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NEXUS WATER, AGRICULTURE, CAATINGA FOR TERRITORIAL WATER GOVERNANCE

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Abstract: The last multi-year drought (2012-2018) in Ceará has challenged the human water supply, the agricultural development and the water resource management of the State. This drought has triggered an increase in the construction of individual small dams which may compete with State strategic dams for human water supply. However, these small dams are part of a logic of multiple water uses and how they contribute to agricultural development have been poorly documented. The objective of this communication is to look at these individual small dams in a systemic and territorial perspective and to understand how they fit into the current agricultural trajectories.

We show how the strong dynamic of dairy development has driven a process of intensification for fodder production in lowland and infiltration areas around dams: these areas are benefited from the humidity of soil and thus can be cultivated during the dry season, becoming a strong productive advantage. We emphasize the need of finding trade-offs between upstream-downstream and macro-micro water infrastructures and more broadly between socio-economic local development and water security for human supply. Finally, we highlight the importance of working on a model of territorial water governance.

Resumo: A última seca plurianual (2012-2018) no Ceará desafiou o abastecimento humano de água, o desenvolvimento agrícola e a gestão de recursos hídricos do Estado. Essa seca provocou um aumento na construção de pequenos açudes individuais que podem competir com os açudes estratégicos do Estado pelo abastecimento humano de água. No entanto, essas pequenas barragens fazem parte de uma lógica de múltiplos usos da água e a forma como contribuem para o desenvolvimento agrícola tem sido pouco documentada. O objetivo desta comunicação é analisar essas pequenas represas individuais em uma perspectiva sistêmica e territorial e entender como elas se encaixam nas trajetórias agrícolas atuais.

Mostramos como a forte dinâmica do desenvolvimento da pecuária leiteira impulsionou um processo de intensificação da produção de forragem em áreas de planície e de infiltração ao redor das represas: essas áreas se beneficiam da umidade do solo e, portanto, podem ser cultivadas durante a estação

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seca, tornando-se uma grande vantagem produtiva. Enfatizamos a necessidade de encontrar soluções de compromisso entre as infraestruturas hídricas de montante a jusante e macro-micro e, de forma mais ampla, entre o desenvolvimento socioeconômico local e a segurança hídrica para o abastecimento humano. Por fim, destacamos a importância de trabalhar em um modelo de governança territorial da água.

Palavras-Chave – Drought adaptation; Agriculture intensification; Territorial water governance

INTRODUCTION

Ceará northeast semi-arid region was recently affected by a severe multi-year drought (2012-2018) that had drastic consequences for various sectors of society especially human water supply and agriculture production.

This drought has triggered an increase in the construction of small, private dams and wells as a response to the water scarcity issue. In the Ceará Sertão mesoregion, the number of dams reaches today more than 40,000 dams (Funceme, 2021). This trend reflects an individual adaptation strategy where people aim for autonomy and independence in their water supply. These small dams have multiple functions, including increasing resilience do drought by diversifying the water source for domestic and productive supply, enhancing land value, and providing water for animal husbandry and cultivating in water infiltration areas.

Although there is a debate among hydrologists, the multiplication of these small dams likely impacts the global water dynamics of the region. The construction of these dams disturbs the filling of the downstream intermediate and big reservoirs, which are strategic water macro-infrastructure for urban human supply throughout the State (Martins and Vasconcelos Jr, 2022). In the current context of critical filling rates of the Sertão region's main strategic reservoirs, there is a need to seek a balance between the macro-infrastructure reservoirs and these multifunctional small dams. However, to move forward in this direction, it is needed to better understand the systemic causes and underlying factors of this dynamic of small dams' construction. Indeed, the contribution of these dams to agricultural development have been poorly documented. In that sense, the objective of this communication is to look at these individual small dams in a water, agriculture, environment nexus perspective and to document how they fit into current agricultural trajectories.

1. INTENSIFICATION OF LOWLAND PRODUCTION FOR DAIRY FARMING

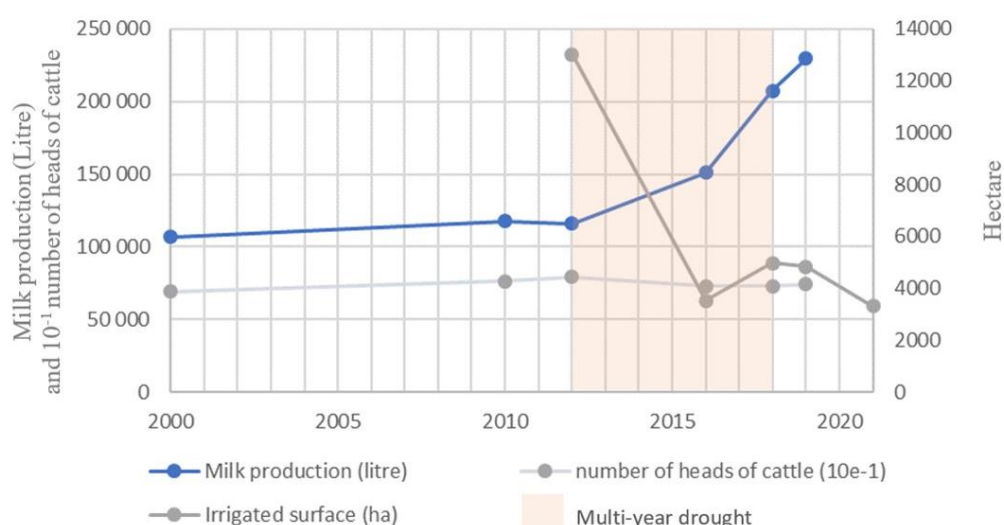
Agricultural trajectories and impact of the last multi-year drought

Traditionally, rural livelihood of family farmers in the Sertão relied on small rainfed shifting agriculture combined with extensive animal rearing. Since the 1990, several public programmes have been directed to promote traditional agriculture and increase income and production while also limiting rural exodus. As a result, family farmers have developed a gradient of intensification ranging from those with the least natural, social, physical and financial capital to those who have been able to accumulate a certain amount of capital, providing opportunities for innovation, often in the most favourable agro-environmental conditions. Meanwhile, those who have remained in traditional production systems now dependent significantly on non-agricultural activities and incomes such as off-farm employment, daily jobs, social programs and rural retirement. For the others, two main trajectories of economic intensification have emerged: small-scale irrigation or cattle ranching for dairy production (Burte and Martins, 2020).

The 2012-2018 multi-year drought has significantly impacted these agricultural trajectories. On one hand, it had a negative impact on the dynamics around small-scale irrigation. The irrigated areas in Banabuiú have decreased from 13,000 ha to less than 5,000 ha during this period (figure 1). This decrease was reinforced by the end of the process of river perennation, a practice of releasing water from dams to perpetuate water flows in drainage networks (Burte and Martins, 2020). On the other hand, the drought has acted as a catalyser for the dairy intensification trajectory. Although the number of animals slightly decreased (-8%) due to the lack of water during the dry seasons, milk production increased by 79% between 2012 to 2018 (figure 2). This increase is mainly because non-specialised livestock was sold and replaced by genetically improved livestock supported by specific programs and public policies (Dantas, 2021). However, these two trajectories may be mixed in the field as multiple activities remain a major characteristic of family farming in the region, providing greater flexibility and adaptation to farms (Ellis, 2000). This is particularly true in the alluvial zones where small-scale irrigation remains important but is increasingly combined with dairy production to supplement incomes and enhance farm resilience.

Figure 1. Evolution of dairy production and irrigated area during drought

Source: Banabuiú watershed irrigated areas from Funceme (2022); Milk production and number of animals in the census mesoregion 'sertões cearenses' (including the Banabuiú, Crateus and part of Alto Jaguaribe watersheds) from IBGE (2023)



Adaptation to drought and the structuration of a strong dairy value chain

In terms of agricultural development, the intensification of dairy sector has appeared as an interesting economic opportunity, particularly in the Sertão Central region, the dryer region of the State where structured value chains are very few. Dairy sector is beneficiated from an important domestic market and attractive prices for farmers (IPECE, 2018) and is seen as more resilient to drought than irrigated agriculture as it may consume at farm scale less water than intensive irrigated crops. Moreover, in the event of drought, part of the livestock can be sold instead of losing the whole production as it is with rainfed crops or even irrigated crops in case of the drying up of the water source. In this context, the dairy sector for family farming has been strongly encouraged in Ceará semi-arid region by both private and public actors (Dantas, 2021).

The Federal and State's government have implemented several programs and public policies³ aimed at developing dairy production chain including specialized technical assistance, micro-credit lines and technological innovations for production intensification such as livestock genetic improvement or enhancement of feed and pasture management. Local milk transformation to aggregate value, production chain, market structuration and expansion were also supported (Dantas, 2021). On top of that, the private milk industry which is an economically and politically powerful actor has also strongly supported the development of the dairy chain providing technical assistance, investment and financing options in a perspective of agglomeration economy (ex. Betânia, 2019).

These actions have improved productivity, quality and efficiency gains of the dairy value chain and have proportioned an important increase in milk production in family farming sector (IPECE, 2018). Indeed, between 2010 and 2019, milk production has almost doubled in the Sertão region achieving a production of more than 200,000 litres in 2019, representing almost 30% of the Ceará state's milk production (IBGE, 2023). Thus, in the last decade, milk production has become a significant contributor to the Sertão rural economy and a structuring factor of the territories (IPECE, 2018; Dantas, 2021).

Transformation of agricultural practice and intensification of lowland production

This process of dairy intensification has strongly transformed the agricultural practices, with farmers redirecting a significant portion of their traditional rainfed crops towards livestock feed production in more intensive crop systems.

Firstly, most producers have begun to produce maize and sorghum silage in mechanised monoculture cropping systems with little rotation and the use of herbicides and pesticides. In addition to silage production, some also produce corn grain for animal feeding in more intensive cropping systems on permanent cropland or in the traditional shifting agriculture system.

Secondly, production of Gramineae forage has been intensified in lowlands and infiltration areas around dams. These areas are beneficiated from the humidity of soil and thus can be cultivated during the dry season as if it was a 'passive irrigation'. Thus, they become a strong productive advantage. In order to optimized the planting infiltration areas throughout the dry season, successive dams are built: the dam located further upstream releases its water infiltration planting areas first, followed by the second and so on. The dams that have emptied from below the wall are also planted downstream of the dam, creating a green continuum of grass in the lowlands (figure 2). Thus, the 'shallow' dam, although considered inferior in engineering terms due to its susceptibility to under seepage and its lower efficiency between storage and evaporation than 'deep' dam, becomes a good model for the farmers as it provides a large planting area throughout the dry season. Consequently, small dams are particularly concentrated in regions with intensive dairy production regions, such as Milhã, a Sertão municipality where milk production has increased by more than 700% from 2010 to 2021 (IBGE, 2023) and where there are more than 5 dams por km² in many areas (figure 3).

In addition, some farmers are investing in small irrigation systems to irrigate areas of Gramineae (*capim*) to increase fodder production. In fact, *capim* irrigation requires less capital to get started than fruit or horticulture.

³ For exemple: Infoleite (1998); Leite Fome Zero (2004); Pronaf for cooling tank (2006), Leite Ceará (2009) (Ipece, 2018) and support for dairy production is an important part of the programmes Hora de plantar (sorghum silage and cactus palm) and São José. According to the Government of Ceará, more than R\$ 13.5 million were invested in the dairy chain of the Sertão Central region through the São José III program (Sda, 2019) and R\$ 26 million is engaged for 2023.

However, the dynamic of planting intensification in lowland areas has various environmental impacts. The suppression of riparian forests leads to greater erosion and silting up (Anbumozhi *et al.*, 2005), affecting the water supply. There is also a tendency for agricultural pollution to increase due to the presence of cattle and the use of agrochemicals in the drainage areas, which contributes to the eutrophication of the reservoirs, increasing evaporation. Finally, this intensification of lowland and the redirecting of part of the irrigation to *capim* contributes to a strong dynamic of territorial specialization for dairy production.

Figure 2. Successive small dams and the creation of a green continuum of grass in the lowlands (Milha region, Banabuiú watershed). Fonte: Burte and Martins, 2020

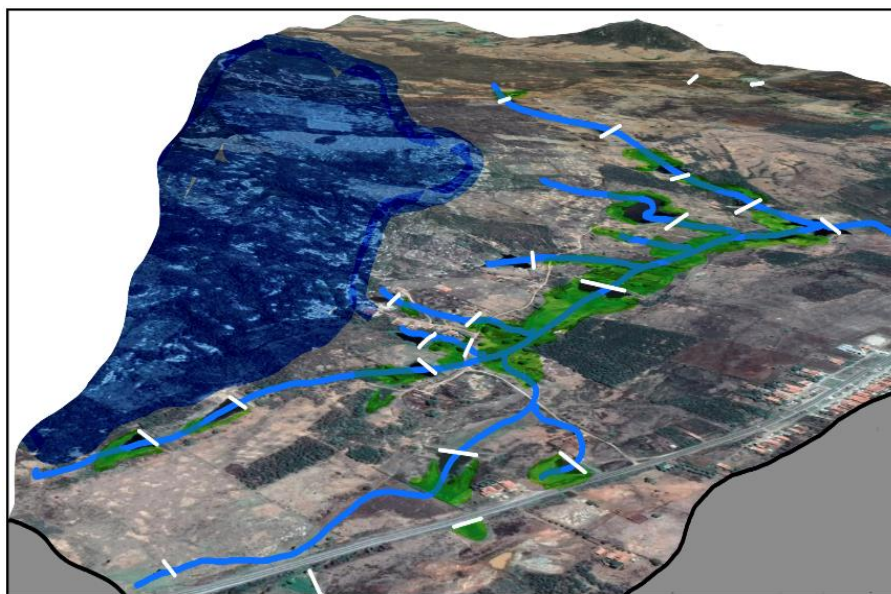
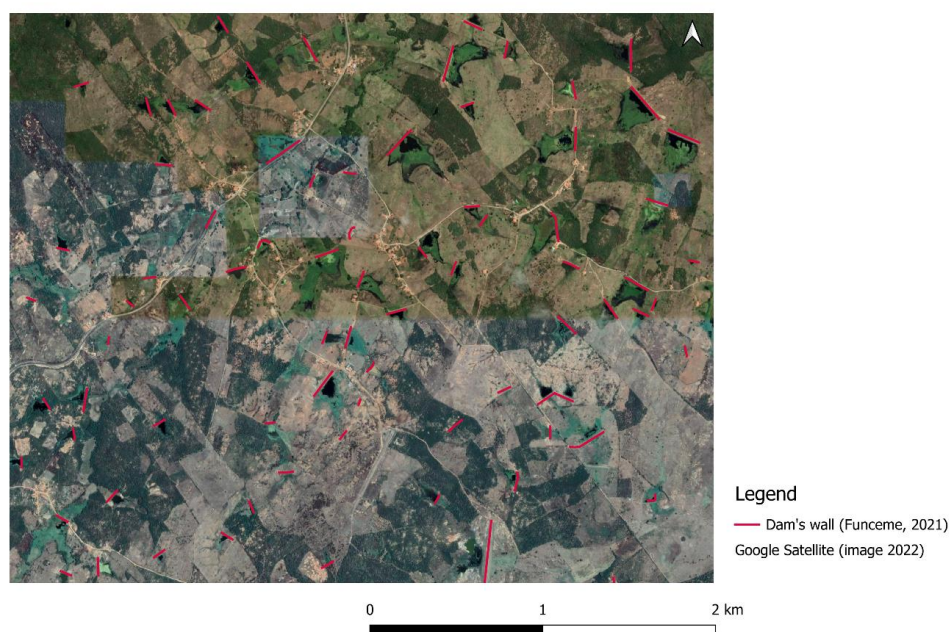


Figure 3. Illustration of the dam densification in Milhã and the building of successive small dams



2. BALANCING WATER INFRASTRUCTURE THROUGH TERRITORIAL GOVERNANCE AND CROSS-SECTORAL APPROACH

The proliferation of small dams in the upstream zone of intermediate and large strategic dams for human water supply has disrupted their filling and created the challenge of finding an upstream-downstream trade-off between macro water infrastructures (dams of collective importance for the human supply of rural communities or cities) and micro infrastructures (small individual dams and wells mainly for productive uses). However, like in other semi-arid regions around the world (eg. Venot et Cecci, 2011), small individual water infrastructures play a crucial role in the rural Sertão world. Due to their multi-functional uses, they have been the foundation of the region's socio-economic and agricultural development. For this reason, it should be clarified that the issue at hand it is not the existence of small dams and wells for productive purposes but rather their recent uncoordinated multiplication.

To address this trade-off, we argue that a cross-sectoral approach is necessary, bringing together the water resources sector and the agricultural and cattle sector to work on an agrarian dynamic that is compatible with both the filling of strategic reservoirs for human water supply and the rural socio-economic development. In the Brazilian semi-arid context, where the State has a significant role in drought fighting against and coping with (Souza Filho, 2018), integrated programs and public policies for territorial development and water resilience at multiple scales should be launched by decompartmentalising the actions of the secretariats of water resources, agrarian development and environment (SRH, SDA, SEMA). Moreover, this State initiative should be complemented by actions at municipalities and territories levels, engaging local stakeholders in the same cross-sectoral and systemic approach to think sustainable development trajectories.

To further enhance this effort, we also maintain that supporting territorial governance and capacity building of rural communities in their natural resources management should help manage water resources in a more integrated way and address local trade-offs and territorial specificity. Indeed, territorial governance models based on a multi-level and multi-stakeholders participatory processes, and grounded on the empowerment of local stakeholders, have shown promising results in constructing sustainable and resilient territorial trajectories in semi-arid region (Hassenforder *et al.*, 2020). Definitely, territorial governance can strengthen the connection between multiple stakeholders, promote an inclusive and cross-sectorial dialogue and fostering the process of cross-learning and knowledge hybridization (between local empirical knowledge, technical, and scientific knowledge) (Côte *et al.*, 2022; FAO *et al.*, 2023).

The construction of such a cross-sectorial, multi-level and territorial model of water governance is the proposition of the Sertões projects clusters implemented by the State of Ceará (and in particular Funceme), AFD and Cirad since 2019. It is argued that the participation of local actors in territorial governance will contribute to designing sustainable pathways that take into account the territorial specificities and the multiple use of water. From this perspective, the agroecological transition for family farming is also seen as a strong lever for leading territories towards greater sustainability and water resilience, with agroecology recognised as offering options for enhancing territorial specificities and improving the resilience and adaptation of agriculture to the semi-arid climate and the context of climate change (Milhomens *et al.*, 2022). For example, agroecology could help to reevaluate the dairy production strategy at individual and territorial levels, and determine its compatibility with agro-environmental and water territorial specificities, warranting in which conditions dairy intensification is sustainable and compatible with the multiple uses of water at various scales.

CONCLUSION

The multi-year drought from 2012 to 2018 had a significant impact on the agricultural sector of Sertão region. Associated with strong public policies to support dairy production, the region has experienced a strong dynamic of dairy intensification, resulting in a high demand for water in the lowlands and a strong increase of small water infrastructures. As too much water infrastructures can compete with each other in a closed basin (Molle *et al.*, 2010), it is likely that the multiplication of these small dams impacts the global water dynamics of the region emphasizing the need of finding trade-offs between upstream-downstream and macro-micro water infrastructures and more broadly between socio-economic local development and water security for human supply. This displays the importance of a nexus approach of water resource management to understand and take into account the various interrelated dimensions around water resource.

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