Impacts of agricultural commodity frontier expansion on smallholder livelihoods: an assessment through the lens of access to land and resources in the Argentine Chaco

Olivia del Giorgio[a*], Brian E. Robinson[a], Yann le Polain de Waroux[a,b]

[a] McGill University, Department of Geography, Burnside Hall Building, 805 Sherbrooke Street West, Montreal, Quebec H3A 0B9, Canada
[b] Institute for the Study of International Development, Peterson Hall, 3460 McTavish Street, Room 126, Montreal, Quebec H3A 0E6, Canada
[*] Corresponding author: McGill University, Department of Geography, Burnside Hall Building, Room 321, 805 Sherbrooke Street West, Montreal, Quebec H3A 0B9, Canada; email: olivia.delgiorgio@mail.mcgill.ca (O. del Giorgio)

Keywords: Livelihoods, access, commodity frontiers, land-use change, land control

This is the accepted version of the manuscript; please cite the published version:

del Giorgio, O., Brian E. Robinson & le Polain de Waroux, Y. (2022). Impacts of agricultural commodity frontier expansion on smallholder livelihoods: an assessment through the lens of access to land and resources in the Argentine Chaco. *Journal of Rural Studies*, 93. DOI: 10.1016/j.jrurstud.2022.05.014

Abstract

The global restructuring of productive systems in the last few decades has led to the rapid expansion of large-scale, industrial agriculture. This agricultural expansion has occurred by means of the acquisition and consolidation of vast tracts of land by agribusinesses, fundamentally changing the dynamics of land control. In order to secure access to resources, agribusinesses employ tactics of privatization and enclosure, which are supported by state-led processes of legalization and territorialization, as well as tactics of intimidation and violence. For smallholders faced with such pressures, maintaining access to land and resources is of critical importance. Here, we examine how changing access to land and resources influences what livelihood strategies smallholders are able to pursue in the Argentine Gran Chaco, a region that is experiencing high rates of deforestation for the expansion of large-scale soybean and cattle production. Our findings indicate that the ability of smallholders to engage in activities critical to their livelihoods has been impacted by changes in access brought about by the expansion of commodity frontiers in the Gran Chaco, leading to a restructuring of these activities. In particular, we found that cattle and goat herding were constrained by the spatial conditions and relational pressures associated with frontier expansion, possibly leading to a greater reliance on pig rearing, but that smallholders who deployed access mechanisms, such as working with lawyers to obtain land titles, were better able to maintain these activities. Our results demonstrate the value of adopting a disaggregated view on the different dimensions of smallholder access, and more generally highlight the need to assess smallholders' access to land and resources, rather than merely the availability of resources, in order to better understand the impacts of agricultural commodity frontier expansion and properly target policy to reduce smallholder vulnerability.

1. Introduction

In recent decades, growing commercial returns, market pressures, and policy changes have incentivized investment in the food industry, leading transnational companies to become increasingly involved in agricultural production (Holt Giménez and Shattuck, 2011; Le Billon and Sommerville, 2017). High inputs of capital and technology, as well as subsidies for agriculture, have allowed agribusiness to rapidly consolidate and convert large tracts of land to industrial agriculture (Borras et al., 2011; Cotula, 2012). Agricultural expansion has thus become the principal driver of land use change globally (Curtis et al., 2018; Lambin and Meyfroidt, 2011). Along with the ecological implications of the conversion of natural habitats to cropland, the expansion of large-scale, commodity agriculture has entailed drastic changes in the dynamics of land control and resource distribution, prominently in regions characterized by high levels of poverty and tenure insecurity. Unable to confront agribusinesses, many smallholders globally have been displaced as a result (Amanor, 2012; Araghi, 2009; Havnevik, 2011). Yet the consequences of the expansion of large-scale agriculture for smallholders are not limited to their physical expulsion - changes to smallholders' ability to access land and resources may affect the viability of their livelihood strategies, even where they manage to resist displacement (Cáceres, 2015; Li, 2014). To fully understand the extent of these effects, we therefore need to examine how the ability of smallholders to engage in different activities critical to their subsistence changes along with the expansion of commodity agriculture.

Argentina provides a suitable case study to explore the impacts of modern agricultural expansion on the livelihood strategies of historically forest-dependent smallholders. The adoption of an agro-export model for socioeconomic development has led the country to become, in under thirty years, a major producer and exporter of agricultural commodities (Otero, 2012; Richardson, 2009; Sly, 2017). Argentina's rapid ascension to the top tier of the global commodity market has required the drastic restructuring of both its territory and its productive systems. The cornerstone of the country's productive reconfiguration has been the uptake of the "*modelo sojero*" (soy model) - the large-scale mechanized production of genetically-modified (GM) soybeans (Leguizamón, 2014). Between 1996 and 2015, the surface area dedicated to soybean cultivation in the country increased by 308% (MAGyP, 2021) and by 2017, Argentina had become the third largest global producer and exporter of raw and processed soy products (after the U.S.A. and Brazil) (FAO, 2021).

To attain the production levels that have positioned the country as a global export power, there has been an important shift away from cattle rearing and maize production towards soybean cultivation in the Pampean region of central Argentina (MAGyP, 2021). But the expansion of soybean farming has not remained contained within Argentina's central agricultural core. Due to a number of climatic, technological, and market factors that converged to simultaneously broaden the area suitable for soy cultivation and increase the profitability of export-oriented agriculture (Basualdo, 2006; Hoyos et al., 2013; Satorre, 2005), soybean production rapidly expanded into the sub-tropical dry forests of the Gran Chaco ecoregion of northern Argentina at the turn of the century (Gasparri 2016; Gasparri *et al.* 2013). From 1996 to 2018, the area of soybean cultivation in the northern provinces of Formosa, Salta, Chaco, and Santiago del Estero increased by 2,500% (24,000 ha), 265% (274,012 ha), 380% (343,994 ha) and 791% (898,772 ha) respectively (MAGyP, 2021). These increases have been tightly coupled to deforestation for cattle production, as the expansion of soy occurs predominantly on pastures, which are consequently pushed further outwards into forestland (Fehlenberg et al., 2017; Gasparri and le Polain de Waroux, 2015). Together, the advance of coupled soybean and cattle production frontiers have resulted in the deforestation of approximately 5 million hectares in the Argentine Gran Chaco in the last two decades (Chisleanschi, 2020).

The advance of commodity frontiers into the forests of the Argentine Gran Chaco has been paralleled by changes in the dynamics of land control that have significant implications for how, and by whom, land and resources can be accessed. Through the legal, political, and economic empowerment of agribusiness, the *modelo sojero* has led to the concentration and accumulation of land and resources by the latter, principally by means of physical enclosures (i.e., fencing) and the formalization of private ownership through land titling (Cáceres 2015). Amongst the most impacted by these changes are rural smallholders, whose minimal financial, technological, and political capabilities stand in stark contrast to those of large-scale commodity producers. Multiple factors including lack of state intervention, the high entry costs of transgenic soy production, and the increasing valuation of land, have contributed to

effectively excluding smallholders as participants in Argentina's "soy-ization" process (Lende, 2015). High levels of tenure insecurity in the Gran Chaco have further exacerbated processes of exclusion. Indeed, few smallholders hold formal legal titles in the region, relying rather on protections afforded through rights of continued occupancy (Law 20396 relating to "prescriptive acquisition") (Barbetta, 2009; Verbic, 2016). Yet the legal and illegal acquisition of land titles by agribusiness, as well as the leasing of land through contractual agreements, have occurred irrespective of smallholder presence (Cáceres *et al.* 2011). As a result, the expansion of commodity frontiers in the Gran Chaco has led to the widespread displacement of smallholder communities towards urban centers (Gorenstein and Ortiz, 2016; Sacchi and Gasparri, 2016).

For smallholders who have so far resisted displacement, the changes to land control that have accompanied the expansion of commodity frontiers pose serious challenges to the reproduction of their livelihoods. Where deforestation for commodity production has taken place, smallholders must contend with the absence of forest resources that are critical to their subsistence. But the potential impacts of commodity frontier expansion on smallholders go beyond forest availability. Notably, the fencing and privatization of land create barriers across a landscape where smallholder resource use and management has traditionally been at least partly communal (Altrichter and Basurto, 2008; Jara and Paz, 2013). Consequently, along with displacement pressures, the access constraints faced by smallholders are likely pressuring them to adapt by shifting livelihood strategies (Aguiar *et al.* 2016; Cáceres *et al.* 2010; Bessire 2014). Yet there is little understanding of how these novel constraints posed by the expansion of commodity frontiers shape smallholder decisions about and opportunities for different livelihood activities.

The goal of this paper is to address this knowledge gap by assessing the effects that temporal and spatial differences in access have on rural smallholder strategies. To do so, we first build on the theoretical literature on access to develop three constructs to empirically describe smallholder access. We use original data from interviews with smallholders in Argentina to produce metrics of these constructs and apply statistical models to assess how they relate to common livelihood strategies in the region. We put our quantitative results in context with qualitative data from the same population. Finally, we conclude with some theoretical and practical implications from the study.

2. Conceptual framework and background

2.1 Frontiers of land control

At a broad conceptual level, a land frontier has been defined as a situation where there is simultaneously an abundance of land and natural resources and a scarcity of labour and capital (Barbier, 2012; Di Tella, 1982). The potential for expansion of a given set of practices (i.e., the exploitation of new sources of relatively abundant resources for production purposes (Barbier, 2010)) is premised on the existence of an "abnormal" rent – in other words, an economic rent that exceeds the bid rent or land price (Barbier, 2012; Di Tella, 1982). The formation of this abnormal rent and, accordingly, the "opening" of the frontier from an economic stand-point, is driven by factors such as the availability of cheap labor, changing agro-environmental conditions, technological innovations, changes in producer and consumer prices, and the instauration of legal and economic incentives (Gasparri et al., 2015; le Polain de Waroux et al., 2018).

Land frontiers also constitute spaces in which the governance of land is defined or re-defined (Thaler et al., 2019). Peluso and Lund (2011, p. 668) refer to "new frontiers of land control" – "sites where authorities, sovereignties, and hegemonies of the recent past have been or are currently being challenged by new enclosures, territorialization, and property regimes". The "newness" of these frontiers pertains not only to the modern land grabbing process, but also to the contexts created by the arrival of new actors, new labour processes, new rules of ownership and access, and new mechanisms for challenging previous land control regimes (Peluso and Lund, 2011). Within these contemporary frontiers of land control, the state often plays an active role in the redesign of the norms of access to resources, by facilitating the establishment and expansion of agribusiness into areas deemed to have productive "potential" (d.L.T. Oliveira, 2013; Rudel, 2007). Large-scale commodity producers have (or are given) the power to enclose and to privatize vast tracts of land (Kelly and Peluso, 2015; Rasmussen

and Lund, 2018). Their claims are often strengthened by the legalization and institutionalization of their new ownership (d.L.T. Oliveira, 2013; Wily, 2012), as well as by the use of violence (or the threat of it) (Nolan et al., 2020; Schetter and Müller-Koné, 2021). Meanwhile, rural smallholders with lower financial, technological, and social capabilities, typically lack such state support and face high levels of tenure insecurity and poverty (Rigg, 2006; Scoones, 2015; Shalizi, 2003), making contemporary frontiers arenas of competition characterized by stark power asymmetries (Dhingra and Tenreyro, 2021; Thompson, 2021).

These asymmetries strongly disadvantage rural smallholders. While some smallholders may benefit from higher returns to land and labour as large farms expand (Deininger and Xia, 2016; Reardon et al., 2009; Rist et al., 2010), large-scale land acquisitions rarely lead to poverty reduction (Li, 2011). More commonly, changes in land control associated with the expansion of commodity agriculture result in the partial or complete dispossession of rural smallholders – in other words the loss of their ability to benefit from land and resources (Amanor 2012; Havnevik 2011; White *et al.* 2012, Cáceres, 2015). In the most extreme case, the claiming of land by commodity producers leads to the displacement of smallholder communities. But where smallholders manage to remain in place, dispossession may take subtler forms. In situations where their livelihood opportunities have been limited, smallholders may shift strategies in order to "hang in" (Dorward et al., 2009). Such shifts can, in the long term, undermine the sustainability of their livelihoods. For example, in shifting to extractive activities that are more immediately remunerative, such as logging, smallholders may step into poverty traps where poverty reinforces the depletion of forest resources (Sunderlin *et al.* 2005). Dispossession in commodity frontiers thus goes beyond displacement, as it can also entail the physical and institutional exclusion of people from their means of production and reproduction (Li, 2014; Makki, 2014).

2.2 Access and livelihoods

The livelihood implications of commodity frontier expansion for smallholders ultimately depend on whether and to what extent they are dispossessed of their means of production. Dispossession, as defined by Cáceres (2015) building on Harvey (2003), refers to the process by which people are impeded from gaining or maintaining access to resources. As such, access, or the "multiplicity of ways people derive benefits from resources, including, but not limited to, property relations" (Ribot and Peluso 2003, p. 154), is a key concept for understanding the social impacts of commodity frontier expansion. To examine how differences in access in commodity frontiers shape the livelihood capabilities and strategies of smallholders, we draw on three complementary frameworks: the Sustainable Livelihoods Framework (Scoones, 1998, 2015), the Theory of Access (Ribot and Peluso, 2003), and the Powers of exclusion framework (Hall et al. 2011).

The Sustainable Livelihoods Framework describes people's livelihoods based on their livelihood context, their livelihood capitals (i.e., assets), the institutions and processes that mediate people's livelihood strategies, and their livelihood outcomes and trade-offs (Scoones, 1998). Characterizing the livelihood context are the conditions, trends, shocks, and seasonality that influence a person's vulnerability. Within a given livelihood context, people have a set of available assets, characterized as human, social, natural, physical or financial capital. The amount, diversity, and balance between assets (i.e., the asset bundle) influences the livelihood strategies adopted (i.e., the livelihood portfolio), with more assets creating more livelihood strategy options from which a person or household may choose (Ifejika Speranza et al., 2014). While the Sustainable Livelihoods Framework identifies that access (and influence) link people's asset bundle to their livelihood strategies (Donohue and Biggs 2015; DfID 1999), several authors have highlighted the fact that the framework does not expand further on the elements of access and power that form the critical connection between people's capabilities and their strategies (for example Haan and Zoomers, 2005; and Scoones, 2015).

These elements can be unpacked through the Theory of Access (Ribot and Peluso, 2003), a heuristic framework in which access is understood by analyzing three interacting processes: the social actions of gaining, maintaining, and controlling access. Ribot and Peluso (2003) refer to '*gaining access*' as the process by which access is established, '*controlling access*' as the mediation of another's access, and '*maintaining access'* as the process of expending resources to keep a particular form of resource access open (Ribot and Peluso, 2003). The overall condition of a person's access is characterized by the relative importance of each of the three processes. To illustrate, in the case of commodity frontier settings,

agribusinesses and state actors often control resources, meaning that smallholders must maintain their resource access through negotiation with the latter. Although the processes of gaining, maintaining, and controlling access are dependent of one another, the importance that each has at any given time can vary depending on what access mechanisms are used by a given actor. According to the categorization proposed by Ribot and Peluso (2003), access mechanisms can be either rights-based, including both legal (e.g., property) and illegal mechanisms (e.g., theft), or structural and relational, which include the technology, capital, markets, knowledge, authority, social identities, and social relations that shape how and to what extent people are able to gain, maintain, and control access.

When examining the impact of changes in land control on the livelihood strategies of a specific actor, as is the intent here, it is useful to examine both the processes by which people maintain their ability to benefit from land and resources by deploying access mechanisms and the counter process of *exclusion* by which people are prevented from benefiting from them. In the Powers of Exclusion framework, the power to exclude others is seen to operate through regulation ("It is not allowed"), force ("I'll get hurt if I try"), markets ("I can't afford it"), and legitimization ("It's wrong") (Hall et al. 2011). As noted by Hansen et al., (2020) the "Powers of Exclusion" framework runs parallel to and often overlaps with "A Theory of Access", but emphasizes "force" (which Ribot and Peluso only discuss under "illicit access").

To assess people's ability to benefit from land and resources, and the effect of this ability (or lack of ability) on which livelihood strategies they can or cannot employ, we build on these three frameworks and disaggregate smallholder access as: 1) the mechanisms they deploy to gain and maintain their access to land and resources [*access mechanisms*]; 2) the relational processes with other actors through which they are excluded from benefiting from land and resources [*relational access pressures*]; and 3) the spatial conditions to access to which they are exposed [*spatial conditions*]. The latter serves more specifically to assess the effect of access and exclusion to sufficient *space* to perform different livelihood activities, a critical element in the dynamics of land use in agricultural commodity frontiers (del Giorgio et al., 2021). We draw on these three conceptual constructs to guide our assessment of the effects of differences in access (both spatially and temporally) on smallholder livelihood strategies in commodity frontier settings.

2.3 Land control dynamics in the Argentine Gran Chaco

Two main categories of smallholder actors are commonly differentiated in the Argentine Gran Chaco. One of these are Indigenous groups, who practice a mix of hunting, craft-making, and forest product harvesting, as well as small-scale agriculture, seasonal wage labor, and public-sector employment (Braunstein and Meichtry, 2008; Gordillo, 2004; Miller, 1999). The thirteen Indigenous groups of the Argentine Gran Chaco (Censabella, 1999) are mostly confined today to areas much smaller than their traditional lands, and oftentimes do not have titles to the land they occupy (Luna, 2018). This situation is a product of historical changes in land and resource control and the imposed servitude (*encomienda*), imprisonment, and killing of thousands of Indigenous peoples by Spanish colonists in the late 1700s (Gordillo 2004; Salinas 2008) and by the Argentine Republic through the 1800s and 1900s (Corte and Recalde, 2011) – practices which were supported by state narratives of the Gran Chaco as a vast, hostile, and backwards desert (Gordillo and Hirsch 2008).

A second smallholder actor of importance in the region are *criollos*, a term that is used in Argentina to refer to people of either Spanish or of mixed Indigenous and European descent (Dasso, 2010). In the Chaco, criollos commonly live in homesteads called *puestos* and practice a mix of subsistence farming, livestock herding, hunting, and occasional contract work (Chamosa, 2008; Krapovickas and Longhi, 2013; Miller, 1999). In forested areas, they also extract wood to produce charcoal or fence posts which are generally sold to local intermediaries (Morello et al., 2013). Criollo *puestos* were historically often developed in areas with unresolved property rights (Altrichter and Basurto 2008). The implementation of neoliberal policies in the 1980s and the ensuing privatization of land considered "empty" by the state resulted in few criollo families holding formal land titles (Gomez, 2009; Jara and Paz, 2013).

The majority of criollo and Indigenous smallholders of the Argentine Gran Chaco live in conditions of precarity. Along with the highest proportion of tenure-insecure inhabitants in Argentina

(Barbetta, 2009), the northern provinces also have the highest levels of rural poverty (Bolsi and Meichtry, 2006; Cattania et al., 2011). Cardona (2006) notes the lack of market infrastructure, inadequate social services, and insufficient water provisioning in the region. The capabilities of these smallholders stand in stark contrast to those of large-scale commodity producers, who have access to important streams of financial and technological capital and are generally able to secure formal land titles. Along with financial and technological capabilities, agribusinesses are supported by state-led strategies of territorialization and legalization which institutionalize, and thus effectively facilitate, large-scale investment in land for the purpose of commodity production (Dietz & Engels, 2017; Jara and Paz, 2013). Examples include the "*Plan Estratégico Agroalimentario*" (PEA 2010-2020), a federal initiative aimed, among other things, at promoting the expansion of large-scale industrial agriculture, and which proposed to increase the total area under cultivation in Argentina by 27% and the number of cattle heads by 5 million (PEA, 2010); or the national "*Plan Estratégico Territorial*" (PET 2011), which, in concordance with the PEA (2010), proposed to improve infrastructure for the development of the industrial sector but neglected to support other agricultural models, thereby excluding most rural smallholders from the development strategy (Secretaría de Obras Públicas, Argentina, 2018) (Abt, 2015; Kossoy and Jovanovich, 2011).

The process of consolidation and accumulation of land and resources that is taking place as commodity frontiers expand in the Chaco reflects the power asymmetries between smallholders and agribusinesses. In the stages leading up to the deforestation of plots for the eventual production of agricultural commodities, agribusiness companies (largely hailing from the provinces of Santa Fe, Córdoba, and Buenos Aires) consolidate their control of and access to land through a number of mechanisms. Land titles may be purchased or otherwise acquired for a given area. Because there is little to no control by the state over which lands are formally placed for sale, legal land transactions regularly occur for land under smallholder occupancy (Goldfarb and Haar 2016). Investors may also illegally appropriate land by falsifying property titles (Abt, 2015). Where that land is occupied, investors may resort to several strategies. Families may be offered land elsewhere or financial compensation in exchange for leaving their land, or they may be asked to pay rent in return for their continued occupancy. In situations where families refuse to negotiate, investors may resort to threats, violence, and other means of coercion (Estrada, 2010). Although the Argentine constitution recognizes the rights of smallholders as formal landowners after twenty consecutive years of active occupancy (Art. 4015 and 2384 of the Civil Code), state officials and judges oftentimes fail to enforce the "twenty-year" law (Jara and Paz, 2013). Smallholders are thus often left without legal recourse to claims of private ownership by outsiders.

Paralleling these legal and illegal tactics, agribusinesses consolidate control over land and resources through the erection of wire fences (*alambrados*). The fencing of the perimeter of claimed land is a mechanism used simultaneously to exclude people and livestock and to strengthen legal claims to private ownership (del Giorgio et al., 2021), and has led to the fragmentation of a landscape where resource use by smallholders is oftentimes communal (Altrichter and Basurto 2008; Paz and Jara 2012). Together, the physical enclosure and titling of land by agribusiness, along with supporting practices of territorialization, legalization, and violence, are fundamentally changing the dynamics of land control in the Argentine Gran Chaco (Goldfarb and Haar 2016).

3. Data and Methods

3.1 Study area

The study area was delimited by the legislative boundaries of the department of Pellegrini, which is located in the province of Santiago del Estero (Figure 1). In the department, most people identify as criollo. Here, we will refer to them using the term *campesino* (peasant), which denotes social class rather than ethnicity and is applied locally to both Indigenous and criollo smallholders. Population rose in the department of Pellegrini by 21% between 1991 and 2001 and by 5% between 2001 and 2010, to reach a population of 20,514 inhabitants (mostly concentrated in towns) in 2010 (INDEC, 2021). Although more recent statistics were not available, local informants report that the population of

the largest town of the department, Nueva Esperanza, grew from less than 5000 in 1990 to between 10,000 and 15,000 inhabitants in 2019, due in part to *campesino* families moving from rural to urban areas (both from within Pellegrini and from neighboring departments and provinces). As such, there were likely many more people living in Pellegrini in 2019 than reported in the Argentine Nacional Census of 2010 (INDEC, 2010).

At the time of the study, commodity frontiers in Pellegrini were expanding from the core agricultural areas of the province of Tucumán. The department had a combination of old frontier conditions in the south-west (where the consolidation of land for commodity production by agribusiness began prior to 2000), active frontier conditions in the center and centre-north (characterized by the development of large-scale soybean and maize cultivation and/or cattle production operations, initiated between 2010-2019), and early frontier conditions in the south-east and north-east of the department (where land speculation and exploratory activities were taking place in still-forested areas). Pellegrini thus presented a suitable range of frontier conditions within a relatively limited study area (7,330 km^2), permitting the study of the impacts of differences in access on livelihood activities.

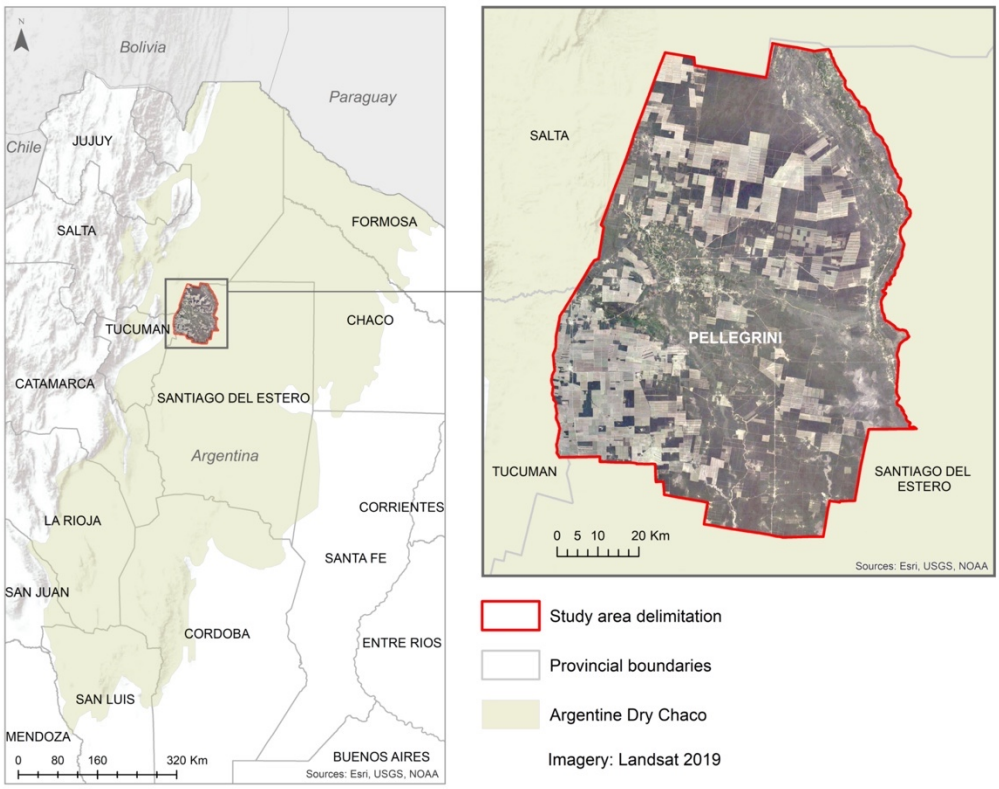

Figure 1. Map of the Department of Pellegrini, located in the Province of Santiago del Estero, Argentina.

3.2 Data Collection

Primary data were collected by the first author through 80 structured interviews with *campesinos* in the study area between May and August 2019. Prior to formal data collection, a one-month exploratory period was dedicated to forming local contacts, establishing trust with *campesino* communities, and refining interview questionnaires. The structured interviews, conducted in Spanish by the first author, covered three main topics: Livelihood strategies, practiced today (2019) and about twenty years ago (approx. 2000)[1]; assets, income and demographics; and access dynamics (discussed subsequently). A combination of purposive and snowball sampling was used to identify households for interviews. Households were approached through local collaborators, with explicit attention to

[1] Survey questions relating to baseline conditions were structured as "About twenty years ago, around the year 2000, what were conditions relating to x livelihood/access dynamic".

representing all main livelihood strategies present within community groupings. All respondents were heads of households (either men or women) who identified as criollo.

Primary data on land control dynamics were also collected by the first author through four focus groups, through casual conversations and observations reported in a journal, and through six unstructured key-informant interviews with community leaders and elders. During three of the four focus groups, participants (numbering between 7 and 15) were asked to discuss the dynamics of land control and access within the community. The fourth focus group was held during a meeting of the land committee (*Mesa de Tierra*) of Pellegrini. Land committees in the region were formed by local priests as a form of *campesino* resistance during the peak of land conflicts (2000-2010). Although in fewer numbers, community leaders from Pellegrini continue to meet to discuss issues of land grabbing and conflict in the department. Following one such meeting, the first author mediated a mapping exercise through which the assembled community leaders (10) were prompted to discuss changes in the dynamics of access due to the expansion of large-scale agriculture in Pellegrini. All data collection protocols were reviewed and approved by the Research Ethics Board Office of McGill University.

3.3 Qualitative analysis

We analyzed qualitative evidence from data collected through focus groups, key informant interviews, and informal interviews. Field notes were first transcribed and individual observations and entries were subsequently coded and grouped according to three main themes: changes in livelihood strategies; dynamics between actors; and access mechanisms and changes in land control. We then used inductive coding within each theme to identify emergent narratives and categories. Our qualitative findings on land control dynamics and changes in smallholder livelihoods informed the variable selection for the empirical models and provided a platform with which to interpret the quantitative results.

3.4 Empirical models

To complement our qualitative results on the relationship between access to resources and *campesino* livelihoods, we developed a first empirical model to analyze the effects that differences in access across space have on smallholder livelihood activities (hereafter "cross-sectional analysis"). This model integrates our three dimensions of access, which we call *access mechanisms*, *relational access pressures*, and *spatial conditions of access*.

Access mechanisms, following Ribot and Peluso's Theory of Access (2003), can be conceptualized as a portfolio of observable characteristics that relate to the agency and choices that smallholder households make to maintain their access to land and resources, such as whether the household is able to and chooses to deploy tactics of privatization, enclosure, or representation - in other words, a person's "bundle of powers" or capabilities (Leach et al., 1999; Sen, 1989). *Relational access pressures* relate to dynamics of smallholder exclusion through a portfolio of powers exerted by others. *Spatial conditions of access* in turn refers to the degree of physical restrictions experienced by smallholders more generally to space. Thus, while the first dimension emphasizes smallholder agency at the household level and the second dimension emphasizes pressures transmitted to smallholder households through their interactions with other actors, the third dimension emphasizes the spatial distribution of access mechanisms and pressures that are simultaneously applied and experienced by different actors.

The model for the cross-sectional analysis can be represented as follows:

$$L_i^a = f(M_i, P_i, S_i^a, C_i) \; (Eq. 1)$$

where: L_i^a is a measure of a livelihood activity *a* for household *i*; M_i is an index of the access mechanisms deployed by household *i*; P_i is an index of relational access pressures experienced by household *i*; S_i^a, is an index of spatial conditions of access at the location of household *i* and specific for livelihood activity *a*; and C_i are a vector of controls (demographics, education, other endowments etc.).

Additionally, to assess the effects of differences in access across time, rather than space, on smallholder livelihood strategies, we developed a second model that incorporates changes in livelihood strategies over time:

$$\Delta L_i^a = f(M_i, P_i, \Delta S_i^a, C_i)\ (Eq. 2)$$

where Δ indicates change between times t_0 (~2000) and t_1 (2019) for the different variables. Ideally this model would include changes in access mechanisms and access pressures over time as well. However, our data do not contain information on mechanisms and pressures at the earlier time period, so we use the data collected in 2019 as a static indictor in equation 2.

We expect relational access pressures experienced by *campesinos* to constrain their capabilities and thus to negatively affect both their likelihood of participating in a given livelihood activity and the intensity of that participation. In contrast, we expect the access mechanisms deployed by *campesinos*, as well as better spatial access conditions more generally experienced at the location of the household (i.e., the higher the *S*, the fewer spatial access restrictions) to increase their capabilities, and thus to positively affect the likelihood of participating in a given livelihood activity and the intensity of that participation.

3.5 Variable selection and index calculation

We developed two indices from observable variables that represent *access mechanisms* and *relational pressures*. We first discuss variable selection for each of these in turn. Based on the main access mechanisms applied by *campesinos* to maintain their access, as identified through our qualitative analysis (discussed subsequently), we chose seven access variables to form the *access mechanisms index* (Table 1), encompassing both rights-based and structural and relational mechanisms as characterized by Ribot and Peluso in the Theory of Access (2003). The first four represent different legal mechanisms used to maintain and strengthen control over land and resources: whether the household had a property title and, if not, whether they were involved in an active legal process to obtain a property title; whether the household paid land taxes; whether the household was represented by a lawyer; and whether the household had cleared forest to demarcate their land. A fifth variable, whether the family had erected fences around forested land, captured both legal and technological mechanisms used by *campesinos*, since fences are recognized as legal claims of occupancy while also serving to physically exclude external claimants from accessing land and resources. The last two variables, whether the household was involved or had support from MOCASE (a local *campesino* organization) and whether the household was represented by a community association, both served to capture whether *campesino* families had access to knowledge about their rights as well as support, legally and emotionally, when sustaining claims. These last two thus more directly represented the social relationships that enable people to benefit from land and resources.

Table 1. Variables included in the access mechanism index

Access mechanisms	Description	Response
Property title/In legal process	Whether the household has a property title and if not, whether they are involved in an active legal process to obtain a property title.	Property title Active legal process No property title/legal process
Pay/paid land taxes	Whether the household pays or used to pay land taxes.	Yes Before yes, now no No
Represented by lawyer	Whether the family is currently represented by a lawyer.	Yes No
Family cleared demarcations	Whether the household has cleared forest to demarcate their land.	Yes No
Family fenced forest	Whether the household has fenced forest.	Yes No
Involved/supported by MOCASE	Whether the household is involved or has support from MOCASE (campesino organization).	Not involved or supported Involved or supported
Represented by association	Whether the household is represented by a community association.	Yes No

We chose eight variables to form the *relational pressures index* (Table 2). The first variable, whether a member or members of the household had experienced violence or threats, captured powers of force used by external actors to gain and control access to land and resources. Whether the family was in conflict with farms, neighbors, or others (i.e., speculators, investors etc.) served to capture processes of exclusion due to both powers of regulation and force resulting from interactions between each of these different pairs of actors. Whether actors directly or indirectly involved in commodity production had fenced land in the vicinity of the household captured whether there were processes of physical and institutional exclusion of campesinos in the area surrounding the household, relating to powers of regulation, legitimization, and market. The last three variables (i.e., whether the household had been asked to sign papers; whether the household was offered a sum in exchange for their land; and whether the household had been offered a certain amount of land) captured powers of force and market enacted through processes of negotiation and coercion, and thus pressures for *campesino* households to relinquish control over their access.

Table 2. Variables included in the relational access pressures index

Relational access pressures	Description	Response
Received violence or threats	Whether a member or members of the household have experienced violence or threats made by actors directly or indirectly involved in commodity production.	Yes No
Conflict with farms	Whether the household is involved in a conflict with a farm.	Yes No
Conflict with neighbors	Whether the household is involved in a conflict with neighbors.	Yes No
Conflict with others	Whether the household is involved in a conflict with others (i.e. speculators, investors etc.).	Yes No
Fences erected by others	Whether actors directly or indirectly involved in commodity production have fenced land in the vicinity of the household.	Yes No
Offered to buy land	Whether the household has been offered sum in exchange for their land. Measure of pressure.	Yes No
Asked to sign papers	Whether the household has been asked to sign papers. Measure of pressure.	Yes No
Offered amount of land	Whether the household has been offered a certain amount of land. Measure of pressure.	Yes No

We aggregated these variables into two indices using factor analyses on polychoric correlation matrices[2]. We used the first factor obtained from each of the polychoric factor analyses to represent access mechanisms and relational access pressures respectively. These indices thus represent the state of access mechanisms and pressures across the period analyzed, and therefore the same indices are used for the cross-sectional and the change analyses.

To represent *spatial conditions of access index*, we used an index developed by del Giorgio et al. (2021), which is a quantitative measure of restrictions on access to space for different livelihood opportunities. The index is based on the density and spatial arrangement of barriers to access (e.g., fences, roads) within a livelihood-specific buffer. We use the index values for different livelihood

[2] Given that the selected access mechanism variables were either bivariate or ordinal, traditional principal component analysis (PCA) using Pearson's correlation was not well suited to produce the aggregate indices (Drasgow, 1986). In order to meet the assumption of normality and of equal correlations between the discretized versions of the variables and the "true" correlations of the unobserved variables underlying the PCA (Kolenikov and Angeles, 2004), we first computed a polychoric correlation matrix for each set of variables using the polycor package (Fox, 2019). With the polychoric matrices as primary inputs, we then conducted factor analyses using the psych package in R (Revelle, 2021; R Core Team, 2020).

activities (e.g., cattle rearing, goat rearing, charcoal production etc.) as proxies for the amount of land available for use at the location of each household in each of the corresponding livelihood activity models. The index was available for the two timepoints analyzed, allowing us to calculate a difference in spatial conditions of access between 2000 and 2019, at the location of each household surveyed, for the change analysis[3].

We used the following explanatory variables in our cross-sectional models to represent livelihood strategies: number of cattle; number of goats; number of pigs; charcoal production (assessed by the number of kilns per household); whether the family produced fence posts; whether members the household hunted; whether the household engaged in agricultural employment (including seasonal migration and/or local wage labour on farms); and whether the household engaged in non-agricultural employment (which grouped whether household members had or worked in a commerce or if one or more household members was employed as a teacher in 2019).

For the change models, we proceeded differently for numeric and binary variables. We included the number of cattle, goats, and pigs (i.e., numeric activity variables) as differences between 2000 and 2019. The change between 2000 and 2019 in participation for binary strategy variables (i.e. fence post production, charcoal production, hunting, and agricultural employment) was captured as one of the following three "paths": If the household participated in the activity both in 2000 and 2019, or if the household began participating in the activity after 2000, the change path was coded as "Entry or Always"; if the household did not participate in the activity in either 2000 or 2019, the change path was coded as "Never"; and if the household participated in the activity in 2000, but no longer did in 2019, the change path was coded as "Exit". We were not able to assess the effect of access on the change in non-agricultural employment, due to insufficient data.

Lastly, we used a combination of primary and secondary data for control variables (Table 3). The cost-distance from households to towns allowed us to control for remoteness as well as spatial clustering of the data, as community history, preferences, and location could influence livelihood choices. We used Euclidean distance to rivers (perennial or intermittent) to control for accessibility of water, which can influence whether *campesinos* are able and choose to engage in different livelihood activities. These distance metrics were calculated based on data provided by Argentine national ministry of agriculture, livestock, and fisheries (MAGyP, 2020). We also included the dependency ratio, education level of each household, and femininity index, as demographic controls that could influence activity choice. Due to high levels of multicollinearity, we did not include the household size (i.e., number of members), soil organic carbon stock, or the number of years since the household's establishment as controls in the models.

Table 3. Summary of independent variables included in the empirical models.

Independent variable	Description
Access mechanisms (M)	Composite of access mechanisms variables, produced using polychoric factor analysis.
Relational access pressures (P)	Composite of relational access pressures variables, produced using polychoric factor analysis.
Spatial conditions of access (C)	Indicator of access condition for a specific livelihood at the household's location. Produced for the study area by del Giorgio et al. (2021).
Dependency ratio (%)	Number of household members over the age of 15 and under the age of 65, divided by the total number of household members.
Average member education (score)	Levels of education assigned as follows: <5 years of education = 0; 5-10 years of education = 0.5; +10 years of education = 1. Levels then averaged across all members 15 years or older.
Femininity index (score)	Sex assigned as: Male = 0; Female = 1. Household femininity averaged across all members 15 years or older.
Distance to town (weighted km)	Cost distance calculated by distinguishing between dirt roads (cost = 10), consolidated roads (cost = 1), and no roads (cost = 1000), and then applying a cost-distance function to extract the least-cost distance value to town for each household.
Distance to water (km)	Euclidean distance from household to nearest river (intermittent or perennial).

[3] Due to respondent's difficulty to report area values, we were not able to complement the index with data collected through surveys on the amount of land actually held or used by households. The spatial dimension of the models thus captured the total potential amount of land available for use by a household for a given livelihood activity.

3.6 Statistical analysis

After compiling summary statistics on the collected quantitative data, we used a combination of multivariate regression techniques to assess whether the different access indices significantly impacted smallholder livelihood activities. For the cross-sectional analysis (Eq. 1), we used binomial logit regressions to estimate the effects of access on whether households participated in fence post production, hunting, agricultural employment, and non-agricultural employment in 2019. These models are well suited to predict the probability that an observation falls into one of two categories of a dichotomous dependent variable (Hilbe, 2009). We then applied double-hurdle models to estimate the effect of access on (separately) the number of cattle, goats, pigs, and kilns for charcoal production in 2019 (Kleiber et al., 2008). Double hurdle models account for overdispersion produced by an excess of naturally occurring zeros (Cragg, 1971; Mullahy, 1986) and partition the model into two components that mimic smallholders' decision-making process. First, a binary outcome model (usually probit or logit) estimates the probability that a zero threshold is crossed (here, whether or not a household engages in the livelihood activity). Second, a left-truncated count function models the factors that relate to the intensity of participation in that livelihood activity (i.e., in the case that they have cattle, how many cattle they choose to have) (Cameron and Trivedi, 1998). We applied binomial logit and Poisson with log link models for the first- and second-stage components, respectively.

For the change analysis (Eq. 2), we applied multinomial logistic regressions to assess the effects of access on changes in the livelihood activities that we recorded in categorical terms as "entry or always", "never" or "exit" pathways[4]. Multinomial logistic regressions are a simple extension of binary logistic regression that allows for the estimation of unordered categorical responses (Hilbe, 2009) and this type of model was thus suitable for the variables that had been coded for these three change "paths". For other livelihood activities that were recorded in quantitative terms at the two time points analyzed, we used double-hurdle models to assess the effects of access on the change in the number of animals held[5].

4. Results and discussion

4.1 Changes to *campesino* livelihoods

Prior to the arrival of large-scale, industrial agriculture beginning in the 1980s, people report that the livelihood portfolio of *campesinos* living in Pellegrini was composed mainly of livestock rearing (principally of goat and cattle, but also to a lesser extent of sheep) in open or communally managed forest, hunting, and small-scale agriculture for subsistence purposes. Charcoal production represented one of the only income-generating activities in the region, and was either conducted independently, with families owning their kilns and selling the charcoal to intermediaries, or *campesinos* were hired by second parties to work in timber workshops known as *obrajes*. Many people also traveled seasonally for agricultural employment in other provinces, principally in Tucuman and Salta. These were still the main activities in the early 2000s, when the impacts of agribusiness expansion started being felt in the degree to which *campesinos* participated in these activities.

Between 2000 and 2019, the mean number of cattle, goats, and pigs per household decreased significantly, from 37 to 20, 43 to 10, and 12 to 7, respectively. In 2019, most of these animals were still grazing in open or communally-managed forests (63% of respondents, with 19% reporting that their livestock also fed in private or fenced forest, and 14% of respondents reporting that their livestock also fed in private or fenced pasture) and kept for subsistence (23% of respondents reported selling cattle and

[4] All households reported having been established before the year 2000 or being associated to the productive activities of their family nucleus (in the four cases where a young couple moved into a new house but reported that their family had been established over twenty years ago in the region).

[5] There were two possible ways of obtaining a zero from calculating the change in livestock: zero produced due to no change in livestock number ("always" and, furthermore, constant production path), and zero produced by the household never having had that livestock (a "never" path). To distinguish between these two zeros types in the double-hurdle models, a constant was added to all the observations except the "never" observations. In this way, the binary outcome function modeled the probability of the "never" threshold being crossed, and the left-truncated Poisson function modeled the degree of change for all observations that crossed the "never" threshold.

18% reported selling pigs, while only 9% reported selling goats). Meanwhile, many respondents (42%) indicated that they no longer practiced subsistence hunting, and no households indicated taking it up between 2000 and 2019. One-third (32%) also reported having exited charcoal production between 2000 and 2019, more than those who maintained (18%) or took up the activity (13%; 37% never produced charcoal). Similarly, 37% of households said they exited the production of fence posts between 2000 and 2019, and very few (6%) took up the activity in the same time frame - another 46% reported never having produced fence posts, pointing to the potential selectivity of this activity based on exposure to demand from agribusiness. Lastly, the vast majority (74%) of households reported exiting agricultural employment (i.e., employment on nearby farms and/or migration for seasonal agricultural employment). This general decline in the participation in multiple livelihood activities was only partially compensated by the availability of pensions and family support, and by employment outside of agriculture (e.g., trade, employment in schools or as taxi drivers).

4.2 Dynamics of access and land control at the frontier

Our interviews revealed the land control dynamics exerted by small- and large-holders in Pellegrini today, highlighting the enormous power differentials between these actors. Agribusinesses, politicians, and investors typically claim ownership to land by acquiring property titles. When the land in question is occupied or actively used by campesinos, these external actors resort to several strategies. They may first offer *campesinos* a sum of money, usually much below the formal land price, to leave their land, or they may ask them to sign documents handing over the rights of occupancy, often on the false premise that what they are signing are documents in support of infrastructural improvements. Because many *campesinos* in the region are illiterate, the signing of written documents can be considered a coercive strategy. Of the households that participated in the survey, 19% reported being offered a sum in exchange for their land, 18% reported having been asked to sign papers, and 12% reported having been offered land elsewhere in exchange for ceding way to agricultural operations. External actors also erect wire fences (*alambrados*) along the perimeter of the claimed land, which simultaneously serves to physically exclude campesinos and to reinforce claims of ownership by active use. Seventy-seven percent of surveyed households reported that fences had been erected by external actors in the vicinity of their household, with about as many of those (76%) stating that the fences had been erected by agribusiness actors. Forest demarcations and infrastructure such as charcoal kilns and water pumps also serve to demonstrate active occupancy. If an inspection by an official is required as part of the titling process, interviewees reported that investors could go as far as to build temporary kilns on the land. Respondents noted that officials from the office of the cadastre may also be offered bribes to hasten the titling process.

In contrast to agribusinesses and other investors, *campesinos* have fewer mechanisms at hand to maintain access to land and resources. One is to pay land taxes, which allows them to claim rights of occupancy. However, only 28% of households reported paying land taxes. We identified three main reasons for this. First, many lacked knowledge about how to do so and/or lacked personal identifying documents (i.e., passport or national identity document) that are legally necessary for the process. Second, many of those who had paid land taxes in the past stopped doing so because they felt that ultimately it did not help them secure land titles. Third, the financial burden of paying taxes made that option inaccessible for many *campesino* families. Another mechanism used to maintain access is fencing land: while this runs counter some of the management traditions in the area, many households did consider fencing an option. Yet even where *campesinos* wish to enclose land, the high cost of metal wire and the labour required to erect fences limit the extent to which they are able to do so. Of the households surveyed, just over a quarter (27%) reported that they had fenced forestland in the vicinity of their household – the majority (54%) saying that they had done so to protect their land and resources. The clearing of forest demarcations, another important tactic used to claim rights of occupancy, is less costly than fencing, and is thus more commonly used as a mechanism to secure access by *campesino* families – about half (47%) of the surveyed households had cleared forest to demarcate their land.

All these strategies ultimately serve as proofs of occupancy in support of obtaining land titles. However, the prohibitive cost of land titling makes it an inaccessible tactic for many *campesino* families. Despite the fact that families claimed to have been established in the area for over 80 years on average, only 22% of surveyed households held a property title for their land. Those families with the means to start a land titling process (as 31% of surveyed households were doing at the time) were faced with a

lengthy and difficult process. The family must legally prove before a jury the active and continued occupancy of land over ten years ("short" acquisition) or over twenty years ("long" acquisition) to qualify for "prescriptive acquisition" as part of Art. 4015 and 2384 of the Civil Code. If incapable of doing so, they must follow the conventional titling process and present, among other documents, the following: identity document/passport, shareholders' register, last registration of the administrative body, cadastral certificate, tax valuation, cadastral plan, and demonstration of compliance with Article 10 of Law No. 26737 signed by a qualified professional registered in the jurisdiction (province). Many *campesinos* in the region have invested significant portions of their income to have land plans drawn and to pay lawyers for the titling process, which can drag on for years. At the time of the survey, 31% of households were represented by a lawyer, and the average amount of time since a family had begun a legal process to claim a land title or to contest claims made by others was ten years. Ultimately, these families were commonly told that their land plans had been lost during processing, and people felt that their lawyers often failed to represent their interests due to bribing by agribusinesses.

Along with the enclosure and privatization of land, external actors seeking to consolidate control over land may also resort to intimidation, threats, and violence. During the height of deforestation in the region between 2001 and 2010, armed guards hired by agribusinesses commonly patrolled fenced perimeters. Although the presence of these *matones* (translating to "killers") is less common today, *campesinos* continue to face intimidation. Multiple informants reported that their livestock had been purposely run over by trucks when grazing close to roads, and that it was common for large landowners to shoot livestock that crossed into their farms. This is consistent with findings by Cáceres (2015) and Abt (2015), who discuss similar tactics of intimidation and violence used against *campesinos*. Multiple people also reported that they and their families did not want to venture into the forest anymore, for fear of being shot at or beaten. The vast majority of surveyed people (73%) reported that a member or members of their household had experienced violence or threats made by actors involved in agricultural commodity production. Family members routinely receive verbal threats by farm managers and intermediaries, including children as they walk to school. Less commonly, there have been instances where *campesinos* who contested land claims were not delivered water by local distributors. This occurred in at least four communities over the last five years. To explain this, people alluded to collusion between communal mayors, provincial-level politicians, and agribusinesses. According to key informants, the high level of corruption makes it difficult to gain the support of local politicians in land disputes.

4.3 Enclosures, privatization, and changes to *campesino* society

The changes in land control that have taken place in the region are fundamentally altering the ways in which *campesino* society functions. Prior to the arrival of large farms, land tenure was principally communal – people use the term "*compartido*", or shared, when referring to that form of management, and 95% of surveyed households reported that the community possessed and used communal land as of 20 years ago. According to informants, there were no barriers in the landscape, save occasionally for small *potreros* (livestock paddocks) made of *cerco-rama* enclosures (interweaved vegetal enclosure). Livestock thus grazed in the open forest, returning to the communities to drink water. Early on in the expansion of the commodity frontier, in the 1970s to 1990s, informants reported that the boundaries of large farms were delimited by forest demarcations rather than fences, making it possible to enter these farms to let animals graze. The arrival of the wire fence coincided with the arrival of large soybean operations starting in the 1990s. Between 1990 and 2010, the production of wooden posts used by agribusiness to fence the perimeter of the land they claimed became an important source of income for local *campesino* families. *Campesinos* were also regularly employed by the farms to clear deforested plots of debris and prepare them for soybean cultivation. During the explosive period of expansion of the commodity frontier in Pellegrini between 1995 and 2010, many *campesino* families sold their land or were offered small plots elsewhere in exchange for giving way to agricultural operations. As a result, families that remain living in Pellegrini commonly have access to little land, oftentimes under a couple of hectares. In 2019, 37% of surveyed households reported being in conflict with a large farm, and 20.5% reported being in conflict with other external actors, such as politicians and other land investors.

The subdivision and privatization of land by agribusiness and the taking up of privatization and enclosure as mechanisms used by *campesino* families to confront external pressures has resulted, in turn,

in the weakening of *campesino* social networks, as also noted by Cáceres *et al.* (2010; 2011) for people in the province of Cordoba. The fencing of land by some and not by others heightens tensions surrounding communal access to land and resources. Of the surveyed households, one fifth (19%) reported being involved in a conflict with a neighbor. There are also reports of increasing livestock theft between neighbors. Moreover, the practice of collective maintenance of infrastructure, such as the building and repair of canals for irrigation, has all but disappeared in under twenty years. In communities that have been particularly fragmented by competing interests, factions have formed between families that challenge agribusinesses and those that support them. The latter are sometimes offered money, medication, and transposition by the municipal mayor or directly by farm managers, in exchange for their continued support of agricultural projects. For example, a single mother reported that she was offered monthly transportation to a clinic where one of her children received critical medical treatment, in exchange for supporting the municipal mayor, who in turn openly supported a nearby agricultural expansion project. Overall, the weakening of *campesino* social networks is further enhancing the problematic of *campesino* dispossession, by adding internal conflicts over access to externally induced ones.

4.4 Access loss and livelihood change

4.4.1 Indices of access

The first dimension of the polychoric factor analysis for the *access mechanisms index* (M) explained 34.6% of the variance of the selected data. Of the variables included in the factor analysis, whether the family was represented by a community association, and whether the family was actively represented by a lawyer had the greatest contributions to the first dimension (0.96 and 0.82 loadings, respectively), followed by whether the family was involved or supported by MOCASE (0.48), whether the family had cleared forest demarcations (0.46), whether the family had a property title or was involved in a legal process (0.44), whether the family paid taxes (0.37), and lastly whether the family fenced forest (0.22).

The first dimension of the polychoric factor analysis for the *relational pressures index* (P) explained 36.3% of the variance of the selected data. Of the variables included in this second factor analysis, the largest contributors to the first dimension were whether the family was asked to sign papers (0.97), whether it received violence or threats (0.81), and whether it was offered a certain amount of land (0.78), followed by whether the family was offered to buy their land (0.65), whether it was in conflict with others (0.38), with farms (0.30) or with neighbors (0.29), and whether fences had been erected by others in the vicinity of the household (0.06). The contributions of the included variables are summarized in Table 4, and correlation matrices for the variables included in each of the two indices can be found in Appendix A.

Table 4. Contribution (loadings) of variables to the first dimension of the polychoric factor analyses for access mechanisms (left) and relational access pressures (right).

Access mechanisms Proportion of variance: 0.346		**Relational access pressures** Proportion of variance: 0.363	
Represented by association	0.96	**Asked to sign papers**	0.97
Represented by lawyer	0.82	**Received violence or threats**	0.81
Involved in/supported by MOCASE	0.48	**Offered amount of land**	0.78
Family cleared demarcations	0.46	**Offered to buy land**	0.65
Property title/In legal process	0.44	**Conflict with others**	0.38
Pay/paid land taxes	0.37	**Conflict with farms**	0.30
Family fenced forest	0.22	**Conflict with neighbors**	0.29
		Fences erected by others	0.06

4.4.2 Changes in livestock rearing

The results from our empirical models provide insights into how the changes in land control described above and the ensuing dynamics of access to resources in Pellegrini relate to changes in *campesino* productive strategies. While the access measures were not strongly linked to having or not

having cattle in 2019, the number of cattle a family had was positively linked to the *access mechanism index* (*M*, strategies deployed by families, notably representation by an association or by a lawyer) and the *spatial conditions index* (*S*, the degree to which a household had access to space for cattle rearing), and negatively associated with the *relational access pressures index* (*P*, pressures applied against them, such as whether they were pressured to relinquish access and whether they had experienced violence or threats) (Model 1, Table 5) . Changes in livestock rearing over time (on average decreases in all livestock numbers) were also significantly related to the access indexes (M5, Table 6): the more relational access pressures were experienced by a household, the greater the decrease in their number of cattle between 2000 and 2019. In contrast, there was a positive relationship between the *access mechanisms index* (*M*) and the number of cattle that households were able to keep or incorporate between 2000 and 2019.

Campesino households that deployed access mechanisms and had favourable spatial conditions of access for goat rearing were also more likely to rear goats in 2019 (M2, Table 5). Surprisingly, however, the number of goats reared by a family in 2019 was positively related to *P* and negatively related *S*. This might mean that while making the choice to rear goats depends on the mechanisms a family exercises to maintain their access, rearing more goats could be a strategy adopted by families that face higher external pressures with respect to their access. However, since this is not something that people reported in interviews, it could also reflect a reverse causal effect, where families experienced more negative pressures (e.g., violence, external fencing, etc.) and spatial constraints (fencing) because they had more goats. Over time, however, the same is true for goats as is of cattle: greater deployment of access mechanisms (*M*) is associated with people having retained more goats, whereas greater relational pressures (P) are associated with people having retained fewer (Table 6, M6).

Whether a family engaged in pig rearing in 2019, and how many pigs they had, were both positively related to relational access pressures (Table 5, M3). The positive sign of the spatial conditions index shows that people rear pigs if they have the necessary space for them[6]. Given the positive association of *M* with the number of pigs, it appears that having more pigs may be a strategy for *campesino* families facing high access pressures, but that the ability to do so depends on the household's ability to deploy access mechanisms to maintain their access. These effects are not confirmed, however, in the change analysis, for which the coefficients of access mechanisms are not significant, except for the spatial conditions index (Table 6, M7). Complete summary statistics and model results for both the cross-sectional and change analyses can be found in Appendices B, C, and D, respectively.

These quantitative results partially coincide with our qualitative findings, which indicate that *campesino* families that are more exposed to commodity frontier pressures, and less able to confront them, have turned away from cattle and goat rearing and towards the rearing of pigs, both for subsistence purposes and for sale (18% of households reported selling pigs). This transition was repeatedly stressed by informants, who credited it to the relative ease of rearing pigs within small enclosures, limiting their wandering and subsequent loss or robbery (61% of households surveyed indicated that they had lost livestock to theft); the demand for pigs from both commercial butchers and local families; and the ability for pigs to feed almost exclusively on maize. Indeed, compared to the source of cattle, goat, and sheep feed, which 70% of all households reported were grasses obtained from grazing in the forest, the source of pig feed was dominated by both grazing in the forest (48% of all respondents) and maize and/or soybean bought by the household (43% of all respondents). Moreover, while many *campesinos* buy maize to feed their pigs, others rely on the pigs feeding on maize or soybean from nearby farms. Some have agreements with farm managers or owners to either collect left-over crops, or to let the pigs graze directly in the plots. Indeed, a high proportion of households reported either buying maize (57%), growing maize (24%) (with an increase in the average number of hectares cultivated per household, from 2.5 in 2000 to 3.2 in 2019, further substantiating this shift), or letting their pigs feed in farms (17% with agreement, 6% without agreement from the farmers). These results are further substantiated by reports that the number of pigs reared by *campesino* families in the province of Santiago del Estero is increasing, in part also due to capacitation support offered to families by the Argentina National Institute of Agricultural Technology (INTA) (Razas Porcinas, 2021).

[6] Because the index is calculated over a radius specific to the needs of pig rearing (1km), it only reflects conditions in the immediate vicinity of the farm.

Table 5. Summary double hurdle model results – Cross-sectional analysis

Double Hurdle – Cross-sectional analysis summary

Zero hurdle model coefficients (binomial with logit link):

	Does the household have…			
	… cattle? (M1)	…goats? (M2)	… pigs? (M3)	… kilns? (M4)
(Intercept)	-0.821	-2.480*	-1.231	1.717
Access Mechanisms (M)	0.284	0.795*	-0.290	-0.085
Access pressures (P)	0.218	0.211	0.958*	0.725*
Spatial conditions (2018) (S)	0.160	0.404*	0.488*	0.051
Average member education	2.743	-3.697*	-1.328	-4.690
Femininity index	1.431	1.470	3.480*	1.064
Dependency ratio	-0.019	-0.028	-1.298	-2.109
Distance to town	0.004	0.027	0.041	-0.304.
Distance to water	-5.839	8.601.	-4.750	-16.20

Count model coefficients (truncated Poisson with log link):

	# Cattle (M1)	# Goats (M2)	# Pigs (M3)	# Kilns (M4)
(Intercept)	4.631***	2.659***	1.935***	-0.953
Access Mechanisms (M)	0.230***	0.0378	0.187***	-0.154
Access pressures (P)	-0.109***	0.211***	0.239***	0.471
Spatial conditions (2018) (S)	0.156***	-0.098***	-0.030	-0.025
Average member education	-1.316***	-1.386***	0.248	-15.311*
Femininity index	-1.297***	0.790***	-0.145	3.915
Dependency ratio	-1.083***	-0.131	0.170	-1.584
Distance to town	-0.065***	0.061***	0.053***	0.527
Distance to water	-6.202***	1.795*	-1.036	-18.85**

Signif. Codes (Pr(>|z|)): '***' = p ≤ 0.001; '**' = p ≤ 0.01; '*' = p ≤ 0.05; '.' = p ≤ 0.1.

Table 6. Summary double hurdle model results – Change analysis

Double Hurdle – Change summary

Zero hurdle model coefficients (binomial with logit link):

	Was there a change in whether the household…		
	...had cattle? (M5)	...had goats? (M6)	...had pigs? (M7)
(Intercept)	-0.464	1.907.	1.741
Access Mech (M)	-0.276	0.059	-0.082
Access pressures (P)	0.899*	0.228	0.346
Change Spatial Conditions (2018-2000) (S)	0.232	-0.134	0.589*
Average member education	2.384	-2.810	-4.138
Femininity index	1.403	-0.745	2.491
Dependency ratio	0.768	-0.637	-0.786
Distance to town	0.128	0.102	0.199
Distance to water	3.836	4.808	-3.018

Count model coefficients (truncated Poisson with log link):

	Change in # of cattle (M5)	Change in # of goats (M6)	Change in # of pigs (M7)
(Intercept)	6.191***	5.608***	3.784***
Access Mech (M)	0.026**	0.048***	-0.003
Access pressures (P)	-0.015*	-0.021**	0.012
Change Spatial Conditions (2018-2000) (S)	-0.006	-0.008	0.001
Average member education	-0.045	-0.601***	-0.613***
Femininity index	0.053	0.094*	0.100
Dependency ratio	-0.053	-0.171***	-0.233**
Distance to town	0.0004	0.002	0.005
Distance to water	-0.274	0.346**	0.861

Signif. Codes (Pr(>|z|)): '***' = p ≤ 0.001; '**' = p ≤ 0.01; '*' = p ≤ 0.05; '.' = p ≤ 0.1.

4.4.3 Changes in other livelihood activities

While access was not related to engagement in the production of fence posts, hunting, agricultural employment, and non-agricultural employment across space (Table 18 of Appendix C), it did appear to influence families' paths for some of these activities over time. We found the likelihood of either beginning or maintaining charcoal production to be higher than that of exiting that activity if the household was exposed to more relational access pressures, and that the likelihood of a household never having produced charcoal was lower in places with decreasing spatial access over time (Figure 2). Given the similar effect of relational access pressures on charcoal production across space (Table 5, M4), the activity thus appears to have been a strategy adopted by families experiencing more pressures on access between 2000 and 2019. This may be because of the increased availability of timber for charcoal production following the deforestation of plots or demarcations by agribusiness. In areas where fences impede livestock rearing, it is also possible that *campesino* families turn towards extracting wood for charcoal production, as this can be done irrespective of fences. Qualitative data on charcoal production was limited due to the sensitive nature of fuelwood extraction in the region, which is often done illegally.

With respect to agricultural employment, we found that the greater the decrease in spatial access, the more likely a household was to either maintain or begin agricultural employment, in comparison to the likelihood of the household exiting that activity (Figure 2). It thus appears that seasonal migration for agricultural employment and/or employment in nearby farms was a strategy adopted more frequently by families facing increasing or already severe access restrictions. That being said, the stark decline in participation in agricultural employment between 2000 and 2019 we noted previously also indicates that the entry or the maintaining of this strategy was not widely possible. *Campesinos* reported that the reduced employment in farms was a result of the replacement of manual labor with machinery (specifically for fruit harvesting, and so relating to seasonal employment in other provinces), and of the dwindling demand for labour to clear plots following deforestation in local farms. The decline in employment in farms, as well as the lack of demand for fence posts, points to the rapid opening and then closing in avenues of economic employment for *campesinos* that parallel the transition from early to late stages of commodity frontier expansion.

While we did not find change in hunting participation to be related to the quantitative access measures, *campesino* families did report noticeable declines in wildlife abundance between 2000 and 2019 (half (49%) of households reported no longer being able to hunt certain species), and subsequent difficulties in engaging in hunting activities. These difficulties, which are likely driven by the destruction and fragmentation of habitat for the expansion of agriculture, are substantiated by the large proportion of households that stopped hunting in that time period. A complete summary of the results for the multinomial logistic regressions of the change analysis is provided in Table 23 of Appendix D.

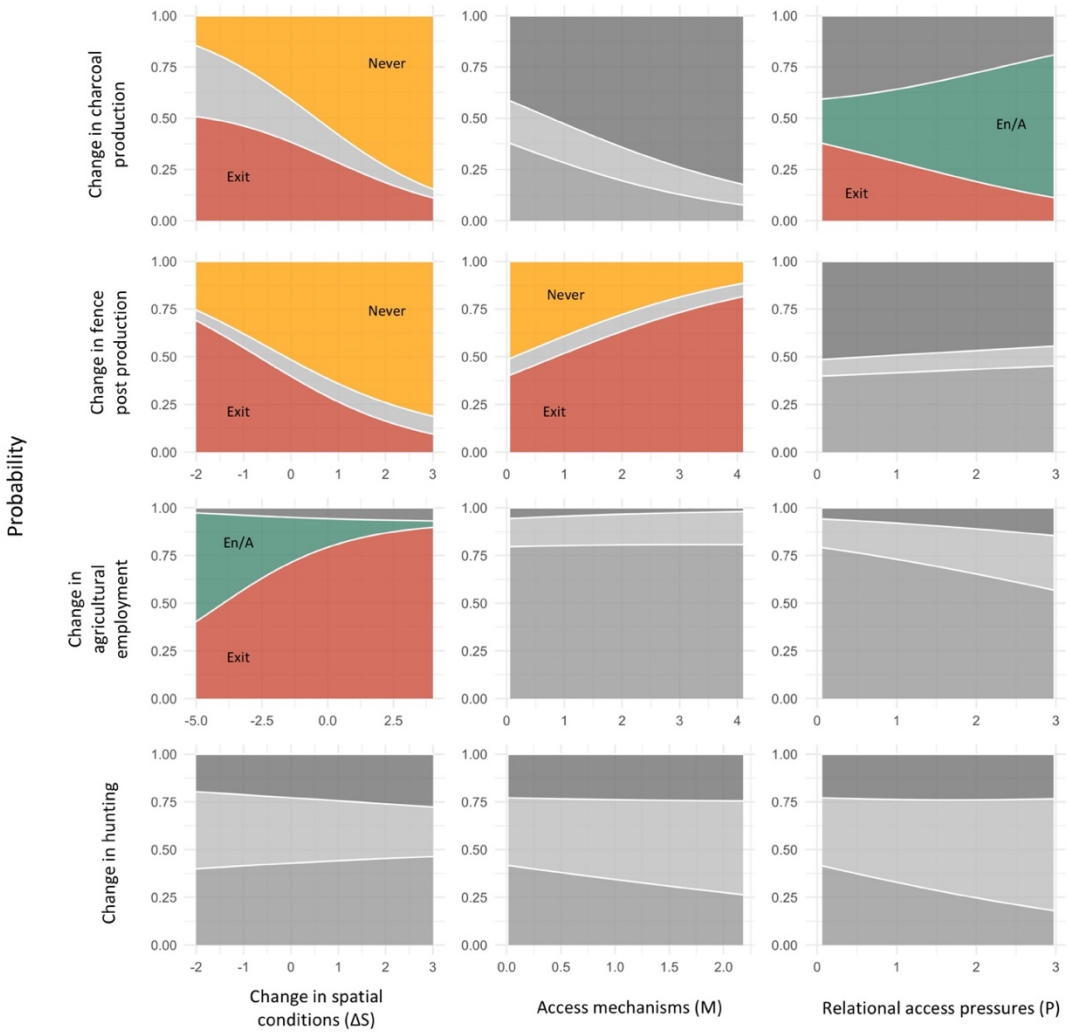

Figure 2. Likelihood of change trajectories along differences in access indices – Change analysis results for multinomial logistic regressions of categorical variables. Coloured models are significant ($p<0.05$) for the given access index, while grey-scale models are insignificant for the given access index.

5. Conclusion

In the Argentine Gran Chaco, the convergence of high levels of tenure insecurity, rural poverty, deforestation, and resource concentration creates a context where access to land and resources for smallholders has direct consequences on their vulnerability. The empirical results from this study indicate that the viability of some smallholder activities is being compromised due to changing land control dynamics in commodity frontiers. These productive issues are likely enhanced by a weakening of smallholder social networks. Moreover, our qualitative findings highlight the difficulties faced by smallholders in maintaining access to their land and resources. As compared to agribusinesses, smallholders have limited access to mechanisms to support their claims. Within the changing landscape of the Gran Chaco, these deep power asymmetries are resulting in the displacement of rural communities, but also in the dispossession of smallholders from their means of production and reproduction.

Together, our qualitative and quantitative results suggest that the ability of campesinos to rear livestock, as well as their ability to engage in the production of charcoal and fence posts and in agricultural employment, is impacted by changes in access across time and space in regions experiencing the expansion of agricultural commodity frontiers. More specifically, our results show that cattle and goat rearing, two activities central to *campesino* livelihoods in the Gran Chaco, are particularly constrained by changes in access. Paralleling these findings, our qualitative data supports, and our

quantitative data partially supports, the thesis that households in Pellegrini are operating a shift towards pig rearing, which may be driven at least in part by the greater stability of this activity in the face of changing land control dynamics as well as by government support for small-scale pig rearing in the province of Santiago del Estero. Moreover, people in situations of high access pressure appear to be relying more on charcoal production and agricultural employment (despite notable decreases in participation in both), indicating that financially remunerated activities may be favoured where access to land and resources is limited.

Overall, we found that how and to what extent smallholders manage to maintain their access to land and resources when faced with increasing spatial access constraints and relational pressures depends on their capabilities, namely the set of mechanisms they have at their disposal to defend their access. Strengthening these access mechanisms through policy and government intervention (e.g., facilitation of legal representation) could thus be a targeted way to support smallholders in the region. Our results also point to the possibility of leveraging the current interest and apparent shift towards small-scale pig rearing to support smallholders in areas where access constraints are limiting opportunities for other livelihood activities.

The implications of our findings go beyond the case at hand. The expansion of large scale, industrialized agriculture throughout the world threatens the livelihoods of millions of rural smallholders. Compared to the visibility of physical displacement of smallholders, their dispossession from their means of production is often subtler and therefore easier to overlook. This creates a risk that crucial productive and social issues will be neglected. We demonstrate that the portfolio of access mechanisms deployed by smallholders, the relational access pressures they face, and the degree to which access to space is restricted for different activities each affect participation in their livelihood activities differently. By disaggregating the effects of these different dimensions of access to land and resources, we show that it is possible to unpack the link between access and livelihoods, allowing to capture more-nuanced impacts for smallholders that might otherwise go unnoticed. Ultimately, in contexts of commodity frontier expansion, identifying and analyzing the different dimensions of smallholder access to land and resources is crucial to designing appropriate policies to reduce their vulnerability.

Author contributions (CRediT roles):

Olivia del Giorgio: Conceptualization; Funding acquisition; Project administration; Primary data collection; Investigation; Methodology; Formal analysis; Visualizations; Writing - original draft; Writing - review & editing; **Yann le Polain de Waroux**: Conceptualization; Funding acquisition; Supervision; Methodology; Writing - review & editing; **Brian E. Robinson**: Methodology; Writing - review & editing.

Declaration of conflict of interest: None

Acknowledgments

We thank Dr. Nestor Ignacio Gasparri for his feedback on an earlier version of this paper, as well as the editor and an anonymous reviewer. We would also like to thank: Feliz Francisco Córdoba, Mariano Hernandez, and the members of the land committee of the department of Pellegrini for their support in the coordination of the data collection; the Institute of Regional Ecology (IER) of the University of Tucuman for providing accommodation and a workspace; Isabel and Maximo Colombres for providing accommodation; as well as all of the people who participated in focus groups, surveys, and key informant interviews.

References

Abt, M.M., 2015. El bosque como espacio multifuncional para las familias campesinas de Santiago del Estero, Argentina. Facultad de Ciencias Forestales.

Aguiar, S., Texeira, M., Paruelo, J.M., Román, M.E., 2016. Conflictos por la Tenencia de la Tierra en la Provincia de Santiago del Estero. Su relación con los cambios en el uso de la tierra 29.

Altrichter, M., Basurto, X., 2008. Effects of land privatisation on the use of common-pool resources of varying mobility in the Argentine Chaco. Conservation and Society 6, 154–165.

Amanor, K.S., 2012. Global resource grabs, agribusiness concentration and the smallholder: two West African case studies. The Journal of Peasant Studies 39, 731–749. https://doi.org/10.1080/03066150.2012.676543

Araghi, 2009. Accumulation by Displacement: Global Enclosures, Food Crisis, and the Ecological Contradictions of Capitalism. Review (Fernand Braudel Center), Political Economic Perspectives on the World Food Crisis 32, 113–146.

Barbetta, P.N., 2009. En los bordes de lo jurídico: conflictos por la tenencia legal de la tierra en Santiago del Estero. Universidad de Buenos Aires Press.

Barbier, E.B., 2012. Scarcity, frontiers and development. The Geographical Journal 178, 110–122. https://doi.org/10.1111/j.1475-4959.2012.00462.x

Barbier, E.B., 2010. Scarcity and Frontiers: How Economies Have Developed Through Natural Resource Exploitation. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9780511781131

Basualdo, E.M., 2006. Estudios de historia económica argentina: desde mediados del siglo XX a la actualidad. FLACSO: Siglo Veintiuno Editores, Buenos Aires, República Argentina.

Bessire, L., 2014. Behold the black caiman: A chronicle of Ayoreo life. University of Chicago Press.

Bolsi, A., Meichtry, N., 2006. Territorio y Pobreza en el Norte Grande Argentino. Revista Electrónica de Geografía y Ciencias Sociales 10, 23.

Borras, S.M., Hall, R., Scoones, I., White, B., Wolford, W., 2011. Towards a better understanding of global land grabbing: an editorial introduction. The Journal of Peasant Studies 38, 209–216. https://doi.org/10.1080/03066150.2011.559005

Braunstein, J., Meichtry, N., 2008. Liderazgo, representatividad y control social en el Gran Chaco. EUDENE.

Cáceres, D.M., 2015. Accumulation by Dispossession and Socio-Environmental Conflicts Caused by the Expansion of Agribusiness in Argentina. Journal of Agrarian Change 15, 116–147.

Cáceres, D.M., Silvetti, F., Guillermo, F., Gustavo, S., Catalina, B., 2011. Los Impactos de la Agriculturización en el Norte de Córdoba. Descampesinización y Persistencia, in: Repensar La Agricultura Familiar: Aportes Para Desentrañar La Complejidad Agraria Pampeana. CICCUS, pp. 77–96.

Cáceres, D.M., Soto, G., Ferrer, G., Silvetti, F., 2010. La expansión de la agricultura industrial en Argentina Central. Su impacto en las estrategias campesinas. Cuadernos de Desarrollo Rural, Bogotá (Colombia), 7, 91–119.

Cameron, A.C., Trivedi, P.K., 1998. Regression Analysis of Count Data. Cambridge University Press, New York, UNITED STATES.

Cardona, G., 2006. Problemas ambientales y socioeconómicos asociados a las actuales formas de uso de la tierra en un área de la Región Chaqueña (Argentina). Revista Ecosistemas 15. https://doi.org/10.7818/re.2014.15-3.00

Cattania, S.L., Rodríguez, A., Rivas, A.I., 2011. Distribución de la Tierra y Pobreza Rural: Análisis comparado entre el Área Campesina Santiagueño-Tucumana y el Gran Chaco Aborigen (Argentina). Revista Geográfica de America Central 1–23.

Censabella, M., 1999. Las lenguas indígenas de la Argentina: una mirada actual, 1. ed. ed, Lenguas indígenas de la Argentina. Eudeba, Buenos Aires.

Chamosa, O., 2008. Indigenous or Criollo: The Myth of White Argentina in Tucuman's Calchaqui Valley. Hahr-hispanic American Historical Review 88, 71–106. https://doi.org/10.1215/00182168-2007-079

Chisleanschi, R., 2020. Los bosques perdidos del Gran Chaco argentino. Mongabay. URL https://es.mongabay.com/2020/05/deforestacion-gran-chaco-argentina-bosques/ (accessed 10.26.20).

Corte, G.D., Recalde, F.V., 2011. La conquista y ocupación de la frontera del Chaco entre Paraguay y Argentina: los indígenas tobas y pilagas y el mundo religioso en la misión Tacaaglé del río Pilcomayo, 1900-1950. Edicions Universitat Barcelona.

Cotula, L., 2012. The international political economy of the global land rush: A critical appraisal of trends, scale, geography and drivers. The Journal of Peasant Studies 39, 649–680. https://doi.org/10.1080/03066150.2012.674940

Cragg, J.G., 1971. Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods. Econometrica 39, 829–844. https://doi.org/10.2307/1909582

Curtis, P.G., Slay, C.M., Harris, N.L., Tyukavina, A., Hansen, M.C., 2018. Classifying drivers of global forest loss. Science 361, 1108–1111. https://doi.org/10.1126/science.aau3445

Dasso, M.C., 2010. Memorias y representaciones sobre el criollo del chaco argentino. Confluenze. Rivista di Studi Iberoamericani 2, 236–253. https://doi.org/10.6092/issn.2036-0967/2008

Deininger, K., Xia, F., 2016. Quantifying Spillover Effects from Large Land-based Investment: The Case of Mozambique. World Development 87, 227–241. https://doi.org/10.1016/j.worlddev.2016.06.016

del Giorgio, O., Messager, M.L., le Polain de Waroux, Y., 2021. Fenced off: Measuring growing restrictions on resource access for smallholders in the Argentine Chaco. Applied Geography 134, 102530. https://doi.org/10.1016/j.apgeog.2021.102530

Dhingra, S., Tenreyro, S., 2021. The rise of agribusinesses and its distributional consequences. CEPR Discussion Papers 15942, C.E.P.R. Discussion Papers.

Di Tella, G., 1982. The Economics of the Frontier, in: Kindleberger, C.P., di Tella, G. (Eds.), Economics in the Long View: Essays in Honour of W. W. Rostow. Palgrave Macmillan UK, London, pp. 210–227. https://doi.org/10.1007/978-1-349-06287-4_13

d.L.T. Oliveira, G., 2013. Land Regularization in Brazil and the Global Land Grab, in: Governing Global Land Deals. John Wiley & Sons, Ltd, pp. 71–92. https://doi.org/10.1002/9781118688229.ch4

Donohue, C., Biggs, E., 2015. Monitoring socio-environmental change for sustainable development: Developing a Multidimensional Livelihoods Index (MLI). Applied Geography 62, 391–403. https://doi.org/10.1016/j.apgeog.2015.05.006

Dorward, A., Anderson, S., Bernal, Y.N., Vera, E.S., Rushton, J., Pattison, J., Paz, R., 2009. Hanging in, stepping up and stepping out: livelihood aspirations and strategies of the poor. Development in Practice 19, 240–247. https://doi.org/10.1080/09614520802689535

Drasgow, F., 1986. Polychoric and polyserial correlations. The Encyclopedia of Statistics 7, 68–74.

Estrada, M. de, 2010. Geografía de la Frontera: Mecanismos de Territorialización del Agronegocio en Frontera Agropecuaria de Santiago del Estero, Argentina. Revista Nera 0, 81–93.

FAO, 2021. Crops and livestock products. Food and Agriculture Organization of the United Nations, FAOSTAT. URL http://www.fao.org/faostat/en/#data/QCL (accessed 10.4.21).

Fehlenberg, V., Baumann, M., Gasparri, N.I., Piquer-Rodriguez, M., Gavier-Pizarro, G., Kuemmerle, T., 2017. The role of soybean production as an underlying driver of deforestation in the South American Chaco. Global Environmental Change 45, 24–34. https://doi.org/10.1016/j.gloenvcha.2017.05.001

Fox, J., 2019. 'polycor' - Polychoric and Polyserial Correlations. R package. CRAN.

Gasparri, N.I., 2016. The transformation of land-use competition in the Argentinean Dry Chaco between 1975 and 2015, in: Land Use Competition. pp. 59–73. https://doi.org/10.1007/978-3-319-33628-2

Gasparri, N.I., Grau, H.R., Gutiérrez Angonese, J., 2013. Linkages between soybean and neotropical deforestation: Coupling and transient decoupling dynamics in a multi-decadal analysis. Global Environmental Change 23, 1605–1614. https://doi.org/10.1016/j.gloenvcha.2013.09.007

Gasparri, N.I., le Polain de Waroux, Y., 2015. The Coupling of South American Soybean and Cattle Production Frontiers: New Challenges for Conservation Policy and Land Change Science: The coupling of soy and cattle frontiers. Conservation Letters 8, 290–298. https://doi.org/10.1111/conl.12121

Goldfarb, L., Haar, G. van der, 2016. The moving frontiers of genetically modified soy production: shifts in land control in the Argentinian Chaco. The Journal of Peasant Studies 43, 562–582. https://doi.org/10.1080/03066150.2015.1041107

Gomez, C., 2009. Conflictos de tierras en la provincia de Chaco (Argentina). Una aproximación a las organizaciones indígenas y sus estrategias territoriales. Revista Geográfica 171–203.

Gordillo, G., 2004. Landscapes of Devils: Tensions of place and memory in the Argentine Chaco. Duke University Press.

Gordillo, G., Hirsch, S., 2008. Indigenous Struggles and Contested Identities in Argentina Histories of Invisibilization and Reemergence. Journal of Latin American Anthropology 8, 4–30. https://doi.org/10.1525/jlca.2003.8.3.4

Gorenstein, S., Ortiz, R.D., 2016. La tierra en disputa. Agricultura, acumulación y territorio en la Argentina reciente. Revista Latinoamericana de Estudios Rurales 1.

Haan, L.D., Zoomers, A., 2005. Exploring the Frontier of Livelihoods Research. Development and Change 36, 27–47. https://doi.org/10.1111/j.0012-155X.2005.00401.x

Hall, D., Hirsch, P., Li, T., 2011. Powers of exclusion: land dilemmas in Southeast Asia. University of Hawai'i Press, Honolulu.

Hansen, C.P., Myers, R., Chhotray, V., 2020. Access Revisited: An Introduction to the Special Issue. Society & Natural Resources 33, 139–145. https://doi.org/10.1080/08941920.2019.1664683

Harvey, D., 2003. The new imperialism. Oxford University Press, Oxford; New York.

Havnevik, K., 2011. Grabbing of African lands for energy and food: implications for land rights, food security and smallholders. Biofuels, land grabbing and food security in Africa 20–43.

Hilbe, J.M., 2009. Logistic Regression Models. Chapman and Hall/CRC. https://doi.org/10.1201/9781420075779

Holt Giménez, E., Shattuck, A., 2011. Food crises, food regimes and food movements: rumblings of reform or tides of transformation? Journal of Peasant Studies 38, 109–144. https://doi.org/10.1080/03066150.2010.538578

Hoyos, L.E., Cingolani, A.M., Zak, M.R., Vaieretti, M.V., Gorla, D.E., Cabido, M.R., 2013. Deforestation and precipitation patterns in the arid Chaco forests of central Argentina. Applied Vegetation Science 16, 260–271. https://doi.org/10.1111/j.1654-109X.2012.01218.x

Ifejika Speranza, C., Wiesmann, U., Rist, S., 2014. An indicator framework for assessing livelihood resilience in the context of social–ecological dynamics. Global Environmental Change 28, 109–119. https://doi.org/10.1016/j.gloenvcha.2014.06.005

INDEC, 2021. Instituto Nacional de Estadística y Censos de la República Argentina. URL https://www.indec.gob.ar/indec/web/Nivel4-Tema-2-41-135 (accessed 10.25.21).

INDEC, 2010. Censo Nacional de Población, Hogares y Viviendas. URL https://www.indec.gob.ar/indec/web/Nivel4-Tema-2-41-135 (accessed 10.31.21).

Jara, C.E., Paz, R.G., 2013. Ordenar el territorio para detener el acarpamiento mundial de tierras: La conflictividad de la estructura agraria de Santiago del Estero y el papel del estado. Proyección 171–195.

Kelly, A.B., Peluso, N.L., 2015. Frontiers of Commodification: State Lands and Their Formalization. Society & Natural Resources 28, 473–495. https://doi.org/10.1080/08941920.2015.1014602

Kleiber, C., Zeileis, A., Jackman, S., 2008. Regression Models for Count Data in R. Journal of Statistical Software 27.

Kolenikov, S., Angeles, G., 2004. The Use of Discrete Data in PCA: Theory, Simulations, and Applications to Socioeconomic Indices 59.

Kossoy, M., Jovanovich, O., 2011. Plan Estratégico Territorial Argentina 2016. Ministerio Secretaría General de la Gobernación, Proyecto SIT SantaCruz 2, 18.

Krapovickas, J., Longhi, F., 2013. Pobrezas, ruralidades y campesinos en el Chaco Argentino a comienzos del siglo XXI. Estudios Rurales 4, 38–76.

Lambin, E.F., Meyfroidt, P., 2011. Global land use change, economic globalization, and the looming land scarcity. PNAS 108, 3465–3472. https://doi.org/10.1073/pnas.1100480108

Le Billon, P., Sommerville, M., 2017. Landing capital and assembling 'investable land' in the extractive and agricultural sectors. Geoforum 82, 212–224. https://doi.org/10.1016/j.geoforum.2016.08.011

le Polain de Waroux, Y., Garrett, R.D., Heilmayr, R., Lambin, E.F., 2016. Land-use policies and corporate investments in agriculture in the Gran Chaco and Chiquitano. Proceedings of the National Academy of Sciences 113, 4021–4026. https://doi.org/10.1073/pnas.1602646113

Leach, M., Mearns, R., Scoones, I., 1999. Environmental Entitlements: Dynamics and Institutions in Community-Based Natural Resource Management. World Development 27, 225–247. https://doi.org/10.1016/S0305-750X(98)00141-7

Leguizamón, A., 2014. Modifying Argentina: GM soy and socio-environmental change. Geoforum 53, 149–160. https://doi.org/10.1016/j.geoforum.2013.04.001

Lende, S.G., 2015. Soybean model in Argentina (1996-2014), an example of accumulation by dispossession. Mercator (Fortaleza) 14, 7–25. https://doi.org/10.4215/RM2015.1403.0001

Li, T.M., 2014. Land's End: Capitalist Relations on an Indigenous Frontier. Duke University Press.

Li, T.M., 2011. Centering labor in the land grab debate. The Journal of Peasant Studies 38, 281–298. https://doi.org/10.1080/03066150.2011.559009

Luna, C., 2018. La problemática de los pueblos originarios en la Argentina y el impacto social de la gestión de los bosques nativos. RLDH 29. https://doi.org/10.15359/rldh.29-2.6

MAGyP, 2021. Estimaciones Agrícolas, Ministerio de Agrícultura, Ganaderia y Pesca. URL http://datosestimaciones.magyp.gob.ar/ (accessed 10.31.21).

MAGyP, 2020. Datos Abiertos Geoespaciales, Ministerio de Agricultura Ganadería y Pesca de la Nación. URL https://geoadmin.agroindustria.gob.ar/geonetwork/srv/spa/catalog.search#/metadata/0f24d92f-fad2-4bbf-a557-f2839297c2b7 (accessed 10.13.20).

Makki, F., 2014. Development by Dispossession: Terra Nullius and the Social-Ecology of New Enclosures in Ethiopia. Rural Sociology 79, 79–103. https://doi.org/10.1111/ruso.12033

Miller, E.S., 1999. Peoples of the Gran Chaco. Bergin & Garvey, Westport, Conn.

Morello, Pengue, Rodriguez, 2013. Un Siglo de Cambios de Diseño del Paisaje: El Chaco Argentino. Transformaciones metabólicas en la Cuenca Baja del río Paraná Proyecto 32.

Mullahy, J., 1986. Specification and testing of some modified count data models. Journal of Econometrics 33, 341–365. https://doi.org/10.1016/0304-4076(86)90002-3

Nolan, C., Goodman, M., Menga, F., 2020. In the shadows of power: the infrastructural violence of thermal power generation in Ghana's coastal commodity frontier. Journal of Political Ecology 27, 775–794.

Oliveira, G. de L.T., 2013. Land Regularization in Brazil and the Global Land Grab, in: Governing Global Land Deals. John Wiley & Sons, Ltd, pp. 71–92. https://doi.org/10.1002/9781118688229.ch4

Otero, G., 2012. The neoliberal food regime in Latin America: state, agribusiness transnational corporations and biotechnology. Canadian Journal of Development Studies / Revue canadienne d'études du développement 33, 282–294. https://doi.org/10.1080/02255189.2012.711747

Paz, R., Jara, C., 2012. El campesino en Santiago del Estero (Argentina): la pobreza de un sector que se resiste a desaparecer (1988-2002). Ager: Revista de estudios sobre despoblación y desarrollo rural = Journal of depopulation and rural development studies 149–175.

PEA, 2010. FAOLEX. Food and Agriculture Organization of the United Nations. URL https://www.fao.org/faolex/results/details/es/c/LEX-FAOC142929/ (accessed 10.31.21).

Peluso, N.L., Lund, C., 2011. New frontiers of land control: Introduction. The Journal of Peasant Studies 38, 667–681. https://doi.org/10.1080/03066150.2011.607692

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Rasmussen, M.B., Lund, C., 2018. Reconfiguring Frontier Spaces: The territorialization of resource control. World Development 101, 388–399. https://doi.org/10.1016/j.worlddev.2017.01.018

Razas Porcinas, 2021. Crece la producción de cerdos en Santiago del Estero. Razas Porcinas – Cría y Producción Porcina y de Carne. URL https://razasporcinas.com/crece-la-produccion-de-cerdos-en-santiago-del-estero/ (accessed 10.30.21).

Reardon, T., Barrett, C.B., Berdegué, J.A., Swinnen, J.F.M., 2009. Agrifood Industry Transformation and Small Farmers in Developing Countries. World Development, Agrifood Industry Transformation and Small Farmers in Developing Countries 37, 1717–1727. https://doi.org/10.1016/j.worlddev.2008.08.023

Revelle, W., 2021. 'psyc' package - Procedures for Psychological, Psychometric, and Personality Research. CRAN.

Ribot, J.C., Peluso, N.L., 2003. A Theory of Access. Rural Sociology 68, 153–181. https://doi.org/10.1111/j.1549-0831.2003.tb00133.x

Richardson, N.P., 2009. Export-Oriented Populism: Commodities and Coalitions in Argentina. St Comp Int Dev 44, 228. https://doi.org/10.1007/s12116-008-9037-5

Rigg, J., 2006. Land, farming, livelihoods, and poverty: Rethinking the links in the Rural South. World Development 34, 180–202. https://doi.org/10.1016/j.worlddev.2005.07.015

Rist, L., Feintrenie, L., Levang, P., 2010. The livelihood impacts of oil palm: smallholders in Indonesia. Biodivers Conserv 19, 1009–1024. https://doi.org/10.1007/s10531-010-9815-z

Rudel, T.K., 2007. Changing agents of deforestation: From state-initiated to enterprise driven processes, 1970–2000. Land Use Policy 24, 35–41. https://doi.org/10.1016/j.landusepol.2005.11.004

Sacchi, L.V., Gasparri, N.I., 2016. Impacts of the deforestation driven by agribusiness on urban population and economic activity in the Dry Chaco of Argentina. Journal of Land Use Science 11, 523–537. https://doi.org/10.1080/1747423X.2015.1098739

Salinas, M.L., 2008. Encomienda, trabajo y servidumbre indígena en Corrientes. Siglos XVII-XVIII (Thesis).

Satorre, E.H., 2005. Cambios tecnológicos en la agricultura argentina actual. Universidad de Buenos Aires Press 6.

Schetter, C., Müller-Koné, M., 2021. Frontiers' violence: The interplay of state of exception, frontier habitus, and organized violence. Political Geography 87, 102370. https://doi.org/10.1016/j.polgeo.2021.102370

Scoones, I., 1998. Sustainable Rural Livelihoods: A Framework for Analysis. IDS Working Paper.

Scoones, Ian., 2015. Sustainable livelihoods and rural development, Agrarian change and peasant studies series ; 4. Fernwood Pub., Blackpoint, Nova Scotia.

Secretaría de Obras Públicas, Argentina, 2018. Plan Estratégico Territorial. Argentina.gob.ar. URL https://www.argentina.gob.ar/obras-publicas/secretaria/plan-estrategico-territorial (accessed 10.31.21).

Sen, A., 1989. Development as Capability Expansion. Journal of Development Planning 19, 41–58.

Shalizi, Z., 2003. Sustainable Development in a Dynamic World: Transforming Institutions, Growth, and Quality of Life. World Bank Publications.

Sly, M.J.H., 2017. The Argentine portion of the soybean commodity chain. Palgrave Communications 3, 1–11. https://doi.org/10.1057/palcomms.2017.95

Sunderlin, W.D., Angelsen, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L., Wunder, S., 2005. Livelihoods, forests, and conservation in developing countries: An Overview. World Development, Livelihoods, forests, and conservation 33, 1383–1402. https://doi.org/10.1016/j.worlddev.2004.10.004

Thaler, G.M., Viana, C., Toni, F., 2019. From frontier governance to governance frontier: The political geography of Brazil's Amazon transition. World Development 114, 59–72. https://doi.org/10.1016/j.worlddev.2018.09.022

Thompson, C.D., 2021. Layers of Loss: Migrants, Small Farmers, and Agribusiness, in: University of Texas Press, pp. 55–87. https://doi.org/10.7560/781771-009

Verbic, F., 2016. An Overview of Administrative Justice in Argentina. BRICS Law J., National University of La Plata School of Law and Social Sciences 3, 57–66. https://doi.org/10.21684/2412-2343-2016-3-2-57-66

White, B., Jr, S.M.B., Hall, R., Scoones, I., Wolford, W., 2012. The new enclosures: critical perspectives on corporate land deals. The Journal of Peasant Studies 39, 619–647. https://doi.org/10.1080/03066150.2012.691879

Wily, L.A., 2012. Looking back to see forward: the legal niceties of land theft in land rushes. The Journal of Peasant Studies 39, 751–775. https://doi.org/10.1080/03066150.2012.674033

Supplementary material

Appendix A - Access variable correlation matrices

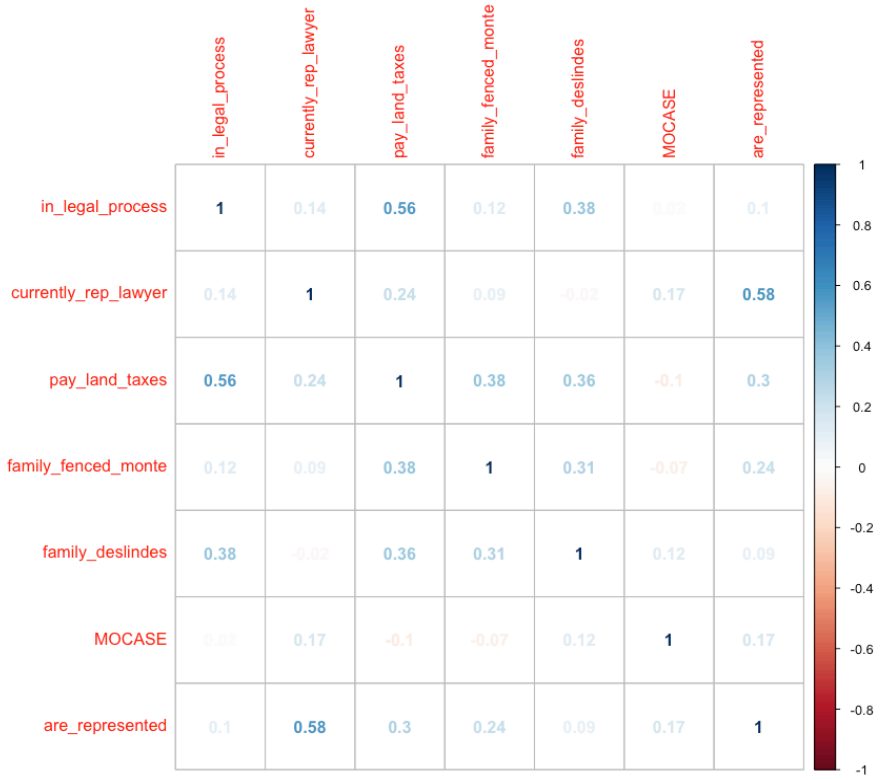

Figure 1. Correlation matrix for access mechanism variables

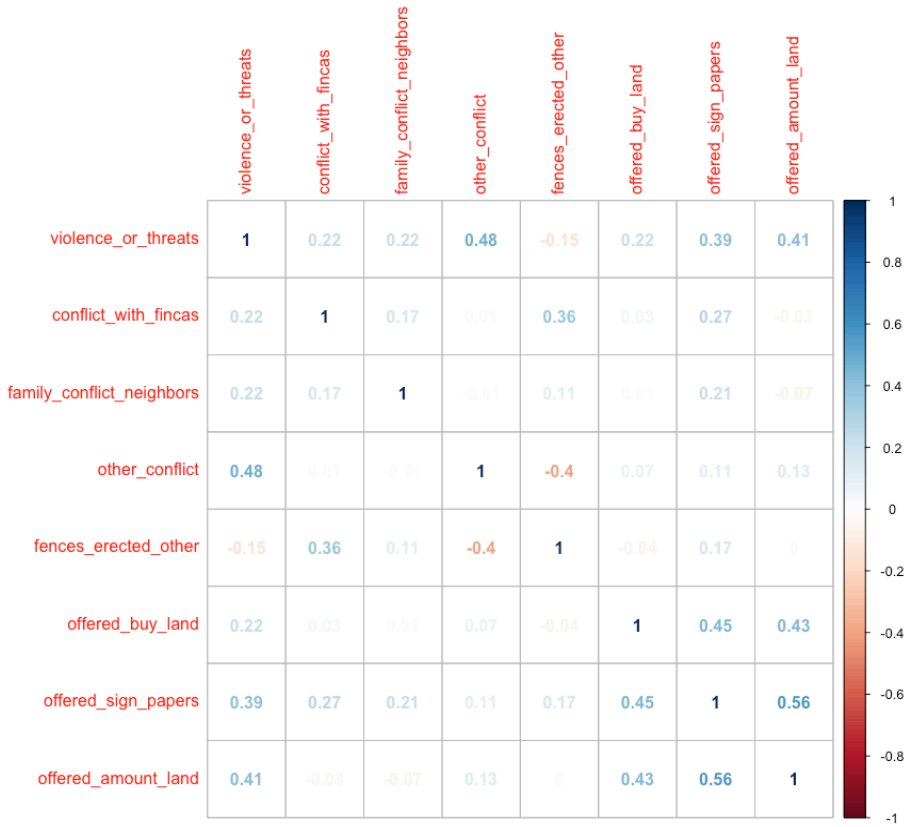

Figure 2. Correlation matrix for relational access pressure variables

Appendix B – Summary statistics

Table 1. Summary statistics – Access mechanism variables

Access mechanisms	Description	Response	Frequency	Percentage
Property title/In legal process	Whether the household has a property title and if not, whether they are involved in an active legal process to obtain a property title.	Property title	22	22.2
		Active legal process	24	30.8
		No property title/legal process	32	41
Pay(ed) land taxes	Whether the household pays or used to pay land taxes.	Before yes, now no	13	16.7
		Yes	22	28.2
		No	43	55.1
Represented by lawyer	Whether the family is currently represented by a lawyer.	Yes	24	30.8
		No	54	69.2
Family fenced forest	Whether the household has fenced forest.	Yes	21	27.3
		No	56	72.7
Family cleared deslindes	Whether the household has cleared forest to demarcate their land.	Yes	36	47.4
		No	40	52.6
Involved/supported by MOCASE	Whether the household is involved or has support from MOCASE (campesino organization).	Not involved or supported	68	87.2
		Involved or supported	10	12.8
Represented by organization	Whether the household is represented by a community association.	Yes	24	30.8
		No	54	69.2

Table 2. Summary statistics – Relational access pressure variables

Relational access pressures	Description	Response	Frequency	Percentage
Received violence or threats	Whether a member or members of the household have experienced violence or threats made by actors directly or indirectly involved in commodity production.	Yes	21	73.1
		No	57	26.9
Conflict with farms	Whether the household is involved in a conflict with a farm.	Yes	28	36.8
		No	48	63.2
Conflict with neighbors	Whether the household is involved in a conflict with neighbors.	Yes	15	19.2
		No	63	80.8
Conflict with others	Whether the household is involved in a conflict with others (i.e. speculators, investors etc.).	Yes	16	20.5
		No	62	79.5
Fences erected by others	Whether actors directly or indirectly involved in commodity production have fenced land in the vicinity of the household.	Yes	60	76.9
		No	18	23.1
Offered to buy land	Whether the household has been offered sum in exchange for their land. Measure of pressure.	Yes	15	19.2
		No	63	80.8
Asked to sign papers	Whether the household has been asked to sign papers. Measure of pressure.	Yes	14	18.2
		No	63	81.8
Offered amount of land	Whether the household has been offered a certain amount of land. Measure of pressure.	Yes	9	11.7

Table 3. Summary statistics – Other access variables

Other access variables	Description	Response	Frequency	Percentage
Tenure form	Tenure form according to argentine national census (CNA 2002) categories.	*Ocupación con permiso*	1	1.3
		Ocupación de hecho	55	71.4
		Sucesión individual	4	5.2
		Property	17	22.1
Character of legal process	The type of legal process the family is involved in.	Communal	13	16.9
		In group	5	6.5
		Individual	5	6.5
		No legal process	54	70.1
Historic communal land use	Whether, historically (>20 years ago), community had and used communal land.	Yes	35	94.6
		No	2	5.4
Family uses communal forest	Whether the family uses communal forest.	Yes	49	67.1
		No	24	32.9
Origin conflict	Origin of the actor(a) that the family is in conflict with.	Another department in Santiago del Estero	12	32.4
		Foreigner	2	5.4
		From the community	6	16.2
		Pellegrini	4	10.8
		Buenos Aires	9	24.3
		Salta	2	5.4
		Tucuman	13	35.1
		Cordoba	2	5.4
Purpose of fencing	Purpose for which family fenced or is currently fencing.	Facilitates livestock production	16	21.6
		To claim/protect land	40	54.1
		To exclude livestock	1	1.4
Communal forest fencing	How communal forest is delimited/protected.	Demarcated	17	85.0
		Partially fenced	2	10.0
		Fully fenced	1	5.0
External fencing by whom	Whom, excluding family, fenced in the surroundings.	Large farms	58	76.3
		Politicians	4	5.3
		Individuals (not neighbors)	10	13.2
		Businessperson	1	1.3

Table 4. Summary statistics – Livestock-related livelihood activities

Activity variable - Livestock	Mean (2000)	SD (2000)	Mean (2019)	SD (2019)	Average change (2019-2000)	Average change SD
Number of cattle	36.8	71	19.8	38.7	-17	62.8
Number of goats	42.6	50.4	9.6	14.5	-33	48
Number of pigs	12.3	16.2	6.8	9.8	-5.5	11.7

Table 5. Summary statistics – Change in non-livestock-related livelihood activities

Activity change summary	Response	Frequency	Percentage
Change fence post production	Always	8	10.3
	Entry	5	6.4
	Exit	29	37.2
	Never	36	46.2
Change charcoal production	Always	14	17.9
	Entry	10	12.8
	Exit	25	32
	Never	29	37.2
Change hunting	Always	24	35.8
	Entry	0	0
	Exit	28	41.8
	Never	15	22.4
Change agricultural employment	Always	14	18.2
	Entry	0	0
	Exit	57	74
	Never	6	7.8

Table 6. Summary statistics – Control variables

Control variable	**Calculation**	**Mean**
Dependency ratio (%)	Number of household members over the age of 15 and under the age of 65, divided by the total number of household members.	0.3
Average member education (score)	Levels of education assigned as follows: <5 years of education = 0; 5-10 years of education = 0.5; +10 years of education = 1. Levels then averaged across all members 15 years or older.	0.1
Femininity index (score)	Sex assigned as: Male = 0; Female = 1. Household femininity averaged across all members 15 years or older.	0.4
Distance to town (weighted km)	Cost distance calculated by distinguishing between dirt roads (cost = 10), consolidated roads (cost = 1), and no roads (cost = 1000).	3.7
Distance to water (km)	Euclidean distance from household to nearest river (intermittent or perennial).	0.1

Table 7. Summary statistics – Other demographic variables

Other demographic variables	**Mean**
Average member age (years)	40.8
Average number of household members	4.1
Average years since family arrival	88.3

Table 8. Summary statistics – Livestock feeding location (2019)

Livestock feeding location (2019)	**Response**	**Frequency**	**Percentage**
Private/fenced forest	Yes	15	19.2
	No	50	64.1
	No livestock	13	16.7
Private/fenced pasture	Yes	11	14.1
	No	54	69.2
	No livestock	13	16.7
Private/fenced paddocks	Yes	6	7.7
	No	59	75.6
	No livestock	13	16.7
Private enclosure - cerco rama	Yes	2	2.6
	No	63	80.8
	No livestock	13	16.7
Open/communal forest	Yes	49	62.8
	No	16	20.5
	No livestock	13	16.7
Inside farms	Yes	7	9.0
	No	58	74.4
	No livestock	13	16.7

Table 9. Summary statistics – Source of bovine/caprine/ovine feed (2019)

Source of bovine/caprine/ovine feed (2019)	Response	Frequency	Percentage
Alfalfa	Yes	24	31.2
	No	34	44.2
	No bovine/caprine/ovine	19	24.7
Tuna	Yes	5	6.5
	No	53	68.8
	No bovine/caprine/ovine	19	24.7
Forest fruits	Yes	4	5.2
	No	54	70.1
	No bovine/caprine/ovine	19	24.7
Grazing in the forest	Yes	54	70.1
	No	4	5.2
	No bovine/caprine/ovine	19	24.7
Family cultivates grasses	Yes	19	24.7
	No	39	50.6
	No bovine/caprine/ovine	19	24.7
Family cultivates corn	Yes	11	14.3
	No	47	61.0
	No bovine/caprine/ovine	19	24.7
Family buys corn	Yes	19	24.7
	No	39	50.6
	No bovine/caprine/ovine	19	24.7
Family harvests remaining crop from farm with agreement	Yes	5	6.5
	No	53	68.8
	No bovine/caprine/ovine	19	24.7
Animals enter farms to graze, without agreement	Yes	9	11.7
	No	49	63.6
	No bovine/caprine/ovine	19	24.7

Table 10. Summary statistics – Source of pig feed (2019)

Source of pig feed (2019)	Response	Frequency	Percentage
Grazing in the forest	Yes	36	48.0
	No	15	20.0
	No pigs	24	32.0
Family cultivates grasses	Yes	6	8.0
	No	45	60.0
	No pigs	24	32.0
Family buys grasses/hay/alfalfa	Yes	2	2.7
	No	49	65.3
	No pigs	24	32.0
Family cultivates corn	Yes	1	1.3
	No	50	66.7
	No pigs	24	32.0
Family buys corn/soybean	Yes	43	57.3
	No	8	10.7
	No pigs	24	32.0
Family harvests remaining crop from farm/animals allowed to graze with agreement	Yes	13	17.1
	No	40	52.6
	No pigs	24	32.0
Animals enter farms to graze, without agreement	Yes	4	5.3
	No	47	62.7
	No pigs	24	32.0

Table 11. Summary statistics – Livestock sale (2019)

Livestock sale (2019)	Response	Frequency	Percentage
Sell cattle	Yes	18	23.1
	No	69	76.9
Cattle sale to whom	Producers from the area	4	5.1
	Local butchers	14	17.9
	Neighbors	5	6.4
	Intermediary runners	1	1.3
Sell goats	Yes	7	9.0
	No	71	91.0
Sell pigs	Yes	14	17.9
	No	64	82.1

Table 12. Summary statistics – Reason for loss of livestock (2019)

Reason for loss of livestock (2019)	Response	Frequency	Percentage
Disease	Yes	23	29.9
	No	41	53.2
	No livestock	13	16.9
Theft	Yes	47	61.0
	No	17	22.1
	No livestock	13	16.9
Road collision	Yes	6	7.8
	No	58	75.3
	No livestock	13	16.9
Pesticides	Yes	2	2.6
	No	62	80.5
	No livestock	13	16.9
Malnutrition	Yes	11	14.3
	No	53	68.8
	No livestock	13	16.9
Dehydration	Yes	7	9.1
	No	57	74.0
	No livestock	13	16.9
Loss in open forest	Yes	8	10.4
	No	56	72.7
	No livestock	13	16.9
Loss due to fences	Yes	37	48.1
	No	27	35.1
	No livestock	13	16.9
They do not know	Yes	4	5.2
	No	60	77.9
	No livestock	13	16.9
There is no loss	Yes	4	5.2
	No	60	77.9
	No livestock	13	16.9

Table 13. Summary statistics – Activity variable – Non-livestock related

Activity variable - Non-livestock	Response	Frequency (2000)	Percentage (2000)	Frequency (2019)	Percentage (2019)
Produce fence posts	Yes	37	47.4	13	16.7
	No	41	52.6	65	83.3
Produce charcoal	Yes	39	50	24	30.8
	No	39	50	54	69.2
Family hunts	Yes	52	77.6	34	43.6
	No	15	22.4	44	56.4
Agricultural employment (including seasonal migration)	Yes	71	91	14	18.2
	No	7	9	63	81.8
Non-agricultural Employment	Yes	-	-	20	25.6
	No	-	-	58	74.4

* - signifies no data

Table 14. Summary statistics – Reason for change in fence posts/charcoal production (2019)

Reason for change in fence posts/charcoal production (2019)	Reason	Response	Frequency	Percentage
Reason for not producing fence posts	No more trees	Yes	28	36.8
		No	35	46.1
		Produce fence posts	13	17.1
	Because of fences	Yes	8	10.5
		No	55	72.4
		Produce fence posts	13	17.1
Reason for not producing charcoal	No more trees	Yes	16	21.1
		No	37	48.7
		Produce charcoal	23	30.3
	They aren't allowed	Yes	3	3.9
		No	50	65.8
		Produce charcoal	23	30.3
	Because of fences	Yes	7	9.2
		No	46	60.5
		Produce charcoal	23	30.3
Reason no fence posts/charcoal	Protect the forest	Yes	2	2.7
		No	47	62.7
		Produce posts/charcoal	26	34.7

Table 15. Summary statistics – Cultivation (2019)

Activity - Cultivation (2019)	Response	Frequency	Percentage
Plant corn	Yes	19	24.4
	No	59	75.6
Plant grasses	Yes	20	25.6
	No	58	74.4
Tuna cultivation	Yes	6	7.7
	No	72	92.3
Other cultivation	Yes	11	14.1
	No	67	85.9

Table 16. Summary statistics – Other livelihood variables (numeric)

Other livelihood variables (numeric)	Mean	n
Hectares cultivated today	3.2	78
Hectares cultivated 20 years ago	2.5	61
Number kilns (2019)	0.6	78
Diameter kilns (2019)	1.8	77
Number pensions (per child)	1	78
Number pensions (disability)	0.2	78
Number pensions (retired)	0.7	78

Table 17. Summary statistics – Forest livelihoods (2019)

Forest livelihoods (2019)	Response	Frequency	Percentage
Change capacity to obtain wood	Yes	36	75.0
	No	12	25.0
Wildlife is more abundant today	Yes	3	3.9
	No	51	66.2
	Do not hunt	23	29.9
No longer hunt certain species	Yes	38	49.4
	No	13	16.9
	Do not hunt	26	33.8
Family eats wildlife	Yes	38	48.7
	No	40	51.3
Family sells wildlife	No	32	42.1
	Do not hunt	44	57.9
Organized hunting	Yes	13	16.7
	No	65	83.3
Hunt using weapons (as opposed to dogs)	Yes	22	28.2
	No	12	15.4
	Do not hunt	44	56.4

Appendix C – Cross-sectional analysis results

Table 18. Binomial (link logit) single time-point models

	Hunting	Fence post production	Agricultural Employment	Non-agricultural Employment
(Intercept)	-0.75	-2.65	-0.24	-0.76
	(1.01)	(1.64)	(1.12)	(1.17)
Access mechanisms (M)	0.40	0.41	-0.22	-0.09
	(0.30)	(0.44)	(0.37)	(0.32)
Relational access pressures (P)	0.20	-0.10	0.38	0.18
	(0.26)	(0.38)	(0.31)	(0.31)
Spatial access conditions (S)	0.09	0.48	-0.17	-0.26
	(0.18)	(0.27)	(0.20)	(0.22)
Average member education	-1.12	-1.60	-1.53	6.37 **
	(1.77)	(3.27)	(2.56)	(2.10)
Femininity index	2.06	2.95	0.82	0.47
	(1.31)	(2.12)	(1.59)	(1.49)
Dependency ratio	-0.85	-3.82	-1.60	-0.10
	(0.94)	(2.19)	(1.38)	(1.18)
Distance to town	0.06	-0.20	-0.06	-0.28
	(0.06)	(0.17)	(0.09)	(0.17)
Distance to water	-5.68	-8.39	-3.82	0.88
	(4.14)	(6.40)	(5.19)	(5.10)
N	72	72	71	72
AIC	104.01	62.83	79.98	82.53
BIC	124.50	83.32	100.34	103.02
Pseudo R2	0.22	0.36	0.12	0.30
Model dispersion	1.136477	0.9827524	1.007231	1.045602

Table 19. Double-hurdle results – Single time-point analysis – Number of cattle

Number cattle

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.821379	0.988035	-0.831	0.406
Access mechanisms (M)	0.284296	0.304139	0.935	0.350
Relational access pressures (P)	0.218239	0.271654	0.803	0.422
Spatial access conditions (S) – Cattle (2018)	0.159870	0.169948	0.941	0.347
Average member education	2.742623	1.688979	1.624	0.104
Femininity index	1.431144	1.318177	1.086	0.278
Dependency ratio	-0.019133	0.905174	-0.021	0.983
Distance to town	0.004136	0.049496	0.084	0.933
Distance to water	-5.839189	4.117123	-1.418	0.156

Count model coefficients (truncated Poisson with log link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	4.63082	0.13575	34.114	<2e-16 ***
Access mechanisms (M)	0.23049	0.03708	6.215	**5.12e-10 *** **
Relational access pressures (P)	-0.10871	0.02608	-4.168	**3.07e-05 *** **
Spatial access conditions (S) – Cattle (2018)	0.15652	0.01707	9.171	**<2e-16 *** **
Average member education	-1.31571	0.18701	-7.035	1.99e-12 ***
Femininity index	-1.29670	0.19323	-6.711	1.94e-11 ***
Dependency ratio	-1.08299	0.11207	-9.664	<2e-16 ***
Distance to town	-0.06497	0.00686	-9.471	<2e-16 ***
Distance to water	-6.20205	0.46861	-13.235	<2e-16 ***

Model dispersion	4.015062
Number of iterations in BFGS optimization:	19
Log-likelihood:	-640.6 on 18 Df

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 20. Double-hurdle results – Single time-point analysis – Number of goats

Number goats

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-2.48471	1.11974	-2.219	0.0265 *
Access mechanisms (M)	0.79508	0.33582	2.368	**0.0179 ***
Relational access pressures (P)	0.21068	0.28058	0.751	0.4527
Spatial access conditions (S) – Goats (2018)	0.40375	0.18900	2.136	**0.0327 ***
Average member education	-3.69765	1.82664	-2.024	0.0429 *
Femininity index	1.47036	1.27836	1.150	0.2501
Dependency ratio	-0.02830	0.93020	-0.030	0.9757
Distance to town	0.02716	0.05153	0.527	0.5982
Distance to water	8.60104	4.63964	1.854	0.0638 .

Count model coefficients (truncated Poisson with log link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.658925	0.208175	12.773	<2e-16 ***
Access mechanisms (M)	0.037856	0.044159	0.857	0.391307
Relational access pressures (P)	0.210872	0.034438	6.123	**9.17e-10 *** **
Spatial access conditions (S) – Goats (2018)	-0.097615	0.029136	-3.350	**0.000807 *** **
Average member education	-1.386211	0.371226	-3.734	0.000188 ***
Femininity index	0.789927	0.219944	3.591	0.000329 ***
Dependency ratio	-0.130697	0.164443	-0.795	0.426740
Distance to town	0.061218	0.006459	9.478	<2e-16 ***
Distance to water	1.794637	0.755214	2.376	0.017486 *

Model dispersion	2.242336
Number of iterations in BFGS optimization:	18
Log-likelihood:	-244 on 18 Df

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 21. Double-hurdle results – Single time-point analysis – Number of pigs

Number pigs

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.23082	1.03501	-1.189	0.2344
Access mechanisms (M)	-0.29058	0.33250	-0.874	0.3822
Relational access pressures (P)	0.95804	0.42499	2.254	**0.0242 ***
Spatial access conditions (S) – Pigs (2018)	0.48839	0.22855	2.137	**0.0326 ***
Average member education	-1.32810	1.86464	-0.712	0.4763
Femininity index	3.48019	1.57993	2.203	0.0276 *
Dependency ratio	-1.29840	0.99765	-1.301	0.1931
Distance to town	0.04118	0.09625	0.428	0.6687
Distance to water	-4.74988	5.26636	-0.902	0.3671

Count model coefficients (truncated Poisson with log link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.935380	0.214296	9.031	<2e-16 ***
Access mechanisms (M)	0.187549	0.048226	3.889	**0.000101 *** **
Relational access pressures (P)	0.239079	0.043183	5.536	**3.09e-8 *** **
Spatial access conditions (S) – Pigs (2018)	-0.030490	0.039002	-0.782	0.434361
Average member education	0.247801	0.437897	0.566	0.571470
Femininity index	-0.145379	0.295508	-0.492	0.622745
Dependency ratio	0.170270	0.230776	0.738	0.460625
Distance to town	0.052760	0.009156	5.762	8.29e-09 ***
Distance to water	-1.035937	1.115631	-0.929	0.353114

Model dispersion	2.775747
Number of iterations in BFGS optimization:	16
Log-likelihood:	-217.8 on 18 Df

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 22. Double-hurdle results – Single time-point analysis – Number of kilns

Number kilns

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.71746	1.16162	1.479	0.13927
Access mechanisms (M)	-0.08545	0.38057	-0.225	0.82235
Relational access pressures (P)	0.72508	0.34166	2.122	**0.03382 ***
Spatial access conditions (S) – Charcoal (2018)	0.05132	0.21380	0.240	0.81030
Average member education	-4.69026	2.91755	-1.608	0.10792
Femininity index	1.06388	1.62521	0.655	0.51272
Dependency ratio	-2.10891	1.35887	-1.552	0.12067
Distance to town	-0.30417	0.16848	-1.805	0.07103 .
Distance to water	-16.19970	5.32618	-3.042	0.00235 **

Count model coefficients (truncated Poisson with log link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.95292	1.90095	-0.501	0.6162
Access mechanisms (M)	-0.15363	0.49791	-0.309	0.7577
Relational access pressures (P)	0.47129	0.29289	1.609	0.1076
Spatial access conditions (S) – Charcoal (2018)	-0.02542	0.17455	-0.146	0.8842
Average member education	-15.31063	7.14192	-2.144	0.0321 *
Femininity index	3.91535	3.25088	1.204	0.2284
Dependency ratio	-1.58435	1.62816	-0.973	0.3305
Distance to town	0.52734	0.42312	1.246	0.2127
Distance to water	-18.84889	12.84360	-1.468	0.1422 **

Model dispersion	1.019288
Number of iterations in BFGS optimization:	86
Log-likelihood:	-44.55 on 18 Df

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Appendix D – Change analysis results

Table 23. Multinomial logistic regressions – Change analysis results for categorical variables. Entry/Always, Exit, and Never "paths" are simplified as EN/A, EX, and N, respectively.

	Change charcoal production		**Change fence post production**		**Change hunting**		**Change agricultural employment**	
Reference Path	*EX (23)*		*EX (28)*		*EX (26)*		*EX (52)*	
	EN/A	N	EN/A	N	EN/A	N	EN/A	N
n	21	28	11	33	23	13	13	6
Access mechanisms (M)	0.216	0.564	-0.229	**-0.542***	0.360	0.243	0.038	-0.270
	(0.419)	(0.425)	(0.441)	(0.319)	(0.419)	(0.462)	(0.383)	(0.614)
Relational access pressures (P)	**0.818****	0.156	0.017	-0.093	0.455	0.294	0.335	0.427
	(0.402)	(0.401)	(0.399)	(0.285)	(0.365)	(0.396)	(0.308)	(0.475)
Change Spatial access conditions (S) – (2000-2018)	-0.114	**0.654****	0.500	**0.627****	-0.118	0.039	**-0.402***	0.017
	(0.292)	(0.294)	(0.326)	(0.255)	(0.252)	(0.281)	(0.225)	(0.296)
Average member education	-3.466	4.424*	-2.247	1.131	-2.781	1.698	-1.470	-6.081
	(3.420)	(2.346)	(3.435)	(1.792)	(2.773)	(2.126)	(2.620)	(4.895)
Femininity index	1.423	-0.161	2.130	-1.238	2.747	0.494	0.695	-0.593
	(1.753)	(1.816)	(2.129)	(1.379)	(1.690)	(1.674)	(1.670)	(2.273)
Dependency ratio	-2.249	0.814	-4.856**	-0.786	-2.027	-0.738	-1.901	0.104
	(1.483)	(1.220)	(2.245)	(0.999)	(1.282)	(1.234)	(1.457)	(1.637)
Distance to town	-0.139	0.304**	-0.075	0.093	0.099	0.029	-0.089	-0.138
	(0.183)	(0.132)	(0.167)	(0.082)	(0.072)	(0.099)	(0.102)	(0.202)
Distance to water	-14.604**	10.757	-8.499	0.934	-6.028	-1.993	-5.890	2.578
	(5.946)	(6.692)	(6.319)	(4.674)	(5.394)	(5.999)	(5.397)	(7.319)
(Intercept)	1.753*	-2.823**	0.346	0.376	-0.224	-0.705	-0.363	-1.366
	(1.030)	(1.374)	(1.139)	(0.919)	(0.996)	(1.107)	(0.973)	(1.319)
Akaike Inf. Crit.	139.661	139.661	155.382	155.382	150.965	150.965	128.960	128.960
Model dispersion	0.5785095		0.6820057		0.6294984		0.511319	
Note:	*p<0.1;* ***p<0.05;*** p<0.01							

Table 24. Double-hurdle results – Change analysis – Change in cattle

Change cattle

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.46415	0.87633	-0.530	0.596
Access mechanisms (M)	-0.27627	0.31252	-0.884	0.377
Relational access pressures (P)	0.89925	0.44638	2.015	**0.044***
Change Spatial access conditions (S) – Cattle (2018-2000)	0.23258	0.22986	1.012	0.312
Average member education	2.38430	2.29566	1.039	0.299
Femininity index	1.40276	1.59931	0.877	0.380
Dependency ratio	0.76782	1.15332	0.666	0.506
Distance to town	0.12796	0.09577	1.336	0.182
Distance to water	3.83616	4.56589	0.840	0.401

Count model coefficients (truncated Poisson with log link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	6.1911990	0.0229863	269.343	<2e-16***
Access mechanisms (M)	0.0260716	0.0082867	3.146	**0.00165****
Relational access pressures (P)	-0.0150954	0.0062588	-2.412	**0.01587***
Change Spatial access conditions (S) – Cattle (2018-2000)	-0.0057987	0.0051188	-1.133	0.25729
Average member education	-0.0450242	0.0383424	-1.174	0.24029
Femininity index	0.0525782	0.0337085	1.560	0.11881
Dependency ratio	-0.0529425	0.0227657	-2.326	0.02004*
Distance to town	0.0004268	0.0011629	0.367	0.71358
Distance to water	-0.2740204	0.1030731	-2.659	0.00785

Model dispersion	1.341227
Number of iterations in BFGS optimization:	16
Log-likelihood:	312 on 18 Df

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 25. Double-hurdle results – Change analysis – Change in goats

Change goats

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.90742	1.04324	1.828	0.0675 ·
Access mechanisms (M)	0.05958	0.35681	0.167	0.8674
Relational access pressures (P)	0.22852	0.39021	0.586	0.5581
Change Spatial access conditions (S) – Goats (2018-2000)	-0.13450	0.19963	-0.674	0.5005
Average member education	-2.80995	2.03328	-1.382	0.1670
Femininity index	-0.74461	1.65079	-0.451	0.6519
Dependency ratio	-0.63732	1.18940	-0.536	0.5921
Distance to town	0.10233	0.11326	0.904	0.3663
Distance to water	4.80774	5.42507	0.886	0.3755

Count model coefficients (truncated Poisson with log link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	5.607843	0.024494	228.948	<2e-16 ***
Access mechanisms (M)	0.048031	0.008729	5.502	**3.75e-08 *** **
Relational access pressures (P)	-0.021085	0.008017	-2.630	**0.00853 ** **
Change Spatial access conditions (S) – Goats (2018-2000)	-0.008459	0.005819	-1.454	0.14601
Average member education	-0.601191	0.059477	-10.108	<2e-16 ***
Femininity index	0.094270	0.039135	2.409	0.01600 *
Dependency ratio	-0.170609	0.030919	-5.518	3.43 e-08 ***
Distance to town	0.002364	0.001483	1.595	0.11081
Distance to water	0.345903	0.132756	2.606	0.00917 **

Model dispersion	1.544784
Number of iterations in BFGS optimization:	15
Log-likelihood:	-568.3 on 18 Df

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 26. Double-hurdle results – Change analysis – Change in pigs

Change pigs

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.74072	1.19447	1.457	0.1450
Access mechanisms (M)	-0.08198	0.42318	-0.194	0.8464
Relational access pressures (P)	0.34655	0.44807	0.773	0.4393
Change Spatial access conditions (S) – Pigs (2018-2000)	0.58882	0.26840	2.194	**0.0282 ***
Average member education	-4.13800	2.28053	-1.814	0.0696 .
Femininity index	2.49098	1.93801	1.285	0.1987
Dependency ratio	-0.78564	1.27189	-0.618	0.5368
Distance to town	0.19888	0.21177	0.939	0.3477
Distance to water	-3.01765	6.15592	-0.490	0.6240

Count model coefficients (truncated Poisson with log link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	3.783999	0.059867	63.206	<2e-16 ***
Access mechanisms (M)	-0.002936	0.021931	-0.134	0.89350
Relational access pressures (P)	0.012133	0.019344	0.627	0.53049
Change Spatial access conditions (S) – Pigs (2018-2000)	0.001204	0.013977	0.086	0.93136
Average member education	-0.613022	0.157230	-3.899	9.66e-05 ***
Femininity index	0.100463	0.098358	1.021	0.30706
Dependency ratio	-0.233011	0.077144	-3.020	0.00252 **
Distance to town	0.004682	0.003490	1.342	0.17975
Distance to water	0.861274	0.316203	2.724	0.00645

Model dispersion	1.848042
Number of iterations in BFGS optimization:	16
Log-likelihood:	-266.1 on 18 Df

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1