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## A policy mix approach for assessing rural household resilience to climate shocks: Insights from Northeast Brazil

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### ABSTRACT

Climate change adaptation is a cross-cutting policy issue that accounts for a diversity of policy approaches, tools, and goals. Unclear conceptualization and the absence of comparable metrics are challenges that hinder the assessment of progress toward policy goals. This study draws on a policy mix approach to analyze adaptation efforts at the subnational level. It examines the complex pathways by which rural households in Northeast Brazil build resilience capacities and deal with drought with policy support. Particular emphasis is placed on the implementation of policy mixes composed of climate-related and broader development instruments as well as on the coordination of these instruments in the mix. The resilience of households benefiting from different instrument mixes is examined, and the results show a trend toward an intermediary value for our composite resilience metric highlighting the adoption of coping rather than transformative adaptive strategies. However, changing these trends toward enhanced resilience pathways depends on the improved implementation of the policy mixes and on political factors that include administrative issues, but also coordination and negotiation among policy actors.

### KEYWORDS



Climate change adaptation; policy mix; policy integration; resilience assessment; Northeast Brazil



### Introduction

Climate change presents significant threats to rural populations and food systems, and water insecurity is a major concern regarding these impacts (IPCC, 2014). Consequently, climate adaptation has emerged as a core component of climate policy agendas. There is a growing urgency for national and subnational governments to develop resilience to climate shocks (Biesbroek & Lesnikowski, 2018; Vogel & Henstra, 2015). Nevertheless, as a complex and cross-cutting policy issue, climate adaptation accounts for diverse and sometimes competing policy approaches, tools, and goals. Unclear conceptualization has been a key barrier to improving adaptation efforts and assessing progress in policy goals.

The lack of consistent definitions and practices, agreed metrics, comparable baselines, and standardized approaches to data collection exhibit some challenges in tracking adaptation progress (Dupuis & Biesbroek, 2013; Olazabal et al., 2019). Unlike mitigation metrics (e.g. reduction of parts per million of carbon dioxide concentrations in the atmosphere, or tons of carbon dioxide equivalent emissions), adaptation goals are very broad and context-sensitive (Biesbroek & Lesnikowski, 2018).

Composite metrics have been considered a first step in evaluating adaptation progress. These include resilience metrics, used to assess the intermediary outcomes required to achieve long-term adaptation goals. Resilience is understood as the

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ability of individuals, households, communities, institutions, and higher-level systems to deal with and adequately recover from shocks and stressors; here, 'adequately' refers to the ability to avoid short- and long-term negative impacts (Béné et al., 2015; Folke et al., 2010). However, there is still a lack of knowledge regarding complex interactions between the assessed components (Olazabal et al., 2019). Furthermore, conceptual and empirical work elucidating the linkages between climate policies and smallholders' adaptation, and more broadly, resilience capacities, is still limited (Eakin & Lemos, 2010; Lemos et al., 2016; Lindoso et al., 2014). An additional challenge is that a complex mix of interventions influences resilience outcomes differently, and the patterns of coordination in the implementation of these different instruments are critical. This indicates a need to understand the concrete implementation of these interventions and their coordination in territories where adaptation is actually shaped, and to downscale adaptation assessment systems to subnational scales (Lindoso et al., 2014; Milhorance et al., 2020).

A parallel effort emerged to measure changes in policy outputs as a response to the argument that there is no clear end point or final state of 'being adapted', but rather a continuous process of adjustment and change (Biesbroek & Lesnikowski, 2018; Candel & Biesbroek, 2016; Dupuis & Biesbroek, 2013). In this respect, Lesnikowski et al. (2019) introduced a policy mix approach to provide a context-sensitive analysis of adaptation policies. By focusing on the interactions of policy instruments, rather than on particular types of instruments or their standalone effects, such an approach better accounts for the complexity of climate adaptation policy. Policy instruments include the various techniques employed by governments to achieve their policy goals (Howlett, 2005), while policy mixes are associated with the processes from which these techniques emerge and are combined to pursue multiple goals. The notion of policy mix is useful as it considers political factors such as conflicting policy goals and actors' coordination as potential sources of implementation gaps (Lesnikowski et al., 2019; Pacheco-Vega, 2020; Vogel & Henstra, 2015). For instance, distinct government departments may compete for financial resources and political influence in a given territory, or leadership in defining policy goals, which often creates political conflicts and policy overlap (Milhorance et al., 2020; Milhorance & Bursztyn, 2019).

This study addresses the conceptual challenge of analyzing the role of public policies in promoting climate adaptation at the territorial level. Specifically, it examines the influence of distinct policy mixes in increasing the ability of rural households in the Brazil's Northeast semiarid region to deal with and recover from drought, based on an analysis of their specific resilience capacities and types of coping strategies.

The choice of the case study is justified by the increasing occurrence of dry spells and severe droughts in this region, which has been associated with the effects of global climate change (Marengo et al., 2017). Almost 40% of the region's population lives in rural areas and depends mainly on rainfed agriculture and pastures, being particularly exposed to climate change impacts. Nevertheless, compared to other Brazilian areas such as the Amazon, the region has received less scholarly attention (Marengo et al., 2017; Martins et al., 2017).

In other semiarid regions of the world, the negative effects of droughts on agricultural productivity and livelihoods have been showed (Simtowe et al., 2021). There is a growing interest in these regions for the role of public policies in fostering climate adaptation, particularly regarding the way policies shape adaptive strategies; however, most studies either analyze the decision of farmers to adopt conservation agriculture practices or address the political factors as broad contextual factors (Manalo et al., 2020; Shapiro-Garza et al., 2020; Xavier et al., 2020). Others isolate policy interventions to assess their individual impacts on resilience (Béné et al., 2020; De Souza et al., 2015; Rodriguez et al., 2016; Ziervogel, 2018). Moreover, studies adopting a policy mix approach are still underdeveloped in the Global South (Pacheco-Vega, 2020).

We contribute to the existing literature by emphasizing the notion of policy mix and exploring the argument that resilience capacities may be influenced in different ways through distinct combinations of policy instruments. These combinations can be shaped by political factors such as actors' coordination and divergences towards policy goals and implementation approaches. The study also contrasts with adaptation assessment systems available for the Brazilian context, as they mostly use indicators aggregated at the municipal level (Lindoso et al., 2014; MMA, MI, & WWF, 2017). A more in-depth analysis of the adaptive capacity dimension is provided, with an emphasis on farmers' assets and their associated

policy options. Particular emphasis is placed on the implementation of mixes composed of climate-related and broader development instruments, as proposed by Lemos et al. (2016). To do this, the analysis builds on previous research that showed that the policies implemented in the semiarid region prioritized the goals of reducing social vulnerability (related to cash transfer, water security, and traditional farming support) rather than the improvement of production sustainability or management of climate risks (Milhorance et al., 2020).

## Analytical framework

### Theory and scope

This study identifies the distinct policy mixes being implemented in the *Sub-medium São Francisco River* region (Figure 1) and analyzes differential impacts of these mixes in increasing resilience of rural households and reinforcing coping strategies to deal with and recover from drought. Finally, it discusses the political factors influencing the coordinated implementation

of these policy mixes. This section presents the analytical framework of the study, specifically the notion of resilience adopted, its components (e.g. capacities and strategies), and its relationship with climate adaptation.

### Challenges of assessing resilience to climate shocks

First of all, it is important to note that resilience should not be considered the final goal of adaptation policy, but an intermediate outcome required to achieve long-term development ambitions, including climate adaptation, water and food security, and improved well-being (Béné et al., 2015; Constat et al., 2014). Originating from an ecological perspective, the concept was initially conceived as the capacity to confront, absorb, and adapt to shocks without changing. However, it has recently evolved to a more dynamic definition, as the initial idea of a return to a state of normality has been challenged by a current understanding of multiple equilibria and dynamic changes (Córdoba et al., 2020).

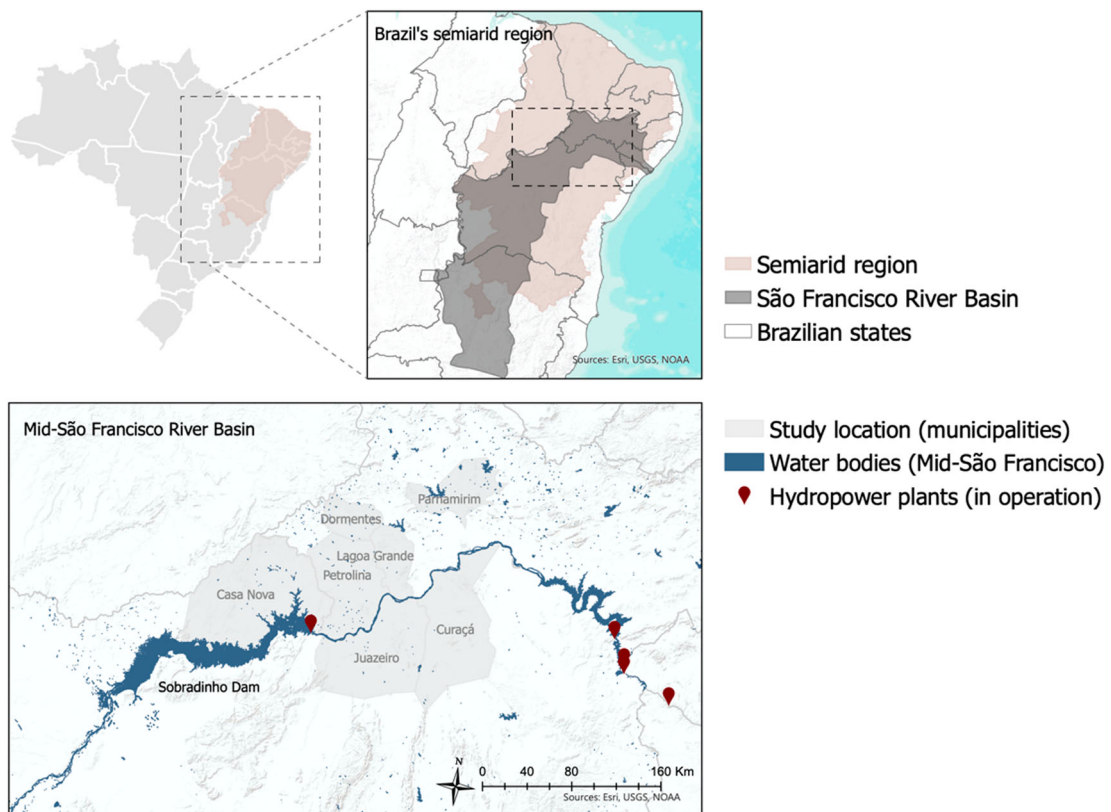


Figure 1. Study location in Brazil's Northeast semiarid region. Source: Authors.

Importantly, resilience is a latent variable that cannot be captured using a single metric, and no strong consensus has yet been reached on appropriate measurement methods (Béné et al., 2017, 2020; Béné & Doyen, 2018; Cains & Henshel, 2021; FAO, 2016; Frankenberger et al., 2013). Most resilience assessments require the identification of proxy variables to serve as indicators of capacity. However, these must be specific to the analyzed systems and the existing sources of risks, suggesting that resilience means different things to different actors depending on the context and time (Cains & Henshel, 2021; Jones, 2019; Pelletier et al., 2016). This allows evaluators to justify distinct combinations of indicators in the design of assessment toolkits, which may lead to different measures. While recent studies have progressed in the formalization of more generalizable metrics, there is ongoing debate. Furthermore, these assessments often require considerable amounts of socioeconomic and farming data to be collected (Béné & Doyen, 2018; Jones, 2019).

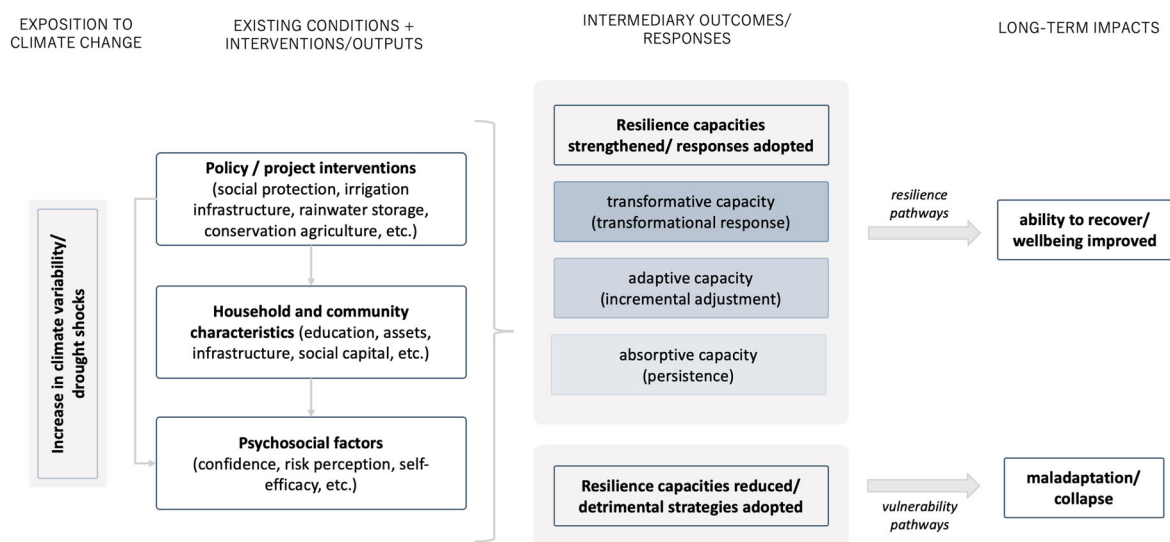
Hence, the present study does not provide a new assessment toolkit to measure resilience or evaluate the degree of improved well-being of the target populations. This would require a larger sample and further conceptual elaboration, which is beyond the scope of this paper. This study builds on existing literature to identify resilience indicators and ensure transparency of the assumptions made in the research outline. By adapting the broader theory of change

proposed by Béné et al. (2014, 2015, 2019) in the Brazilian context, the analysis is limited to the stage of enhancing resilience capacities and adopting appropriate responses in the face of droughts. Figure 2 identifies policy interventions, household and community characteristics, and psychosocial aspects as factors for building resilience capacities and promoting adaptation to climate change.

### Focus on resilience capacities and strategies

The specific responses adopted by households when faced with disaster events have received growing academic interest (Paumgarten et al., 2020). Several studies point out how factors such as income, assets, livelihood strategies, knowledge, social capital, and access to infrastructure and services can shape resilience, although additional research is required to fully understand their specific contributions in each context (Béné et al., 2019; FAO, 2016; Frankenberger et al., 2013; Jones & Tanner, 2017).

Building on earlier studies, Darnhofer (2014) suggests that farm resilience derives from the combination of buffer, adaptive, and transformative capacities. Some studies identify up to five types of resilience capacities, which can be placed along a continuum and represent different types of coping strategies (or responses) to shocks or stressors (Béné et al., 2016; Folke et al., 2010; Frankenberger et al., 2013). However, some studies also recognize the disputable



**Figure 2.** Generic climate adaptation theory-of-change and analytical framework. Source: Adapted from (Béné et al., 2014, 2015, 2019; Clay & King, 2019).

character of the boundaries of these categories, implying that they are case-specific and subject to interpretation (Béné & Doyen, 2018). Recognizing these challenges and providing more robustness to definitions, the analysis here is limited to three aggregated categories of capacities, which are assumed to lead to distinct resilience pathways.

First, **absorptive capacity** involves risk management strategies in which individuals and/or households moderate or cope with the impacts of shocks on their livelihoods and basic needs. Policy interventions often consist of preventative measures, early warning systems, informal safety nets, and emergency responses that allow for quick recovery from stressors while avoiding permanent negative impacts. There is no change or a temporary change in the system (Béné et al., 2015; Béné & Doyen, 2018).

Second, **adaptive capacity** reflects the capacity to learn, combine experience and knowledge, and adjust responses to changing drivers. These capacities are strengthened by improving households' and communities' abilities to make proactive and informed decisions about alternative livelihood strategies. Interventions in this case include both humanitarian and development initiatives and typically focus on livelihood diversification, human capital (e.g. education), asset accumulation and diversification, and access to financial services (e.g. credit). Changes or adjustments within the system are considered here (Béné et al., 2015; Béné & Doyen, 2018).

Third, **transformative capacity** refers to the ability of actors to create an enabling environment that constitutes the necessary conditions for systemic change; in other words, it creates a fundamentally different system (Béné et al., 2015; Folke et al., 2010). Situating resilience-building initiatives within the historical, political, and cultural contexts of rural communities raises issues of human agency, autonomy, and development transformations (Córdoba et al., 2020; Pelletier et al., 2016). Policy interventions include investments in landscape conservation, broader infrastructure, basic service delivery, resource distribution, support to shift production practices and locations, and social protection mechanisms (Carter et al., 2018; Frankenberg et al., 2013).

Finally, resilience can also be observed in negative coping behaviours, which may lead to long-term negative consequences (Béné et al., 2017; Devereux, 2007; Maxwell & Caldwell, 2008). **Detrimental coping strategies** include unsustainable tree cutting for charcoal, reducing food consumption, changing

the type of food consumed, reducing family expenses, and selling animals and other assets (Béné et al., 2020). Note that households' coping strategies are often distinguished between ex-post and ex-ante strategies, with the former considered reactive strategies in the context of limited control over coping options and the latter as more precautionary and active (Paumgarten et al., 2020).

### Data collection and analysis

The methodological framework is based on three steps. First, semi-structured interviews were conducted with public, private, and civil society actors at all governance levels (Number of interviews [ $N$ ] = 88; November 2018–March 2019). These interviewees provided information regarding the opportunities and challenges in implementing several key policies. Subsequently, semi-structured interviews with farmers benefiting from these policies were conducted in the Sub-medium São Francisco River region (Figure 1) ( $N=63$ ; May 2019). Interviewees were asked to list new on-farm activities or strategies they initiated in anticipation of droughts and present the outcomes and challenges of policies they benefited from. They also indicated the distinct instruments that supported each household. Data derived from farmers' statements were tabulated (as yes/presence or no/absence) and quantified. Based on this information and on previous analysis (Milhorance et al., 2020), distinct policy mixes implemented in the study area were identified and categorized (Figure 3). Moreover, in-depth interviews with community leaders ( $N=15$ ) were added to farmers' data by providing rich details on policy implementation issues at the community level, power relations, and the existence of conflicts at the territorial level.

The on-the-ground survey included questions concerning the period before and after the drought period (2012–2017), allowing qualitative analysis of changes in terms of income, assets, food security, and drought effects in the aftermath of the shock. This is considered a proxy for analyzing the potential impacts of climate change in rural households, as it is expected to intensify climate variability and shocks. The selection criteria of the households interviewed were a combination of farming category (smallholder farming), geographic criteria, and access to at least one of the policies analyzed in the study (Figure 3). Further information on the study location is provided in the next section.

**Table 1.** Resilience scoring matrix.

Indicators	Proxies/ scores
<b>Social and human capital</b>	
<b>Linking social capital</b>	
<ul style="list-style-type: none"> <li>Membership to community associations;</li> <li>Membership to marketing, political or resource-governance associations (collective agency).</li> </ul>	<ul style="list-style-type: none"> <li>No membership = 0;</li> <li>Community association membership = 1;</li> <li>Community association and other marketing, political, resource-governance local associations = 2</li> <li>Community association and other organizations promoting linkages beyond local level = 3</li> </ul>
<b>Human capital</b>	
<ul style="list-style-type: none"> <li>Education level;</li> <li>Exposure to information;</li> <li>Food access/ quality: access to drinking water and food availability / variety.</li> </ul>	<ul style="list-style-type: none"> <li>No access to school = 0;</li> <li>Low education degree = 1;</li> <li>Medium education degree = 2;</li> <li>High education degree = 3</li> </ul> <ul style="list-style-type: none"> <li>No access to climate information and technical advice = 0;</li> <li>Access to climate information or punctual access to technical advice = 1;</li> <li>Access to climate information and punctual technical advice = 2;</li> <li>Access to climate information or frequent technical advice = 3.</li> </ul> <ul style="list-style-type: none"> <li>No access to drinking water (home cistern or tap water) and self-consumption = 0;</li> <li>Access to drinking water and self-consumption (purchase) = 1;</li> <li>Access to drinking water or varied food products (home garden) = 2;</li> <li>Access to drinking water and varied food products (home garden) = 3.</li> </ul>
<b>Asset ownership and saving</b>	
<b>Liquid assets and savings</b>	
<ul style="list-style-type: none"> <li>Size of herds;</li> <li>Access to seeds and saving;</li> <li>Income level.</li> </ul>	<ul style="list-style-type: none"> <li>No herd ownership = 0</li> <li>Herd of goats and sheep &lt;50 = 1;</li> <li>Herd of goats and sheep &gt;50 and &lt;200 = 2;</li> <li>Herd of goats and sheep &gt;200 = 3.</li> </ul> <ul style="list-style-type: none"> <li>No access to seeds and savings = 0;</li> <li>Access to seeds and savings = 1.</li> </ul> <ul style="list-style-type: none"> <li>Very low income (no credit access) = 0</li> <li>Low income (<i>Pronaf A/B</i> profile*) = 1;</li> <li>Medium income (<i>Pronaf V</i> profile) = 2;</li> <li>High income (Other than <i>Pronaf</i> profile) = 3.</li> </ul>
<b>Durable assets</b>	
<ul style="list-style-type: none"> <li>Land titling and size;</li> <li>Access to production equipment and water infrastructure.</li> </ul>	<ul style="list-style-type: none"> <li>No access to land titling = 0</li> <li>Land size &lt;10 ha = 1;</li> <li>Land size &gt;10 ha and &lt;60 ha = 2;</li> <li>Land size &gt;60 ha = 3</li> </ul> <ul style="list-style-type: none"> <li>No access to water system = 0</li> <li>Access to basic rainwater collection and storage system = 1;</li> <li>Diversified sources of water = 2;</li> <li>Diversified sources of water and access to permanent supply (irrigation systems) = 3</li> </ul>
<b>Access to formal markets</b>	
<ul style="list-style-type: none"> <li>Access to formal markets;</li> <li>Dependency on market intermediaries;</li> </ul>	<ul style="list-style-type: none"> <li>If products are commercialized, no access to formal markets (intermediaries) = 0;</li> <li>If products are commercialized, access to at least one formal market (local fair, public market, other) = 1;</li> <li>Access to more than one formal market = 2;</li> <li>Access to larger and stable markets (non-timber forest products, agroindustry cooperatives, extra-regional sales) = 3</li> </ul>
<b>Availability of safety nets and drought assistance</b>	
<b>Access to social protection mechanisms</b>	
<ul style="list-style-type: none"> <li>Access to emergency responses to shocks/ humanitarian assistance;</li> <li>Access to formal social protection programmes;</li> <li>Access to disaster early warning/ preparedness systems.</li> </ul>	<ul style="list-style-type: none"> <li>No access to emergency responses to shocks = 0</li> <li>Access to emergency responses to shocks / humanitarian assistance = 1;</li> <li>Access to emergency responses and formal social protection = 2;</li> <li>Access to formal social protection and disaster early warning/preparedness system = 3</li> </ul>

(Continued)



**Table 1.** Continued.

Indicators	Proxies/ scores
<b>Livelihood diversification</b>	
<b>Crop and income diversification</b>	
<ul style="list-style-type: none"> <li>• Diversified sources of income;</li> <li>• Access to pensions, seasonal migration, or formal employment;</li> <li>• Agricultural production diversification (production sites, crops, animals).</li> </ul>	<ul style="list-style-type: none"> <li>• One source of income = 0</li> <li>• More than one source of income, including pensions and seasonal migration = 1;</li> <li>• More than one source of income, including informal employment = 2;</li> <li>• More than one source of income, including formal employment = 3</li> </ul>
<b>Ecosystem and soil conservation</b>	
<b>Adoption of conservation farming practices</b>	
<ul style="list-style-type: none"> <li>• Number of conservation practices adopted.</li> </ul>	<ul style="list-style-type: none"> <li>• No diversification = 0</li> <li>• Low diversification (production sites &gt;1 or crops &gt;3 or animals &gt;2) = 1;</li> <li>• Medium (production sites &gt;1 and crops &gt;3 or animals &gt;2) = 2;</li> <li>• High (production sites &gt;1 and crops &gt;3 and animals &gt;2) = 3;</li> </ul>
<b>Perception of drought</b>	
<b>Confidence in climate future</b>	
<ul style="list-style-type: none"> <li>• Negative/ positive expectations regarding future climate, drought, and farm succession.</li> </ul>	<ul style="list-style-type: none"> <li>• No adoption of conservation practices = 0;</li> <li>• Adoption of at least one conservation practice (farm rotation, bioinputs, genetic improvement, water management, integrated systems, conservation methods) = 1;</li> <li>• Adoption of three conservation practices = 2;</li> <li>• Adoption of more than three conservation practices = 3</li> </ul>
<ul style="list-style-type: none"> <li>• Concern with future climate and farm succession = 0;</li> <li>• Concern with future climate, expectation of drought increase, and no concern with farm succession = 1;</li> <li>• Concern with future climate, expectation of drought decrease/remaining equal, and no concern with farm succession = 1;</li> <li>• No concern with future climate and farm succession = 3</li> </ul>	

\*See definition in the supplemental materials.

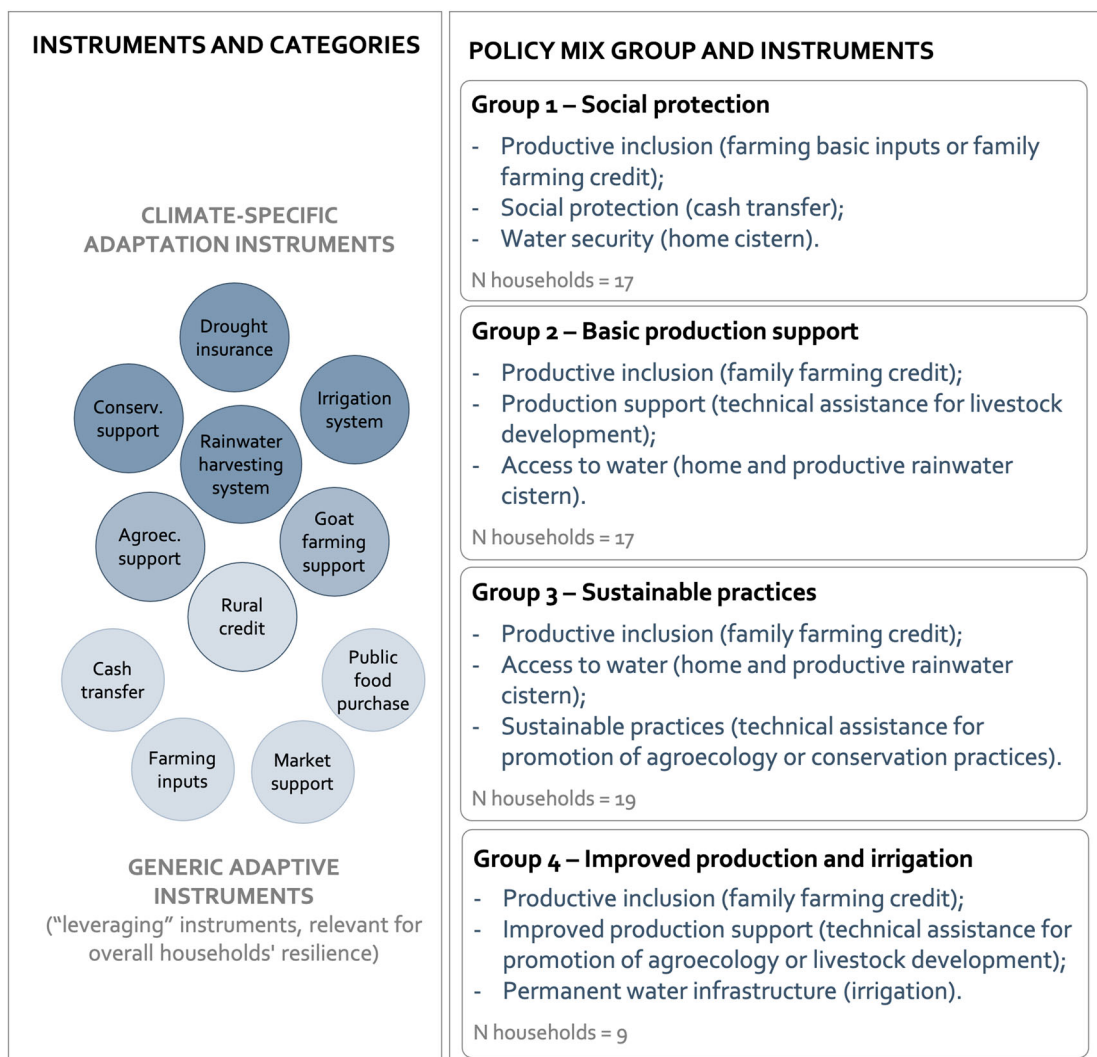
A brief overview of how the metric and households' associated resilience scores were built is presented in Table 1. Scores were based on a literature review for each variable and followed a standard 0–3 scale, where 3 represents transformative capacities, 2 represents adaptive capacities, 1 represents absorptive capacities, and 0 represents no or detrimental coping strategies/capacities. Literature justifying these choices is presented in supplemental material. Following literature on composite indicators of climate adaptation in the same region (Lindoso et al., 2014), the computation of resilience scores for each household followed the same scale, and equal weights were assumed for each metric. An arithmetic mean was used to calculate the aggregate score of the capacities. This score was then normalized using a standard min–max transformation with a range of [0,1]. Resilience scores and types and/or frequencies of coping strategies adopted by households to face drought were compared with policy mix access using bivariate comparison of means, bivariate correlation, chi-square, and multivariate analysis of variance (ANOVA). A second analysis focused on the types and/or frequencies of responses adopted by households benefiting from different policy mixes in order to identify the main coping/adaptive strategies. These results were compared with farmers'

perceptions of policy outcomes, and followed by an analysis of the institutional and political barriers to implement climate adaptation policy mixes.

## Resilience assessment from a policy mix perspective

### Policy mixes in Brazil's semiarid region

A total of eight policy instruments compositions were found, all of which were characterized by multiple policy goals (Figure 3). They were aggregated into four groups according to their main strategies and contributions regarding climate adaptation objectives. The policy mixes combine interventions that address not only climate-related risks, but also structural deficits such as lack of income. As defined by Lemos et al. (2016), specific capacities refer to the ability to respond to and manage an identified climate hazard (e.g. drought emergency response plans, climate forecasting, design and construction of protective infrastructure such as irrigation and public works such as reservoirs). In contrast, generic capacities refer to the ability to respond to more general social, economic, political and ecological stressors (e.g. income, access to education and health, physical assets, social capital).



**Figure 3.** Policy mix types and goals identified in the study area. Source: Authors.

Notably, the combination of social protection, productive inclusion, decentralized water infrastructure, and local training / mobilization reflect a development strategy for smallholder farmers in Northeast Brazil, which became known as the 'coexistence with the semiarid' paradigm. This territorial development paradigm was built on the notion that it is possible to live and produce in the semiarid region, through relying on the sustainable use of the natural resources available, community development, and stocking of water and forage to be used during scarcity periods (Lindoso et al., 2018; Pérez-Marin et al., 2017). These instruments have been recognized by Brazil's National Adaptation Plan as a means of strengthening the

resilience of rural populations to climate shocks (Brazil, 2016).

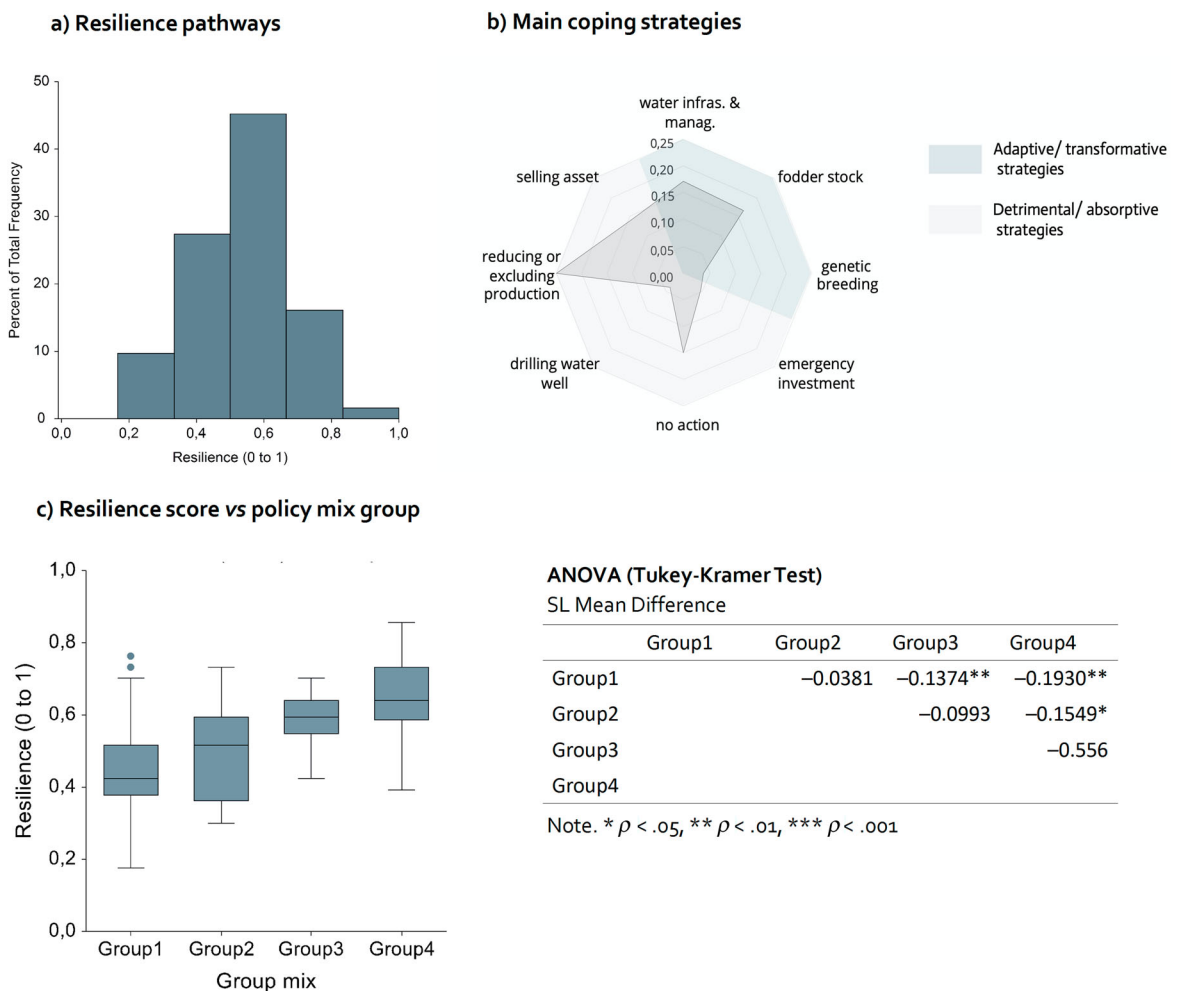
### *Resilience pathways and coping strategies*

We identified a general tendency toward an intermediary value for the resilience composite metric described above among surveyed households (Figure 4a). Furthermore, there was a significant difference in terms of resilience between households benefiting from different policy mixes, reflecting different types of capacities to recover from droughts (Figure 4c). This aligns with results previously found in the region that demonstrate the role of productive inclusion, social protection, and rainwater storage

systems in facing droughts, although they have not been sufficient to shift sustainability pathways (Lemos et al., 2016; Lindoso et al., 2014, 2018; Mattos, 2017; Milhorance et al., 2020; Nogueira et al., 2020; Petersen & Silveira, 2017).

Interestingly, the presence of micro-irrigation systems in the policy mix was not sufficient to considerably increase households' resilience in comparison with other mixes combining instruments of productive inclusion, rainwater cisterns, and promotion of sustainable farming practices. Note that ANOVA tests did not show significant differences between Policy Mix Groups 3 and 4 (the latter including deployment of micro-irrigation system). In addition, the resilience difference between

households benefiting or not from irrigation support (LS mean difference = 0.13;  $p < 0.05$ ) is lower than the difference between those benefiting or not from technical assistance (LS mean difference = 0.16;  $p < 0.01$ ). These results suggest caution regarding the promotion of irrigation systems as the main driver towards the resilience transformative pathway in a water-scarce region. Although reliable sources of water are key in a context of increasing droughts, and distinct irrigation systems are currently available, this type of instrument should not be seen as the only policy solution to increase resilience and water security. Comparable results have been found in other countries (Grafton et al., 2018). However, this assumption should be nuanced as it requires



**Figure 4.** Results of resilience assessment and households' main coping strategies. (a) histogram of household resilience scores; (b) households' main coping strategies and respective types of strategies (% of total frequency); (c) adaptation policy mix groups and respective resilience scores (ANOVA). Source: Authors.

further analysis using a larger sample and more policy mix categories.

An additional result showed that, although goat farming has been identified by surveyed farmers as more resistant to drought than traditional cattle farming, no significant difference has been found for the resilience composite metric of farmers accessing or not the policy supporting livestock production (Group 2). Further progress is required in goat livestock management to make it more environmentally sustainable, decreasing the degradation of native vegetation and associated negative effects on the hydrological cycle (Schulz et al., 2016). Genetic breeding for goats to improve productivity in dry conditions has also been supported as a resilience strategy; however, its dissemination remains limited. Moreover, bottlenecks in market access hinder the ability of households to increase autonomy and income related to this activity. This is detailed below.

Furthermore, water systems and fodder stocks have been reported as the main strategies adopted to prepare for drought, whereas reducing productive area or excluding non-resistant products and selling assets (goats) consisted of coping strategies adopted during the drought events (Figure 4b). The literature shows that detrimental long-term effects of some specific coping strategies can lead to maladaptation, that is, interventions in one location or sector that increase the vulnerability of other locations, sectors, or group to future climate change (Béné et al., 2020; Clay & King, 2019; IPCC, 2014). When the main coping strategies between households accessing different policy mixes were compared, no significant differences were found. The types of coping strategies were shared by households, independent of the policies they benefited from. Larger samples can provide more accurate results.

Finally, the results discussed above and displayed in Figure 4 are in line with farmers' perceptions of policy impacts (Figure 5). Farmers were asked to indicate the programmes with the greatest positive impact on production, marketing, food quality, and ability to face drought. As a result, rural credit and technical assistance (including advice in agroecology and goat farming support) showed the greatest importance to production improvement. These were also the same instruments helping farmers deal with drought periods in addition to the dissemination of different types of rainwater harvesting systems. A distinction between resilience metrics and farmers' perceptions can be noted in the role of rural credit. In

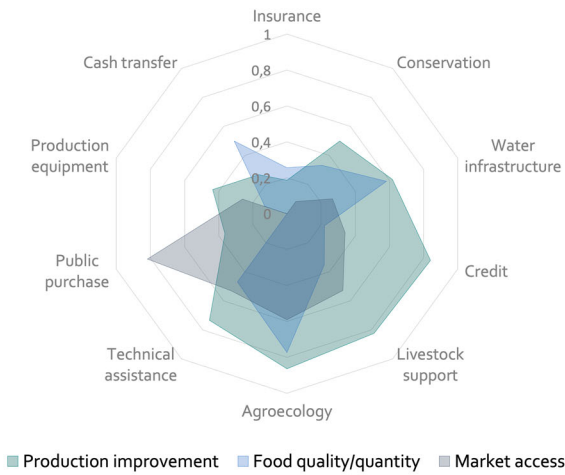
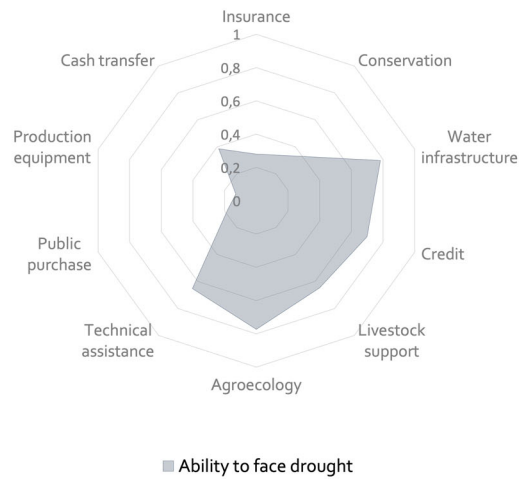
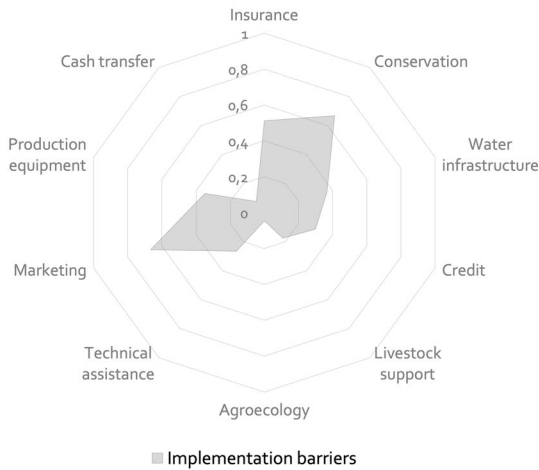
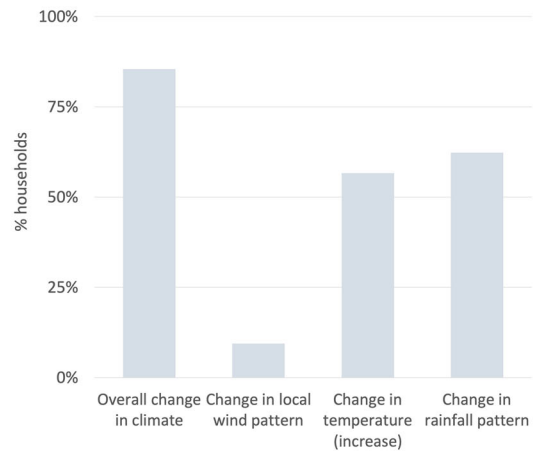
Northeast Brazil, microcredit is a key source of financial resources for rural households. For instance, the *Agroamigo Program* has significantly expanded credit access; however, the ability of this programme to promote more sustainable practices, beyond extensive livestock farming, has been questioned (de Aquino & Bastos, 2015). Conclusions reflect the need to consider policy instruments conjointly; however, the coordination patterns in the implementation of these combined instruments face institutional and political constraints. These are even stronger when shifting resilience outcomes toward more transformative pathways, as changes in political priorities and actor coordination are required. These are discussed in the following section.

## Improving policy integration toward a transformative pathway

### Challenges to policy mix implementation

The results presented above provide insights on the interest of combining resilience assessments with research on the implementation of policy mixes. Previous studies showed that generic-development instruments (e.g. social protection) should be combined with climate-specific instruments (e.g. irrigation systems, drought insurance) to promote adaptive capacity of rural populations in Brazil's semiarid region (Clay & King, 2019; Lemos et al., 2016). These results are supported here. We further argue that access to markets, credit, and social protection mechanisms are key to overall household resilience, whereas climate-specific instruments and the promotion of more sustainable farming and water management practices are still required to shift resilience toward a more transformative pathway. Nevertheless, combining and coordinating policy instruments to promote these multiple adaptation goals is not a simple task, as it reflects institutional barriers and political conflicts. Some examples are presented hereafter.

First, enabling elements for credit, market support, and disaster assistance are missing in the policy mixes identified in the study location. For instance, *Garantia Safra* is the main smallholder farming drought-related insurance in the region. However, in practice, the programme became a regular cash transfer associated with regular crop loss rather than actual insurance. Interviews showed that these transfers were mainly used for households rather than productive expenses.

**a) Policy influence on production, market access, and food****b) Policy influence on the ability to face drought****c) Barriers to policy implementation****d) Perception of climate variability**

**Figure 5.** Farmers' perceptions regarding policy outcomes on (a) production, market access, food quality/access, (b) ability to face drought, (c) implementation barriers (% of households accessing each policy instrument), and (d) farmers' perception regarding climate variability (% total households). Source: Authors.

Furthermore, grants are requested for crops such as corn and beans, which are systematically lost, and payment delays have been reported as key concerns. Incorporating better climate information in policy design and crops that are more resistant to drought in the design of climate-related insurance is necessary for achieving adaptation goals. This includes strategies that consider the regional history of droughts as well as climate projections and prospective impacts of global warming on the region (Lemos

et al., 2016; Lindoso et al., 2018; Marengo et al., 2017; Milhorance et al., 2020).

This argument aligns with studies showing that, although social protection and insurance can assist rural populations in dealing with periods of extreme weather, it is uncertain how well these programmes will function as climatic conditions shift over the long term (Carter et al., 2018; Lemos et al., 2016; Mesquita & Milhorance, 2019). Consequently, these social protection instruments must be combined with those

promoting climate-specific capacities, livelihood diversification, and overall agroecosystem resilience.

Second, the intensive use of land for agriculture, livestock, and forestry is the main vector for desertification in Brazil's semiarid region; hence, landscape restoration is central to promoting resilience. Spatial data showed that the municipalities in the study lost around 12% of the natural vegetation cover and 18% of the water bodies between 1985 and 2019. Conversely, farming areas increased by 37% and comprised mainly irrigated agricultural and pasture land (MapBiomas, 2020). Restoring native vegetation, recovering pastures, promoting agroecological practices, and establishing integrated systems are crucial as the region has approximately 14 million hectares of native pastures and 10 million planted pastures, at different levels of degradation and desertification levels (Angelotti et al., 2015).

However, farmers' perceptions indicate that the restoration of native vegetation activities faces key implementation issues (see 'conservation' category in Figure 5c). There are only a few initiatives for the dissemination of seedling nurseries for restoration, and the results of these initiatives have been criticized because the employed techniques were inadequate in the semiarid environment and most nurseries have been lost during drought periods. Currently, less work-intensive methods such as enclosed goat pastures and rotation are being tested; however, they also require environmentally oriented technical advice and credit.

Additionally, although the *Agroamigo Program* notably expanded credit access, its investments focused on conventional production systems, especially extensive cattle and goat farming, with insufficient orientation toward sustainable production and ecological intensification (de Aquino & Bastos, 2015). Moreover, the conservation of native vegetation in rural properties has been supported through the protection of riparian forests and springs in the framework of the *Rural Environmental Registry (Cadastro Ambiental Rural)*; however, its low level of implementation and inability to condition credit access has negatively affected conservation targets. The instrument can influence livelihoods positively and negatively, depending on the initial amount of natural vegetation on farmers' properties (Jung et al., 2017). In our study region, overgrazing is a key concern in goat farming; thus, additional efforts to improve management and to effectively combine credit with technical advice and incentives

for sustainable production are required (Schulz et al., 2016).

Finally, implementation gaps have also been identified for the promotion of market access (Figure 5c). The lack of formal requirements such as smallholder farming certificates and health inspection labels have been reported by interviewees as the main challenges to enhancing access to markets and increasing agricultural processing. Some projects support farmers in obtaining registration, but their coverage remains still low. It is worth mentioning that some products, such as milk, are commercialized through public food procurement; however, the interruption of purchases due to governmental shift in 2019 and change in overall governmental priorities weakened efforts to structure this activity. This episode highlights the role of political factors in implementing the policy mix.

### *Rethinking policy design and improving actors' coordination*

Transformative capacity refers to system-level changes required to enable long-lasting resilience. As such approaches may benefit some groups over others, this option often challenges the status quo in a substantial way (Béné et al., 2015; Clay & King, 2019; Córdoba et al., 2020). Sustainability transitions may require change in agri-food regimes and trade-offs to be considered between the multiple food systems goals (Gaitán-Cremaschi et al., 2020). Furthermore, the degree of actors' coordination can be a significant challenge to achieve the multiple goals of a policy mix and to mainstream climate action, which is often limited to environmental ministries and agencies. Therefore, resilience and adaptation research should further analyze the political, social, and economic factors that condition policy implementation and populations' vulnerability to climate risks (Carter et al., 2018; Córdoba et al., 2020; Turner et al., 2003).

Although the policy mixes analyzed in this study have been presented in Brazil's National Climate Policy as a means of fostering climate adaptation, they have not been initially designed for this purpose. This approach of layering existing instruments with new goals such as climate adaptation faces challenges of non-coherent juxtaposition of instruments, omission of climate risks, and inability to foster transformative resilience pathways (Henstra, 2016; Milhorance, Sabourin, Chechi, & Mendes, 2021).

For instance, the design of climate insurance instruments for the semiarid region (e.g. *Garantia Safra*, mentioned above) has neglected the increase of climate risks and, consequently, became a permanent cash transfer instrument that do not consider climate information and do not achieve insurance goals. Redesigning these instruments and combining them with rural credit has already been pointed out as key adaptation strategies (Milhorange, Sabourin, Le Coq, & Mendes, 2020).

Additionally, establishing cross-sectoral policy strategies can lead to heightened conflict and increased costs, owing to the involvement of multiple actors with diverse interests (Baulenas & Sotirov, 2020). In this case study, political bottlenecks include divergence over the enforcement of the *Rural Environmental Registry*, which attracts criticism from domestic economic groups and is still not operational in the semiarid region. This implementation gap follows conflicts between agribusiness and environmentalist coalitions over the 2012 change of the Forest Code to establish this instrument. Another example refers to disputes between subnational actors for leading the installation of rainwater harvesting cisterns. The main issue concerns the role of local NGOs as implementing partners and their ability to connect the installation of cisterns with community mobilization and the dissemination of sustainable farming practices. These NGOs lost their leading role in policy implementation after a change in the programme's design in 2011 – that excluded the technical assistance requirement for cistern installation – and were actively marginalized after the governmental shift in 2016 (Nogueira et al., 2020).

Finally, weak coordination between actors involved in climate policy appeared as a key and overlooked challenge to reaching climate adaptation goals. Previous research has shown that organizations designing climate policy and restoration plans in Brazil do not substantially interact with the organizations involved in the territorial and rural development strategies for the semiarid region (Milhorange et al., 2021). In other words, there is a lack of coordination between actors involved in the climate/environmental policies, on the one side, and rural/territorial policies, on the other side. These are, however, key components of policy mixes needed to promote climate adaptation, as discussed in this study. Moreover, while environmental agencies design climate adaptation plans at the national level, there has been minimal involvement or dialog with subnational

agencies and civil society organizations promoting the development of smallholder farmers in the semiarid region. The same study evidenced a very low level of concern or association between increasing droughts and the effects of global climate change by subnational actors, which contrasts farmers' perceptions of a changing climate (Figure 5d) (Milhorange et al., 2021). Hence, fragmentation can also be observed between actors involved in policy design and policy implementation. This is probably one of the reasons why the adaptation instruments implemented in the semiarid region do not consistently integrate restoration measures, sustainability principles, and climate risks' information.

Adaptation policy literature highlights that the separate handling of cross-cutting issues produces persistent governance deficits which requires redesigning current policies (Biesbroek & Candel, 2020). Policy mixes studies also remind us to consider structural principles for policy design, considering new governance architectures (Pacheco-Vega, 2020). In this sense, the establishment of dialog venues for bringing together actors from the environmental and the territorial development fields, namely those involved in the 'coexistence with the semiarid' paradigm, can encourage coordination and learning between these groups to improve policy design and foster transformative resilience capacities. This includes not only climate and environmental analysts at the national level but also environmental agencies at the subnational level, and the agencies and civil society organizations implementing territorial development policies.

## Conclusion

The study relied on a policy mix approach to track adaptation policies at the subnational level and assess their influence on increasing the resilience of rural households. It shed light on the coordination of policy instruments and goals in a mix, sustaining that distinct coordination patterns can lead to different resilience outcomes. The results add to the existing literature by addressing the effects of complex interactions of policy interventions on local-level resilience. This debate could potentially contribute to critical policy evaluation research and provide adaptation assessment frameworks with greater analytical significance.

The focus on implementing the policy mix also requires a better understanding of the institutional

and political factors driving or hindering the coordination of instruments, agendas, and policy actors. Land titling, access to markets and credit, climate information, and ecosystem conservation zonings and guidelines are preconditions for designing strategies with greater transformative potential; however, these can be associated with change in the status quo. Moreover, coordination gaps or differential emphasis on distinct instruments in the mix can mean an imbalance in adaptation goals. Although social protection and climate insurance can assist rural populations in dealing with droughts, in a context of shifting climatic conditions, these instruments must be combined with those promoting climate-specific capacities, livelihood diversification, and overall agroecosystem resilience. Likewise, inadequate combinations of instruments can lead to maladaptation, such as increased risk of degradation associated with goat farming without adequate training and financing for sustainable management. Such issues can arise from decisions that only consider short-term goals without considering a more systemic view of potential effects of particular adaptation measures.

An additional factor that is less examined is the weak interaction of actors involved in the a cross-cutting agenda and the separate handling of policy issues in design processes. In this study, the disassociated conception of climate and territorial development policies has led to fragmentation of the adaptation strategies for the semiarid region and insufficient results in terms of promoting household resilience. Promoting coordination and learning between these groups is one possible mechanism for designing more integrated policy approaches. As argued by Pacheco-Vega (2020), currently turbulent times require us to be much more adaptive and specify innovative ways in which we design policy instruments so we can foster their potential for transformation change.

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## References

- IPCC. (2014). *Climate change 2014: Synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change*. Intergovernmental Panel of Climate Change.
- Brazil. (2016). *National adaptation plan to climate change: Sectoral and thematic strategies—Volume II*. Ministry of Environment.
- FAO. (2016). *Resilience index measurement and analysis—II*. Food and Agriculture Organization.
- MMA, MI, & WWF. (2017). *Índice de vulnerabilidade aos desastres naturais relacionados às secas no contexto da mudança do clima*. Ministério do Meio Ambiente.
- MapBiomass. (2020). *Projeto MapBiomass – Coleção 5.0 da Série Anual de Mapas de Cobertura e Uso do Solo do Brasil*. <https://mapbiomas.org>.
- Angelotti, F., Signor, D., & Giongo, V. (2015). Mudanças Climáticas no Semiárido Brasileiro: Experiências e Oportunidades para o Desenvolvimento. *Revista Brasileira de Geografia Física*, 8(IV), 484–495. <https://doi.org/10.5935/1984-2295.20150009>.
- Baulenas, E., & Sotirov, M. (2020). Cross-sectoral policy integration at the forest and water nexus: National level instrument choices and integration drivers in the European Union. *Forest Policy and Economics*, 118, 102247. <https://doi.org/10.1016/j.forpol.2020.102247>
- Béné, C., Chowdhury, F. S., Rashid, M., Dhali, S. A., & Jahan, F. (2017). Squaring the circle: Reconciling the need for rigor with the reality on the ground in resilience impact assessment. *World Development*, 97, 212–231. <https://doi.org/10.1016/j.worlddev.2017.04.011>
- Béné, C., & Doyen, L. (2018). From resistance to transformation: A generic metric of resilience through viability. *Earth's Future*, 6(7), 979–996. <https://doi.org/10.1002/2017EF000660>
- Béné, C., Frankenberger, T., Griffin, T., Langworthy, M., Mueller, M., & Martin, S. (2019). 'Perception matters': New insights into the subjective dimension of resilience in the context of humanitarian and food security crises. *Progress in Development Studies*, 19(3), 186–210. <https://doi.org/10.1177/1464993419850304>
- Béné, C., Frankenberger, T., & Nelson, S. (2015). *Design, monitoring and evaluation of resilience interventions: Conceptual and empirical considerations* (IDS Working Paper No. 459). Institute of Development Studies. [https://doi.org/10.1163/2210-7975\\_HRD-0148-2015183](https://doi.org/10.1163/2210-7975_HRD-0148-2015183)
- Béné, C., Headey, D., Haddad, L., & von Grebmer, K. (2016). Is resilience a useful concept in the context of food security and nutrition programmes? Some conceptual and practical considerations. *Food Security*, 8(1), 123–138. <https://doi.org/10.1007/s12571-015-0526-x>
- Béné, C., Newsham, A., Davies, M., Ulrichs, M., & Godfrey-Wood, R. (2014). Review article: Resilience, poverty and development. *Journal of International Development*, 26(5), 598–623. <https://doi.org/10.1002/jid.2992>
- Béné, C., Riba, A., & Wilson, D. (2020). Impacts of resilience interventions – Evidence from a quasi-experimental assessment in Niger. *International Journal of Disaster Risk Reduction*, 43, 101390. <https://doi.org/10.1016/j.ijdr.2019.101390>
- Biesbroek, R., & Candel, J. J. L. (2020). Mechanisms for policy (dis)integration: Explaining food policy and climate change adaptation policy in the Netherlands. *Policy Sciences*, 53(1), 61–84. <https://doi.org/10.1007/s11077-019-09354-2>
- Biesbroek, R., & Lesnikowski, A. (2018). Adaptation: The neglected dimension of polycentric climate governance? In A. Jordan, D. Huitema, H. van Asselt, & J. Forster (Eds.), *Governing climate change* (1st ed., pp. 303–319). Cambridge University Press. <https://doi.org/10.1017/9781108284646.018>
- Cains, M. G., & Henshel, D. (2021). Parameterization framework and quantification approach for integrated risk and resilience assessments. *Integrated Environmental Assessment and Management*, 17(1), 131–146. <https://doi.org/10.1002/ieam.4331>
- Candel, J. J. L., & Biesbroek, R. (2016). Toward a processual understanding of policy integration. *Policy Sciences*, 49(3), 211–231. <https://doi.org/10.1007/s11077-016-9248-y>
- Carter, R., Ferdinand, T., & Chan, C. (2018). Transforming agriculture for climate resilience: A framework for systemic change. *Working Paper*. World Resources Institute. Available online at [www.wri.org/publication/transforming-agriculture-framework](http://www.wri.org/publication/transforming-agriculture-framework)
- Clay, N., & King, B. (2019). Smallholders' uneven capacities to adapt to climate change amid Africa's 'Green revolution': Case study of Rwanda's crop intensification program. *World Development*, 116, 1–14. <https://doi.org/10.1016/j.worlddev.2018.11.022>
- Conostas, M., Frankenberger, T., Hoddinott, J., Mock, N., Romano, D., Béné, C., & Maxwell, D. (2014). *A common analytical model for resilience measurement: Causal framework and methodological options* (Technical Series No. 2; Food Security Information Network (FSIN)). World Food Programme. <https://www.fsnnetwork.org/common-analytical-model-resilience-measurement-causal-framework-and-methodological-options>.
- Córdoba, C., Triviño, C., & Toro Calderón, J. (2020). Agroecosystem resilience. A conceptual and methodological framework for evaluation. *PLOS ONE*, 15(4), e0220349. <https://doi.org/10.1371/journal.pone.0220349>
- Darnhofer, I. (2014). Resilience and why it matters for farm management. *European Review of Agricultural Economics*, 41(3), 461–484. <https://doi.org/10.1093/erae/jbu012>
- de Aquino, J. R., & Bastos, F. (2015). Dez anos do programa Agroamigo na região Nordeste: Evolução, resultados e limites para o fortalecimento da agricultura familiar. *Revista Econômica do Nordeste*, 46(0), 139–160.
- De Souza, K., Kituyi, E., Harvey, B., Leone, M., Murali, K. S., & Ford, J. D. (2015). Vulnerability to climate change in three hot spots in Africa and Asia: Key issues for policy-relevant adaptation and resilience-building research. *Regional Environmental Change*, 15(5), 747–753. <https://doi.org/10.1007/s10113-015-0755-8>
- Devereux, S. (2007). *Vulnerability and social protection in Malawi*. Institute of Development Studies, University of Sussex.
- Dupuis, J., & Biesbroek, R. (2013). Comparing apples and oranges: The dependent variable problem in comparing and evaluating climate change adaptation policies. *Global Environmental Change*, 23(6), 1476–1487. <https://doi.org/10.1016/j.gloenvcha.2013.07.022>

- Eakin, H., & Lemos, M. C. (2010). Institutions and change: The challenge of building adaptive capacity in Latin America. *Global Environmental Change*, 20(1), 1–3. <https://doi.org/10.1016/j.gloenvcha.2009.08.002>
- Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society*, 15(4). <https://doi.org/10.5751/ES-03610-150420>
- Frankenberger, T., Mueller, M., Spangler, T., & Alexander, S. (2013, October). *Community resilience: Conceptual framework and measurement feed the future learning agenda*. Westat.
- Gaitán-Cremaschi, D., Klerkx, L., Duncan, J., Trienekens, J. H., Huenchuleo, C., Dogliotti, S., Contesse, M. E., Benitez-Altuna, F. J., & Rossing, W. A. H. (2020). Sustainability transition pathways through ecological intensification: An assessment of vegetable food systems in Chile. *International Journal of Agricultural Sustainability*, 18(2), 131–150. <https://doi.org/10.1080/14735903.2020.1722561>
- Grafton, R. Q., Williams, J., Perry, C. J., Molle, F., Ringler, C., Steduto, P., Udall, B., Wheeler, S. A., Wang, Y., Garrick, D., & Allen, R. G. (2018). The paradox of irrigation efficiency. *Science*, 361(6404), 748–750. <https://doi.org/10.1126/science.aat9314>
- Henstra, D. (2016). The tools of climate adaptation policy: Analysing instruments and instrument selection. *Climate Policy*, 16(4), 496–521. <https://doi.org/10.1080/14693062.2015.1015946>
- Howlett, M. (2005). What is a policy instrument? In M. Howlett, P. Eliadis, & M. M. Hill (Eds.), *Designing government* (pp. 31–50). McGill-Queen's University Press; JSTOR. <http://www.jstor.org/stable/j.cttq938d.6>
- Jones, L. (2019). Resilience isn't the same for all: Comparing subjective and objective approaches to resilience measurement. *Wiley Interdisciplinary Reviews: Climate Change*, 10(1), e552. <https://doi.org/10.1002/wcc.552>
- Jones, L., & Tanner, T. (2017). 'Subjective resilience': Using perceptions to quantify household resilience to climate extremes and disasters. *Regional Environmental Change*, 17(1), 229–243. <https://doi.org/10.1007/s10113-016-0995-2>
- Jung, S., Rasmussen, L. V., Watkins, C., Newton, P., & Agrawal, A. (2017). Brazil's national environmental registry of rural properties: Implications for livelihoods. *Ecological Economics*, 136, 53–61. <https://doi.org/10.1016/j.ecolecon.2017.02.004>
- Lemos, M. C., Lo, Y.-J., Nelson, D. R., Eakin, H., & Bedran-Martins, A. M. (2016). Linking development to climate adaptation: Leveraging generic and specific capacities to reduce vulnerability to drought in NE Brazil. *Global Environmental Change*, 39, 170–179. <https://doi.org/10.1016/j.gloenvcha.2016.05.001>
- Lesnikowski, A., Ford, J. D., Biesbroek, R., & Berrang-Ford, L. (2019). A policy mixes approach to conceptualizing and measuring climate change adaptation policy. *Climatic Change*, 156(4), 447–469. <https://doi.org/10.1007/s10584-019-02533-3>
- Lindoso, D., Eiró, F., Bursztyn, M., Rodrigues-Filho, S., & Nasuti, S. (2018). Harvesting water for living with drought: Insights from the Brazilian human coexistence with semi-aridity approach towards achieving the sustainable development goals. *Sustainability*, 10(3), 622. <https://doi.org/10.3390/su10030622>
- Lindoso, D., Rocha, J. D., Debortoli, N., Parente, I. I., Eiró, F., Bursztyn, M., & Rodrigues-Filho, S. (2014). Integrated assessment of smallholder farming's vulnerability to drought in the Brazilian semi-arid: A case study in Ceará. *Climatic Change*, 127(1), 93–105. <https://doi.org/10.1007/s10584-014-1116-1>
- Manalo, J. A., van de Fliert, E., & Fielding, K. (2020). Rice farmers adapting to drought in the Philippines. *International Journal of Agricultural Sustainability*, 18(6), 594–605. <https://doi.org/10.1080/14735903.2020.1807301>
- Marengo, J. A., Torres, R. R., & Alves, L. M. (2017). Drought in Northeast Brazil—past, present, and future. *Theoretical and Applied Climatology*, 129(3–4), 1189–1200. <https://doi.org/10.1007/s00704-016-1840-8>
- Martins, M. A., Hochrainer-Stigler, S., & Pflug, G. (2017). *Vulnerability of agricultural production in the Brazilian semi-arid: An empirical approach including risk*. 23.
- Mattos, L. C. (2017). *Um tempo entre secas: Superação de calamidades sociais provocadas pela seca através das ações em defesa da convivência com o semiárido* [Tese de Doutorado, Universidade Federal Rural do Rio de Janeiro]. Plataforma Sucupira.
- Maxwell, D., & Caldwell, R. (2008). *The coping strategies index: Field methods manual* (2nd ed.). CARE/ Usaid.
- Mesquita, P., & Milhorce, C. (2019). Facing food security and climate change adaptation in semi-arid regions: Lessons from the Brazilian food acquisition program. *Sustentabilidade Em Debate*, 10(1), 30–42. <https://doi.org/10.18472/SustDeb.v10n1.2019.23309>
- Milhorance, C., & Bursztyn, M. (2019). Climate adaptation and policy conflicts in the Brazilian Amazon: Prospects for a Nexus + approach. *Climatic Change*, 155(2), 215–236. <https://doi.org/10.1007/s10584-019-02456-z>
- Milhorance, C., Le Coq, J.-F., & Sabourin, E. (2021). Dealing with cross-sectoral policy problems: An advocacy coalition approach to climate and water policy integration in Northeast Brazil. *Policy Sciences*. <https://doi.org/10.1007/s11077-021-09422-6>
- Milhorance, C., Sabourin, E., Chechi, L., & Mendes, P. (2021). The politics of climate change adaptation in Brazil: Framings and policy outcomes for the rural sector. *Environmental Politics*, 1–23. <http://doi.org/10.1080/09644016.2021.1907097>
- Milhorance, C., Sabourin, E., Le Coq, J.-F., & Mendes, P. (2020). Unpacking the policy mix of adaptation to climate change in Brazil's semiarid region: Enabling instruments and coordination mechanisms. *Climate Policy*, 20(5), 593–608. <https://doi.org/10.1080/14693062.2020.1753640>
- Nogueira, D., Milhorance, C., & Mendes, P. (2020). Do Programa Um Milhão de Cisternas ao Água para Todos: Divergências políticas e bricolagem institucional na promoção do acesso à água no Semiárido brasileiro. *IdeAs*, 15. <https://doi.org/10.4000/ideas.7219>
- Olazabal, M., Galarraga, I., Ford, J., Sainz De Murieta, E., & Lesnikowski, A. (2019). Are local climate adaptation policies credible? A conceptual and operational assessment framework. *International Journal of Urban Sustainable Development*, 11(3), 277–296. <https://doi.org/10.1080/19463138.2019.1583234>
- Pacheco-Vega, R. (2020). Environmental regulation, governance, and policy instruments, 20 years after the stick, carrot, and sermon typology. *Journal of Environmental Policy & Planning*, 22(5), 620–635. <https://doi.org/10.1080/1523908X.2020.1792862>

- Paumgarten, F., Locatelli, B., Witkowski, E. T. F., & Vogel, C. (2020). Prepare for the unanticipated: Portfolios of coping strategies of rural households facing diverse shocks. *Journal of Rural Studies*, 80(2020), 91–100. <https://doi.org/10.1016/j.jrurstud.2020.05.013>.
- Pelletier, B., Hickey, G. M., Bothi, K. L., & Mude, A. (2016). Linking rural livelihood resilience and food security: An international challenge. *Food Security*, 8(3), 469–476. <https://doi.org/10.1007/s12571-016-0576-8>
- Pérez-Marin, A. M., Rogé, P., Altieri, M. A., Forer, L. F. U., Silveira, L., Oliveira, V. M., & Domingues-Leiva, B. E. (2017). Agroecological and social transformations for coexistence with semi-aridity in Brazil. *Sustainability*, 9(6), 990. <https://doi.org/10.3390/su9060990>
- Petersen, P. F., & Silveira, L. M. (2017). Agroecology, public policies and labor-driven intensification: Alternative development trajectories in the Brazilian semi-arid region. *Sustainability*, 9(4), 535. <https://doi.org/10.3390/su9040535>
- Rodriguez, R. D. G., Pruski, F. F., & Singh, V. P. (2016). Estimated per capita water usage associated with different levels of water scarcity risk in arid and semiarid regions. *Water Resources Management*, 30(4), 1311–1324. <https://doi.org/10.1007/s11269-016-1236-7>
- Schulz, K., Voigt, K., Beusch, C., Almeida-Cortez, J. S., Kowarik, I., Walz, A., & Cierjacks, A. (2016). Grazing deteriorates the soil carbon stocks of Caatinga forest ecosystems in Brazil. *Forest Ecology and Management*, 367, 62–70. <https://doi.org/10.1016/j.foreco.2016.02.011>
- Shapiro-Garza, E., King, D., Rivera-Aguirre, A., Wang, S., & Finley-Lezcano, J. (2020). A participatory framework for feasibility assessments of climate change resilience strategies for smallholders: Lessons from coffee cooperatives in Latin America. *International Journal of Agricultural Sustainability*, 18(1), 21–34. <https://doi.org/10.1080/14735903.2019.1658841>
- Simtowe, F., Makumbi, D., Worku, M., Mawia, H., & Rahut, D. B. (2021). Scalability of adaptation strategies to drought stress: The case of drought tolerant maize varieties in Kenya. *International Journal of Agricultural Sustainability*, 19(1), 91–105. <https://doi.org/10.1080/14735903.2020.1823699>
- Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, A., Martello, M. L., Polsky, C., Pulsipher, A., & Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences*, 100(14), 8074–8079. <https://doi.org/10.1073/pnas.1231335100>
- Vogel, B., & Henstra, D. (2015). Studying local climate adaptation: A heuristic research framework for comparative policy analysis. *Global Environmental Change*, 31, 110–120. <https://doi.org/10.1016/j.gloenvcha.2015.01.001>
- Xavier, J. H. V., Gomes, M. C., dos Anjos, F. S., Scopel, E., da Silva, F. A. M., & Corbeels, M. (2020). Participatory multicriteria assessment of maize cropping systems in the context of family farmers in the Brazilian Cerrado. *International Journal of Agricultural Sustainability*, 18(5), 410–426. <https://doi.org/10.1080/14735903.2020.1788253>
- Ziervogel, G. (2018). Climate adaptation and water scarcity in Southern Africa. *Current History*, 117(799), 181–186. <https://doi.org/10.1525/curh.2018.117.799.181>