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Climate adaptation and policy conflicts in the Brazilian Amazon: prospects for a Nexus + approach

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Abstract
In a scenario of the apparent adverse effects of climate change, adaptation strategies are needed. The complex cross-sector nature of climate challenges provides a compelling case for a more coherent policy approach. Combinations of policy instruments take different shapes and involve a different set of actors depending on the territory in which they materialise. In this article, the spatial distribution patterns of climate public investments are analysed by mapping the territoriality of policy priorities, functional overlaps and instrument conflicts. It provides an analytical framework named Nexus+, which heuristically defines the scope and interfaces of adaptation strategies. The framework is applied to the case of the northern border of Mato Grosso, located in the south-eastern region of the Brazilian Amazon, where the effects of climate change are expected to impact key economic and social activities.

1 Introduction

The adverse effects of climate change are already becoming apparent. They include higher average temperatures, more frequent extremes and increased climate variability. These have associated impacts on a range of ecosystems and human systems including agriculture and energy generation (IPCC 2014). This scenario suggests that carbon mitigation will remain relevant, but alone will not suffice to circumvent on-going change. Thus, adaptation strategies are needed to improve the resilience of human and natural systems (Scarano 2017). In the Amazon region, global warming is operating simultaneously and interacting nonlinearly with other large-scale drivers of environmental change, particularly deforestation. These interacting drivers are expected to induce a higher frequency of extreme climate events and vegetation fires, combined with the large-scale process of 'savannisation' of its southern and eastern regions (Nobre et al. 2016).

The causes and vectors of climate change and adaptation are embedded across several policy sectors (e.g. energy, agriculture, water, industry), each of which has different priorities

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and involve distinct sets of actors with varying interests. The complex cross-sector nature of climate challenges provides a compelling case for a more coherent policy approach (Adelle and Russel 2013). Analysing the spatial patterns of policy implementation in a specific territory can help researchers communicate with decision-makers about situations where multiple—sometimes divergent—policies are implemented simultaneously in the same geographical space (Ring and Barton 2015).

Furthermore, defining the scope of adaptation policies has become a challenge. Kasecker et al. (2018) emphasise that adaptation and sustainable development are not synonyms. Drawing on the work of Agrawal and Lemos (2015), the authors argue that whereas adaptation policies primarily address vulnerability and risks, sustainable development policies aim to reduce poverty via economic growth, address inequality through the redistribution of wealth and prevent environmental degradation by using resources sustainably. However, when adaptation hinders climate risks without negatively impacting human and natural systems, it becomes an important component of the sustainable development agenda (Scarano 2017; Kasecker et al. 2018). This explains why, empirically, climate adaptation strategies are often considered equivalent to sustainable development policies, making analytical efforts more complex and diffuse.

In this article, an analytical framework is developed to operationally identify policies that can both advance and hinder adaptation goals. Named 'Nexus+', it combines a theoretical background inspired by the water-food-energy nexus and the literature on sustainable livelihoods, and a methodological approach to analyse the interactions and spatial incidence of distinct public actions. The framework is then applied to the case of Mato Grosso, particularly its northern border, located in the south-eastern region of the Brazilian Amazon, where the effects of climate change are expected to impact key economic and social activities.

2 Nexus+: defining the scope of climate adaptation strategies and challenges

2.1 Theoretical background

The analytical framework proposed in this article converges with the works of Biggs et al. (2014) and Agrawal and Lemos (2015), but explicitly combines the concepts of 'sustainable livelihoods', 'climate risks' and 'environmental security' with the 'nexus approach'. The nexus approach is based on the argument that the limited emphasis on the interfaces of water, energy and food securities commonly leads to contradictory interventions and the inefficient use of natural resources (Howells et al. 2013). It is argued that sectorial strategies can increase vulnerabilities by restricting capabilities or increasing risks in another location or sector, and that the interactions between these three systems affect their availability (Biggs et al. 2014; Rasul and Sharma 2016).

The term is considered an evolution of the concepts of *integrated water resources development and management* recommended by the United Nations Conference on Water in Mar del Plata in 1977. This literature was consolidated in the late 2000s, particularly in the context of the 2007–2008 food global crisis (Allouche et al. 2014; Artioli et al. 2017). Historically, it has emphasised the centrality of water resources, although currently a more resource-centred perspective is adopted. The analysis of nexus through an environmental lens enables its association with the idea of 'security', which according to Biggs et al. (2014), can be achieved

when the unit of analysis (from country to individual) has the capabilities and assets to sustainably use environmental resources to promote its wellbeing.

In this article, this literature is connected to that underpinning the concepts of sustainable livelihoods, climate risks and environmental security. In empirical terms, this implies that the scope of adaptation strategies adds the social and environmental dimensions to the water-food-energy nexus. This link is referred to as Nexus+, inspired by the inclusion of '+' in the concept of REDD (Reducing Emissions from Deforestation and Forest Degradation) when at the COP16 in Cancun, the Parties sought to focus on the broader social and environmental dimensions of the climate mitigation mechanism (Gupta et al. 2013). Emphasising these dimensions in adaptation strategies is justified, because increasing climate risks are expected to unequally expose populations to volatile earnings and livelihoods, render a large number of households destitute and require more robust social and policy mechanisms to address environmental change (Agrawal and Lemos 2015).

This approach explicitly considers the negative synergy between poverty and vulnerability to climate change. Hence, the framework does not focus on risk management, but on a form of development that mitigates climate risks without negatively influencing the wellbeing of human subjects and ecosystems.

Similarly, the term 'environmental security' addresses the problem of the vulnerability of particular human groups to environmental stresses, which may be related to natural phenomena or unsustainable social activities. As in the works presented above, it is expected that environmental insecurity will be most adversely felt by the poor and vulnerable populations of developing countries (Upreti 2013). Rather than focusing on the issue of environmental scarcity, the term has been associated with social, economic and political factors that determine access and the ability of these populations to use resources (Pritchard 2014). In fact, definitions of environmental security may vary, but issues such as access, availability and the quality of livelihood resources are often present. In addition, this is closely related to issues pertaining to water, energy and food security.

Noteworthy is that the nexus literature often seeks to optimise efficiency in the management of natural resources, recognising interdependencies between social and environmental systems. However, a significant part of this literature does not explain what ensures coherence across sectors (Weitz et al. 2017). Stein et al. (2018) remarked that the literature does not sufficiently consider the relationship between the actors involved in the governance of the three policy fields and their social practices. Drawing on this criticism, this article is based on the idea that inconsistencies are an inherent part of cross-sectorial public action—not simply the result of weaknesses in the management process—and should therefore be integrated into the governance analysis (Stevens 2018). The need to 'politicise nexus' (Artioli et al. 2017) considering the existence of conflicts of interest and asymmetric distribution of power renders access to the resources and capabilities of actors and institutions key.

To summarise, the Nexus+ framework considers the interdependencies between food, energy, water and socio-environmental security by clarifying the interactions between public policy instruments in a given territory. In this way, social, political, institutional and infrastructure issues related to access, availability and the quality of essential livelihood resources are more explicitly associated with adaptation strategies. Figure 1 illustrates the approach, applied to the case of Mato Grosso. It showcases the connections among the Nexus+ policy fields (food, energy, water and socio-environmental security) and among a number of interventions on the territory (regarding each axis). The objective is to represent the multiple interdependencies among these interventions. Moreover, climate-related risks bring

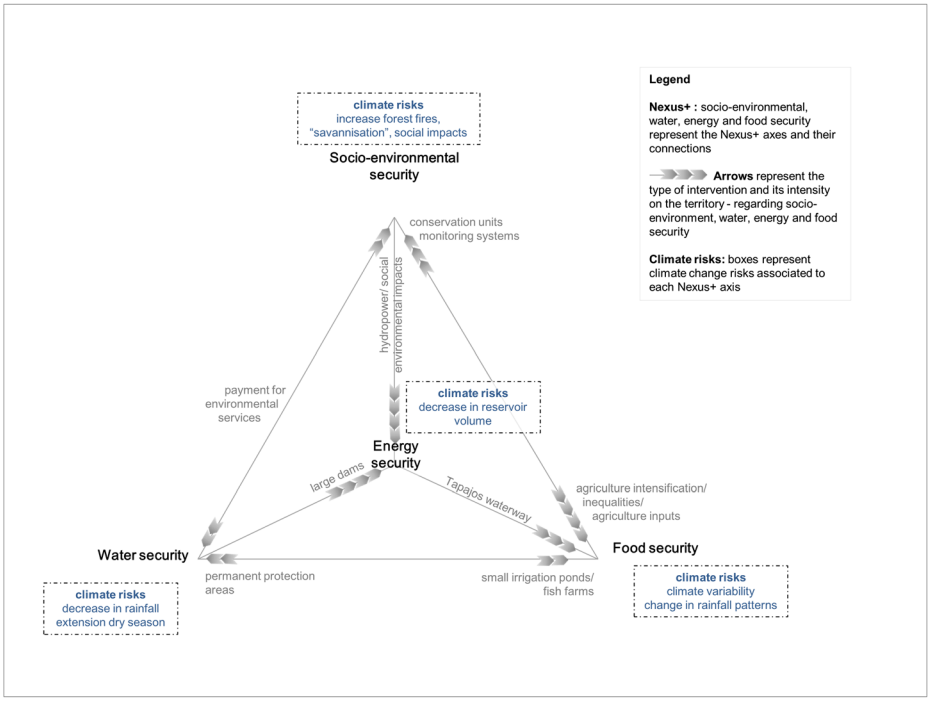

Fig. 1 Scheme of the analytical framework applied to the Mato Grosso case: main interventions on the territory regarding the Nexus+ security axes and their related climate risks. Source: authors

complexities to the system and add a number of challenges to the promotion of Nexus+ securities. These will be discussed throughout the article, particularly the predominant policy responses and sources of governance failures.

2.2 Methodological steps and options

The first step of the study was a survey of the main federal and state government programmes and projects targeting Mato Grosso in Brazil. The survey was limited to the Nexus+ policy fields: food, energy, water and socio-environmental security. In this case study, the analysis focuses on rural landscapes; therefore, the policies identified are limited to those that influence the dynamics of land use and change.

The survey was based on the jurisdictional unit of Mato Grosso state. Noteworthy is that threats to socio-environmental security do not always respect jurisdictional boundaries. However, an approximation in this case is important to ensure a direct dialogue with public policies and public investments. This definition does not imply examining only the instruments of state jurisdiction. It also includes federal instruments that target Mato Grosso and interact with state instruments. Regarding the timeframe, the survey was limited to programmes implemented over 5 years (2013–2017).

The relation between each category of programme considered here, the Nexus+ axes and climate change is summarised in Table 1. It should be noted that policies contributing to climate adaptation and mitigation are not necessarily labelled as such, although climate purposes are reflected in practice (Wamsler et al. 2014). In the case of Brazil, the National

Table 1 Connection between policy strategies related to several Nexus+ policy fields and the objectives of promoting climate change mitigation and adaptation

Policy field	Relation to climate change mitigation and adaptation objectives	Relation to Nexus+ axes	Examples of programmes
Agricultural production, productivity	• Policy instruments that incorporate climate uncertainty, through the development of information systems and the promotion of insurance that protect producers from the risks generated by increased climate variability, contribute to promoting the adaptive capacity of the sector • The increase in agricultural productivity may contribute to reduce forest conversion to agriculture. However, in Brazil, these are not always correlated, and agriculture intensification has also been followed by the use of agro-chemicals that slow down climate mitigation efforts. Moreover, rural credit is not directly conditioned by environmental performance which could prevent funds allocation to producers employing unsustainable practices	• Agriculture intensification may contribute to increase food security at a regional/national level; however, the multiplication of irrigation dams and the increase of economic inequalities may hinder socio-environmental and water security at the territorial level • The priority of water resources management to the establishment of waterways for transporting agricultural products may affect energy security objectives	Traditional rural credit (FCO rural, BNDES Agro); rural insurance (Proagro, PSR)
Sustainable production	• Increased efficiency in the use of agricultural inputs, for greater precision in their application, and the replacement of industrial inputs by ecological processes, are strategies that contribute to the adaptation of agricultural systems to the effects of climate change. Agro-ecological practices, for example, increase biodiversity and the complexity of agro-systems, making them more resilient. The adoption of sustainable production practices, in particular soil and water conservation as well as the maintenance of ecosystem services, also contributes to increasing the resilience of production systems • Rural credit lines (and other instruments) exclusive for fostering activities targeted at increasing the area under sustainable agricultural production may contribute both to climate adaptation and mitigation	• Policy strategies promoting sustainable production systems shall contribute to increase both food and socio-environmental security	Ecoforte/National Plan for Agroecology and Organic Production; Low Carbon Agriculture Plan (ABC)
Land and traditional communities	• Social vulnerabilities associated with structuring socio-economic, ethnic and cultural inequalities increase the sensitivity of the population to the effects of climate change. The poorest groups will tend to be more heavily affected by the increase in climate variability, as they have fewer alternatives for ensuring livelihoods than wealthier segments of the population	• Policy strategies promoting the distribution of land titles to vulnerable populations and supporting the livelihoods of traditional communities are crucial to assure socio-environmental security. These should be integrated to productive inclusion and environmental conservation policies in	Amazon Fund; National Policy for Territorial and Environmental Management of Indigenous Lands (PNGATI); National Agrarian Reform Policy (PNRA); Terra Legal

Table 1 (continued)

Policy field	Relation to climate change mitigation and adaptation objectives	Relation to Nexus+ axes	Examples of programmes
	• Policies promoting legal security with respect to land tenure, respect for identity and ties to the territory, and consideration of existing cultural norms guarantee access to essential resources for the livelihoods of traditional populations, as well as the development of their capacities, reducing the vulnerability to climate and other environmental changes.	order to improve aspects of food, energy and water security	
Family farming, food and nutritional security, social protection	• Vulnerable farmers usually employ 'conservative' production strategies that seek to reduce risks regarding climate variability, but which can become costly in terms of lost opportunities and revenues. Policies promoting productive inclusion and structured access to markets help to circumvent these challenges • Social protection and food and nutrition security policies contribute to the protection of the most vulnerable populations to climate risks, the prevention of coping strategies considered harmful, the promotion of resilience to climate-related shocks through the diversification of livelihoods and the reduction of social and political vulnerability	• Productive inclusion, social protection and food and nutritional security strategies promote food security; however, these strategies could progressively incorporate climate and environmental risks in order to foster climate adaptation and socio-environmental security	National Program to Strengthen Family Agriculture (Pronaf); Food Acquisition Programme (PAA); National school feeding programme (PNAE); Bolsa Familia (family grant)
Environment/protected areas	• Climate is a determining factor for the distribution of living organisms. Policies of biodiversity conservation and of maintenance of ecosystem services contribute to reducing human (and ecosystem) vulnerability to the impacts of climate change. Ecosystem-based adaptation approaches are grounded upon the management, conservation and restoration of ecosystems that can contribute, for example, to enhancing carbon sequestration, climate regulation, and ensuring food and water security	• Environmental management, restoration strategies and the establishment of protected areas (particularly of riparian vegetation) are directly connected to the promotion of water and environmental security. Finding balance between these strategies and agricultural, social and energy interventions are still conflictive in Mato Grosso	National Plans for Deforestation Reduction (PPCDam, PPCerrado); Amazon Fund
Hydropower production	• Renewable energy is considered a means of reducing greenhouse gases emissions and promoting climate mitigation. Brazil's main electricity source is hydropower, whereas other renewable and fossil-fuel energy sources complement the system • However, electricity security may be hindered by climate variability as continuous decrease in rainfall trends may impact water availability in hydropower plants' reservoirs. Moreover, the	• The construction of big hydropower dams in Mato Grosso has affected traditional populations living in the regions chosen for the infrastructure projects. These strategies are important to assure energy security at a regional (and national) perspective; however, existing experiences have	Programme for Acceleration of Growth (PAC)

Table 1 (continued)

Policy field	Relation to climate change mitigation and adaptation objectives	Relation to Nexus+ axes	Examples of programmes
	construction of big hydropower dams may affect the capacity of local populations (traditional communities and riverine populations) to adapt to climate change by negatively impacting their livelihoods	displaced local populations and hindered socio-environmental security	
Water management	• Variations in temperature and rainfall patterns brought on by climate change are likely to cause significant impacts on water availability (volumes and distribution) affecting the multiple uses of water. Extreme water-related climate events (flooding and drought) are likely to become more intense. Water-related issues are likely to be among the first impacts of global climate change felt by populations • Impacts of extreme events attributed to climate change may also be exacerbated by other pressures on water resources, including inappropriate land-use and settlement in river basins, increasing demand for urban water supply, agriculture and power generation • Policies addressing uncertainties and information gaps with respect to measurement of the impacts of future climate on water balance, and promoting a strengthened and integrated water resources management increase the capacity of society, ecosystems and the economy to cope with expected changes	• Assuring the 'multiple uses' of water resources is a policy objective which implicitly intends to promote all the Nexus+ axes. However, governance failures and conflicts with other sectors are very common. Initiatives of payment for environmental services in the northern border of Mato Grosso have the intent to promote water security in a context of expansion of the agricultural frontier and increasing climate variability. Including family farmers and traditional populations in these initiatives may produce positive effects towards socio-environmental security	National Policy on Water Resources (PNRH)

Source: Authors, based on Brazil's National Adaptation Plan (2016)

Adaptation Plan (NAP), launched in 2016, brings together existing sectorial strategies which are considered relevant to the climate adaptation objectives. Therefore, this analysis draws on the programmes of Brazil's NAP and of the National Policy on Climate Change (NPCC) related to land use and change; however, the point made here is on the need to improve integration between sectoral strategies. The Nexus+ approach is developed as a means of shedding light on their interactions, which may contribute to (or hinder) adaptation and mitigation efforts. The results also show that adaptation and mitigation strategies are not always consistent in terms of objectives and effects when the socio-environmental dimension is included.

The information regarding the objectives and targets of each programme was obtained from the official documents and decrees available on federal and state websites, while the information regarding funds was obtained from public transparency websites (*Portal da Transparência* and *Portal Siga Brasil*) as well as from management reports.

Data visualisation drew on the geo-referencing of direct support public investments (credit, development, insurance, infrastructure investment, income transfer, public procurement and food distribution). Note that the resulting maps do not include regulatory or institutional instruments, as these do not target a specific territory. Instruments of direct support inform us about the patterns of distribution of public policies throughout the jurisdiction, showcasing the territoriality of recognised or induced vocations.

3 The policy landscape for climate adaptation in Mato Grosso

3.1 Beyond forest monitoring and agriculture intensification: the challenge of including vulnerable populations in climate policies

The state of Mato Grosso, located in Brazil's Midwestern region (Fig. 2), is the country's largest producer of grains and livestock (IPEA 2017) and a major producer and processor of timber. Soy crops and the related transportation infrastructure have been important drivers of deforestation, but the conversion of crops into pasture areas has also displaced the production frontier into previously undisturbed forests in the north and northwest regions of the state territory (Brando et al. 2013).

In this context, the state is the largest single source of deforestation and related greenhouse gases emissions in Brazil, and as such, is responsible for a significant share of global emissions (Milhorance and Bursztyn 2018). As a major emitter, Mato Grosso is a target for the observance of Brazil's Intended Nationally Determined Contributions adopted after the 2015 United Nations Climate Change Conference held in Paris. In addition, climate change is currently a significant source of risk to rural development, agricultural production and biodiversity in the state. Climate models suggest critical impacts on agriculture, with forecasts of a more than 90% reduction in maize and 80% in Brazil's soy production, primarily affecting Mato Grosso (Assad et al. 2016; Zanin et al. 2016). The north of Mato Grosso is located in the south-eastern region of the Brazilian Amazon, which is more likely to be negatively impacted by climate change and continuous deforestation, namely the decreasing wet season rainfall trend (Nobre et al. 2016).

A first highlighted pattern in the policy landscape is that deforestation rates for the Brazilian Amazon have significantly reduced over the past decade (more than 80% from 2004 to 2014). Several factors contributed to this sharp decline, including improved satellite monitoring

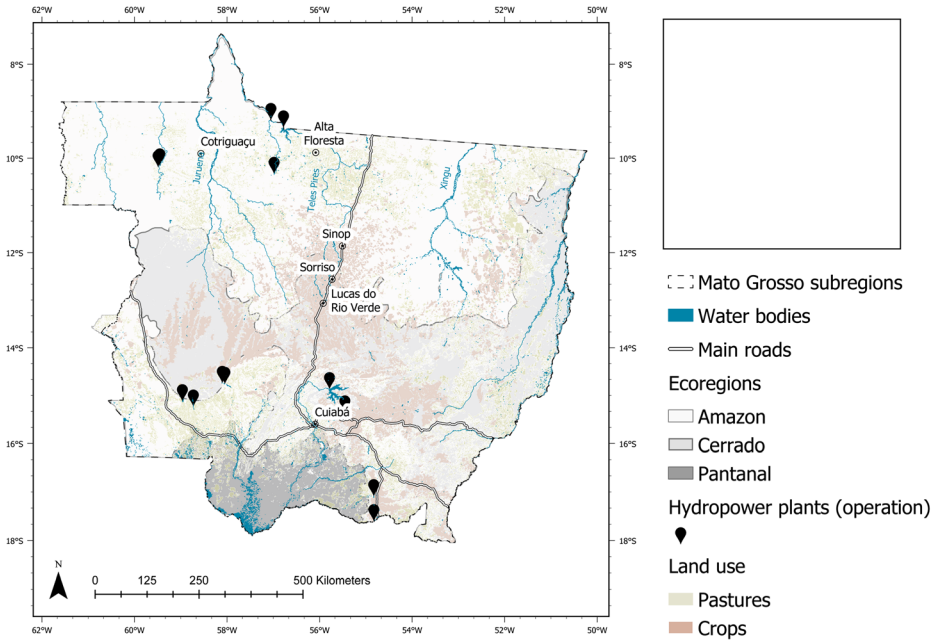

Fig. 2 Location of Mato Grosso in Brazil, including administrative and eco-regions, infrastructure (hydropower plants and roads), pastures and commodities crops. SOURCE: authors, based on IBGE (2014), MAPBiomas (2016) and ANEEL (2016)

capabilities, effective enforcement and compliance of environmental law, private sector agreements like the soy moratorium, restrictions on access to credit for farms located in high deforestation zones and expansion of protected areas and indigenous lands (Nobre et al. 2016). In the agricultural sector, this decade has been marked by a decoupling of deforestation and soybean production thanks to initiatives promoting the intensification of agriculture, which contributed to Brazil's mitigation efforts (Arvor et al. 2017). These factors are elaborated in this section and critically analysed in terms of their contribution to promoting broader climate adaptation objectives.

In 2004, the federal government set up the National Plan for Deforestation Reduction (PPCDam in Portuguese), which consolidated an effort of command and control. This included sanctions on producers, increased enforcement of environmental laws, improved monitoring, establishment of new protected areas and incentives for zero-deforestation production practices (Brando et al. 2013). A 'red list' of municipalities reflecting their deforestation rates restrained rural credit in these sites. Together with these public strategies, soy products trading companies began not funding or acquiring soybeans from deforested areas, establishing the Soy Moratorium in 2006. This type of agreement, based on voluntary commitments by companies, has proliferated in the commodities sector and produced major effects in reducing deforestation and promoting climate mitigation, despite some criticism regarding their lack of alignment with the Forest Code (Rudorff et al. 2011; Gibbs et al. 2015).

The Forest Code instituted the rural environmental registration (CAR), the main legal instrument regulating land use in rural properties. In this context, several private, civil society and international actors including the NGO 'The Nature Conservancy', the German bank KfW and Mato Grosso Agribusiness Federation (FAMATO) have provided farmers with technical

and financial support in registering their properties in the state. The Amazon Fund, managed by the Brazilian Development Bank with international resources, also created a portfolio to reach this objective (Milhorance and Bursztyn 2018). The alignment of CAR and rural credit—at least institutionally—represented a step in integrating environmental and agricultural policies in the Amazon region. However, challenges remain in assuring the effectiveness of this measure and promoting change in agricultural practices among all categories of producers.

The continuous and growing demand for agricultural commodities in international markets, corporatist local institutions and large hydropower infrastructure projects remain underlying and proximate drivers of the continuity of deforestation rates (Nobre et al. 2016). Furthermore, recent studies directly relate the land tenure deficit to social and environmental challenges, as public agrarian reform settlements (*assentamentos*) are responsible for around 30% of deforestation in the Brazilian Amazon and 18% in Mato Grosso (Azevedo et al. 2016; Assunção and Rocha 2016). Also important is that 95% of the deforestation in Mato Grosso is considered 'illegal', in other words, not in accordance with Brazil's Forest Code. In addition, while deforestation has declined in the Amazon region, since 2011, it has grown in the Cerrado (Sampaio et al. 2015; Milhorance and Bursztyn 2018).

The CAR registration is carried out at Mato Grosso's Department of the Environment (SEMA). In 2017, there were more than 112,500 registered properties, equivalent to 69 million ha and approximately 95% of the total area of the state (SBF/MMA 2017). However, with low levels of validation, CAR has a limited role in controlling deforestation. In addition, agrarian policies have not yet incorporated the environmental dimension into the social and productive dimensions. As mentioned, rural settlements still play a prominent role in deforestation, despite the reduction in absolute terms of the deforested area (Alencar et al. 2016). The procedures, costs and slowness of certification mean that the geo-referenced registration of small properties and rural settlements is not yet a reality in the state. Thus, an important portion of the rural population faces socio-economic challenges and struggles to access social policies and credit that increasingly depend on land tenure titles and the CAR.

As a second trend, it is important to highlight that the 2000s corresponded to a phase of agricultural intensification symbolised by the generalisation of no-tillage sowing and double-cropping systems, that is, a crop of maize, cotton and sorghum or millet sown after the soy harvest (Arvor et al. 2013). These trends have been followed by public policies such as the Low Carbon Agriculture Plan (*Plano ABC*), launched in 2010 as a component both of the NPCC and the NAP. The plan is divided into seven programmes, namely recovery of degraded pastures, integration of crop-livestock-forest and agroforestry systems, no-tillage system, biological nitrogen fixation, planted forests, animal waste and adaptation to climate change.

However, the ABC credit line represents less than 2% of the total rural credit provided in the country since its implementation. According to reports from the Ministry of the Environment, the amount of this type of credit available to priority municipalities to foster climate mitigation, by combatting deforestation in the Amazon, is still inexpressive (MMA 2016). Moreover, its adaptation strategy has not been detailed or implemented yet. Note that the progressive growth of the ABC interest rates, coupled with a low investment economic environment, negatively impacted the volume of disbursements, which was already insufficient, making the credit line uncompetitive in relation to traditional rural credit lines. In addition, the technical requirements demanded by the programme are much higher than are those demanded by traditional lines. In the case of Mato Grosso, the tendency is the greater inclination of producers and technical assistance professionals to use traditional lines (e.g.

Center-West Fundamental Constitutional Fund) to the detriment of the ABC Programme (Observatório ABC 2017).

Furthermore, these lines are not accessible to smallholders. According to representatives of the Brazilian Ministry of Agrarian Development,[1] the ABC Plan has been designed for medium- and large-sized agriculture, considering that the carbon emissions of this public generate greater impact (Mendes 2014). For family farming, specific instruments are the green credit lines of the National Programme for Strengthening Family Agriculture (Pronaf). However, according to the Central Bank, they represent less than 1% of the total volume of rural credit provided annually. Thus, despite the recognised results of partially decoupling deforestation and agricultural production in the Amazon frontier, major challenges remain in scaling-up access to credit that favours a change in agricultural practices, particularly that accessible to family farmers.

Assessing climate mitigation efforts, based upon land use sustainability, and adaptive capacity to climate change implies analysing the impacts of environmental changes on people's ability to cope with these changes, including considering social indicators other than deforestation reduction and economic growth. The frontier areas where deforestation persists are marked by weaker socio-economic indicators; thus, deforestation can be associated with economic precariousness and is a marker of inequalities in the Amazon. According to analysts (Laurent et al. 2017), without complementary policies, the 'zero deforestation' strategy advocated by public authorities may foster mitigation; however, they may also impact those who cannot afford to abandon slash-and-burn practices at the expense of forest resources or stop using fire to clear pastures.

For instance, Table 2 illustrates the high GDP of the northern administrative region of Mato Grosso in comparison with other regions, particularly regarding the agriculture sector. However, when it comes to socio-environmental indicators, several deficits can be highlighted. The region presents the highest cumulated deforestation, with an emphasis to the Aripuanã microregion (identified by the city of Cotriguaçu in Fig. 2). The region is also marked by high inequality rates (Gini = 0.520), low social indicators (IDH = 0.658) and low access of population to water, sanitation and electricity. Equally challenging results may be observed for Alta Floresta.

Several authors claim that the social and environmental dimensions of sustainability other than deforestation reduction deserve exploration (Arvor et al. 2017). They point out that economic development through agricultural intensification may both improve living conditions and lead to the eviction of people from rural areas because of monoculture and land concentration, thus increasing inequality among local populations. Moreover, recent studies indicate that the Human Development Index is being decoupled from soy production as the potential result of efficient social policies and diversification of economic and agricultural activities (Arvor et al. 2017). Note that soy clusters in Mato Grosso—such as Sorriso, Lucas do Rio Verde and Sinop—had become nationally renowned for their high domestic product and human development indices (Milhorance and Bursztyn 2018).

Efforts to extend the sustainable path towards all categories of producers remain weak or localised. For instance, Fig. 3 shows the prevalence of public support across the state's territory to increase agricultural production and productivity, in contrast with those oriented towards family farming, rural settlements, and sustainable production. The figure illustrates the allocation of the volume of public resources invested by municipality and sector, normalised by municipal population and the type of policy instrument (proportional volume of investments).

[1] Dissolved in 2016.

Table 2 Socio-economic and environmental indicators in Mato Grosso subregions

	GDP (R$ 1000 in 2016)	GDP per capita (R$ 100 in 2016)	GDP Agriculture (R$ 1000 in 2016)	Gini (2010)	Municipal IDH (2010)	Inadequate water and sanitation (% population in 2010)	Lacking access to electricity (% population in 2010)	Cumulated deforestation (2013–2017)
Centre-South	34,517,630	393,355	1,347,914	0.490	0.676	11.3	1.9	407,589
Northeast	10,058,465	847,133	3,120,012	0.528	0.666	9.7	7.4	2,023,509
North	46,706,592	2,465,379	13,753,315	0.520	0.690	6.4	4.0	6,389,469
Alta Floresta	2,642,366	131,414	309,887	0.520	0.678	12.0	3.7	840,554
Alto Teles Pires	16,221,181	706,469	4,953,237	0.494	0.725	1.8	0.7	882,057
Arinos	2,627,370	229,452	1,104,905	0.482	0.679	4.3	2.0	967,291
Aripuanã	3,488,898	171,465	739,272	0.541	0.658	15.9	11.8	1,252,690
Colíder	3,489,814	193,260	529,597	0.544	0.691	5.4	2.1	954,310
Paranatinga	1,257,549	131,382	538,496	0.563	0.647	3.8	9.1	397,450
Parecis	9,555,631	534,992	4,310,098	0.510	0.723	4.2	2.3	215,134
Sinop	7,423,784	366,944	1,267,823	0.516	0.701	3.7	2.1	879,983
Southeast	22,983,019	*883,256*	4,971,103	0.478	0.702	*2.6*	1.9	298,693
Southwest	9,568,547	543,991	1,890,840	0.500	0.679	*5.9*	1.6	1.466.053

Sources: IBGE (2017), IpeaData (2017) and Prodes (2018)

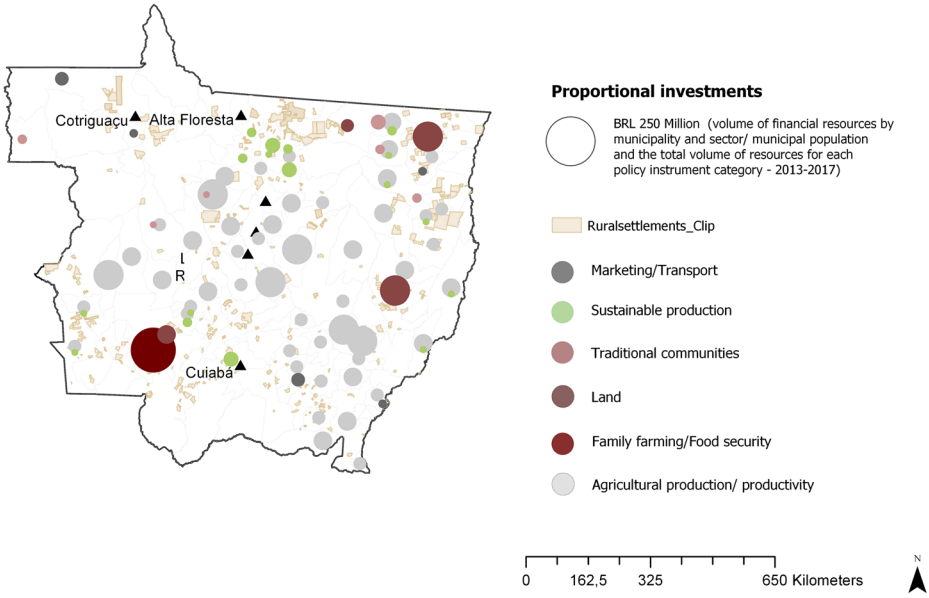

Fig. 3 Public investments in the rural sector in Mato Grosso and rural settlements: proportional volume of resources invested in each type of policy instrument (credit, productive inclusion grants and infrastructure) between 2013 and 2017. Source: authors

The selected visualisation parameter was the graduated symbols. Aspects such as the number of initiatives and the presence of very low investments per municipality are not visible in the map.

Quantitative data support the visual patterns as it shows a high correlation between total public investments per municipality and municipal GDP per capita ($\rho = 0.656$; $p < 0.001$), followed by even higher correlation with municipal agriculture GDP ($\rho = 0.762$; $p < 0.001$). An equally high correlation was found between public investments in agricultural production/ productivity and these two parameters (respectively $\rho = 0.656$ and 0.799; $p < 0.001$). However, no significant correlation was found between public investments in productive/social inclusion and GDP per capita or agriculture GDP. Both the qualitative and quantitative data support the idea that public investment is not only oriented by the geographic presence of an agribusiness sector, but it lacks interaction with productive and social inclusion strategies.

Interesting is that in the region of Cotriguaçu (Aripuanã microregion), direct support from the government for the rural sector is almost absent, although this region is known for demonstrating significant socio-economic deficits and the highest deforestation rates in the state (INPE 2018). On the other hand, the commercialisation of Brazil nuts has been increasing since 2008 in this region, signalling the prospect of adding value to local smallholder production (Melo and Halla 2016). The Integrated Chestnut Programme and tax exemption for certain native products (Decree No. 2212/2014) contributed to increasing the volume of production. In addition, non-timber products have been included in the public calls of the national school feeding programme, but the resources allocated have not been sufficient to include such products in school menus.

In the context of low public direct investments in this region, several non-governmental actors have shown to be active in promoting socio-environmental strategies. For instance,

initiatives related to REDD+ have been implemented. Currently, the state has several experiences focused on mechanisms related to REDD+, particularly in indigenous lands (like Xingu, Suruí and Parecis). These have more often been promoted by NGOs and international agencies, but the launch of the National Strategy on REDD+ in 2015 has the potential to align these initiatives, which are historically localised, to a broader policy strategy. At the state level, the connection between these projects and the Produce, Include, and Conserve strategy institutionalised by the state government in 2016 could promote the multilevel alignment of public actions in promoting deforestation reduction and adaptation strategies for vulnerable populations such as indigenous peoples and other family farmers (Milhorance and Bursztyn 2018).

In summary, decoupling deforestation and agricultural production may have provided important results in terms of deforestation reduction and climate mitigation in the Amazon frontier. However, the low capacity of public policies to extend these results to publics other than medium to large producers results in persistent deforestation and the exclusion of vulnerable populations from these public strategies. Thus, a high level of inequality among Amazonian populations is retained. In a climate adaptation scenario, improving the alignment of environmental and production policies with social and equity concerns is crucial. This may also be evident in the spatial distribution of public support that currently reflects this asymmetry through the existence of empty spaces and localised islands that could be targeted to support vulnerable populations including traditional communities and family farmers. Therefore, aligned to the framework presented above, it is important to implement policies that consider the multiple components of the risks of climate change impacts.

3.2 Water management in a changing climate: trade-offs between conservation, infrastructure construction and irrigation

As mentioned, the potential effects of climate change in Mato Grosso may not only affect agricultural crops, but also water resources in general. Although water abundance has played a crucial part in the public imagery and perception of this territory for centuries (Schulz et al. 2017), several studies have demonstrated decreasing rainfall as related to the length of the rainy season. These results are significant in the north and northwest of Mato Grosso, where rainfall trends (measured by the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks—Climate Data Record for the period of 1983–2008) showed a decrease of -2.7 ± 5.3 (in Alta Floresta) and of 10 days/decade in the rainy season (in Juína, Aripuanã). In these regions, downward trend of rainfall has already been perceived by agricultural producers (Dubreuil et al. 2017).

Currently, the region faces further challenges regarding the governance of water resources. Divergent strategies oppose the conservation of water bodies through protected areas, the use of these resources to support local livelihoods and the cultural reproduction of indigenous peoples, proliferation of small irrigation dams and construction of large infrastructure plants to expand the production of hydropower and waterways to transport commodities to international markets. These divergent strategies are analysed in this section. According to Schulz et al. (2017), the historic perception of 'water abundance' in Mato Grosso could have led to governance failures. As water management does not represent a political priority, it is often poorly coordinated and implemented, or driven by responses to crisis. The governance of water resources in the northern region of the state is analysed here in terms of its interaction with the Nexus+ policy fields.

First, the impacts of climate change combined with extreme deforestation in the municipality of Alta Floresta led to an unprecedented water scarcity. Dubreuil et al. (2012) showed a significant decrease in total precipitation, especially at the end of the dry season and at the beginning of the rainy season. According to the authors, the deforested area of Alta Floresta is in general warmer and drier (5% to 10%) than the forested areas, including day and night temperatures.

In 2008, the municipality was included by the Ministry of the Environment on the list of priority for efforts to monitor and control deforestation, which also restrained access to rural credit and other investments. In addition to these economic constraints and despite being an Amazonian municipality at the centre of natural watercourses and springs, in 2010, the region faced a major crisis that led to several weeks of a water shortage. Considering the southern areas of the Amazon basin, a climatological water deficit of more than 50% and an increase of fire counts of more than 100% (compared to the mean of the 1998–2011 period) was observed in August/September (Gatti et al. 2014). River levels during the droughts of 2010 were among the lowest of the last 40 years (Marengo et al. 2013). According to interviews with local representatives in 2017, more than 60% of springs were degraded and it was necessary to burst fish breeding dams to drain the water and alleviate the effects of the crisis.

Consequently, the municipal secretariat of the environment launched the project 'Olhos d'Água', which was supported by the Amazon Fund. The project comprised efforts to tackle the rural environmental degradation problem, especially the springs located on small properties, to prevent water shortages. Among the activities implemented was support to help small rural producers adhere to the CAR (Amazon Fund 2018). Part of the strategy relied on payment initiatives for environmental services for the conservation and recovery of water springs.

An evaluation report indicated that the project allowed Alta Floresta to emerge from a situation of environmental illegality through local governance initiatives coordinated by municipal public authorities. The project decreased the deforestation rate by 72.7% in the period 2011–2014 (related to 2007–2010) and relied on high levels of adherence and commitment among beneficiaries. The environmental regularisation of the municipality enabled an agreement with McDonald's fast food chain to purchase meat from two Alta Floresta suppliers, opening the way for funding from other sources such as the Moore Foundation, Vale Fund and Althelia Climate Fund. Nevertheless, most of the farmers involved in sustainable production activities did not obtain direct economic results from these activities. Thus, improving direct incentives for sustainable production activities and more integration with policies to strengthen family agriculture was considered crucial (Anache et al. 2016).

Second, the region has become a priority in national governmental plans to expand national hydropower production (see hydropower dams in Fig. 2). It is planned to construct 36 large dams (accounting for more than 30 MW of installed capacity) in the Tapajos River tributaries of Mato Grosso: 6 in the Teles Pires River Basin and 30 in the Juruena River Basin. Furthermore, numerous 'small hydropower plants' are planned, which are exempt from the federal government's environmental impact study. Most of these have been promoted under the federal Programme for Acceleration of Growth (PAC), a large-scale public works programme launched in 2007 and intended to speed up the economy.

Some potential impacts of the construction of dams in the Amazon were summarised by Fearnside (2015a) as follows: loss of terrestrial and aquatic biodiversity, greenhouse gas emissions, loss of fisheries and other natural resources supporting local livelihoods and large population displacement. The author also mentions fragilities in Brazil's legal treatment of

licencing, which is not effective in preventing social and environmental impacts resulting from these infrastructure projects. Impacts of the hydropower dams complex in the Tapajós River Basin potentially include the displacement of *Mundukurus* indigenous peoples, negative impacts on fishing communities and deforestation associated with the construction of large dams (Barreto et al. 2014; Fearnside 2015b). Therefore, there is a clear contradiction among public policies for this region, as the impacts of large dams include damage to indigenous lands and the flooding of protected areas, both being part of the public national system of conservation units (Fearnside, 2015b).

Figure 4 shows the incidence of public investments by sector. The first image illustrates the amount of public resources allocated in each municipality, normalised by the municipal population and compared to the type of policy instrument (proportional volume of investments). This means that energy investments are not compared to social protection at the same level, but within each instrument category. The second image illustrates the actual amount of public resources in each municipality by sector (not considering population or the type of instrument). It is possible to attest the importance of actions of support for the agricultural sector across the territory in absolute and comparative terms. In the north, a high concentration of energy investments overlaps with protected areas and indigenous lands.

Quantitative data showed no significant correlation between public investments in energy and GDP or population. These investments are commonly driven by the presence of specific natural resources and not by local economic or social dynamics, which often results in policy overlapping. The distribution of public investments based on the Nexus+ policy fields, by administrative region, is illustrated in Fig. 5. From the figure, it is possible to observe that the direct interventions are concentrated on the northern region of Mato Grosso, particularly in agricultural and energy production. These specific investments are not directly related to the population or to socio-environmental deficits, as described above.

As stated in the most recent energy expansion national plan (2017–2026), hydropower still represents a central pillar of the growth of electricity supply, and the higher expansion potential is in the Amazon region (MME/EPE 2017). According to the document, the restriction of this energy source would increase the use of mineral coal, the most competitive alternative. Nonetheless, this would also increase greenhouse gases emissions. The document does not consider wind and solar power as reliable sources to progressively replace hydropower. Nobre et al. (2016) note, conversely, Brazil's vast underexploited central and distributed renewable energy generation and energy efficiency potential in regions closer to consumption centres versus energy demand in the Amazon that can be met by local renewable sources. Thus, it should be feasible to plan for increased energy generation capacity that does not rely on new hydropower capacity from the Amazon.

Noteworthy is that many of the dams in the Tapajós River are currently paralysed for irregularities in licencing processes, a scenario of juridical insecurity for investments according to some proponents of these large dams. Furthermore, Fearnside (2015a) describes continuous changes in planning processes to favour dams comprising the waterways to transport commodities from the Mato Grosso hinterlands to international ports (in Pará state) and postponing dams that are not part of these routes (Fearnside, 2015a). Still, according to the author, the implementation of the so-called *Tapajós Waterway* could potentially encourage future deforestation to produce commodities in northern Mato Grosso, benefiting from this infrastructure.

Third, an additional factor of pressure regarding water resources in the region is the establishment of pivot irrigation systems and artificial ponds as the result of the processes of agriculture intensification based on irrigation practices and diversification based on fish

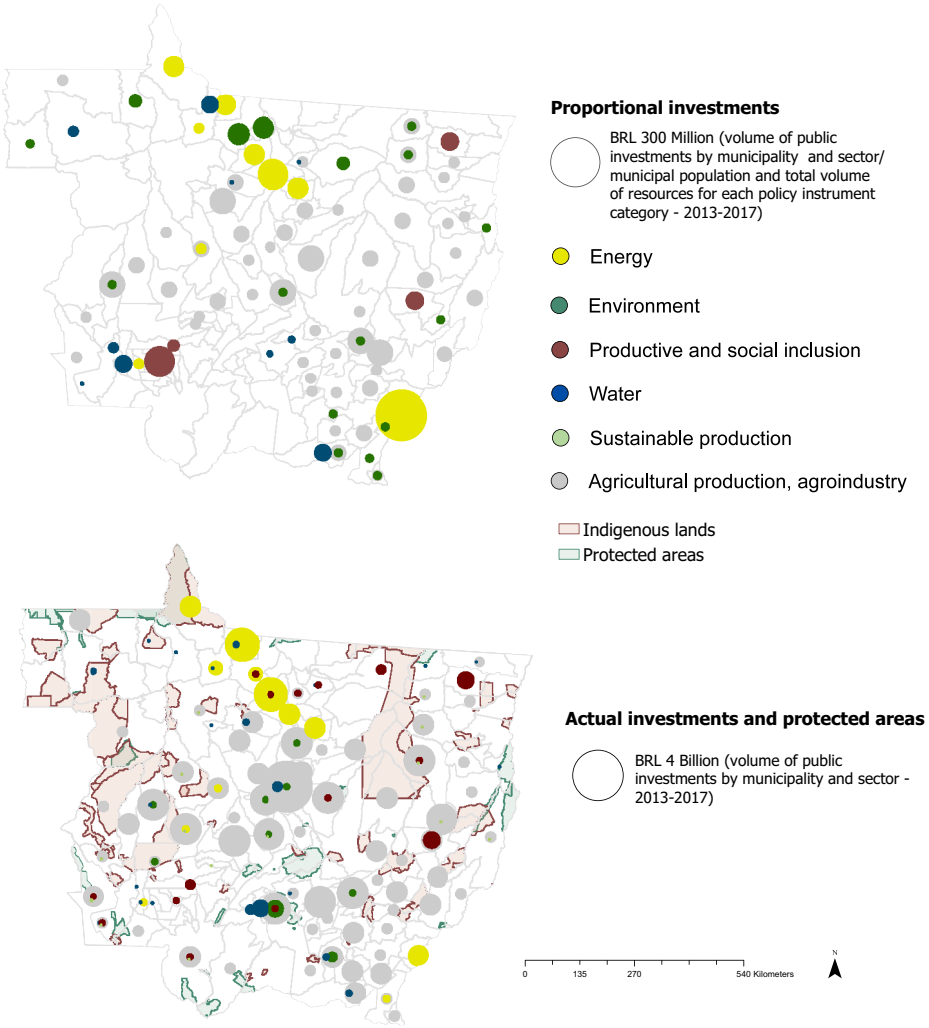

Fig. 4 Public investments in the Nexus+ policy fields in Mato Grosso and protected areas: actual and proportional volume of resources invested in each type of policy instrument (credit, productive inclusion grants, environmental management and infrastructure) between 2013 and 2017. Source: authors

farming. Arvor et al. (2018) identified more than 500 artificial water reservoirs in the municipality of Sorriso in 2015 (most important soybean producer in Mato Grosso located in the Teles Pires Basin). These have been installed on river networks to ensure water supply for maize and cotton crops, water livestock and fish farms. According to the authors, although assessments are still partial, many studies concluded that a high number of small dams in the landscape could have similar or greater impacts than one single large dam. On the other hand, well-planned run-of-river dams may help regulate the hydrological network (water flows and sediment fluxes) in the deforested landscapes. Thus, further to the already known impacts of the construction of water dams to produce hydropower, the potential negative effects of the multiplication of poorly planned water dams on hydrology, biodiversity, water quality and

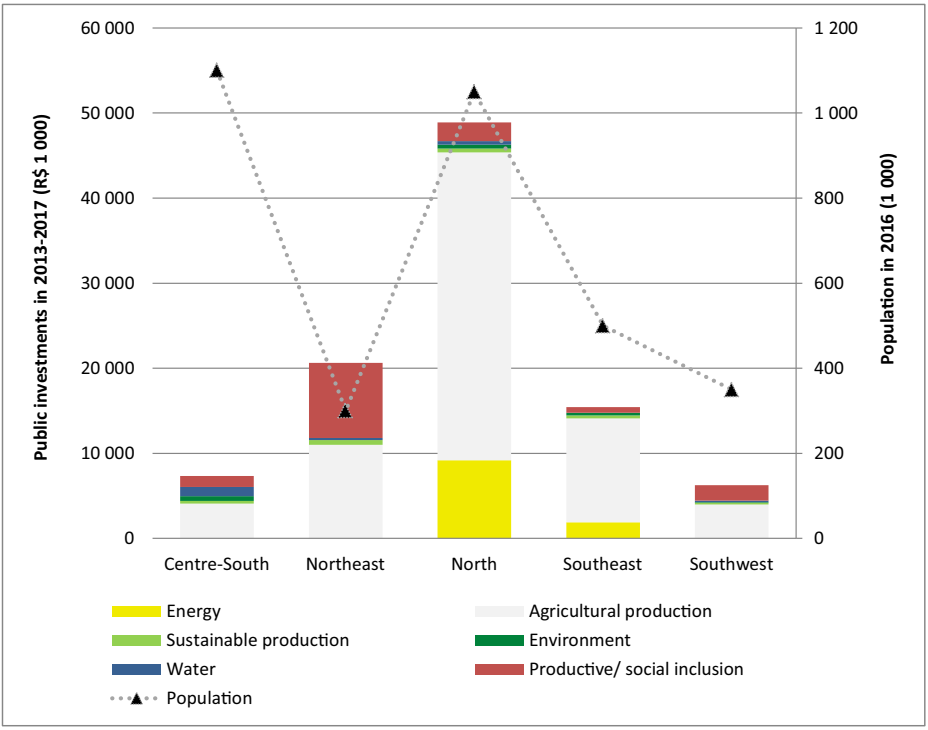

Fig. 5 Regional distribution of public investments and population in Mato Grosso. Source: authors and IBGE (2017)

global warming are important to consider. Their potential role as a source of conflict over access to water should also be analysed (Arvor et al. 2017, 2018).

Therefore, water management trade-offs and land use conflicts are expected to increase in the context of a changing climate. By focusing on these complex interactions, we aim to provide a framework that elucidates the main challenges of reducing vulnerabilities to climate and environmental changes. An important question by Agrawal and Lemos (2015) is how can the unequal burden of underdevelopment be mitigated and redistributed to reduce the riskiness of livelihood choices.

4 Conclusion

The article discussed the climate vulnerabilities of Mato Grosso and analysed the policy landscape for mitigation and adaptation in the state. It showed how adaptation strategies are needed in a context characterised by the apparent effects of climate change on agriculture, natural ecosystems and local populations. These effects can be amplified, as they operate simultaneously with other large-scale drivers of environmental change like deforestation. The southern region of the Brazilian Amazon is considered an important spot for these negative impacts including extreme climate events, vegetation fires and the large-scale process of

savannisation. Mato Grosso is also one of the largest single sources of deforestation and related greenhouse gases emissions in Brazil and worldwide.

Although there is an increasing impetus for implementing climate adaptation policies, there are theoretical and empirical challenges to overcome. First, the scope of adaptation policies is sometimes considered equivalent to sustainable development initiatives. This renders policy-mapping and analyses of their interactions more complex and not climate-specific. Second, the complex cross-sector nature of climate challenges emphasises the point already made in the literature for more coherent and integrated policy approaches. This article provided a framework to identify the public strategies that promote or hinder climate adaptation. Herein, first-hand public funding data was employed to analyse the spatial distribution of these strategies and their interactions along the state territory.

The analytical framework, namely Nexus+, more explicitly combined the concepts of 'sustainable livelihoods', 'climate risks' and 'environmental security' with the 'nexus approach'. By explicitly including in the nexus approach the social and environmental dimensions of security as well as the climate risks of the water, energy and food interfaces, our framework reinforced the understanding that climate risks are expected to unequally expose populations and that adaptation policies should consider these circumstances. The framework also delimited the scope of adaptation strategies to policy fields considered key to human livelihoods and vulnerable to climate change.

Furthermore, each policy mix takes a different shape in the territories in which they are implemented. In this context, the interfaces of the Nexus+ policy interventions have been analysed from a spatial viewpoint. This was done by drawing on the spatial distribution of public investments in the north of Mato Grosso, which made it possible to identify situations where divergent policies are being implemented. Such conflicts or inconsistencies were incorporated as an inherent part of cross-sectorial governance based on the political economy divergences of development models and plans.

In Mato Grosso, the reduced deforestation rates in the 2000s mostly relied on command and control strategies on the one hand and agriculture intensification and private agreements on the other. Nevertheless, several challenges remain in scaling-up access to policies and credit that favours change in agricultural practices, particularly for family farmers. Deforestation rates and land degradation remained high among vulnerable populations like farmers located in rural settlements, indicating that policies for sustainable land use struggled to reach this public. Thus, climate policies should include social and equity indicators other than deforestation reduction, particularly those related to people's ability to cope with these changes and that consider the multiple components of the risks of climate change impacts.

Finally, climate change may not only affect agricultural crops, but also water resources in Mato Grosso. Water resources have often been poorly managed or driven by responses to crisis. The article described the opposing political strategies being implemented in the northern region of the state. These included the creation of protected areas and use of resources to support indigenous peoples, proliferation of small irrigation dams and construction of large infrastructure plants to expand the production of hydropower and waterways to transport commodities to international markets. In a context of increasing water scarcity risks, the analysis of interfaces of sectorial policies targeting water resources locally is relevant in elucidating the main challenges to reducing vulnerabilities to climate and environmental changes. Hence, the study aims to contribute to a growing literature on the human dimensions of climate change in the Brazilian Amazon (Parry et al. 2018).

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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