple, layered, and dynamic identities that are derived from social relations, history, and structures of power (Kerr, 2004; Castro Varela and Dhawan, 2009). Intersectional analysis attends to the interactions of identity categories such as sexuality, ethnicity, age, ability, ethnicity, race, education, marital status, geography, age, etc. (Hankivsky, 2014) and how these shape experiences (Kim-Puri, 2005). These interactions occur within a context of connected systems and structures of power, such as where individuals and groups are members of communities and polities with different state and non-state laws, policies, and systems of governance at different scales (Hankivsky et al., 2014). Analysis is attentive to the complex relationship between mutually constituting factors of social location and structural disadvantage, and maps and conceptualizes determinants of equity and inequity in and beyond sustainable agri-food systems (Grace, 2010) more accurately. Employing such an approach is also in keeping with the recent shift in agricultural studies toward understanding the role of culture and identity in mediating farmer behavior and outcomes (Burton et al., 2020; Settee and Shukla, 2020), and which is likely to be of especial significance in local and indigenous food systems such as in the Andes region.

Critical, intersectional discourse analysis is also useful to practice, as both action and analysis can inform one another (Collins, 2019). It is useful for helping researchers and decision makers move beyond singular identity categories that are typically favored in equity driven analyses to influence public policy (Dhamoon, 2011). Its sensitivity to specific contexts and distinct experiences provides a means of transcending dichotomous and binary thinking about power and differs from some of the more prominent gender and development and diversity approaches (AWID, 2004; Winker and Degele, 2011). To advance conceptual and methodological richness within critical policy analysis, there is also a growing interest in intersectionality for transcending isolation and linear thinking (Kantor and Apgar, 2013). Intersectional thinking interrogates these identity categories within broader structures and processes of power and shows why the need to transform conventional equity-driven policy analyses is urgent (Hankivsky et al., 2014). AWID (2004) emphasizes on the importance of having a complete analysis of the situations and contexts for planning to achieve full potential. Yet this cannot be categorical or top-down, otherwise, the full-range of vulnerabilities, activities, and experiences of diverse women is unlikely to be recognized (Collins, 1990; Agrawal and Gibson, 1999; Hankivsky and Cormier, 2011).

Second, local resilient agri-food systems provide sufficient, appropriate, and accessible food in the face of disturbances and shocks (Berkes and Turner, 2006) and reduces vulnerabilities. These systems differ, qualitatively and quantitatively, from mechanized industrial agricultural systems, and, not infrequently, practices reflect historical or contemporary relationships within and among ethnic groups, or other culturally specific patterns of symbolism, identity, and meaning making (Berkes and Berkes, 2009). These systems have been largely explored from a top-down perspective, however, overlooking local initiatives and their connections to other levels of the agri-food system, such as policy and governance. The shortcomings of such a narrow perspective indicates a need to understand and analyze local and indigenous initiatives in more depth, to consider more fully the dynamics of the distinctive characteristics of social and natural interactions, and the potential to analyze these for the perspectives of policy and governance. As of yet, agri-food governance and planning has been absent in rural planning and policy making and there is a need to begin considering local or indigenous or traditional agri-food planning for their role in food security.

Calls for linking these systems to territorial or regional policy as well as national policies have been made, as such responses can help secure territorial sustainability. The results can be beneficial both for the rural communities and for solving broader issues affecting urban and rural areas. For example, issues of land use, food production, environmental management may be addressed by linking rural and urban communities in a given region (Berdegu et al., 2014). This local perspective on agri-food systems can support resilient, just, and sustainable food systems and territories through the following precepts: (i) food produced in rural areas contributing to urban areas food supply; (ii) rural watersheds suppling drinking water to urban areas and provide irrigation for urban, peri-urban, and rural agriculture; (iii) organic and agricultural waste resources produced in urban and small rural areas being used to generate energy and fertilizers, which are used in urban and rural areas, respectively; and (iv) preservation and sustainable management of agricultural lands in rural and peri-urban area for helping enhance water retention, reduce flooding, or mitigate increasing temperatures, thus reducing the climate change vulnerability of both urban and rural areas.

Finally, a socioecological resilience component (Gunderson et al., 1995; Gunderson and Holling, 2002) responds to the ways community culture and identity may be intimately connected to local resources and ecosystems (Rotarangi and Russell, 2009; Walsh-Dilley et al., 2016; Matin et al., 2018), and bound up in the resilience of social ecological systems. In these settings, resilience is generated through power and authority sharing arrangements over natural resources, for example through devolved or inclusive decision-making and governance structures and processes (Ford et al., 2020). These underscore the cultural dimensions of resilience and holistic core concepts of indigenous and local communities, and culturally specific local dynamics, connections to context, language and social relationships (Ensor et al., 2018; Matin et al., 2018).

Materials and methods

Site selection

The study was conducted in five different peasant communities in the Central Andes of Peru; the peasant community of Racracalla, Junin; the peasant community of Laraos, North Yauyos Region, Lima; the peasant community of Quispillaccta, Ayacucho; and the Pazos community, Huancavelica (Figure 2). The selection of the four communities was made to capture variation in: (i) geography (located along the Central Andes–rural or remote community) (ii) community planning (community living based on social and cultural worldviews, resources that include agrobiodiversity, management of resources in integral forms); (iii) physical, social, or economic factors that influence communities' communal practices and behaviors. The selection of the Racracalla and Pazos communities also reflected variation in the levels of poverty associated with these rural communities.

Diverse ecological zones can cover an individual community. These "vertical ecosystems or ecological zones" are denominated the *Quechua, Suni, Puna and Janca* Regions (Pulgar Vidal, 1996). Each zone brings specific characteristics and services. The *Quechua* region lies between 2,300 and 3,500 masl, is temperate and constitutes the center of production of various Andean crops and animal species. The *Suni* or *Jalca* region is cold, very steep, and rainy, and is where communities live. It is highly forested and is the source of water for the Quechua region. The *Puna* region is shaped in its widest part by inclined plateaus, and lies between 2,300 and 3,500 masl and includes some of the most productive land in the Central Andes. There are also flat, undulating terrains which are surrounded by several lakes and lagoons. It is used for grazing with the

FIGURE 2
Study sites.

vegetation used to feed cattle, sheep and camelids such as *llamas, alpacas, guanaco and vicuna*. In addition, bitter potatoes for processing and medicinal purposes as well as barley are maintained in that area. In the *Janca* or *cordillera* region, lies between 4,800 to 6,768 masl and is the most inaccessible of all eight Peruvian natural regions. The region is icy and snowy areas a permanent feature. It is characterized by a steep and rocky relief covered with snow in the glaciers, and small lagoons have been naturally developed there for storing water. What is common across these ecological zones is the accidented topography, especially at higher altitudes. On the slopes, which comprise more than 75 percent of the Andean territory, the soils are shallow or eroded (Iturri and Amat León, 1999). Regardless of their position, the soils in the highest and coldest areas are poor and thin because the soil forming factors act very slowly (Brush et al., 1994). In addition, the effects of erosion, when occurring in higher regions, have more permanent damaging effects (Brush, 2005).

The peasant community

The management of land or territory in the Peruvian Andes depends on the "Peasant Community", a core institution recognized through the agrarian reform programme of 1969. There are around 7,267 peasant communities in Peru, 6,138 of which are legally recognized as sharing ownership of a territory (Diez Hurtado, 1998) through ties of kinship and reciprocity (Hall, 2017). A common history strengthens their identity and unity among communities, and provides for their common practices of rites, agricultural and communal practices (Diez, 2012). The land is not only a factor of production, but also the space or territory on which a living society or culture is reproduced (Hall, 2017). The peasant community's main attribute is that it preserves its own cultural mechanisms of organization, which are rooted in traditional knowledge (Urrutia, 2003).

Peasant communities in the study have undergone processes of transformation over recent decades. Some communities such as Quispillaccta and Laraos have adopted new communal functions and internal rules, acquiring new ways of using and controlling collective and individual property, territory and resources (Del Castillo, 2006). All communities in the study have kept most of their communal space and land continues to be used in a way that fosters a sense of community and cohesion (Eraso et al., 2012). Two communities, Pazos and Laraos, have introduced new forms of maintaining their resources and communal networks. However, the communities in this study have maintained some consistency in their internal organization for generations, with agro-centric visions of agriculture and the Andean cosmovision still significant and core to the communities. The control of territorial space, the family property and communal property have not, unlike elsewhere, been a source of internal conflicts (see Table 1 for information about the communities).

Conflict and post-conflict

At the same time, peasant communities in Peru remain marked by the two decades of violent conflict between government forces and communist insurgents. The so-called "internal conflict" lasted from 1980 to 2000 and left 69,280 dead or disappeared, many of whom were peasants and indigenous people with no involvement in militant groups and who were frequently targeted because of "racialized disdain toward rural Indigenous Peruvians" (La Serna, 2012; Heilman, 2018). Peasant highlanders who supported or resisted the insurgency did so for a variety of reasons but one constant, La Serna (2012) notes, was a desire to preserve or return to the local status quo. Yet "many of the values and structures that peasants had begun fighting for in the first place were altered–some of them permanently" on account of civil war conditions (La Serna, 2012, p. 198): for example, expectations around gender roles underwent some change during the conflict in some communities as women came to occupy leadership positions, a consequence of the conflict that appears to have continued in peacetime. In the post-conflict context, highland communities have developed strategies to promote the reintegration of individuals and communities on different sides of the conflict and which emphasize coexistence and "remembering to forget" the past (Theidon, 2012). Rituals such as *pampachanakuy* aim to replace memories of violence and desire for revenge with memories of the past that include coexistence within and between communities (De Vries, 2015).

Data collection and analysis

Data collection and analysis involved multiple steps across four research phases. The purpose of the first phase was to generate a descriptive and thematic account of women's contributions to planning for local-agri-food systems sustainability and resilience. The second phase aimed to generate a picture of the discourses around men's and women's identities vis-à-vis local systems and to propose equity focused policy suggestions. We draw inspiration from McCall's (2005) intracategorical approach which focuses on a specific group (in our case, the Quechua peasant community) identified and located at the intersections of several categories (age, ethnicity, rurality, socio-economic status, education and marital status) to reveal the complexities of their lived experiences (McCall, 2005). This approach often relies on individuals" narratives to draw out power relations and social locations embodied in these individuals" lived experiences (Lepinard, 2014) as well as their intragroup diversities (Manfred and Kets de Vries, 1987). The critical discourse analysis focuses on socio-cultural meaning structures, which are accessed through text, speech or the symbolic aspect of actions, often related to planning, natural resources and culture. This is based on the assumption that reality is constructed through processes of social meaning-making, relying on the use of social practices and knowledge (Foucault, 1973; Keller, 2012). The focus is shifted to the complexity of lived experience and must look for local, specific and historically informed analyses grounded in spatial and cultural contexts.

For phase 1, we conducted a revision of past research carried out with the communities in 2012, 2016 and 2018. The aim was to re-examine data on communities concerning soil erosion control, soil health, biodiversity conservation, water management and community practices. These communities were selected because of their vast knowledge on community planning, conservation of crop biodiversity and close relationship to their Andean Cosmovision (culture and social organization linked to their life experiences and the generation and transmission of knowledge to younger generations).

Based on the information collected, we conducted a critical Discourse Analysis to connect the relationship between three levels of analysis for identifying cases where communities were working in soil conservation and water management (phase 2). We examined newspapers, magazines, posts, interviews, webinars, film narratives, television programs and gray literature for the period 2016–2021 for identifying cases where communities were working in soil conservation and water management. We critically analyzed: (1) the actual text; (2) interesting initiatives happening in the communities–discursive practices; (3) relationships used to produce, receive, and interpret messages (Fairclough, 1995, 2013; Van Dijk et al., 1997; McGregor, 2003).

For phase 3, we conducted ten (10) direct in-depth interviews with key informants for validating and updating information gathered in these initial two steps). Key informants included women and men elders with deep knowledge of reading and interpreting Andean cosmovision principles and concepts, women and men community members with different biographical profiles or identity dimensions (marital status, age, education, socio-economic status). This data was analyzed, and visual, written, and oral data was triangulated and coded by applying the intra-categorical approach to intersectionality (McCall, 2005). Analysis sought to build a picture of the preconceived categories of women's and men's social identities, such as through gender, ethnicity, marital status, and age, education and geographical location, and how this was reflected in men's and women's contributions to land use planning in

TABLE 1 Community background.

Racracalla

The community of Racracalla was recognized on 20 October 1989 and is located between 3600 and 4800 m above sea level in the Department of Junin. Its territorial extension comprises 14,448 ha: 7,638.18 of which is ancestral land and 6,810 of which was transferred to the community *via* agrarian reform. The territory is accidented and steep in the highlands and has a plain in lower areas. A Quechua community, it has 132 registered members of which 117 are men and 15 women. The territory is organized according to areas of agricultural use, pastures (natural), forests, water resources, spaces not suitable for agriculture, and housing. Agriculture is the main source of income and work. Potato production is the main agriculture activity, with over 450 varieties cultivated in community lands. The community owns cultivated land and there are a few individual landowners in lower areas (communitarian tourism). Production is for subsistence in the first instance. Conservation of native potatoes is a priority and is conducted through the Conservationist Association of Native Potato Producers while surplus is sold in local markets. There is an external conflict with neighboring communities of Comas and Pusacpampa concerning Racracalla's loss of access to grazing areas in the highlands and irrigated land in the valleys. Young people tend to stay in the community, although some choose to migrate.

Laraos (Santo Domingo Qocha de Laraos)

The community of Laraos was recognized on 2 September 1938 and is located around 3,500 meters above sea level in the Department of Lima. Its territorial extension comprises 65,742 ha. Ninety-six percent of this land is puna land used exclusively for grazing. The remaining 4% is located in the Quechua region and dedicated to agriculture and occupies the flanks of the small valley of Laraos upstream and downstream from the town. The landscape is accidented and vertical. The slopes range between 20 and 45 degrees. Agricultural plots are terraced from the top of the valley and along the steep slopes on each side of the watercourse. The river flows into the small lake of Qochapampa with temporary waters. The irrigation channels constitute a masterpiece of hydraulic engineering that allow water to be carried from faraway places to the last corners of the platforms. A pre-Inca (Wari) community, it has 636 registered members of which 319 are men and 317 women.

Agriculture is the main activity: corn is the main crop followed by native potatoes, olluco, mashua. Native potato is only grown in dry and community-owned land. The conservation of cultural practices is revealed in their communal festivities: "Cleaning of the ditches" is celebrated on May 15 each year; other festivities include the "Matachines" and "Quia Quia" celebrated on the third Sunday of June, the Palla Larahuina on August 4, the "Nigeria" on August 30 and the dance of the "Lilies and Huachuas" celebrated on December 25. The community owns cultivated land and there are a few individual landowners in lower areas (communitarian tourism). Production is for subsistence and there are no external or internal conflicts. One of the most challenging issues the community faces is the out-migration of youth to cities or mining communities.

Pazos

The community of Pazos was recognized on 31 January September 1951 and is located around 3,840 m above sea level in the Department of Huancavelica. Its territorial extension comprises 6,700 hectares that are owned by the community. Most of the terrain is not irrigated. The landscape is covered by grasses and shrubbery. Terrain is accidented and steep in the highlands and flat in the valleys. Located in the Suni and Quechua regions, there is a cold and dry climate with abundant seasonal rains in cold and undulating bottoms. A Quechua community, there are 200 registered community members of which 100 are men and 100 women. Despite the harsh climate, barley, beans, olluco, native potatoes, maca, oats and others are cultivated. The preservation of native potatoes is one of the most important activities in the community, cultivated in non-irrigated terrains and community land. The community maintains approximately 350 varieties of native potatoes. Land is owned by the community in the highlands. Lower areas are owned individually by citizens for housing. Community members are also members of the cooperative Agropia which sells the native potatoes to niche markets in Europe. Community members are under pressure to produce for new local and international markets for specific native potatoes varieties (2 varieties). Though the community does not have problems with mining industries, it has experienced external conflicts with other surrounding communities in the past decades. Migration is characterized by the movement of young people to the jungle and mining industry for work.

Quispillaccta

The community of Quispillaccta is located between 3,500 and 5,000 m above sea level in the Department of Ayacucho. Some their cultivable land is also located at lower levels (3,000 masl) near to the Pampas river. Its territorial extension comprises 22,220 hectares. The community has three agroecological zones. In the low zone (below 3,500 m above sea level) is located the mother town Villa Vista (also named as Llaccta). In the middle zone (between 3,500 and 4,000 masl) there are another 10 neighborhoods (Unión Portero, Cuchoquesera, Pampamarca, Catalinayocc, Puncupata, Yuracc Cruz, Llacctahuarán, Pirhuamarca, Huertahuasi and Socobamba). In the upper part are located the towns of Tuco and Circi, which are 4,000 m above sea level. The localities share a continuous territory; however, each is autonomous in its organization and communal work. The community owns the grazing lands; each family member has customary access to land. Quispillaccta is surrounded by the Cachi and Pampas rivers, of the high headwaters of the Río Cachi basin, however, its springs, lagoons and slopes derive from the water of the rains, hailstorms and the melting of the waters in the mountains. The community depends on two main economic activities: agriculture and livestock. Agriculture is carried out in dry land, under the of rain and in conditions of high climatic variability, for which its production is irregular and limited to a single campaign. On the other hand, livestock is practically for self-consumption or for internal trade. Collective efforts have generated high dividends since the formation of the Bartolomé Aripaylla Association (ABA—Ayacucho). This is a nucleus of Andean cultural affirmation, one more strand of the fabric of the indigenous community of Quispillaccta. The organization has been strengthening Andean agriculture and the recovery of traditional knowledge, the cultivation of ancestral species, the diversification of seeds, the improvement of soils and grazing areas, in the increase of the vegetation cover and reforestation, in the cultivation of medicinal plants, among others. The community was affected by violence during the Internal Armed Conflict, in particular between 1980 and 1991. Security forces carried out mass kidnappings and executions of indigenous peasants (La Serna, 2012). Traces of this conflict are still visible to this day, especially at the level of community organization and its cultural identity.

TABLE 2 Discursive elements in indigenous or community land use planning and national planning.

1. Power and knowledge generation in community planning

- Community members—comuneros and campesinos mutually depend on one another for maintaining the land and resources for the benefit of the communities. Relations are considered equal and egalitarian and not hierarchical. Knowledge generates diverse power dynamics inside the communities.
- Older men, as heads of the household and community, have more knowledge and life experience and enjoy social privilege over younger, single men. Their power is reflected in the decisions they take in the management of the resources and planning decision-making processes.
- Older men represent the communities at local, regional, and national level because they are perceived as speaking better and able to demonstrate leadership skills and qualities.
- *Comunera* women (widows) represent the household in the community. Their knowledge is respected and followed by older leaders. *Comunera* women have full rights in the community and enjoy power and privileges in the communities.
- Married peasant or *campesina* women that are older hold deep knowledge about planning and are guardians of the knowledge–but do not enjoy the same social privileges of female widows as they are not head of the household.
- Young female daughters without decision-making roles in the community have more formal education and are appreciative of traditional knowledge. Their opinions are heard and followed as they introduce knowledge that integrates traditional knowledge with more technical knowledge. However, their role is that of "innovators" and not of community members. They may have access to land and resources but no control over the land. This is given to them through fathers or widowed mothers.
- Though community members in all communities contribute equally to community land use planning and resource management use planning, the positions they occupy in the communities are unequal distributed. There are men and women who can make decisions and transmit knowledge comfortably (mainly older and head of households). While other only are keepers of knowledge, new or traditional (married and young women). They may have access to land or resources but not control over them. They are represented by older men—fathers or husbands and female mother widows because they are not "formally" members of the community.
- Peasant women suffer different forms of subordination inside the communities, as their status as wives or daughters as opposed to commoners or "*comuneras*"means they cannot access management roles or control over the land. The seed keeping role is assumed as a "reproductive role". They are also unable to represent the household or community if the head of the household is the husband or father. Nevertheless, peasant ("*campesina")* women are the main contributors to community planning, food security and biodiversity (crops and animals) conservation.
- Peasant *campesina* women's contributions to planning for resource management, knowledge generation, conservation and cultural practices do not lead automatically to community membership or land holding in the communities. Knowledge does not necessarily translate or result in holding power in the communities. An older and married women in the community can be a seed guardian or contribute to water management planning, however, she cannot have access or control over the community land.
- Power dynamics in the household are very different to those exercised in the communities as women's domain is the household and food intake. Food intake depends on the resources the families have and maintain inside the household.
- Married women's knowledge and visible power in the households is considered as part of their duties to maintain the family (reproductive roles). Diversity means nutrition and food security. Powerful men depend on wives to make decisions at household level because women.
- Younger, educated women create their own spaces (Quispillaccta, Laraos, and Pazos) and acquire decision-making power despite their age and introduce new activities or innovations for promoting equity and representation of women in community planning and community decision making.
- Younger and educated women and men without any management or decision-making role in the communities are respected as they easily can establish intercultural dialogue and communication with outsiders.

2. Linking customary planning to "state or modern planning"

- Peasant communities hold oral knowledge which is guided by the Andean Cosmovision's principles and influence their ways of living. Though, they are recognized in the legal frameworks of the country, they are not clearly and differentially recognized in policies.
- Peasant communities are heterogeneous not only because of their ecological systems, geographic location and culture. Communities are also diverse on their access and control over resources, socio-economic situation, type of organization and market relations. They are also diverse because of their population characterized by their age, socio-economic status, ethnicity, marital status, etc. The heterogeneity of the communities is represented at individual, household and communities.
- Though, older married men and female widows hold power in the communities, their power is limited to their roles at the community level. Few become national representatives.
- Local conditions of peasant communities are diverse and heterogenous because there is no ideal peasant or *comunero* who can represent the peasant community. They are diverse because their unique knowledge—women or men, social relations, and socio-economic status.
- Policies have not yet considered the communities diversity of activities. Communities plan these at different spaces and time, they are escalated and not conducted at one time.

(Continued)

TABLE 2 (Continued)

- National and sectoral policies do not consider the interrelation and complementarity of communities' activities. Productive activities (crop production, husbandry and forestry depend on each other because one supports the other to produce.
- National policies do not consider the different farming systems or the contribution of the animals (manure or transportation).
- National policies do not consider the influence of agrarian behaviors and organizational systems in the planning of production systems which are determined by natural conditions. This overlooks the use of resources in time and space, and variation of environmental factors (water availability, excessive humidity, etc.) in the production systems.
- National policies have ignored the cultural and historical factors of communities that influence community planning and overlook the communities structures and systems of production as integrated approaches to planning.
- Indigenous, peasant and community planning are ignored in national and sectoral policies. The Ombudsman's Office in Peru nevertheless indicates peasant communities suffer discrimination and exclusion, scant exercise of their duties and rights, limited participation in decision-making, lack of basic services such as health and education. State support is limited or absent. In addition, there is the frequent lack of title to territories (rurality), few protections from land invasion, and communities experience deforestation due to activities such as large-scale cultivation and illegal mining.
- Legal protections and mechanisms have weakened since the early 1990s and do sufficiently not protect the lands and territories of peasant communities. In the 2000s, supreme decrees, legislative decrees and ordinary laws have debilitated communal property, environmental protection in favor of the national economy, extractivist projects and infrastructure.
- Economic interests of large investments are prioritized, emphasizing modern against traditional. Rights protections are weakened to the benefit of investors. legal changes (e.g., Law 30,230, Title III complemented with Legislative Decree 1333) promote the clearing of community land for investment projects.
- Land titling reduces territorial rights of peasant communities. This is in part caused by chaotic regulations and absence of public policies to recognize land titling. Land registration and titling is difficult for peasant communities to achieve. Processes are slow and complex, taking several years to be recognized and usually have to be done in Lima, the capital.
- In 2014, the National Ombudsman's Office concluded that the Peruvian State does not have a public policy suitable for the recognition and certification of the peasant and native communities of the country. Seven structural and institutional issues identified: (i) absence of regulations on community titling; (ii) lack of a governing body to recognize and support titling of communities; (iii) lack of centralized information on the number of peasant communities; (iv) insufficient institutional capacity to recognize and certificate land titling of peasant communities; (vi) lack of awareness and knowledge on rights on adaptation of management instruments; (vii) absence of budget prioritization for the implementation of the recognition process and titling of peasant communities.

local agri-food systems. To complement, we conducted semi-structured interviews with a total of 4 women and 3 men from the communities to address the gaps in the literature and policy review (December 2019–December 2021).

In phase 4, reports of national policy documents and planning legislation were reviewed in relation to peasant communities, family agriculture, natural resources and environmental planning. Data collected across previous phases were further triangulated and analyzed after the codification of data in NVivo 12. We used content analysis and applied the critical discourse analysis approach (Fairclough, 1995, 2013; Van Dijk et al., 1997) to analyze the data to identify the multiple social locations, relations, and structures of power, in relation to these identities. This would allow us to understand discursive practices at the micro-level planning processes and their relation to national planning discourses. With these analyses completed, emerging findings were lined up with the main coding themes obtained through the document analysis, allowing gaps to be revealed in relation to women's and men's identities and contributions to planning in local agri-food systems. Key informants and research participants were selected through a purposive sampling strategy that focused on interesting cases that would help shed light on intersectional identities and generate new and conceptually useful knowledge about each community. The step supports realizing the study aims, where intersectionality is placed in a new context of local or traditional planning. This strategy, which is an appropriate one for qualitative social enquiry, is reflected in our sample size: we do not seek to generalize these findings to Andean communities more broadly (a statistical generalization), but to provide a theoretical generalization that concerns the meanings and feasibility of local or traditional planning for agricultural purposes through an intersectional lens (Seale, 1999).

Results

Findings of our discourse analysis reveal two main discourses around power and knowledge generation at the community level; and modern or state planning at the national level planning. These are summarized in Table 2. We did not identify substantial differences between communities in how identities identified in Table 2 are concretely manifested and how they track principles of the Andean cosmovision and knowledge generation, and their influence on social organization and planning. At the same time, in Table 2 we present and discuss below aspects of location-specific heterogeneity and multiple social locations.

Women's and men's participation and contribution in community planning

Different groups of women and men contribute equally to land use planning in the communities, despite differences in age, socio-economic status, gender, ethnicity, etc. The preservation and conservation of resources such as for agrobiodiversity, water and soil is in the hands of women. Older women have passed the information to younger women and the generational gap has been closed through ceremonials and payment to mother earth (Pachamama). Community members collectively identify, plan, and carry out activities that meet their collective needs. Despite differences in women's and men's social positions in the communities, they all participate and contribute to planning processes. However, differences still arise when an individual becomes a community member, a *comunero* with rights to receive land from the community. Most women cannot be registered as members in the same way. They are restricted from control over the land by being represented by either their husbands or fathers in the community council. Despite these restrictions, women's contributions and presence in land use planning ensures that natural resources are used efficiently. Thus, the needs of the communities and members are met while taking care of their natural resources. Each year, land use planning begins with land distribution for each household.

The head of the household is usually the father or husband who is registered in the community's registers. A female widow, who is usually older with children, may also represent the household. In exceptional cases a single mother can also represent her household. Women and men with full rights in the community are called "*comuneros* or *comuneras*". Those men or women who are not official members of the community are called "*campesinos* or *campesinas*". This social difference emerges from traditional norms and governance practices in the communities, and shape land access and control (Figure 3).

Despite the positions of the different groups of women and men, and the traditional forms of governance in the communities, younger generations–specifically university educated young women are key players for introducing new ideas into communities. They have been able to introduce new knowledge or technology, which has been well received in the communities. Older women and men by contrast depend on traditions and rituals to maintain the natural resources in the communities.

Communal planning

Planning in these communities is conducted under the precepts of the Andean cosmovision and guided by the principles of *Ayni* or Andean reciprocity, and *Minka*, the process through which people work together for a common interest. Ancestors' practices and traditions represent and encourage sharing work, teamwork and collaboration. Planning processes are integral, iterative, and collaborative. Decision-making draws on diverse tools, mostly graphic, oral and written documents. Information, experience, and events accumulated through the years carry a similar level of importance as current information. These are documented chronologically and sequentially. Periodical community assemblies serve to discuss, revise and update information. Planning elements that characterize these discussions are multiple and include for instance the legal status of the community, information on households, and communal activities (Table 2).

Revising territory and ecosystems through community assemblies is done holistically. Community leaders must guarantee that community members participate equally, and participants give their opinion freely. In the assemblies, community members gather and collectively decide on plot distribution for the year. Registers such as in the form of maps and agricultural calendars are revised by community members to decide on land distribution and use. This is a democratic process and conducted through form of public draw. An equal number of plots are assigned to each household head. Quality of the soil is not similar in all plots however and community members must accept the results of the draw. A "communal approach" to land distribution is adopted which starts with "communal zoning". This reflects respect for the Pachamama and communities' experience of territorial management, which is based on adequate and rational use of all the assets that exist in the community. For example, there should be a balance between healthy soil, water, biodiversity, livestock, wild flora, and fauna. Two interview excerpts with women in the community are illustrative:

> ...we have to take care of our home as a whole; nothing goes separated or individually. The natural resources including the land we have in the community are the sources of our food, our health, our homes. This is the place where we relate to our ancestors, to the gods and spirits. We and our ancestors have maintained close connection with nature and lived in harmony. We were prepared to read what the stars, the moon and the sun wanted to say to us. Now, we must be more prepared the weather is changing, and we have to be prepared. If we plan together and everybody participates, we can overcome the challenges.

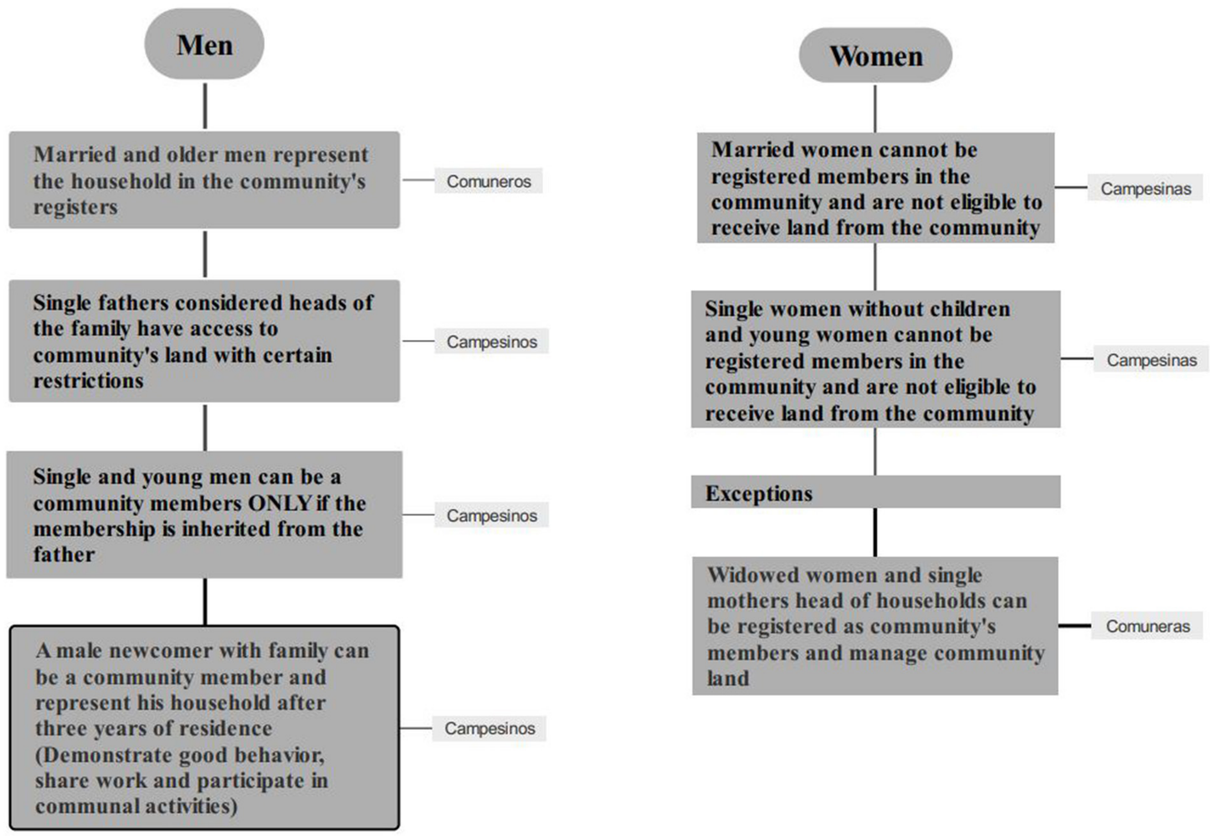

FIGURE 3
Community land distribution.

> It's the place where we live in harmony with nature [the cosmos, stars, sun, moon, the pikes, etc.]. I respect the Pachamama because it gives us food. She feeds us. In my community, we give our respect or "pago" to the Pachamama. Before we start our work in the fields, we have to ask for mother earth's permission. We have to pay tribute to the land so we can keep our animals and plants in peace and harmony.

Communal zoning

After all elements have been assessed and revised (Table 2), community members focus on the elements that might disrupt the functioning of the ecosystem or territory and which are considered critical for "*buen vivir*" (living well) and food security. *Buen vivir* or *sumak kawsay* in Quechua describes a way of doing things that is community centered, ecologically balanced, and culturally sensitive in order to produce the food for households and the communities. The main zoning elements are zones of crop production; zones of forestry production—introduced and native; zones of pastures—introduced and native; zones of recuperation; zones of conservation or protection; sources of water (Table 3). Older women play a critical role in sharing their knowledge with community members when it comes to communal zoning. They are in charge of collecting and selecting the seeds, taking care of the llamas and animals in the household, organizing activities for the cleaning of canals. Though, married women are not members of the community, they actively participate in the community's meetings.

In the zoning processes, natural resources converge for the zoning elements to function (Table 4). This is in harmony with the worldviews, culture and the social interweaving for securing food. Although production is specialized by zones, individual production units are located at different altitudinal zones. Community members can cultivate land in different production zones. This supports community work, labor and *Ayni* and can be coordinated vis-a-vis diverse agricultural cycles. The relationships between the community and families are dynamic and symbiotic, which help families access specialized production zones or different production zones.

Families must follow community protocols by making use of each production zone. This can create some differences

TABLE 3 Elements considered in the planning process.

1. Community information: name, status, legal recognition, plan, statutes, bylaws, and accounting books.
2. Geographic information: location, altitude, ecological zone(s).
3. Demographic information: number of families, people per household, children born in the year, people death in the year, etc.
4. Roads or *caminos*: access, type of roads, conditions of roads.
5. Weather patterns documented in maps and calendars: frequency of rain, drought, hail, storms.
6. Cultural activities: festivities, celebrations to the *Pachamama*, canal cleaning, religious festivities, carnivals.
7. Territorial space: number of hectares, forest, community's geographic limits (north, south, east, west), basin or sub-basin jurisdiction.
8. Terrestrial areas: irrigated land, dry land; natural pastures: irrigated or non-irrigated land; cultivated pastures: irrigated and non-irrigated land. Location of land: around the community, low, middle and higher altitude *(altura* or *puna* and/or *cordillera)*.
9. Types of land: dry, irrigated, cultivated, resting *(descanso)*, abandoned, natural pastures, terraces, *andenes*.
10. Types of water resources: peaks or *nevados*, lake, lagoons, basins, canals, *diques*, *acequias*, ponds, ditches, wetlands, *champas*.
11. Communal activities: community level/community associations/social groups/school activities/producers associations/family level.
12. Soil conservation and forestation: rehabilitation of terraces, construction of terraces, infiltration ditches, gully control, live fences, contour furrows, planting with native, exotic or fruit trees, composting.
13. Water management and crop production: lagoons, *cochas*, acequias, drainage channels, irrigation channels, irrigation systems, irrigation canals, water harvesting, spring maintenance–*faenas*, cultivated pastures in dry land, cultivated pastures under irrigation, natural pastures in dry land, natural pastures with irrigation, crops in dry land, crops with irrigation, family and school gardens, pest and disease control, seed storage.
14. Livestock management: alpacas, llamas, sheep, improved and native cattle, small animals. Livestock breeding, fish (trout) ponds, fences, corrals, sheds, and fodder conservation.
15. Wetlands management: natural pastures, rotation of plots parcels or *topos*.
16. Community activities: conservation of main areas—park, school, health center, storage sites, accessing roads, wells, canals or *acequias* and sanitary landfills.
17. Community management: community plans, bylaws and regulations, accounting books, organized archives, maps, calendars, etc.
18. Community facilities: water reservoirs, seed storages, irrigation and drainage channels, terraces, living fences, native trees, exotic trees, fruit trees, watering systems, cultivated pastures, irrigated cultivated pastures, irrigated natural pastures irrigated crops, vegetable gardens, alpacas, llamas, vicuñas, guanacos, sheep, improved cattle, creole cattle. This also includes small animals (guinea pigs, hens), fences, corrals or paddocks, sheds, silos (for manure and fodder conservation), wetlands, etc.
19. Other infrastructure: community house, housing, small church or *capilla*, schools, health center, mothers" club, latrines, communal kitchen, drinking water, community and family wells, sanitary landfill (dumps).
20. Other community possessions: vehicles, tractors and implements, communication community center.
21. Activities for community work (ayllu): soil management and conservation, water management, crop management, livestock management (herding, transport, migration, meadow management.

among community members, but community mechanisms help mitigate tension such as the agricultural calendar for helping generate common agreement on the factors including the distribution of plots and cultivation. Community members also have to plan shared work or labor, as they are usually involved in two planting seasons: the small and early season (*campaña chica*) and the big or main season (*campaña* grande). Even though most activities are led by men, the most important activities are conducted by women: depending on the plots they have for the year as a household, women plan which crops and seeds they will plant and at what time and ecological zone; and depending on the weather patterns and reading of biological indicators women make recommendations to the community on what, when and where to plant the seeds. When agreements are completed, the duality and complementarity principles of the Andean cosmovision are fulfilled. Communities confront problems of which climate and variability in weather patterns are the most frequent themes. These are considered in community zoning. As one community member described,

> ...respect for the land is understanding occurring changes in the climate and weather. Natural forces such as climate change and weather variations are expressions of mother earth. She wants to transmit her voice now that people are not respecting her and are abusing her. Those who live in the communities know we must be in the field all the time. The plants and animals need to be observed. Changes in the weather and climate can present overnight and unexpectedly.

Traditional knowledge is complemented with modern knowledge and new technologies. These have been useful for strengthening agricultural practices in the communities for dealing with intense, short and unpredictable changes

TABLE 4 Main elements of communal zoning.

Zoning elements	Description
Zones of crop production	Areas used for crop production and located along different altitudinal zones.
Zones of forestry production—introduced and native species	Trees, shrubs and different species of cactus are identified. Introduced species of eucalyptus sit along the riverbanks or as live fences at lower altitudes. Native species (*quinual*, and *aliso)* are found at higher altitudes. Native shrubs and cacti are in middle altitudes forming living fences.
Zones of pastures—introduced (temporal) and native species (temporal and permanent)	Permanent (native species at higher altitudes) and temporal (introduced species at lower altitudes) pastures for livestock production. Permanent pastures are found throughout the year and includes permanent grasslands and puna grass cover or *ichu.* Seasonal grazing areas operate all throughout the year at different altitudes to protect *bofedales* or watersheds and managed pastures.
Zones of conservation or natural protection	National administrated protected natural areas inside the communities with biological diversity and with associated values of cultural, scenic, and scientific value.
Sources of water	Lagoons, ditches, wetlands, and temporary bodies of water. They serve as habitat for birds, fish and drinking water for the communities and animals in the community.
Sources of biodiversity	Seeds, flora and fauna need to be preserved, maintained and exchanged to sustain the biodiversity existent in the different zones.

in the weather, water supply and climate. For instance, young professionals—women and men—have been returning to the communities after periods away and bringing new knowledge with them. Some examples include the three agronomist sisters returning to the Quispillaccta community. In the context of COVID-19, in-migration has also increased, with young people suffering from unemployment in the cities and lack of food. This is the case of the Laraos, Pazos and Quispillaccta peasant communities.

Participatory diagnosis and prioritization: The territory, ecosystems, and community living interface

Once all information for the different zoning elements is shared, community members proceed to identify the problems, challenges and needs they have in these zones (Table 5). They to identify what solutions might address the challenges and needs. These are based on an evaluation they conduct on the conditions of the main natural resources. A combination of traditional practices and introduced practices are considered. In relation to agricultural and livestock production, the main resources that need attention are considered as priority areas for the year (Table 3).

Communities consider the preservation and transmitting of their traditional knowledge, cultural customs, and natural resources to younger generations is critical for creating the conditions for improving their lives. It is of central importance for communities that they maintain the pool of biodiversity, health of the soil, and that a sufficient and adequate supply of water is provided to crops. Doing this will involve women and men elders that are especially familiar with Andean ways of prediction related to reading signs of nature, stars, planets, and the sun and moon as a crucial planning element. This helps communities confront current challenges such as climate change, weather variations and water scarcity. Cultural and community practices contribute to that balance and support the conservation of resources:

> …in our community, we aspire a better future for our children. They need to enjoy what we have in the communities, they need to live well while they co-exist with nature, as it was with our ancestors. It is the reason we also preserve the teachings from our ancestors. We work together to envision how our children will live in the future, what should we do to make it happen. We must think about what we need to amend, what we should not repeat doing…

The conservation and maintenance of natural resources is a community priority and are conducted through worldviews, women's knowledge, and cultural practices. Every decision that is made is based on the agri-food system, with each element viewed as connected to one another. For example, communities must determine what area of land will be cultivated, what piece of land needs to be conserved or put to rest, what type of treatment it needs. Such processes reaffirm notions of property, spaces, or areas the communities possess; their communal territory—agriculture and livestock as well as the people who are part of the community. These exercises help them to confirm delimitations or borders they manage, for instance to prevent conflicts with other communities. This holistic approach to agri-food systems is closely related to the ecosystems in the

TABLE 5 Identification of problems and solutions.

Zoning elements	Problems, challenges and needs	Solutions
Zones of crop production	- Soils degraded by crop cultivation and overgrazing - Soils with erosion—moderate and severe - Unused and deteriorated terraces or *andenes* - Soils contaminated by plagues (nematodes, insects, fungus, etc.) - Low fertility of soils	- Soil erosion control - Production of organic fertilizers and pesticides - Integrated Pest Management - Construction of fences—live stones - Reconstruction of terraces - Multi-cropping - Rotation of crops and use of natural fertilizers
Zones of forestry production	- Excessive flooding in times of rain - Dried soil because of excessive sunlight	- Protection of riverbanks with improved trees (eucalyptus), native shrubs and trees. - Propagation of tree and shrub species - Installation of living fences in plots at lower altitudes
Zones of pastures	- Degraded pastures by excessive grazing - Degraded pastures in wetlands - Unused and deteriorated terraces or *andenes*	- Grazing management in wetlands or *bofedales* - Restoration of degraded pastures in wetlands - Improvement of terraces and *andenes*
Zones for restoration	- Areas degraded by overgrazing - Soils with severe erosion - Areas of pastures degraded - Soil degraded by water ditches	- Communal recuperation of pasture areas - Soil erosion control - Restoration of pasture areas - Recovery of soil degraded by water ditches
Zones of conservation or natural protection	- National protected natural areas in the community	- Communal maintenance of protected natural areas
Sources of water	- Maintenance of water structures	- Cleaning of canals and acequias - Maintenance of lagoons, lakes, springs, etc.
Sources of biodiversity	- Crops damaged by drought and frosting - Degeneration of seeds as a result of diseases and insects - Seed preservation - Limited number of crops	- Enhancing the community seed bank - Promoting multi-cropping and live fences with other crops *(Olluco)* - Enhancing community seed storages - Seed exchange with other communities

communities. The principles of the Andean cosmovision *(ayni, ayllu and minka)* have influence on the preservation of traditional practices.

Traditional practices have occasionally been improved with new and adapted technologies, and technologies from Inca and pre-Inca cultures. In all cases, the precepts of the Andean cosmovision and connections to the gods, nature and the *Pachamama* remain. The adoption and adaptation of new practices is also undertaken by younger generations—women and men—with university education or training. For example, formal programmes in the late 1990s engaged with communities through conservationist associations in the control of soil erosion and the preservation of water to give more importance to local and traditional agricultural engineering. The conservationist associations have been present in Andean communities and these are usually led by older men and women. Overall, existing and new practices are undertaken and incorporated in ways that are consistent with community heritage and tradition.

Planning for resource management in agri-food production

The use of local technology facilitates the management and use of the land and water systems as well as genetic diversity while minimizing climatic and weather risks. Technology has been adopted and adapted with attention to the ecological systems in which the agri-food system is a part. Ancestral, introduced or hybrid technologies hold ecological characteristics to control mechanical and biological processes. These technologies are also mechanical.

Land use

Plot cultivation is the center of people's lives and the place where a sustained a constant relationship with nature is indistinguishably interwoven with the land and its health. As a result, cultural practices such as *ayni, ayllu* and *minka* are performed on the plot. Family and community members share work and resources to maintain genetic diversity. They control and minimize risks associated with ecological variability, water scarcity, and soil degradation. The use of plots is subject to rotation in *aynocas*[3] *(*Laraos, Pazos and Racracalla) to maintain soil fertility and quality and to control insects and pests.

Soil conservation

Conserving the land and keeping it healthy is achieved through a variety of practices, for example, tillage systems are used in combination to minimize soil erosion and prevent losses in productivity, pest control and water run-off. For example, *the "barbecho"* tillage system for lower altitudes in areas with water availability and conducted in the small planting season *"campaña chica"* between June and August. It consists of turning compact masses of crop-free land to be converted in loose soil. Another ancestral practice is cultivation in terraces or *andenes*, which were built in the pre-inca period to control drought. The terraces can reduce soil erosion and protect crops from frost, as well as promote the diversity of food species, such as potatoes and grains. Terraces also diminish surface runoff and act as sponges by promoting water penetration and infiltration.

Water management

Water management in the communities is done collectively but relies on young men to maintain the structures of water and women to secure the sources of water. If the water proceeds from rainfall, the community decides on its maintenance or building different structures. For water runoff control they build or maintain stripes containment and embankments. For the same purpose in the streams and springs, communities maintain the "acequias", ditches or drains, or canals to spread the water to flood by gravity cultivated areas and natural pastures (Laraos, Racracalla, Quispillacta and Pazos). It depends on the source of water, and volume of water that can be available in each community. Communities design the use and maintenance of a series of techniques related to water management. These are closely associated to soil management and the control of runoff caused by rainwater, soil formation and agroclimatic sources. The modification of the physical geography, especially on slopes, is the result of the evolution and adaptation of tillage tools and practices. Modifications include for example the use of Inca "*cochas*" structures that store water in natural lagoons in the high areas as watering holes.

Biodiversity management

Women of different ages are engaged in these activities and they start with seed selection (post-harvest practice and bartering) and varietal identification (plant selection and plant marking in the field). Older, married and Quechua speaking women in the communities play a crucial role in contributing to planning regarding what to plant and what seeds to use. They select best seeds for the next season. Men also participate in the activities, but it is women's decisions that contribute to the preservation and maintenance of the seeds and livestock. Multi-cropping helps the peasant producers use crops as insect repellents or live fences. Communities use plants, animals, physical phenomena, and stars as indicators of behavior of time for predicting climatic occurrences. Through these phenomena they forecast the next agricultural year. It is nature that determines the optimal time for planting, harvesting and livestock management. Preparing the soil and land according to the indicators allows Andean peasants to anticipate or delay the planting season. Community seed banks are led and organized by the community to maintain, at household and community levels, agrobiodiversity and practices related to its use. This traditional knowledge is transmitted from generation to generation as diversity of crops is achieved at long term. Communal banks serve as seed sources for replacing those seeds lost in the fields. This is important for families" nutrition because crop diversity carries nutrient diversity.

Older, married and Quechua speaking women are in charge of plant health. They consider taste, color, resistance to diseases and insect pests, adaptation to soil, and agro-climatic aspects. They preserve seeds through local or traditional methods. Younger married women pair with their husbands to travel by foot for exchanging seeds. The older women in the community select the seeds and transmit their knowledge and seed selection skills to their daughters. Older women know the value and differentiate the use of plants for nutrition, food security, health, and income. As a result, they acknowledge which crop and varieties should be preserved and maintained in the household and community. Women take into consideration a plant's multiple uses, providing a balance to the market-oriented pressures that emphasize high yields and uniformity.

Cultural practices

Ayllu is the basic unit of the social organization in the community, where the community owns the communal lands that are produced and maintained. *Ayni* is a reciprocal work system family among the members of the *ayllu*, destined to agricultural work, management of water structures and upkeep of biodiversity. It is based on helping one another on the basis of reciprocity if needed. In return, the hosting family serves meals and drinks. *Minka* is another type of collaborative work. It synthesizes relationships of reciprocity, commitment, and complementarity. The community comes together to work, for example, toward the planting season or raising the harvest. It is always greeted with a large meal or a commitment for reciprocity.

3 The *aynoca* land, located in the hills, is cultivated for some years and left to rest for other years.

Bartering with other communities at different locations and altitudes strengthens networking and diversification of foods. This also helps communities exchange seeds and maintain a genetic diversity of crops and livestock. *Faenas*, cleaning of canals, acequias or aqueducts are Inca traditions. They are based on communal work where all members of the community participate: men, women, boys, girls, and the elderly. Field work takes place after a communal assembly and unfolds in a festive atmosphere, accompanied by music, consumption of fermented beverages and chewing of coca leaves. The activities are held every year to clean all water supply structures.

Discussion of results

Diverse relationships and intersectional interactions in the Andean agri-food system have been identified in local planning processes. These relations and interactions are fostered between Andean women and men of diverse ages and identities (age, marital status, socio-economic background, education, etc.) and biophysical or social-ecological systems. They are also among and between the diverse groups of women and men in the community (comunera women, campesina women, campesino men, comunero men), between communities (different altitudinal locations), institutions and policy making. These relationships reproduce power dynamics and representations in the territory ecosystem context.

Social-ecological relations and social interactions

Findings support the presence of dynamic, iterative forms of feedback between the Andean ecosystem and its social system (Levin et al., 2013). On the social side, the use and sharing of these resources in socially and environmentally sustainable ways supports the functioning and conservation of local agri-food systems in the Andes through collective action and agency (Isbell, 2005). However, adaptation and adoption of technologies are subject to environmental conditions, such as climate stress, as Mayer (2002) has shown, and reflected in the interfacing of the system's biophysical and social components that support the delivery of different services (Carpenter et al., 2001; IPCC., 2019). These include provisioning (such as food, raw materials, water, and medicinal resources), supporting biodiversity, habitat, and cultural (reciprocity, collective living, worldviews, relationship with nature) services (Sarapura et al., 2016). At the same time, services such as land use, soil health, soil erosion control, biodiversity upkeep and water management are regulated through community planning and implementation.

Andean women and men of different ages understand and value the relationships and interactions of traditional and emic knowledge systems of land-use and natural resource management (Tapia, 1996). Interactions with nature are rooted on collective land ownership and worldviews of reciprocity, collectivism, and respect (Berkes, 2018). While different groups are considered as contributing on an equal basis, this unfolds without recognition of the different experiences of women and men in relation to agriculture and food production. As results indicate, there is differentiation in men's and women's contributions that are shaped as well by gender intersections with other categories, such as education, and age.

Older men make decisions for and represent the communities in trainings, national and regional events (agricultural fairs, national conversations, field demonstrations). They are also considered the knowledge keepers and initiators of the "conservation community groups" in Racracalla. Communities' knowledge and biodiversity keepers are older women who speak Quechua (Racracalla, Pazos) and do not have formal education. They keep and transmit the knowledge (emic knowledge) and practice the culture according to the cosmovision perspectives. They are in charge of passing the knowledge and traditions to younger women. Though they are highly valued in the communities, they are not considered in policies and programming.

Young men and women professionals (Quispillacta, Laraos) who bring ideas to the communities have no access and control over the land and other resources. There are still absent in national and regional programs. Young women and men (Laraos, Pazos, Racracalla) have access to elementary schools in the communities. Parents have to send their children to closer cities (Concepcion, Huancayo, Pampas) to be in high school or university. The lack of technical or agricultural schools forces them to emigrate to other cities. Young professionals (men and women) who finish university come back to the communities (Quispillacta and Laraos) and introduce new ideas and innovations. They have some influence on the communities' planning (Laraos and Quispillacta), however, they may not have access to and control over the resources as they still are presented in the communities by their fathers or widowed mothers (Laraos and Quispillacta).

As such, women position themselves in the communities and in terms of their relations with nature or the ecological system. Older women without formal education and speaking Quechua hold strong oral and practical knowledge for agri-food system sustainability while young women with higher education qualifications help innovate these practices with new knowledge and where planning processes are documented in Spanish. Inclusion of older women and the interactions they have in the decision-making processes is critical for sharing knowledge and information with younger generations.

Intersectional interactions and social relationships inside and outside the communities

Findings yield a dynamic picture of the role of local and indigenous culture in agri-food systems, where local beliefs, rules and norms simultaneously enable forms of planning, decision-making and management for system sustainability and resilience while also marginalizing and constraining opportunities for some individuals and groups. They reveal how more equitable or less equitable forms of resilience (Matin et al., 2018) arise in communities through planning and decision-making processes that are culturally inscribed. For instance, the way younger women and younger single men may formally participate in planning processes but have limited influence and voice because of their position in the communities, and how this reinforces their limited and unequal access and control over resources. Power dynamics are reinforced further through hierarchical and exclusionary relationships with external institutions and actors, where some groups have not yet had the chance to represent their communities and to engage with external actors.

This illustrates again the need for resilience perspectives to be sensitive to the relations, interactions and power dynamics among groups are locally or contextually embedded. Individual and social identities are relationally constructed, coevolving, and adapting with the ecosystem context (Díaz et al., 2015). On the one hand, interactions among peasant people strengthens self-organization for sustainable use of their natural resources (Tapia et al., 2012). This is characterized by informal institutional arrangements, self-governance and informal norms. In principle, everyone has a voice regardless of their status or representative role they have in the communities. On the other hand, these voices are expressed, heard and followed with mixed and contradicting implications for peasant peoples' lives and their representation in agricultural or environmental policies. In national policy and programming, their lives and experiences are reduced to single characteristics of wives, daughters, or sons without considering their knowledge. These findings support recent calls (Matin et al., 2018) for the integration of equitable resilience concerns, and we suggest here an identity component, alongside existing resilience indicators to improve practice, policy and programming in favor more equitable outcomes.

Outside of these communities, Andean peasant producers have been treated in policy and programming as homogenous groups, as poor and suffering from discrimination. Their practices and customary laws do not cohere with the country's statutory laws (Sarapura et al., 2016). They are ignored in national decision making and planning processes as well as at policy making and agricultural laws. The problem is particularly for married women peasant farmers, who are considered the knowledge keepers and biodiversity guardians. They still lack access to basic rights and unequal distribution of resources which is reflected in the traditional sociocultural norms that entrench gender roles and unfair treatment within formal and informal institutional environments. In general, peasant women who are married, single, and young remain the poorest, have higher levels of illiteracy, and are the largest monolingual demographic group in Peru (Deere and Leon, 2003; Sarapura et al., 2016). Young women who are educated and integrate traditional knowledge with modern ideas are still not considered in the national policies and are not provided with any support to continue their work and fully access their rights. Due to their limited access and control over land and resources, they have limited encounters, if any, with agricultural training and technology (Sarapura et al., 2017). They also have lower levels of basic education because local schools are predominantly for elementary schooling. These inequalities remain insufficiently dealt with in agriculture policy and programming which also reflects a narrow understanding of men and women that is not sensitive to intersecting identities. The intersecting identities of peasant people—different groups of women and men in agriculture are largely ignored by external actors in relation to the environment, biodiversity, ecology and natural resource management, and is reflected in terms such as "Andean women" or "Andean youth" that are insensitive to heterogeneity and difference.

These homogenizing approaches in policy and programming reproduce unequal power relations between peasant and non-peasant people and foreclose possibilities for supporting sustainable livelihoods in contexts where access to rights, resources and opportunities for younger people is routinely denied. Even when these groups have been included in external planning and implementation processes, these processes have been overly idealistic and community heterogeneity is overlooked (Wilkinson, 2011). Consequently, views and needs of women and other representatives of marginalized groups are not considered.

Intersectional policy implications in the sustainability and resilience of agri-food systems

For policy, integrating intersectional analysis in social, economic, political, cultural and environmental strategies in local agri-food planning and programming can help make visible the range of intersecting identities in local or traditional agriculture in the Andes that interact to shape resilience. There is, we suggest, an urgency to consider the complex relationship between systems of disadvantage and privilege and the diverse groups of women and men with intersectional standpoints along various social identities and lived realities as an area for further research in local or traditional and indigenous planning

(Masterson et al., 2017). The holistic approach to agriculture and connection to individual and community wellbeing, their diverse knowledges, and diverse ways of being of the different groups of women and men in communities remain to be included at the national level in planning and policy making processes and remains a deficit in the planning literature.

Rights-based practice may offer a potentially useful and culturally sensitive avenue for tackling resilience inequities (Ensor et al., 2015, 2018; Walsh-Dilley et al., 2016). Emerging from development practice and taking inspiration from grassroots and social movement campaigning, a body of rights-based practice demonstrates how such approaches may work directly with communities (Cornwall and Nyamu-Musembi, 2004; Gready and Ensor, 2005; Gready, 2008; Pena et al., 2008; Ako et al., 2013; Coulibaly et al., 2020) to promote transformations in social and political arrangements at different scales through a range of processes, such as advocacy, lobbying, critical consciousness raising and capacity building. Often combining human rights norms with conceptions of rights and entitlements grounded in community traditions and practices, rights-based approaches support marginalized groups to advance claims and demand accountability from the state, private actors and within communities. Rights-based projects with Andean peasant and indigenous communities might seek to modify, contest or negotiate local norms, rules and practices that reify existing and intersectional identities which generate inequities for young women and men (Carella and Ackerly, 2017; Cornwall, 2017; Koutouki et al., 2018). For instance, by challenging tokenistic forms of participation in local planning so that marginalized actors might contribute to agenda setting and decision making. There is precedent for such practices in the Andean region already, for example, the way some women attempt to draw on a combination of external legal frameworks and traditional value systems and traditions in order to formulate intra-cultural critiques of local norms and practices for enhancing their autonomy and participation in local decision making (Sieder and Barrera, 2017).

Engaged and action-oriented research projects might seek to identify and share lessons and good practice, that may also be replicated regionally and elsewhere. In practice research, PAR may be particularly useful for example for strengthening intercultural dialogue (Salas and Tillmann, 2022) where tools emerge and are in agreement with the communities engaged and may be structured in terms of space, time and knowledge. Spatial methods can support a focus on local perceptions of the environment through community mapping, territory and zoning profiling of the locations (e.g., forest). Time methods help express the conceptions of time such as to include daily cycles of agricultural activities or the annual calendar of the celebration of festivals. Knowledge methods provide ways of organizing and explaining the various specific fields of local knowledge such as the ethno-classification of wild foods, matrix of hierarchization of seeds and drawing of the vision of the future of the terraces, to name a few (Salas and Tillmann, 2022).

At the same time, rights-based projects would work with communities to advocate for more substantive forms of participation and decision-making so that national policy processes and programming might better reflect community heterogeneity. One resource that may be of particular use as a normative instrument for addressing resilience inequities in local and indigenous agri-food systems is the recent UN Declaration on the Rights of Peasants. It provides framework that is sensitive to the ways intersectional identities in rural communities shape access to rights, in particular around gender, ethnicity, age and class, and might be leveraged in both community identity work and as an instrument for seeking inclusion in decision making, appraising national processes and outcomes, and developing alternatives (Hoddy, 2021). In practice, decisions about whether and how to embark on these projects is guided by routine strategic context analyses which appraise the social and political opportunities and constraints that emerge dynamically in a given context, and where action might be most productively focused (Vincent, 2018). For example, how groups might exploit existing social and political opportunities to exert pressure policymakers and government actors into taking action. Overall, the approach may provide a framework not only for understanding inequities as rooted in social and political arrangements, but how these might be addressed in practice through social, political and cultural processes for change (Ensor et al., 2015).

At the same time, institutional capacity to foster inclusion, representation of Andean women and men in planning is weak. Too narrow a focus on gender and sex in the context of indigenous planning misses more complex forms of diversity and heterogeneity which then fail to be reflected in policy and governance (The Economics of Ecosystems Biodiversity., 2018). There is a place for intersectional analysis in planning, which can bring about a conceptual shift in how Andean people, practitioners, and policymakers interpret and analyze social categories, their relationships, and interactions. This analysis goes beyond gender issues, requiring consideration of the complex relationship between mutually constituting factors of social location and structural disadvantage to correctly map and conceptualize determinants of equity and inequity in and beyond local agri-food. The processes of analysis can foster spaces for learning from each other, critical analysis, and reflection. These iterative processes help to move away from individual categories of gender or socio-economic status to consider the intersections of multiple categories such as ethnicity, race, age, and context. Policy processes can be informed by new understandings of structures of inequality and exclusion at macro levels and initiatives developed in concert with peasant farmers to address these. This is becoming ever more urgent under conditions of climate hazards and risk (Folke, 2006; Folke et al., 2010). Entry points for policy, programming and practice include local community "innovators" or "promoters" in communities who had once left the communities and returned. They may assist intercultural planning and local agricultural entrepreneurship strengthening. Governance and policy processes should foster spaces to ease inequities and disrupt aspects of power. Their ways of knowing and being should be the core of governance and policy making processes to disrupt the structural relations of power and exclusion these groups have gone through several generations.

Conclusion and recommendations

The challenges peasant people face in agri-food system sustainability and resilience reflect their access to rights, resources, and opportunities (Adger et al., 2011). Government and development programs still adopt patronizing and paternalistic roles through projects that are planned for the short or medium term. These actions are detrimental, unfavorable, and are rejected by local and global ethics of justice and sustainability. The different groups of women and men in the Andes deserve better. They need to be valued for what they have done and achieved to harmoniously safeguard their bio-cultural and ecosystem heritage for agricultural purposes (Ruiz-Mallén and Corbera, 2013; Bruchac, 2014). They have developed and enhanced ways to maintain their resources across generations. By having secured local sustainable and resilient agri-food systems through planning processes, we suggest a paradigm shift and new forms of rights-based engagement are needed to that engage with heterogeneous contexts and the root causes of inequities in Andean agriculture. As an area for future research, efforts at building policy evidence must be informed by the perspectives of all groups and with a responsiveness to gender and its intersection with other social determinants such as age, socio-economic status, education, marital status and ethnicity among others. Moving beyond gender and social determinants, intersectional analysis focuses on the diversity of interacting social contexts, forces, factors and power structures that shape and influence social and ecological interactions. Attention to intersectionality in planning will influence policy processes in favor of recognizing and responding to Andean people's relative power and privileges vis-à-vis their status, empowerment, and wellbeing. As Bacchi and Eveline (2010) state, "policies do not simply "impact" on people; they "create people" Bacchi and Eveline (2010) (p. 52). Therefore, these must include social locations, and access to power and resources (Hankivsky et al., 2014).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The study was reviewed and approved by University of Guelph. The participants provided oral and written consent to participate in the study.

Author contributions

SS-E designed the study and contacted the study participants. SS-E and EH conducted the literature review, conducted the interviews with key informants as well as women and men in the communities, and conducted the data analysis and the reporting. All authors contributed to the article and approved the submitted version.

Funding

The General Purpose Research Account of the University of Guelph funded this study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 07 February 2023
DOI 10.3389/fsufs.2022.855684

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Social Movements, Institutions and Governance, a section of the journal Frontiers in Sustainable Food Systems

RECEIVED 15 January 2022
ACCEPTED 23 December 2022
PUBLISHED 07 February 2023

CITATION
Dring CC, Newman L and Wittman H (2023) Assessing governability of agricultural systems: Municipal agricultural planning in Metro Vancouver, Canada. *Front. Sustain. Food Syst.* 6:855684. doi: 10.3389/fsufs.2022.855684

Assessing governability of agricultural systems: Municipal agricultural planning in Metro Vancouver, Canada

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Effective governance of agricultural systems is needed for achieving goals of food security, resilient food systems, and addressing the impacts of climate change. Local governments have an increasing interest in the role of agriculture in meeting these goals. However, alignment varies greatly between local governing systems and agricultural systems. Governability is a measure of the degree to which a system can be governed for a set of specified purposes or goals. To test the limits of governability in relation to agricultural planning, we interviewed 22 agricultural planners from municipal, regional, and provincial government, and analyzed agricultural plans ($n = 8$) and Official Community Plans ($n = 6$) for six municipalities in Metro Vancouver, Canada to identify interactions between broader municipal governance, agricultural planning, and agricultural systems outcomes. Findings indicate that the governing system for agriculture in this region includes both mandated obligations (conservation of farmland) and voluntary obligations (economic development, advocacy, public awareness). Multiple limits to governing agricultural systems include the promotion and implementation of simple solutions to complex problems, limited ability to engage with the diversity of the agricultural sector and their different needs, and governance mismatches with the boundaries of agriculture (i.e., farm parcels, Agricultural Land Reserve area) and the administrative scale of the municipality. The discussion identifies specific areas where municipal governance systems could transition to improve agricultural outcomes such as farmland protection, farmer economic viability, and integration with broader food systems.

KEYWORDS

agricultural planning, municipal governance, agricultural governance, urban food systems, agricultural systems, Metro Vancouver, Canada

1. Introduction

Food and agricultural systems are continually in flux, as they respond to consumer and social movement demands, shifting trade agreements, and changes (technological, agroecological) in food production, processing, and distribution (Clapp, 2012; Andrée et al., 2019). The vulnerability of food systems has become increasingly apparent due to environmental change (Mbow et al., 2019; Qualman and National Farmers Union, 2019), urbanization (Seto and Ramankutty, 2016), and the COVID-19 pandemic (Clapp and Moseley, 2020; Holland, 2020). These drivers have resulted in food supply chain disruptions (Fernandes, 2020). In response, scholars argue that the state plays a key role in addressing food and agricultural challenges, as "only the state has the authority to mobilize state resources," expropriate and redistribute assets from large companies or landowners, and compel compliance (Borras et al., 2015, p. 612). As urbanization continues, municipalities, and their regional connections to food supply, will play a much larger role in food system governance (Blay-Palmer et al., 2018), as seen in the emerging trends among local (municipal and regional) governments increasingly devoting resources and incorporating food planning into their governance frameworks (Pothukuchi and Kaufman, 1999; Brinkley, 2013; Karetny, 2020). At local levels, urban governments play a key role in the creation of place-based solutions to global food crises through multi-level governance innovations (Sonnino, 2013). In recognition of this role, this paper applies a systems perspective to the challenge of local planning for agricultural landscapes in Metro Vancouver, Canada (Figures 1, 2). Specifically, we explore the questions: What are municipal planning systems currently doing to govern complex agricultural systems? What are the limits to municipal governance of agriculture systems?

2. Agricultural governance and municipal planning

2.1. Agricultural landscapes and complexity

As a complex meta-system comprising multiple sub-systems, agriculture is an expression of many human-environment interactions in dynamic processes shaped by uncertainty, errors, learning, and adaptation (Folke, 2006). For example, multiple socioecological processes arising from other systems (e.g., ecological, socioeconomic, and governing) influence agriculture, such as water availability and quality, pollination, soil and nutrient retention and losses, pest and disease outbreaks, labor availability, market development, and land use legislation (Smith et al., 2012).

The agricultural system includes interconnected ecological and socioeconomic systems. In the ecological system, diversity includes the composition and abundance of biological diversity (crop, wildlife, and pests), and habitat and ecosystem health. Complexity refers to interactions between species, habitats and ecosystems, and human influences (both agrarian and landscape alteration). Dynamics in ecological systems arises from temporal changes (short- and long-term, seasonal) resulting from both internal factors (invasive species, pesticide resistance) and external factors (climate change, wildfires, and flooding). The scale dimension covers the geographical characteristics of the ecosystem (size, boundaries) and its relative uniqueness from other ecosystems (Chuenpagdee and Jentoft, 2009).

In the socioeconomic system of agriculture, diversity includes agricultural and non-agricultural stakeholders and their respective demographics, ideologies (norms, values, and attitudes), relative status and power relations, and land access and ownership models. Governability can be impacted (positively or negatively) based on differential influence over the functioning of the social system. Interactions between stakeholders dictates complexity depending on the degree of interdependency, collaboration, and conflict. Dynamics in socioeconomic systems are functions of change in stakeholder composition, interactions, and the relationships among them. Scale in socioeconomic systems includes the size, range, and mobility of different actors, and groupings of actors. This includes the size and scale of economic operations and livelihoods, and their embeddedness in broader socioeconomic systems (Chuenpagdee and Jentoft, 2009).

2.2. Agricultural governance

Governing agriculture faces both the challenge of complexity and the inclusion of "new" problems, such as climate change, global trade, and food insecurity. The nation-state is no longer the sole governing agent for agriculture (Skogstad, 2008), rather, a governance shift has occurred with broader involvement from private-sector and civil society actors giving shape to policies and legislation (Jessop, 2002; Minnery, 2007). Thus, Canadian agricultural governance, as with other nation-states, is now characterized by broader stakeholder involvement of private sector (e.g., multi-national agri-chemical manufacturers, private consultants, financial institutions) and public sector (e.g., farmers' unions, farmland trusts, sustainable agriculture organizations, and agroecology movements) in governance networks for goal setting, agricultural decision-making, and delivery of services (Haughton et al., 2009; Schmitt and Van Well, 2016). The federal and provincial governments maintain involvement, offering programs to farmers, such as crop and income insurance, environmental farm planning, and agri-business planning. However, local levels of government are experiencing an increasing trend toward shifting and shared responsibilities for agricultural support (e.g., market development, research and innovation) and regulation (e.g., farmland protection, environmental pollution). Additionally, dissolution of government services (e.g., agricultural extension, research) has resulted in private consultants, contractors, and industry associations filling this gap (Markey et al., 2008).

FIGURE 1
Map of regional districts across British Columbia (BC), Canada with Metro Vancouver regional district highlighted (Awmcphee, 2019).

2.3. Challenges in assessing governance of agricultural systems

This shift in governance requires governors, and their agents, to engage with the complexity of interrelationships, interdependencies, and interactions at multiple scales. Scale, as a concept, can be used to demonstrate the way that multiple systems can interact at different conceptual boundaries. For example, farms across an agricultural landscape all have different sub-systems operating simultaneously, such as water, soil, and ecosystem processes and their interactions. These interactions then influence and operate at larger scales as they move beyond farm property boundaries to influence adjacent agricultural landscapes. A challenge is that any planning intervention can influence multiple linkages, altering how the system functions.

Local agricultural governance is influenced by governance processes occurring at the regional, sub-national, national, and global levels. Agricultural planning must consider how nested spatial boundaries and patterns of land use affects various interactions, and processes flowing dynamically across scales (Meyer et al., 2008; Savary et al., 2012). The degree to which these scales interact and are mutually supportive is a key governability issue (Chuenpagdee and Jentoft, 2009). Temporal scales are also relevant to agricultural planning efforts. Farming landscapes arise from historical land use practices developed under strongly coupled, context dependent, socioecological systems (Fischer et al., 2012). For municipalities intervening in agricultural

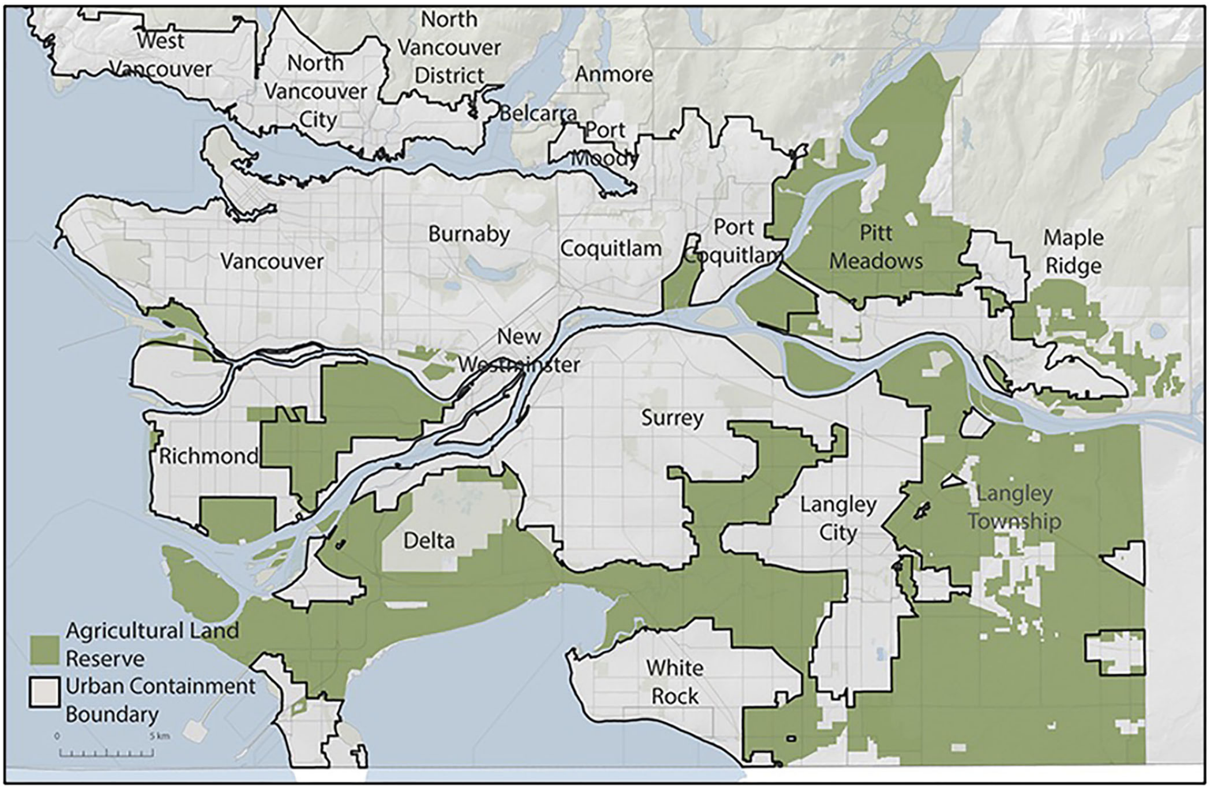

FIGURE 2
Metro Vancouver region, Canada with Agricultural Land Reserve areas shaded (Metro Vancouver Regional District, n.d.).

sectors, interpretation of farming issues and sectoral goals requires examination of current system dynamics in the context of changes arising over growing seasons, multiple years, decades, or centuries (see for example Dale et al., 2013). Systems are dynamic and do not remain in fixed states. For example, changes in precipitation, pest and disease outbreaks, temperature, and other natural disturbances can alter the material and energetic flows (e.g., application of pesticides, pumping excess water) within a system.

Governance modes are also diverse, and can present as hierarchical, collaborative, or self-governing, with both formal and informal institutions utilizing a range of policy and legislative instruments (e.g., quotas, taxation, land uses, and permitting) in the agricultural system (Jentoft, 2004). Complexity is present in how institutions interact with external agencies and stakeholders and the degree to which they overlap, differ, conflict, or cooperate. Power relations play a key role in the formation of institutions, the rules and norms (and their enforcement), determining problems and solutions, and determining who participates and who is excluded (Chuenpagdee and Jentoft, 2009). Power is thus a driver of governance system dynamics, resulting in either maintenance of the status quo or initiating change (incremental and radical) (Holt Giménez and Shattuck, 2011).

2.4. Governability as the tool employed to assess municipal governance of agriculture

The concept of governability refers to the degree to which a system can be governed (Kooiman, 2003; Chuenpagdee and Jentoft, 2009). It assumes that there are inherent limits to governing systems (Jentoft, 2007). In agriculture, limited governability relates to the inability of the governing system (e.g., a municipality) to fully control an agricultural system, because system transitions and changes are non-linear and information about the system is incomplete, leading to uncertain, unintended, and unpredictable outcomes (Degnbol and McCay, 2007). Agricultural governance, in a particular regional context, thus requires engagement beyond a singular governing system and depends on responsiveness to multiple interacting systems to address challenges.

With respect to complex systems, Chuenpagdee and Jentoft (2009) provide an assessment framework for examining governability, noting that the measure of how governable a system is determined by "…the particular features of the natural, social systems to be governed, the governing system(s), and the interaction between them" (p. 113). The governability assessment framework (Figure 3) identifies key

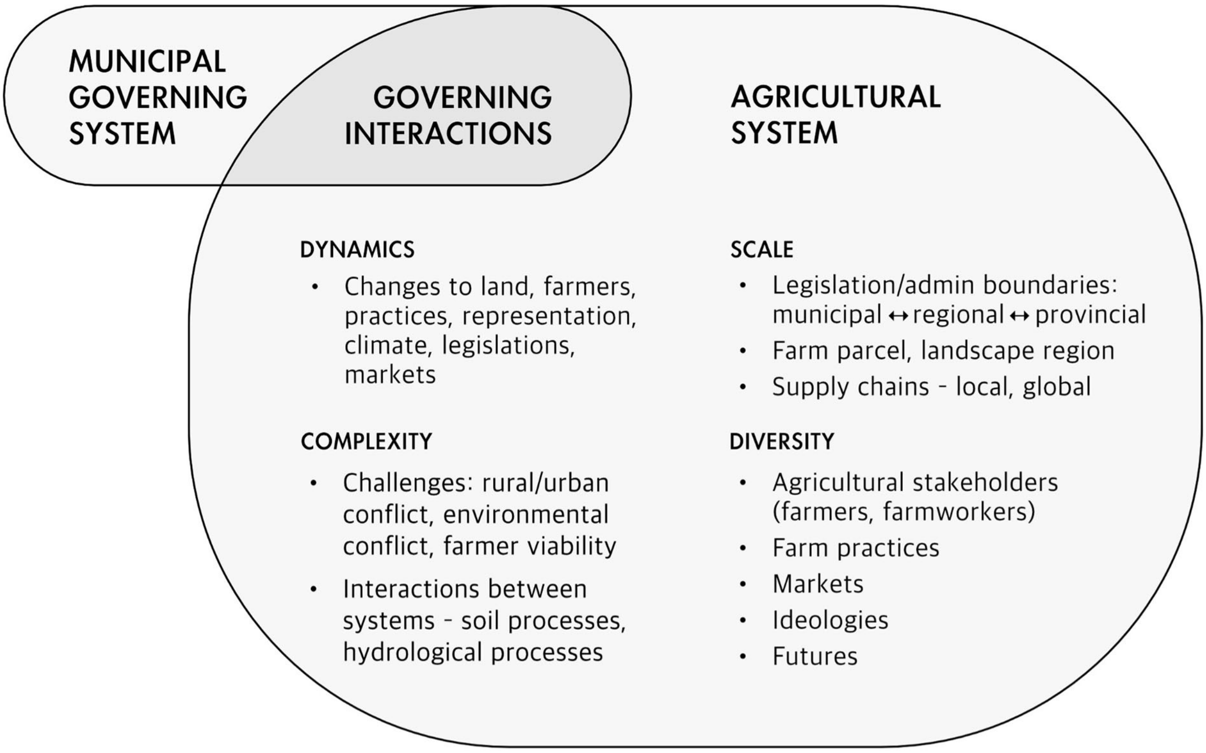

FIGURE 3
Governability model (modified from Chuenpagdee and Jentoft, 2009).

variables to assess to what extent specific governance efforts achieve proposed outcomes, given the complexity of natural, socioeconomic, and governance systems, and their interactions. The framework can be used to elucidate relative success or failure of specific governance arrangements in relation to specific proposed agricultural outcomes, while also providing insights into what is realistically possible from a specified governing system. Initially, qualitative evaluation of governability is a key step in determining potential for governance (Chuenpagdee and Jentoft, 2009).

This study describes the specific governance arrangements employed by municipal governing systems to achieve agricultural outcomes and general societal planning priorities. We determine the limitations of municipal governing systems to intervene in agricultural systems and also identify agricultural issues and outcomes that may require alteration of the governing system. Finally, we demonstrate how the municipal governing system, in a particular region, simplifies the agricultural system to make it legible to the governing systems parameters.

3. Planning for agricultural landscapes: The case of Metro Vancouver, BC

3.1. Agriculture in the Metro Vancouver Region

Metro Vancouver comprises 288,268 hectares of land with a population of 2,463,431, situated across 24 local authorities (21 municipalities, one electoral area, one treaty First Nation, and the Metro Vancouver Regional District (MVRD) (BC Ministry of Agriculture, 2014; Statistics Canada, 2016). The total Agricultural Land Reserve (ALR) area in the region is 57,378 hectares, or 1.5% of the province's total farmland. The BC Ministry of Agriculture (2014) MVRD Land Use Inventory indicated that 29,790 hectares (49%) of the regional ALR were actively being used for farming. Of this land base, only 8,174 hectares (13%) are used exclusively for farming, an additional 34,147 hectares (56%) devoted to farming and other uses, and the remaining 23,231 hectares (38%) not used for farming purposes. Examining the range of uses of farmland demonstrates the wide variety of activities that extend beyond strictly agricultural production. This includes residential, transportation, protected environmental features, commercial, utilities, recreation, dumps/deposits, industrial, military, water management, gravel extraction, and First Nations uses (e.g., band administration, ceremonial, harvesting, culturally significant landforms).

The region accounts for a wide variety of agricultural products such as oilseeds and grains; vegetables; fruit and tree nuts; mushroom; livestock (cattle, poultry, turkey, sheep); dairy; eggs; poultry hatcheries; hay; flowers, nursery, and trees; and horses (Statistics Canada, 2021a). In the 2021 Census of Agriculture, the 2,118 farms within Metro Vancouver reported $1.3B in operating revenues, representing 27.4% of the BC share of agricultural operating revenues (Statistics Canada, 2021a,d). Farm revenue distribution varies greatly with over two-thirds making less than $100,000 per year (Figure 4). While most of the farms (1,434) report selling to distributors and large processors (68%), 684 (32%) farms reported selling direct to consumers (Statistics Canada, 2021e). Of these farms, different land tenures operate across the region. Farmland area owned by farms is 62,259 acres (73% of total farm area) and rented/leased land comprised 21,175 acres (25% of total farm area) (Statistics Canada, 2021b).

3.2. The municipal land use planning system in Metro Vancouver

Canada is a federal state with national government, provincial/territorial governments, and local authorities. Division of power between federal and provincial governments is constitutionally defined; provinces have full autonomy over land use planning (except for federally controlled lands, e.g., airports, military bases, and allocation of funding through programmes, e.g., infrastructure programmes). Canadian provinces have autonomy to create their own legislative frameworks to structure their planning systems.

Municipal planning legislation was introduced by the BC provincial government with the Town Planning Act, R.S.B.C. (1925) extending the powers of municipalities to prepare and adopt an official community plan (OCP), enact zoning bylaws, and establish a planning commission. In 1957, the Town Planning Act was repealed and replaced with the Municipal Act which provided municipalities authority to enact land use controls, beyond existing powers to regulate buildings (Corke, 1983). These new powers for planning were not compulsory, as land use planning is a voluntary activity. Across the province, municipalities that employed land use controls had the unintended effect of city expansion onto surrounding farmland of adjacent municipalities in the Lower Mainland (Garrish, 2002) (i.e., leapfrog development).

In the post-war period, as the economy grew, zoning bylaws continued to be ignored or circumvented. As Weaver (1979) notes of the nature of planning in Vancouver in the 1950s "businessmen have defined the instruments of land use controls and directed their outcome. Whatever the divergent intellectual and legal traditions in American and Canadian urban planning, the economic imperatives in both countries have presented similar and overruling considerations" (p. 219, cited in Corke, 1983, p. 54). Changes made with the establishment of the *Municipal Act* in 1957 gave municipalities additional authority (but not compulsory) to establish a zoning board of appeal and to regulate the subdivision of land (Corke, 1983). In 1968, to address fiscal pressures on municipalities arising from new development, the province introduced the development permit as a legal tool which would declare a development area and require obligations from the developer for services (e.g., sidewalks, streetlights, sewage hookups). However, this legislation would be confined to municipalities which had developed an OCP (of which there were very few) and thus the tool was rarely used (Corke, 1983).

From 1957–1977, major issues around the complexity and multiplicity of local government controls over planning, service delivery, and development of land resulted in amendments to the Municipal Act, R.S.B.C. (1979). These changes established a municipal land use control framework featuring the major contemporary planning controls: zoning and subdivision control bylaws, OCPs (voluntary), site-specific and area-specific development permits, and development cost charges and bylaws. In developing OCPs, municipalities must seek comments from the regional district, adjacent municipalities, and provincial and federal levels of government. If a Regional Growth Strategy is in place for the area, the municipal OCP must include regional context statements and align with these policy goals.

3.3. Agricultural planning in BC

Agricultural planning within municipal governments in Southwestern BC includes policies and actions that are either included in an OCP or, in larger communities with extensive farmland, as a separate plan that complements the OCP, as an agricultural plan or strategy (Public Health Services Authority, 2016). Agricultural planning activities typically focus on farming areas, addressing farming supports, challenges and issues, rural character, and role of agriculture in achieving sustainability outcomes through policies, actions, and land use plans (Public Health Services Authority, 2016; Connell, 2020).

Prior to the establishment of the *Land Commission Act* (now the *Agricultural Land Commission Act*) in 1973, the principal form of public control over private agricultural land uses across the province was through municipal zoning, and in the Lower

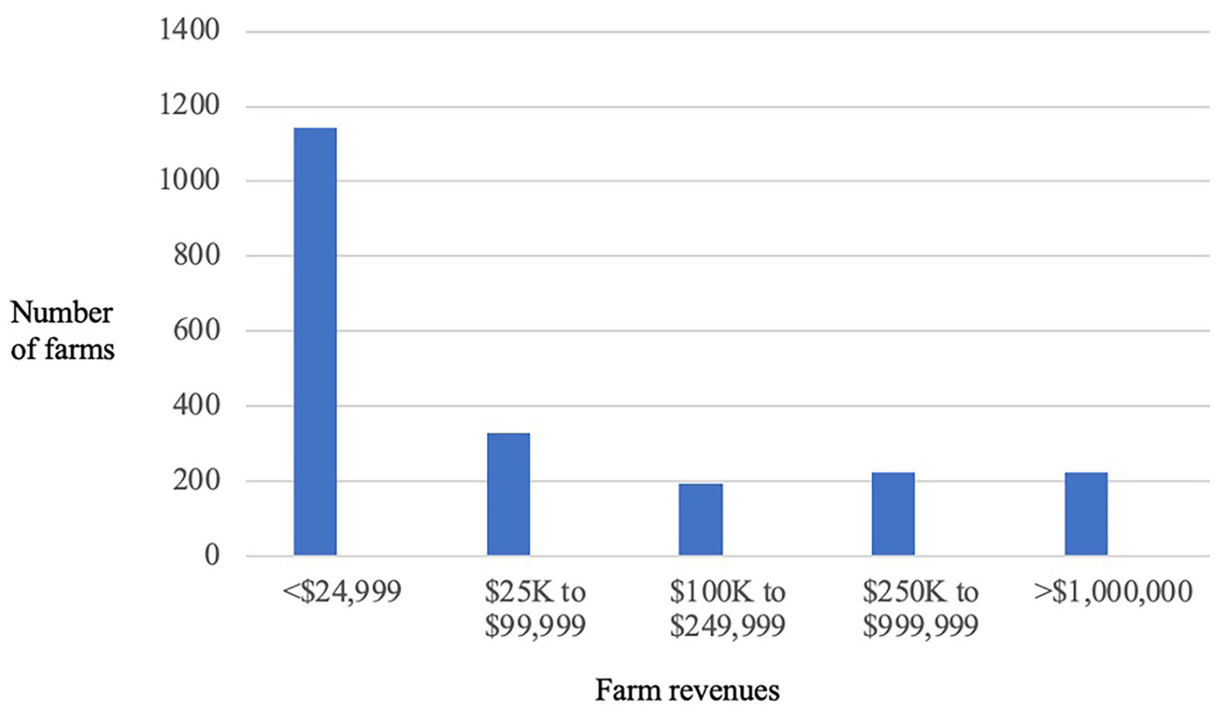

FIGURE 4
Farm revenue distributions across the Metro Vancouver region, Canada (Statistics Canada, 2021c).

Mainland, land use designations in the Official Regional Plan (Smith, 1974). This regional plan would be repealed in the 1980s along with power conferred to regional districts for land use planning (Chadwick, 2002). Thus, agricultural land use planning was subject to the same voluntary controls as other land uses until the creation of the ALR.

Agriculture is identified by Canada's Constitution Act as both a federal and provincial responsibility. The BC Ministry of Agriculture, Food, & Fisheries (BCMAFF) has a role in the delivery of services, programmes, and agricultural policies in support of production, marketing, processing, and sale of agricultural and seafood products. These include programs for business, innovation and market development, crop and farm insurance and income protection, food safety and traceability, environmental sustainability, and farm practices protection, land access and land use planning (Government of BC, n.d.). They have a role in supporting food security, resilient food systems, and economic development in the province.

In 1973, the provincial government created the Agricultural Land Commission Act (ALCA) and the Agricultural Land Reserve (ALR), a provincial land-use zone which would aim to preserve 4.7 million hectares of agricultural lands (Smith, 2012). At the time, estimates of farmland loss were approximately 6,000 hectares annually in the Lower Mainland region (Smith, 1974, 2012). Land use policy issues of additional provincial concern included stabilization of the agricultural land base, increasing concerns with external dependence for food security, recognition that many local authorities were not able to withstand urban development pressures, and a desire to support local authorities' concerns with farmland preservation, global population growth, and food shortages (Smith, 2012). These land use issues set the basis for the top-down establishment of the ALR system from a provincial perspective.

The ALR is based on restrictive land zoning and draws on key elements of the provincial legislative framework including the ALCA (Agricultural Land Commission Act, R.S.B.C., 2002, c. 36), ALR General Regulation (2020) (B.C. Reg. 171/2002), (Agricultural Land Reserve Use Regulation, 2019) (B.C. Reg. 30/2019), (Local Government Act, R.S.B.C., 2015, c. 1), (Land Title Act, R.S.B.C., 1996, Pt. 7, c. 250, s. 86(1)], and (Farm Practices Protection (Right to Farm) Act, R.S.B.C., 1996, c. 131). The Agricultural Land Commission (ALC) is the provincial authority in charge of the ALR. Its mandate is 3 fold:

> To preserve farmland, to encourage farming on agricultural land in collaboration with other communities of interest, and to encourage local governments, First Nations, the government and its agents to enable and accommodate farm use of agricultural land uses compatible with agriculture in their plans, bylaws and policies" (Agricultural Land Commission Act, R.S.B.C., 2002, c. 36, Section 6).

Statutory powers of the ALC include approval of applications (e.g., inclusions/exclusions, soil removals/deposits, non-farm uses), and compliance and enforcement via remediation orders and administrative penalties.

Between 1992 to 1994 the LGA was amended to require that municipal and regional governments adopt and amend bylaws to be consistent with the ALCA, regulations and orders of the Commission (Smith, 2012; Connell, 2020). Local government bylaws that are inconsistent are deemed by the provincial government to be not enforceable by local government. A significant local bylaw is the OCP. OCPs are a voluntary form of bylaw that identify a broad range of policies (e.g., land use, economic, housing, transportation, climate change) to guide decision-making, thus managing current and future growth. Local governments are required to forward to the ALC their OCPs prior to adoption for comments (Smith, 2012). However, the BC Ministry of Agriculture, Food and Fisheries (BCMAFF) and ALC do not have authority to approve or require modification of OCPs and zoning bylaws; their comments are restricted to first readings and these provincial entities not required to be involved in subsequent readings or in local decisions (Connell, 2020). The BCMAFF and ALC can provide comments on bylaws that would contravene the provincial legislation, and if necessary, can regulate a municipality. An OCP may contain agricultural policies and may situate these policies across other dimensions of community planning. For example, agricultural policies around farm vehicle road access could be integrated within transportation policies and farmland protection policies situated under urban growth and development policies. Furthermore, agricultural planning identifies policies and actions that are either included in an OCP or, in larger communities with extensive farmland, as a separate plan that complements the OCP, an agricultural plan or strategy (Public Health Services Authority, 2016). Agricultural planning activities typically focus on farming areas, addressing farming supports, challenges and issues, rural character, and role of agriculture in achieving sustainability outcomes through policies, actions, and land use plans (Public Health Services Authority, 2016; Connell, 2020).

Within the ALR, farming uses are exempt from municipal control (e.g., land cultivation, drainage and irrigation infrastructure, application of pesticides and fertilizers) (Agricultural Land Commission Act, R.S.B.C., 2002). Non-farm uses are generally not permitted in the ALR. However, the Regulation acknowledges that there are certain non-farm uses that are necessary for farming operations and divides permitted non-farm uses into two categories: those that can be prohibited by local government and those that cannot. Those that can be prohibited include: certain types of structures (e.g., parking lots, restaurant) and housing (e.g., over two farm residences), non-agricultural home businesses, and soil removal and infill deposits. Examples of activities that cannot be prohibited include: farm structures, parks, temporary gatherings of less than 150 people (such as wedding venue rentals) (Agricultural Land Reserve Use Regulation, 2019). Prior to the 2019 amendments to the ALCA, residential uses would have been included under non-farm uses. Under the recent legislation, farm residences are subject to ALC approval and are limited to two dwellings per parcel which must abide by the terms laid out by the Agricultural Land Commission Act, R.S.B.C. (2002). Local governments have the authority to adopt and enforce more stringent controls over residential uses of farmland (Agricultural Land Commission Act, R.S.B.C., 2002).

Metro Vancouver region is an ideal case to explore governability as it has experienced the highest rates of urbanization across some of the province's most viable agricultural land and is driven by civil society demands for municipal planning interventions in green infrastructure, food security, resilient food systems, farmland protection, and land use change (Metro Vancouver Regional District, 2009, 2011). In the next section, we describe the specific purposes and limitations of municipal governance of agricultural systems in Metro Vancouver, Canada. Specifically, we explore the questions: What are municipal planning systems currently doing to govern complex agricultural systems? What are the limits to municipal governance of agriculture systems?

4. Methods

This study assessed the limits of municipal governments to govern agricultural systems across six municipalities in MVRD, Canada. We employed a qualitative case study methodology (Yin, 2003) to analyze how municipal governments interact with diverse aspects of municipal agricultural contexts, through framings and characterizations of agricultural planning, that constitute a governance system. Data was drawn from interviews with government planning staff and analysis of municipal and provincial policy and legislative documents related to agricultural policy and planning. This research and analysis were guided by two questions: What are municipal planning institutions currently doing to govern complex agricultural systems? What are the limits to municipal governance of agriculture systems?

This study examines all municipalities across MVRD that have published agricultural policy and planning documents: City of Surrey (1999, 2013), City of Pitt Meadows (2000), City of Richmond (2003, 2021), City of Maple Ridge (2009), Corporation of Delta (2011), and Township of Langley (2013). In addition to the stand-alone agricultural policy and planning documents, all six municipalities have adopted an OCP with sections devoted to agriculture, agricultural and/or rural zoning bylaws, and additional bylaws for various agricultural activities. Assessment of the agricultural planning activities and institutions occurred *via* an examination of municipal agricultural planning documents relevant to the case area including agricultural plans (n = 8), OCPs (n = 6), and provincial legislation ($n = 6$) (see below for analytical approach). Across municipalities the nomenclature of agricultural plan and agricultural strategy are used interchangeably. These documents exhibited common areas of overlap in scope of work, policy objectives and visions, land use planning elements, zoning and bylaw amendments, economic development initiatives, advocacy, issue identification, and stakeholder representation. In this paper, we use the term plan to refer to both plans and strategies.

In addition to document analysis, we conducted interviews with planning staff and other government officials across multiple levels of government ($n = 22$). Municipal planning staff for all municipalities with agricultural plans were interviewed (n = 12), as well as one staff person at the Metro Vancouver Regional District (MVRD), eight staff from the BCMAFF (six current employees; two past), and one staff person at the ALC. Interviews were conducted by Zoom or phone over the period of December 2019 to July 2020 lasting from 37 to 159 min.

Data were analyzed through line-by-line coding of interview transcripts, plans and legislation. We employed a deductive approach, creating the initial coding framework from literature on governance (agricultural, fisheries, and municipal) (Higgins and Lawrence, 2005; Skogstad, 2008; Chuenpagdee and Jentoft, 2009), and planning (agricultural, land use, and rural) (Douglas, 2010; Bousbaine et al., 2017). Coding included examination of definitions of agriculture and agricultural planning, agricultural planning activities/practices (design, implementation, evaluation), purposes and outcomes, challenges and barriers, successes and opportunities, planners' roles, and knowledge sources. This allowed for characterization of the municipal planning system for agriculture, the distinct characterization, framing, and understanding of agriculture for each municipality, and assessment of municipal agricultural governance, which in turn, addresses the question: how are municipalities planning for agriculture and what are the limits to governability?

5. Results

Analysis of agricultural plans for the six municipalities shows blended land use planning and economic development approaches to achieve three main goals: (1) conservation of the agricultural land base, (2) economic development, and (3) addressing agricultural conflicts. Planning processes for creation of agricultural plans were initiated by elected officials and subsequently designed and led by consultants. Three different consultants were responsible for the six agricultural plans; Zbeetnoff Agri-Environmental & Quadra Consulting (City of Surrey, 1999; City of Maple Ridge, 2009; Corporation of Delta, 2011). Don Cameron & Associates (Township of Langley, 2013), and Jack Reams (City of Pitt Meadows, 2000; City of Richmond, 2003). Updates to plans in City of Surrey (2013) and City of Richmond (2021) were staff-led. The agricultural plans consisted of similar processes: (i) characterization of the agricultural system, (ii) agricultural stakeholder and public consultation, (iii) an agricultural plan with vision, goals, and objectives and recommended actions. Implementation and evaluation are outlined within the plans, typically with a 20-year horizon. Primary responsibility for implementation across all six municipalities falls on voluntary citizen agricultural advisory committees (AACs) comprised of farmers, non-profit organizations, and provincial staff. Each committee has a designated municipal staff liaison. The municipalities of Richmond and Langley have a full-time planner position responsible for the agricultural portfolio; in the remaining municipalities, planning responsibility is distributed across staff located in multiple departments (e.g., Engineering, Parks and Recreation). Evaluation of agricultural plans occurs on an *ad hoc* basis depending on direction from mayor and council on specific actions or if a re-design is initiated (Surrey and Richmond).

5.1. Conservation of the agricultural land base

Analysis of the OCPs and agricultural plans for all six municipalities, along with interviews with government, indicates the primary importance of conserving the ALR. Four main rationales for conserving farmland are put forward across the study sites and interviews (i) compliance with the provincial legislation (ALCA), (ii) limiting urban sprawl, (iii) maintaining capacity for future food security, and (iv) ensuring the land base for economic growth. All six municipalities include protection of ALR land as a central policy goal and objective of both agricultural plans and OCPs.

An important purpose for farmland protection is compliance with provincial requirements as municipal planning staff note:

> We are trying to at least protect a land base for agriculture, certainly that is through the ALR. That's provincial so I think that is number one…working with the [ALC], the [BCMAFF] because we have to make sure our bylaw and policies line up with theirs. (Participant 9, 2019)

Responsibility for the ALR governance is shared between local government, BCMAFF and the ALC, with varying interpretations of the differing roles and agency in interpretation and implementation of the legislation. The provincial legislation establishes a mandate to ensure that farmland remains in the ALR and that municipal bylaws are aligned with the ALCA. However, while both the ALR and the OCP have legal status, the development, implementation, and evaluation of agricultural plans are voluntary, even as formally adopted by council. Agricultural plans are not required by the LGA nor the ALCA.

Another key purpose linked to regional requirements around growth and development is around urban containment and urban planning. As a provincial government staff notes:

> …the land that has the best soil, the best water resources, and the best climate to produce the widest range of crops at the highest productivity; that land should be in agriculture. The human habitation, which is in fact more flexible, should be situated not on that area but somewhere else. (Participant 13, 2019)

Additionally, another provincial staff person speaking to the purpose of agriculture planning states: "…good land use planning in general and we're trying to prevent urban sprawl. We're trying to … force these local governments to do good planning in their urban areas" (Participant 1, 2019). They go on to note key planning failures that impact agricultural lands "…in our urban area we're still doing single family sprawl, we're still allowing big box development, and – oh and by the way, now we're running out of industrial land so we're going to come…begging for land out of the ALR" (Participant 1, 2019).

Some interviewees and plans note the future aspect of farmland protection, that it is about conserving the land base for future food security, acknowledging reliance on distant supply chains. Speaking to this purpose, a municipal planner states: "[Maple Ridge] include[s] that food security lens, as an example of [shorter] food supply chains and how it's kind of important to keep at least some [food] either available locally or be able to ramp up production should the need arise quite quickly" (Participant 3, 2019).

> …we need to feed our population this idea for planning for retention of those lands as a reserve is key and so, when we say reserve, it is not land that we farm right now but we need to make sure that that land base is available for whatever farming is available in the future. (Participant 14, 2019)

5.2. Mechanisms to conserve farmland

Under the ALCA, private and public landowners are required to apply to the ALC to include or exclude land in the ALR, subdivide land within the ALR, use land in the ALR for non-farm purposes, and place fill or remove soil. Applications are initially reviewed by local governments and then sent to the ALC for review. The ALC makes the final decision on the application. However, where lands are municipally zoned for agriculture and farm uses, a local government has the power to refuse to forward the application, thus halting the application process. If a municipality wishes to exclude land from the ALR, they also must fill out an exclusion application, provide notice of the application on the farm parcel, provide a public hearing, and notify adjacent local and First Nation governments. Once the public hearing has been held, the municipality must pass a resolution to forward the application along to the ALC. If approved, the ALC holds an exclusion meeting, with representation from local and First Nation government, written submissions, and representation, evidence, opinions from others present. The ALC then provides a decision in writing: refuse, approve (with or without conditions), or approve as an alternate non-farm use (2022).

Agricultural plans aim to achieve the goal of land base conservation by aligning municipal-level bylaws and zoning with upper levels of government and limiting non-farm development on agricultural lands, where non-farm uses do not serve the primary purpose of production. As a result, all agricultural plans analyzed have policies on farmland protection and land use controls for properties in the ALR and along the interface zone between farmland and the rest of the municipality. Agricultural plan policies establish guidance for residences in agricultural and rural zones (e.g., minimum lot size, siting, setbacks, height restrictions, homeplate), permitted land uses, exclusions, and subdivisions, edge planning, and advocacy with different levels of government (e.g., legislative change). Edge planning, managing the interface zone, establishes additional physical separations between the urban and rural through development permit areas which municipalities use to direct and control development (i.e., vegetation, roads, fencing, design standards, and minimum distances).

5.3. Shared jurisdiction for land governance

As provincial government staff describe it, the protection of farmland can be conceived as a three-legged stool. One leg is the ALC, an independent provincial entity charged with the preservation of the ALR. The second leg is the provincial government (BCMAFF) which delivers various programs including support to local government in navigating land uses and questions around farm practices and viability. The third leg belongs to the municipal government with regulatory requirements to maintain the ALR boundary. However, as stated by interviewees and corroborated by OCPs and agricultural plans, the municipal government leg can be "as long or short" as is desired by elected officials. As ALC staff state:

> [The local government] role is probably bigger than [the ALC], legislatively, they take a framework that says you should encourage [farming] and…decide if that is meeting the intent of legislation…which they do or don't want, depending on whether they do or don't like the ALR, and

> the implications it has for growth management and land use planning. So, [the ALCA] is gray in its very design of who has the roles and responsibilities. (Participant 12, 2019)

This power of local government allows for regulatory interpretation which can vary depending on the political will of elected council. For example, restrictions on the size/number of houses on farmland can differ depending on the attitude of elected officials toward farmland protection and development (prior to recent legislative changes). As a municipal employee states:

> Council has always been very much about protection of the ALR and very strict about the elasticity of what can and can't happen. A lot of farmers come to us and say, "Well in Surrey they allow us to have two farmhouses and they can all be really huge and why can't we have any size of house we want, we have a big family" and our Council is like, "This is how we protect the land base." (Participant 8, 2019)

5.4. Economic development

In the previous section, the rationale for the provincial ALR is to protect the capacity for agricultural activities geared toward future food security and urban containment. Municipal agricultural plans advance an additional rationale whereby the protection of farmland for primary production of crops, for sale (direct, local, and international) supports economic development. Agricultural plans for each of the six municipalities each state that economically viable land use is a tool for farmland protection in addition to municipal agricultural zoning and other bylaws, based on a utilitarian logic. This logic states that when agricultural lands that are primarily used for farming purposes, this "soil-bound production" will generate sufficient economic revenue to justify farmland owners keeping farmland within the ALR. This results in a circular, tightly coupled logic that farmland should be regulated to protect the loss of farmland to residential development and other non-farm uses, but also that the primary use of farmland should be farming, as a further protection against prevent farmland losses. For example, the City of Richmond (2021)'s Farming First Strategy includes "Objective 1: Continue to protect the City's agricultural land base in the Agricultural Land Reserve (ALR)" and "Objective 2: Ensure agricultural production remains the primary use of agricultural land." Policies under the first objective focuses on issues of the urban-rural interface ensuring appropriate buffers, and implementing Development Permit Areas (DPAs), and housing issues limiting the area for and number of residential units. Policies under the second objective address land use issues of non-farm uses (e.g., residential), fragmentation (e.g., linear developments and subdivisions), encouraging soil-based farming, limiting ancillary uses (e.g., retail, storing processing), and soil deposits and removals.

Analysis of documents and interviews with representatives from all six municipalities demonstrated a common view that supporting the business of farming, linked to state-driven economic development activities, will lead to viability of agricultural operations (see below on this tension). For example, Guiding Principle 3 of Richmond's first agricultural plan states: "Agricultural economic growth, innovation, diversification and best practices are the best ways to protect agricultural land in Richmond and to ensure the ongoing viability of agricultural operations" (2003, p.6). Thus, municipal support in economic development achieves both farmland protection and farmer viability. However, supporting economic development for viability of agricultural operations is not the sole objective. Rather, municipalities recognize the potential for downstream economic growth through value-added activities and job creation. For example, one of Maple Ridge's agricultural plan goals states: "Diversified agricultural activity (equestrian, agro-tourism) will protect the land base through active use, create demand for services and workers, and support the infrastructure also required for food production" (2009, p.20).

To achieve these objectives, common recommendations across the six municipalities include (i) public awareness raising of the importance of agriculture as an economic driver, (ii) establishing and supporting direct marketing (e.g., farmers' markets, farmgate sales), (iii) supporting agri-tourism and events, (iv) identifying opportunities for innovation and diversification/value-added, and (v) establishing incentives and linkages with food processing operations (Table 1). Thus, economic development, within the municipal government context, is about mobilizing City resources in creating employment opportunities, supporting local businesses, and inviting new types of businesses. For example, Surrey's Economic Development Strategy identifies economic development as expanding "…society's resources that are used to support the public amenities and services that are fundamental to quality of life, including parks, arts and culture amenities, and health care and education programs" (2008, p.iii). Activities that support economic development in municipal agricultural plans include efforts to address farm viability by creating market opportunities within the geographic polity (e.g., farmers' market, institutional procurement, festivals/tourism events, marketing materials – local food guides) and a recognition of the volatility of commodity crop pricing, the availability and rising cost of inputs, and the increasing cost of land (and leasing land).

Interviews and six municipalities' planning documents indicate recognition of shared responsibility across different levels of government for economic initiatives but at different levels of involvement. For example, Delta's OCP policy states: "Work with the Ministry of Agriculture, Food and Fisheries, the Provincial Agricultural Land Commission and other

TABLE 1 Examples of different economic development policies/actions identified across municipal agricultural plans in Metro Vancouver, Canada.

Municipal agricultural plans	Examples of municipal agricultural plan and OCP economic development policies/actions
Agricultural Plan (Corporation of Delta, 2011)	• Create an economic development initiative for agriculture in Delta, tasked with finding and promoting opportunities for agricultural processing in Delta, identifying new crop opportunities, liaising with agricultural researchers and technology providers, attracting business, and identifying funding and programs (p. 6)
Agricultural Plan (City of Maple Ridge, 2009)	• Work with producers to: investigate the potential for marketing cooperatives; brokerages; machinery cooperatives; investigate community storage and handling options; learn about marketing models; branding
Agricultural Plan (City of Pitt Meadows, 2000)	• Support and encourage agri-tourism in Pitt Meadows and liaise with the Canadian AgriTourism Network and the Standing Agricultural Advisory Committee to develop a strategy for agri-tourism options consistent with already existing agricultural enterprises (p. 21)
Farming First Strategy (City of Richmond, 2021)	• Raise public awareness, in coordination with the Food Security and Agricultural Advisory Committee of local farming, farmer's markets, and local food products, produce and programs (p. 3)
Agricultural Plan (City of Surrey, 1999),	• Attract industry into areas adjacent to the ALR with centralized servicing, streamlined business development procedures and transportation links to markets (p. 20)
Agricultural Protection and Enhancement Strategy, (City of Surrey, 2013)	• Partner with Canada's national trade specialists, the Province, producer groups and local businesses to develop new markets (local and global) and marketing strategies for local commodities (p. 16)
Agricultural Viability Strategy (Township of Langley, 2013)	• Develop initiatives to encourage processing as supported by the ALC (p. 11) • Consult stakeholder groups for the development of a food hub (p. 11)

farm stakeholders to determine and encourage appropriate economic diversification initiatives" (2010, p.27). Similarly, Richmond's OCP identifies the following policy: "work with partners to expand food production, urban farming and related employment within the ALR (e.g., food processing, storage and shipping, where approved by the ALC)" (2012, Section 6, p. 20).

Differences in degree of municipal intervention is attributed to variation in municipal capacity, political support for agriculture, and the perceived economic contribution of agriculture to the municipality. For example, in Maple Ridge, elected officials' support for economic growth and development is limited. As one staff person relates: "This council is quite challenged with the economic argument of farming, and they don't necessarily see the jobs being supported with the industry and because we have so many small farms it does make it a slightly more challenging economic argument… most of our farmers are not full-time farmers…" (Participant 3, 2020). Additionally, direct municipal actions for economic development are constrained within the planning boundary over which there is government jurisdiction.

5.5. Tensions between farmer livelihoods and land use planning

While there is a strong emphasis on economic dimensions of municipal agricultural support for agriculture, some allowable farm uses that aim to support viability, such as on-site processing or the installation of greenhouse facilities may negatively impact (i) the integrity of the ALR and (ii) the protection of high-quality soils. The emphasis on economic development at local scales can also simplify the complexity of different farm operations and the supports needed. For example, support for particular kinds of different markets can lead to categories of farmers being left out. As a provincial government staff states:

> …the message we get from the farmer, the producer that's actually feeding into the bigger food chain, is that they're invisible because they're sandwiched in the middle of lifestyle, homestead farmers and the "super processor," like where's that medium scale guy who really is actually producing not just processing? (Participant 12, 2019)

All agricultural plans identify two types of farmers: "hobby/census" and "bona fide" farmers to distinguish farmers that are reliant on the productivity of the land and sale of commodities to support themselves and their families. For example, Delta defines "bona fide" farmer as "…a farm operator who uses farmland to produce agricultural products with the expectation of profit" (2011; p.vi). While Maple Ridge identifies the potential environmental contribution of "hobby/census" farms, others maintain that these farms are problematic as they replace economically productive farms: "The OCP identifies the following issues affecting the farm community: Conversion of farmland to hobby-farm use" (Delta, 2011, p. 11). Agricultural plans, however, do not distinguish between different kinds of market-oriented farmers. Rather, there is a widespread acknowledgment that changes to permitted farmland uses, to allow direct-sales and on-site processing, will generally benefit agricultural operations.

Changes in perceptions about the viability of particular economic orientations of agricultural systems were a driver of legislative changes to the ALR that now allow farmland uses that were previously prohibited. Current provincial legislation now permits several non-soil-based agricultural uses and ancillary activities within the ALR. These can include agricultural activities such as greenhouses, cannabis production, broiler barns, mushroom facilities, on-site processing, tasting rooms, fish pens, and vertical agriculture, and non-agricultural uses such as processing facilities, agri-tourism and events, and secondary residential suites. These changes to what constitutes "agriculture" at the provincial level do not necessarily reflect the social imaginary of farming in particular localities, as understood by municipal government staff and decision-makers.

> As pressure and availability of land in the urban area disappears there's more and more argument about what seems like very highly commercialized or industrialized activity in the ALR that on the surface is associated with agriculture, but you traditionally wouldn't have found them there" (Participant 12, 2019).

Municipal government, through their development permits and approvals powers, have had to adjust their governance approaches by amending zoning bylaws and development permit approval processes to allow these novel forms of agricultural production.

A major challenge identified by municipal government interviewees is balancing farmer livelihoods with protection of farmland, when livelihood activities, such as short-term rentals, parking lots, and processing facilities can have a deleterious, cumulative impact by paving over high-quality soils thus reducing land available for soil-based farming. A provincial staff member at the ALC also noted concerns about blueberry growers being reliant on a central processor, indicating that many blueberry farmers instead prefer to have their own processing plants on their farmland. This employee goes on to note issues of overbuilding processing capacity:

> ...one jurisdiction seems reasonable but then you look at what's happening in all of the jurisdictions, there isn't this cumulative impact assessment on the land base and [the ALC] don't issue the building permits and are not there necessarily when someone's saying "I need to build my own processing plant for my blueberries," and local governments respond: "OK, processing plant for blueberries, approved" (Participant 12, 2019).

This view was a common perspective among interviewees on the development and conversion of farmland. As MVRD staff observe: "[the ALC] accept [non-soil bound production] and then [the farm operation] goes belly up and [the land is] converted and then excluded [from agricultural zoning in the ALR]. That's the problem, it comes in wearing one face and leaves wearing another. Because once you've got the building there, nobody wants to remove the infrastructure" (Participant 15, 2019).

An additional tension arises when looking at agricultural governance from the perspective of soil quality. As an ALC staff puts it, if the model for land use was based on soil capability, then non-soil bound agricultural production [e.g. greenhouses] should be primarily situated in the Kootenay region (a region ∼900 km from Metro Vancouver, characterized by hot/dry summers, severe winters, and silt-dominant soils). They go on to state: "Everybody still wants [non-soil bound production] in Richmond where everything's [high quality soils]... but everyone has the equal right to the same opportunities and yet we find them very highly concentrated most of the time near markets" (Participant 12, 2019). For example, Metro Vancouver has seen significant growth in greenhouse production in the region (from 508 farms in 2011 to 611 farms in 2021) (Statistics Canada, 2011, 2021a). Once non-soil-based kinds of agricultural operations are in place, and ancillary structures are developed (e.g., parking lots, concrete foundations), they can heavily influence land prices across the municipality. Speaking to this example, this participant states: "...the price of agricultural land is valued based on the 'highest and best use' and its 'highest and best use' isn't primary food production" (Participant 12, 2019). That is, agricultural viability is linked to the value-added activities, not to the primary production of commodities, which in turn can drive farmland prices beyond what farmers can afford.

5.6. Addressing agricultural conflicts

Agricultural plans in the study municipalities explicitly address two kinds of agricultural conflict: urban and environmental. Urban conflicts occur as nuisance complaints, typically by non-agricultural stakeholders (e.g., residents, business owners). This includes several impacts that are the result of normal farm practices, as per the Farm Practices Protection Act, such as dust, noise, odor, and visual aesthetics. In response, all municipalities have designated development permit areas in their OCPs along the interface zone between farmland and the rest of the municipality. These aim to separate urban and agricultural landscapes as a mechanism to mitigate conflict. This represents a key mechanism of municipal planning, on the urban side, to mitigate urban/agricultural conflicts by requiring vegetative buffers, minimum separation distances, trail/road siting, and design standards for development. For example, Maple Ridge's Development Permit area guidelines establish a distinct separation between ALR and urban designated areas (City of Maple Ridge, 2009, p. 13). The rationale is stated by provincial government staff: "We cannot protect these operations like a mushroom operation, a greenhouse operation, a poultry operation from noise, dust, odor, light... types of complaints, if they are outside the ALR. And the local government will shut them down" (Participant 13, 2019).

All agricultural plans identify environmental conflicts as areas of planning intervention. Primarily this includes crop predation from wildlife and urban concerns around environmental impacts of agriculture (e.g., water contamination from nutrient runoff and pesticide drift). For example: "Agriculture has been identified as a potential contributor to fish habitat degradation through improper management of manure, nutrients, pesticide and drainage, and reduction of water availability for fish" (City of Surrey, 1999; p. vii). Earlier agricultural plans frame increased environmental regulation and public demands to minimize the impact of agriculture on the environment as negatively impacting farmers. The common response across municipalities is to encourage adoption of Environmental Farm Plans and identifying technologies and practices that can mitigate harm to wildlife, reduce greenhouse gases, and address environmental impacts from farming. For example: "investigate and adopt new technologies to deal with farm wastes, alternative energy sources, and generation of greenhouse gases" (City of Maple Ridge, 2009, p. 22). Similarly, Richmond's latest agricultural plan states: "Encourage sustainable farming practices, in coordination with relevant City departments, the FSAAC, ALC and Ministry of Agriculture, including water and soil conservation, greenhouse gas emissions reductions and soil management" (City of Richmond, 2021, p. 7).

However, across all municipalities, none identify specific farm practices that cause environmental impacts and that should be prioritized for policy implementation. Furthermore, five municipalities' plans (all except Pitt Meadows) conversely point to the environmental benefits of agriculture and a lack of public awareness of these benefits. For example: "Engage with the Delta Farmland and Wildlife Trust (DFWT) to promote initiatives to foster public awareness of how farmland sustains wildlife and habitat and to build support for more equitable sharing of the costs of providing ecological goods and services" (Delta, 2011, p. 13). Furthermore, three of the municipalities extend this counter-framing to include compensation for farmers employing land management practices that carry environmental benefits. As provincial BCMAFF staff note: "What people value in agriculture and what value do they place in it? And they valued local food, green space, and environment. That is what they valued so that is what they'll fight for and so you need to really take that seriously" (Participant 13, 2019).

6. Discussion

The previous sections described how municipal governing systems utilize several mechanisms and framings for farmland protection, agricultural development, and addressing urban and environmental issues. However, limitations of these agricultural governing systems are apparent in relation to the system dimensions of diversity, complexity, scale, and dynamics.

Diversity is a key attribute of agricultural systems. In the study region, over 200 commodities involving soil-based and non-soil-based agriculture are produced across a wide array of biophysical, socioeconomic, and administrative areas. Furthermore, different farm practices, crops, markets, farm sizes, and land tenure operate across the study sites. However, the findings from this study show that while agricultural systems are diverse, they are governed in similar ways. The governing systems employ similar purposes and logics for farmland protection and simplify urban and environmental issues that hide the diversity within agricultural systems.

The municipal governing system for agriculture, as administered *via* government staff and elected officials across the six study sites, provides the basis for authority in decision-making, resource allocation, and determining which agricultural stakeholders are included in formal representation (for example *via* citizen advisory committees). Referring to Chuenpagdee and Jentoft (2009) systems dimensions, the diversity of the agricultural sector is poorly represented within the governing system. Land use bylaws and zoning apply a generalist approach to permitted land uses, treating all agricultural activities equally. Additionally, where the desired principal use of farmland is agricultural production (ideally soil-based), the reality is one of multiple uses occurring simultaneous on a farm parcel. It can include non-farm uses such as residences, farm buildings, parking lots, tasting rooms, processing facilities, dog kennels, community gardens, etc. Regulating multiple uses through a land use planning approach necessitates that the governing system simplifies the agricultural system to make it legible for municipal intervention (Scott, 1998).

Despite the *complexity* of municipal agricultural systems, our findings show that agricultural planning in the study region hierarchically places importance on protecting the agricultural land base over other non-agricultural economic activities. Agricultural plans for all six study municipalities utilized similar mechanisms to regulate agricultural land-use and protect farmland from urban encroachment and other forms of non-agricultural landuse change. Agricultural planning reinforces a logic whereby farm products should be sold, demonstrating an economic rationale for a strong municipal role in supporting the business of farming (e.g., crop diversification, innovation, marketing, public awareness) and highlighting the contribution of agriculture to economic development (e.g., food business and job creation). The emphasis on primary production as the most important use for agricultural land maintains a simplified solution to agricultural viability. Thus, findings show that while common perceptions of the "highest and best use of land" is residential development, in the context of the ALR and the requirement to maintain the agricultural zone, municipalities are diversifying their plans for economic development to incorporate agricultural products and opportunities to achieve their objectives (e.g., job creation, investment, global recognition/status).

Agricultural plans and OCPs frame complex agricultural issues and problems as having specific and targeted solutions (e.g., farmers' markets and agri-tourism as solutions to farmer economic viability are common across all plans studied). Yet, several agricultural issues are "wicked" problems that cannot be resolved through broad policy statements and/or technical solutions that assume linear causality. For example, diversification of crop production, agri-tourism, and the pursuit of processing/value-added are common interventions to issues of economic viability (see Table 1). However, absent across the agricultural plans is the identification of specific and targeted agricultural products, farms, retailers, that would be suitable for financing, pilot projects, or linkages with agricultural researchers. Nor are there details, or evidence provided, of how a proposed action addresses the given issue or other similar cases or examples where the action was implemented with success.

Agricultural systems in the region are *dynamic,* experiencing changes with respect to agricultural production and farming practices, the range of provincially permitted farm uses, the issues facing farming and broader society, and the different needs for different agricultural operations to achieve financial viability. However, as agricultural plans are long-term policy documents (∼20 years), their implementation are at odds with the dynamics of agricultural systems which operate under different temporalities. Furthermore, there is a limited ability of municipalities to respond to agricultural system changes as the approach to evaluation of agricultural plans is *ad hoc* with long time periods between plan updates (14 years for Surrey, and 18 years for Richmond).

An associated challenge are changes to the ALCA, and other provincial legislation, which require municipalities to align their bylaws accordingly. Changing bylaws requires staff capacity and resources, time to determine municipal powers (i.e., can local government implement and enforce stricter requirements), and, depending on how controversial the changes are, time for public consultation and for decision-makers to deliberate. As well, agricultural landscapes can dramatically change as farm operations diversify to include on-site processing facilities, retail spaces, and event spaces. The governing systems tend to be more reactive to both the legislative changes and to how farmland owners/agricultural operations enact these new permitted uses. Furthermore, an additional temporal issue arises as municipal decision-makers operate on 4-year cycles which are incongruent with both agricultural plans and the temporal dynamics of agricultural systems.

Across the study region, municipalities operate at multiple *scales*, from highly urbanized, metropolitan spaces to peri-urban and rural spaces. Municipalities across the study region employ planning approaches to create physical boundaries between farming landscapes and the rest of the municipality through edge planning and interface zones. The governing systems in this case study maintain a division between agriculture (production), as a rural land use, and the rest of the municipality. Maintaining this binary division has contributed to an ongoing paradigm of separation and simplification across municipal planning and agricultural governance activities. This division prevents the governing system from seeing other potential benefits beyond economic growth and development and maintains an antagonistic relationship between urban and agricultural spaces. Other scholars point to agricultural land use patterns and interventions operating across nested, rather than separate, spatial boundaries (Meyer et al., 2008; Savary et al., 2012). Thus, patterns of agricultural and urban land uses produce dynamic interactions and processes between governing scales and agricultural scales. Ultimately, the degree to which scales interact is a key aspect of governability (Chuenpagdee and Jentoft, 2009).

Addressing old and new challenges to agriculture is increasingly seen to range across multiple scales of governance, requiring multi-level governance structures (Curry, 2018). Local levels of government in planning for agriculture are also subject to reconfiguring the objects and subjects of governing agriculture. With the inclusion of new sites of governing (e.g., the environment, animal welfare, consumer safety, recreation, food), these are increasingly incorporated into demands for agricultural space and in notions of place. An ongoing characteristic is the insistence that agriculture is a "unique" and distinct sector; the responsibility of provincial authorities, and the complex challenges facing the sector from urban dynamics and governance. Depending on the level of governance and mandated responsibility to intervene, different spatial imaginaries of agriculture may arise which, in the absence of coordination between levels of government may result in direct impacts to agricultural development and the broader food system. Thus, a key challenge is the scalar focus in agricultural planning on the farm parcel, which, in this region, is mostly under private-property ownership by real estate speculators and/or individual farms as private businesses.

7. Conclusion

Municipalities will continue to play a key role in place-based food systems given their regulatory responsibilities of farmland protection. Their additional powers to go beyond land use mechanisms are timely given impending climate change impacts, and the recognition of unequal power relations and social inequalities arising from food systems, but also the potential of agricultural systems to contribute to more resilient and just food systems. Thus, the objects of agricultural planning practice must transition toward comprehensive food systems planning to incorporate multi-level governance, long-term planning, and inclusion of a broader set of food system stakeholders.

Future research may look to tackle additional questions arising from this study. One set of questions may examine which agricultural subjects are privileged by planning processes, how do these subjects shape the boundaries of municipal governance for agriculture, and how might different agricultural subject formations lead to alternative configurations of agricultural governance. Furthermore, issue identification, visions and goals for agricultural futures, and subsequent interventions/solutions are determined by a key set of actors. These planning processes arise in singular, value-neutral, non-political planning documents and policies. This is quite surprising given the diversity of the agricultural landscape, its stakeholders, and the conflict over land uses and the purpose and form of agriculture. In addition, addressing the question of diversity is key to multi-level governance and comprehensive food system planning. We show that there are multiple planning processes that reproduce a homogenous understanding of agriculture. This research alludes to analyses needed in examining how contemporary agricultural planning may reproduce, or address, social, environmental, and economic inequities. Furthermore, these inequities will have implications for land governance and the role of local government facing new and future challenges, such as environmental and sociopolitical hazards, food insecurity, climate refugees, and ongoing urbanization.

7.1. Study limitations

While the findings of this study are not intended to be generalizable, the insights gathered shed light on municipal approaches to agricultural planning. The influence of urbanization and a dense urban population in Metro Vancouver, as one of the most highly populated areas in Canada, drives issues facing agricultural landscapes and opportunities. With respect to sampling strategies, we were able to recruit agricultural planning staff across the six municipalities. However, even in municipalities where there is a designated staff person, municipal staff roles can touch on agriculture. For example, engineering departments respond to drainage and irrigation infrastructure as part of their responsibilities. These additional staff were not interviewed in this study and could offer deeper insight into each local governments' capacity to govern agricultural systems. A second noteworthy limitation arises in comparisons between municipalities with agricultural plans and those without. Exploring municipalities without designated plans, and their efforts around agriculture and farmland, could prove fruitful to explore barriers to planning system reform and the effectiveness of stand-alone plans and planning outcomes.

Data availability statement

The interview data presented in this article are not readily available as they contain information that could compromise the privacy and anonymity of research participants. Document data (legislation, agricultural plans, official community plans) are publicly available information. Requests to access the datasets should be directed to ccdring@gmail.com.

Ethics statement

The studies involving human participants were reviewed and approved by University of British Columbia's Behavioral Research Ethics Board Certificate number H19-00240. The participants provided their written informed consent to participate in this study.

Author contributions

CD led the conception and design of the study, developed the analytical framework, collected and analyzed data, and wrote the first draft of the manuscript. HW and LN contributed to conception of the study, and development of the analytical framework. All authors contributed to manuscript revisions and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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