# Infrastructure strategy, production technologies and agricultural equipment for adapting Brazilian agriculture to climate change

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Chapter 2 of this compilation adopts an operationally focused approach, with various projects that propose implementing adaptation actions locally and directly in the field. These proposals include proposals to build physical structures and management and production techniques and different types of equipment, although they were not initially proposed as solutions or alternatives in view of the impacts of climate change on agriculture. However, beyond the most intuitive adaptation measures, such as genetic improvement and irrigation, this chapter opens a broader discussion of actions that go from specific local management to actions to be adopted by farmers "within farms", including structural actions that are or may be part of national policies and programs. From analyzing the three components of this chapter, it is intuitive to associate the adoption of management and production technologies and equipment with more "within the farm" tangible actions, and on the other hand, to associate strategic and infrastructure actions as more effective and efficient if approached in integrated ways and incorporated into regional and national programs and policies, however that is not our intention.

On the contrary, this chapter emphasizes the complementarity of approaches, recognizing not only the evident and more tangible actions implemented in the field as actions that promote adaptation, but also the efforts to organize information, research, development, and innovation, increase the adaptive capacity and resilience and, consequently, socio-economic-environmental, and even institutional sustainability. This is the case even if at first glance, they are not explicitly explained as such.

With this focus, the components of this chapter should collaborate for the development of an adaptation strategy that is based on the best set of information and knowledge available, and its effectiveness will depend on the implementation and infrastructure capable of ensuring its continuity over time, and a constant review and improvement process, with planned investments in science and technology. Much can still be developed and perfected regarding this in Brazil and in developing countries and, in terms of extreme events, probably in the developed world as well.

More objectively, in this more comprehensive approach to infrastructure, technologies and adaptation equipment, some main aspects to be considered are:

- Basic environmental information systems with currently used technologies and new technological options that promote resilience and adaptation to the negative impacts of climate change;

- Advancement of knowledge and scientific and technological development to improve knowledge production systems, using a broad definition of information management and universal access to knowledge, developed or adapted, as an innovative product per se;

- Projections of future scenarios integrating the various aspects of agricultural production systems sustainability (social, economic, environmental and institutional) to subsidize decision making on which scenarios to aim for and ways to achieve them, in terms of organization and information management, knowledge progression and the modeling of these systems;

- Models or new elements of rural development that include innovation and transfer of new technological options that promote resilience, adaptation, and sustainability against harmful effects of climate change; and

- Public policies, which are already part of the Plan for Low Carbon Emission Agriculture (ABC Plan), the National Adaptation Plan (PNA) and the National Policy on Climate Change (NPCC).

These aspects will be referenced whenever possible while assessing the studies presented in this compilation.

Given the various action options and local scale up the needs and specificities for the regional and national scope of public policies associated with this chapter in relation to listed fields, a well-defined methodological approach was not identified. However, it aggregates studies that collaborate to the country's evolution regarding these aspects.

Thus, some of the studies focused on identifying solutions for the most vulnerable national region and probably the one with the lowest adaptive capacity, the Semi-Arid. These studies are replicable technological solutions with some adaptation to the entire scope of the biome and even to the driest regions of the Cerrado. In general, they focus on living with drought, proposing better storage and usingless available water mainly through cisterns, wells, and underground dams. One of the studies focuses on usingbiotreatments in aquaculture, using production management technology as a way of adaptation of to increased eutrophication caused by the increased water temperatures. This study also addresses economic aspects, quantifying economic benefits promoted by technology and social aspects related to basic sanitation, involving the various aspects of sustainability and its relationship with climate change. Social technologies were also proposed and should be simple, replicable and developed in integration with the local community with the aim of solving their problems. In addition, social actions are proposed to integrate agroecological techniques in the family farming environment to increase their resilience and reduce vulnerability, by promoting more appropriate techniques for soil management, incorporation of organic matter, biochar and inoculants, as well as the monitoring factors of production, and improving Farmer's decision making, production and income.

In another aspect regarding technology, there are studies scattered throughout the country with a focus on soil recovery and conservation management, covering techniques such as recovering gullies and using biochar and other techniques for accumulating carbon in the soil, such as no-till, crop rotation and crop-livestock-forest integration. Although some of these techniques are mitigating, adequate soil management and carbon accumulation improve soil fertility and water storage capacity, boosting adaptation or reducing these systems' vulnerability to climate change impacts. Some of these studies also address sustainable intensification through these techniques and analyze their economic and social improvements.

Conservation and adaptive management also comprises another set of studies focusing on the sustainability of livestock activities. In the Pantanal, management is associated with degradation and plagued native pastures, from using exotic species and flooding. In the Amazon, management focuses on reforming degraded pastures with no-till techniques. In the state of Rio de Janeiro, management includes a diverse set of techniques in the integrated management of micro-basins, incorporating the training of small farmers and producers, participatory research and social cohesion, focusing on reducing vulnerability and increasing resilience in the face of extreme events.

The last set of studies has as an integrated approach to information and knowledge management, a large part of which is incorporated to computerized support systems for decision making, ranging from farm level to state and national public policies. Several of the studies already commented on in the other groups or fields also incorporate information management and decision-making tools. One of the studies illustrates a tool that, when well suited to the domain being assessed, enables textual data mining and the selection of articles that best relate to a region, crop, biome, etc. thus speeding up the search for technological solutions for adapting to the impacts of climate change as well as more efficiently directing research.

Studies focused on Agricultural Climate Risk Zoning (ZARC) and Agroecological Zoning (ZAEs), integrated to state or national policies, are powerful tools to support public management, since they identify more vulnerable regions, and suggest the systems which are more adapted to regional climatic conditions and act as technological and good practice inducers, especially when integrated with a credit and/or agricultural insurance system. As a result, they increase systems' technical and economic efficiency through collaboration to increase farmers' productivity, income and the social conditions through adaptation and sustainability of their production environment. In the studies focused on simulating future agricultural scenarios, the approach is based on feeding the models applied in the zoning, with future climatic scenarios generated by global and regional atmospheric circulation models, enabling trend analyses of projected climate changes climate change impacts on pests, diseases, weeds and crop vulnerability. Through them, actions can be anticipated to increase the resilience and adaptive capacity of agricultural systems.

The sets of studies that contributed to subsidize the discussion of the theme related to adaptation to climate change are a small sample of a much larger universe of efforts in this regard and, obviously, can - and probably should - be frequently updated to keep track of the subject's evolution to direct actions in a more planned and effective way.

Based on this sample of studies, and knowledge from a slightly larger, but not exhaustive, universe, we can infer that most of them focus on solving local problems or applying techniques and locally adaptable technologies, which is a very positive point. There is also a reasonable amount of work focused on information management for decision making at various spatial scales, another positive point. The diversity of approaches for the different regions of the country, that are careful to respect their specificities, is yet another positive aspect.

This diversity of regions and specific situations, on the other hand, is also one of the greatest challenges, both for producers and for institutions focused on the subject, especially when associated with the diversity of technological options already established or at the frontier of science. We also can observe that infrastructures and even agricultural equipment used as tools for adaptation were not well covered in this sample of studies, with the exception of information management tools and software. Mechanization techniques, precision agriculture and other forms of management, and using drones and UAVs, internet of things in the field, massive data assessment and metadata are tools which still haven't been covered in depth.

This wide range of techniques, regions and situations increases the challenge of adaptation through infrastructure, technologies and equipment in a continental country like Brazil,

requiring capillarity to ensure the adequate diffusion of these technologies. Conducting this process in a positive and well-planned manner, transforming these apparent difficulties into competitive advantages, certainly depends on increased public adaptation policies, in its various spheres, far beyond what the ABC Plan covers today. Although partially covered by public policies, they are not usually associated with and does not aim primarily at adaptation, or the National Adaptation Plan. The National Policy on Climate Change in the agricultural sector and in other sectors is still almost exclusively focused on mitigating emissions, and this needs to change. Especially in the agricultural sector, it needs to focus on adaptation in a more serious and structured way, under the risk that, by focusing too much on reducing emissions, we threaten the sector's sustainability and national food security.

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