CLIMATE RISK IN AGRIBUSINESS: FARMING RESILIENCE PERSPECTIVE

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Executive Summary

The climate is a primary driver to farming through sunlight, temperature, precipitation and interaction with soil. Yet increasing weather variability over the years has heightened the risks faced by crops and livestock production. According to the World Meteorological Organization, the concentration of CO_2 equivalent in the atmosphere has grown by roughly 40% since 1960, the average global temperature has risen by 1.3 °C, and 2024 became the first calendar year above the 1.5 °C threshold set out in the Paris Agreement.

Drawing on a Nuffield Global Agribusiness Program, the report describes that climate can be a risk in agribusiness value chain and the perspectives for farming resilience adaptation in a changing climate reality. The journey started with the participation in the seven-day Contemporary Scholars Conference (CSC) held in New Zealand, followed by 12 weeks of Global Focus Program and individual study travels across the five continents, including Australia in Oceania, Angola and Kenya in Africa, China and Japan in Asia, Poland, Germany and the Netherlands in Europe, and United States and Brazil in the Americas. After 10 countries visited besides Brazil, combined with scientific and market evidence, the report shows that climate change is no longer a farm-gate concern. It has become a systemic value-chain issue, propagating from farming through five interconnected nodes — extreme events, productivity, logistics, cost structure and financial markets.

Climate resilience is not created by one technology or one policy. It emerges from the interaction of natural conditions, infrastructure, education, research, finance, public institutions and market incentives. In this context, it is important to consider agribusiness value chain and the climate beyond farming, also the differences between temperate and tropical regions, which contrast in temperature, rainfall, sunlight and harvest seasons regimes.

Climate risk in agribusiness does not have a single geography or a single expression. Across the five continents, the same global concern appeared in different forms. In every territory, technology has become a resilience infrastructure rather than merely a productivity lever — organized around water, soil health, genetics and digital intelligence, and extended by circularity and the bioeconomy. The single greatest barrier is the difficulty of measuring impact, which is precisely why digital measurement, reporting and verification (MRV) converts good practice into bankable, verifiable resilience. Brazil occupies a distinctive position of high exposure yet genuine progress: having already made the tropical transition once, by choice and ahead of obligation.

The agribusinesses most prepared for a changing climate will be those that treat resilience not as a compliance chapter, but as a strategy for creating durable value.

The call to action is a shift from yield maximization to resilient value creation, treating climate intelligence as core infrastructure, de-risking farmer adoption, investing in measurement, and connecting to the innovation ecosystem rather than building alone.

Keywords: climate risk; agribusiness; farming resilience; value chain; tropical agriculture; climate adaptation; soil health; bioeconomy and circularity; food security; resilient value creation.

Foreword

Fabio has a bachelor's degree in Agronomic Engineering from ESALQ/USP and is Master of Science in Seed Technology from UNESP, while is a third-generation farmer in state of São Paulo in Brazil.

Currently he leads the Agribusiness Center of Excellence and interacts with Agtech Innovation hub in PwC, the consulting firm who sponsored Nuffield Brasil Association.

With 25 years of experience in Agribusiness, has a career focused on strategy, management, technology and sustainability. The professional background includes leading engagements in asset valuation, go to market access, development of drone ecosystems, innovation models, and sustainability frameworks. He is recognized for integrating deep expertise with advanced technologies to support clients in decision-making, risk management, and value creation.

In the Nuffield Global Agribusiness Research Program, his topic aimed to understand agribusiness climate risk, to bring perspective beyond farming, seeking to shift from yield maximization toward resilient value creation.

Along 18 months of the program, Fabio had the opportunity to visit 10 countries besides Brazil, in the five continents: New Zealand, Australia, Kenya, Angola, China, Japan, Poland, Germany, the Netherland and United States.

Through the journey, he engaged with farmers, industries, corporations, startups, investors, universities, research institutions of technology, as well as other stakeholders in agribusiness events, such as conferences and exhibitions.

The report demonstrates that climate risk goes beyond farm-gate issue in isolation, it is a systemic value-chain challenge that must be understood, measured and managed across the entire agribusiness.

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For sure it was one of the best and most valuable experiences of my life, with the power to transform not only me, but all those around that could share some time along the journey.

Abbreviations

ABC	Low Carbon Agriculture Plan (*Agricultura de Baixo Carbono*)
ADEALQ	Alumini Association College of Agriculture “Luiz de Queiroz” (Associação dos Ex-Alunos da Escola Superior de Agricultura Luiz de Queiroz)
AI	Artificial Intelligence
AR6	Sixth Assessment Report (IPCC)
BNF	Biological Nitrogen Fixation
CEPEA	Center for Advanced Studies on Applied Economics (*Centro de Estudos Avançados em Economia Aplicada*)
CO_2	Carbon Dioxide
DSI	Digital Sequence Information
Embrapa	Brazilian Agricultural Research Corporation (*Empresa Brasileira de Pesquisa Agropecuária*)
ESALQ	College of Agriculture “Luiz de Queiroz" (*Escola Superior de Agricultura Luiz de Queiroz*)
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
ILPF	Integrated Crop-Livestock-Forest (*Integração Lavoura-Pecuária-Floresta*)
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
ITDBr	Brazil Digital Transformation Index (*Índice Transformação Digital Brasil*)
LIBS	Laser-Induced Breakdown Spectroscopy
MRV	Measurement, Reporting and Verification
PwC	PricewaterhouseCoopers
SPD	No-Till Farming System (*Sistema de Plantio Direto*)
UN	United Nations
USP	University of São Paulo (*Universidade de São Paulo*)
WMO	World Meteorological Organization
ZARC	Agricultural Zoning for Climate Risk (*Zoneamento Agrícola de Risco Climático*)

Objectives

The climate has always shaped agriculture and livestock across every region of the world. What has changed is the rhythm on which farming depends: in recent years, more intense and less predictable climate events have increased the exposure of production systems to weather extremes and resource constraints, transforming a long-standing agronomic concern into a structural determinant of agribusiness performance. The purpose of this report is to examine how farming can become resilient in managing climate risk across the different value chains of agribusiness, drawing on a global perspective built from field observation in the five continents and combined with scientific and market evidence.

More specifically, the report pursues four interconnected objectives:

- To describe the climate context of tropical and temperate agribusiness, clarifying how differences in temperature, rainfall, sunlight and harvest regimes — together with soil and seasonal conditions — shape distinct agronomic realities and explain why climate adaptation cannot rely on a single, universally transferable model.
- To analyse the climate risk perspective across the five continents, showing how the same global concern takes very different forms in Oceania, Africa, Europe, Asia and the Americas, and how climate risk propagates through five interconnected value-chain nodes: extreme events, productivity, logistics, cost structure and financial markets.
- To assess the role of technology in agribusiness climate resilience, examining how innovation has evolved from a productivity lever into a resilience infrastructure, and how an ecosystem turns data into timely, place-specific decisions.
- To offer insights for agribusiness climate risk management, translating the evidence and field experience into practical conclusions and recommendations for farmers, decision makers, investors and public institutions seeking to shift from yield maximization toward resilient value creation.

Taken together, these objectives frame climate risk not as a farm-gate issue to be defended in isolation, but as a systemic value-chain challenge that must be understood, measured and managed across the entire agribusiness system. In doing so, the report seeks to contribute a transferable method — identifying material exposure, understanding the local production and social system, connecting relevant institutions, creating incentives that make adoption economically rational, and monitoring whether interventions genuinely improve resilience — that can support more sustainable and more resilient farming in a changing climate.

Introduction

The term *agribusiness* is a fusion between agriculture and business. As documented by CEPEA/ESALQ-USP, the word *business* is itself derived from the Latin *negotium*, which denotes economic activity organized to satisfy human needs, whereas *agriculture* refers to the cultivation of land and biological resources to produce vegetal and animal raw materials, so farming is part of agriculture. Agribusiness, therefore, encompasses every economic activity that "would not exist if agriculture and farming activities did not exist".

The climate has always been one of the primary drivers to farming. Because production takes place in the open air, agriculture is a truly nature-based business — one whose fortunes are inseparable from the rhythms of rainfall, drought, and temperature. What has changed is that these rhythms are themselves being reshaped. Climate change is now a measurable reality across agricultural systems worldwide. According to the World Meteorological Organization, the concentration of CO_2 equivalent in the atmosphere has grown by roughly 40% since 1960, while the average global temperature has risen by 1.3 °C — already breaching the 1.5 °C threshold set out in the Paris Agreement.

Nowhere is this shift more consequential than in Brazil, one of the world's largest agribusiness producers and exporters. The country faces an alarming paradox: even as it supplies global markets, it grapples with mounting threats to its own agricultural stability. The evidence is stark — the number of climate-related disasters jumped from just over 400 in the early 1990s to nearly 4,800 in 2023, affecting 92% of municipalities, mentioned in a study from CEPEA. So pervasive are these shocks that variation in their frequency explains an estimated 82% of the deviations in Agribusiness Gross Domestic Product (GDP) from its long-term trend, making the sector increasingly difficult to predict, considering that Agribusiness is 25% of Brazil GDP; yet Brazil also presents a distinctive profile, its energy matrix is 50% renewable (against roughly 20% globally), and its total net emissions have fallen by 21% over three decades, an uncommon combination of high exposure and genuine progress.

These physical realities translate directly into boardroom concern. According to PwC's 29th Global CEO Survey, climate change ranks among the leading threats to agribusiness, with 33% of CEOs in Brazil reporting high exposure. The finding underscores how central extreme weather events, crop volatility, and the challenge of environmental adaptation have become to farming performance and to the resilience of the value chains that depend on it. In response, the private sector is already rethinking its business and risk models, while public policies such as the Agricultural Zoning for Climate Risk (ZARC) seek structural solutions grounded in evidence and data.

Ultimately, the climate crisis is not only a threat to be managed but an opportunity to be seized. It invites a fundamental rethinking on farming, distribution, and consumption, one that unites the ambition of public policy with the drive of business innovation and the rigor of cutting-edge science. Doing so is essential to avoid irreversible collapse and to build fairer, more sustainable, and more resilient agribusiness systems. Understanding the impact of climate on agricultural production is therefore the starting point for any serious discussion of agribusiness resilience within the global climate agenda.

The climate risk perspective in global agribusiness

The climate in tropical and temperate regions

The tropical belt — defined geographically as the band between the Tropics of Cancer and Capricorn — according to the study “A comparative analysis of agriculture in tropical and temperate climates”, covers approximately 38% of Earth's land surface, spans 124 countries across Latin America, sub-Saharan Africa, South and Southeast Asia, and northern Oceania, and hosts about half of the global population. Within this region lie roughly 40% of the world's arable land and 52% of its freshwater resources, distributed across a heterogeneous mosaic of tropical forests, savannas, grasslands, and semi-arid zones such as the Brazilian Caatinga. Latin America — and Brazil in particular — sits at the productive core of this belt: between 1961 and 2021, Latin America more than doubled its arable land from 40 to 83 million hectares, with Brazil expanding by 59% to reach 58 million hectares of cultivated area. This geography of abundance, however, coexists with a set of biophysical conditions that differ fundamentally from those found in the temperate agricultural heartlands of Europe and North America, and it is precisely these differences that made it impossible for Brazil and Latin America to simply import the technological packages developed in the North — forcing them to create a distinct scientific, agronomic, and managerial pathway for producing food in the tropics.

The most immediate contrast lies in the temperature and seasonal regimes. Whereas temperate agriculture in North America, Northern Europe, and parts of Asia is shaped by four well-defined seasons — with the coldest month averaging below 0 °C, at least four months above 10 °C, and a single hot summer that concentrates the entire crop cycle between April and October — the tropics experience an average annual temperature of about 26 °C at sea level, with monthly variation of 6 °C or less between the warmest and coldest months. In practical terms, temperate farmers plant, grow, and harvest a single, highly productive crop cycle per year, taking advantage of long summer days, deep organic soils, and the biological pause imposed by frost. Tropical farmers, by contrast, have no true winter and no thermal barrier to plant growth; the year is instead defined by rainfall — a rainy season and a dry season — and continuous solar radiation allows crops such as common bean to complete up to three cycles per year, or melons and grapes to yield five harvests every two years. This continuous productive window is both an opportunity and a source of complexity: it multiplies annual production capacity, but it also removes the natural sanitation effect that winter provides in temperate systems, sustaining year-round pressure from insects, fungi, weeds, and nematodes that must be managed through active agronomic strategies rather than seasonal dormancy.

The soil profile is equally divergent, and arguably even more decisive for the way agriculture had to be reinvented in the tropics. Temperate systems in central North America and Eurasia sit on comparatively young, shallow, dark soils — such as Chernozems in Russia and Ukraine or Drummer soils in the United States Midwest — which are typically only one to two meters deep, rich in organic matter (often close to 10%), well structured, and naturally fertile, with adequate pH and negligible aluminium toxicity. Because microbial activity and leaching pause during the cold months, organic matter accumulates rather than degrades, and farmers can generally maintain high yields with fertilizer additions calibrated only to replace what the crop removes, without the need for liming or acidity correction. Tropical soils tell the opposite story. Oxisols

and Ultisols dominate the Brazilian and Latin American landscape, together covering nearly 45% of the tropical land area, and they are among the oldest, most weathered soils on the planet, sometimes deeper than five meters, but chemically impoverished, acidic, low in phosphorus, and burdened with high concentrations of aluminium that are toxic to most temperate crops. In the Brazilian Cerrado alone, a 204-millions-hectares biome once considered unsuitable for agriculture, cultivation required correcting soil acidity through large-scale liming, adding phosphate fertilization, adapting cultivars to aluminium-tolerant conditions, and introducing biological nitrogen fixation to reduce dependence on imported inputs, an entire technological package with no parallel in the temperate playbook.

Rainfall patterns compound the challenge. Tropical rainfall is driven by the movement of the Intertropical Convergence Zone (ITCZ), the El Niño–Southern Oscillation, and, at times, tropical cyclones, delivering totals that range from 1,500 mm to more than 10,000 mm per year, often concentrated in short, high-intensity events that generate flash runoff, erosion, and leaching of nutrients from already fragile soils. Temperate systems, by contrast, tend to receive more evenly distributed precipitation with no significant seasonal contrast in rainfall, allowing rainfed cropping to rely on relatively predictable moisture availability. The combination of intense tropical rain, warm temperatures, and continuous biological activity means that organic matter is oxidized and lost far more rapidly, that soil cover becomes indispensable to prevent erosion, and that pest and pathogen cycles are never truly interrupted. It also implies that any agricultural model transferred from temperate latitudes — whether Green Revolution wheat, European crop rotations, or North American tillage-based systems — inevitably underperforms or fails outright when applied without adaptation, as Brazil learned repeatedly through failed wheat trials in the Cerrado during the 1960s and 1970s.

These structural differences explain why, from the early 1970s onward, Brazil could not simply follow the temperate blueprint and had to build an autonomous tropical agricultural science and methodology. A symbol of the turning point was the creation of the Brazilian Agricultural Research Corporation (Embrapa) in 1973, established with the explicit mandate to coordinate research adapted to tropical soils, climates, and ecosystems, and to develop solutions that the Green Revolution designed for temperate wheat belts and fertile Asian irrigated valleys could not provide. Over the following five decades, Brazilian tropical science delivered a suite of methodologies that today define the country's agricultural identity: liming and phosphate fertilization to correct Cerrado acidity, biological nitrogen fixation (BNF) using Bradyrhizobium bacteria that today supplies the nitrogen assimilated by Brazilian soybean and saves tons per year in fertilizers, the adaptation of temperate-origin crops such as soybean to tropical latitudes, transforming a 400,000 hectare crop in 1965 into a 50+ million-hectare global export leader, and the introduction of the "safrinha" second maize and winter crop planted immediately after soybean harvest, and effectively duplicates the annual productive window in a single agricultural year, as cited by Embrapa. Alongside these came the no-till farming system (SPD), in which Brazil is the world pioneer for tropical conditions, preventing the annual erosion of fertile soil while retaining water in the profile — a direct response to the erosive intensity of tropical rainfall, and the integrated crop-livestock-forest (ILPF) systems consolidated through the Low Carbon Agriculture (ABC) and ABC+ Plans, which turn tropical land-use pressure into an opportunity for carbon sequestration, degraded-pasture recovery, and simultaneous production of grain, meat, and timber on the same landscape. This tropical methodology was reinforced by a distinct institutional and economic context: while temperate farmers in Europe and North America historically benefited from substantial

government and multinational subsidies, tropical farmers in Brazil and Latin America generally absorbed the full cost of soil correction, fertilization, and technological adoption, making efficiency, sustainable intensification, and the search for productivity per hectare a matter of economic survival rather than choice.

The result is a fundamentally different agricultural paradigm — according Embrapa, the productivity gains have expanded grain output in Brazil by 496% over three decades while cultivated area grew only 116%, saving an estimated 144 million hectares of native vegetation and consolidating a model that combines high output with 66.3% of national territory still covered by native ecosystems — a model that provides the practical context against which the climate risk and farming resilience discussion that follows in this report must be understood.

The value chain under climate stress

Climate change has moved from a long-term scenario to a structural determinant of agribusiness performance today. The World Meteorological Organization confirmed that 2024 was the first calendar year with a global average temperature above 1.5 °C (1.55 ± 0.13 °C above 1850–1900), with record ocean heat content and accelerated sea-level rise. The IPCC AR6 assessed with high confidence that climate change is already reducing food and water security, with impacts propagating from farming through five interconnected value-chain nodes, extreme events, productivity, logistics, cost structure and financial markets.

Climate risk is no longer a farm-gate issue, it became a systemic agribusiness value-chain challenge. Some transmission mechanisms link the value-chain nodes and define the material implications. The warming and variability erode both the average and the reliability of production, impacting yield gap. The post-farm infrastructure is also climate-exposed, so a single event compounds farms losses through logistics. The cost inflation due to insurance, credit, energy and freight premium in high price simultaneously, squeezes margins across the value chain, from crop inputs, farming, to the consumers. In the end, capital, technology and talent flow toward climate-resilient assets, geographies and business models reshaping competitive advantage in agribusiness.

Extreme events

The first node is also the most visible, because warming arrives not as a gentle trend but as a rising frequency of shocks. In Brazil the signal is unmistakable and according Cherubin's evidence, South America is becoming "warmer, drier and more flammable" — with 2023, 2024 and 2025 ranking as the three hottest years on record — turning this statistic into a lived reality on the frontier. Also floods or even other extremes. All those can impact large-scale production. The extreme event is therefore not an isolated meteorological accident, it is the trigger that sets every other node of the chain in motion, and its first casualty is productivity.

Productivity

Once an extreme event strikes, its most immediate effect is on yield and yield stability, and a central insight of this report is that productivity is, before anything else, a soil-health story. Cherubin's long-term tropical trials show that soil carbon explains around 20% of soybean yield variation, and enzymatic activity (β-glucosidase) about 35% of its productive stability — the very definition of climate resilience — with diversified systems achieving water-use efficiency of 3.1 to 3.5 kg of grain per millimeter of rainfall against only 1.8 kg in degraded ones, and cover-crop mixes cutting yield volatility roughly in half. What a bad year erodes is therefore not only tons but predictability itself. Crucially, climate change does not lower Brazilian productivity uniformly; it redistributes it geographically, while the Global Yield Gap Atlas reminds that closing existing gaps — climate-smart intensification rather than land expansion — remains the resilient path to growth. The diversification needs to be evaluated as alternative to manage production risks from climate, such as forest or even protected cultivation. This geographic reshuffling of output is precisely what carries the shock into the next node: logistics.

Logistics

Because production is redistributed, the infrastructure that moves it becomes the chain's silent point of failure. Post-farm assets are themselves climate-exposed, so a single event compounds farm loss downstream. The 2024 floods in Rio Grande do Sul displaced thousands of people and cost hundreds of lives — disrupted rail, roads and river infrastructure for months, demonstrating how regional climate shock instantly becomes a national logistics problem for grain, protein and pulp exporters alike. The transport, storage and energy infrastructure lose activity and productivity under a warmer scenario, precisely because more correlated extreme events strike production and its arteries in the same cycle. In this case all the value chain is impacted, but those that require cold chain are the most damaged. When navigability, storage and export corridors fail at the harvest, the value created on the farm cannot reach the market on time, and the loss migrates from the field to the balance sheet — the domain of cost structure.

Cost structure

Climate stress rewrites the cost structure of the entire chain in overlapping ways. On the farm, adaptation demands higher upfront capital and higher recurrent input costs — the price of resilience is paid before any premium is earned. Along the supply chain, traceability and compliance costs rise as buyers and regulators push climate credentials ever deeper into farm-level data, a pressure the PwC 29th Global CEO Survey shows is already reshaping Brazilian boardrooms, where 33% of agribusiness leaders report high exposure to climate change — well above the Brazilian cross-sector average (18%) and the global average (13%). The Strategy& Future of Food analysis frames a migration movement of value toward resilience-enabling segments. The consolidated effect is a redistribution of value along the chain — farmers who adopt low-carbon, traceable systems earn premiums, while those who do not, pay higher risk-adjusted costs — which leads directly to the final and now dominant node: the financial markets.

Financial markets

The financial channel is where every earlier shock is finally priced. A strategic study of economics impact due climate change in Brazil, from Brazilian Government, estimates that the cost of global inaction on climate for Brazil reaches R$ 10.3–17.1 trillion by 2050, a range that can be higher than 2024 country's GDP. Yet the same channel also opens an opportunity. The Climate Policy Initiative records that finance aligned with climate objectives averaged US$ 2.6 billion per year between 2021 and 2023, still dominated by loss compensation rather than prevention, underscoring the need to redirect capital toward adaptation and measurable resilience by connecting credit conditions to soil recovery, water management and traceability. The Strategy& Future of Food study points to the same destination: capital, technology and talent increasingly flow toward climate-resilient assets, geographies and business models, with the food ecosystem's resilience-enabling segments projected to reach US$ 3.1 trillion by 2035. In the end, climate risk propagates from an extreme event, through productivity and logistics, into cost structure, and settles in the financial markets — completing the circuit into a systemic reshaping of competitive advantage across the whole agribusiness value chain.

Agribusiness climate resilience across the continents

Climate risk in agribusiness does not have a single geography or a single expression. During a journey through five continents, the same global concern appeared in very different forms: as water scarcity and fire in a technologically advanced export economy in Oceania; as the daily vulnerability of rain-fed family farming in Africa; as an intensely regulated transition in high-productivity European systems; as a matter of national food security and technological sovereignty in Asia; and as a systemic risk to production, trade, infrastructure and capital in the Americas. What connects these landscapes is the realization that climate resilience is not created by one technology or policy. It emerges from the interaction of natural conditions, infrastructure, education, research, finance, public institutions, and market incentives. The regional perspectives that follow combine personal observations and publications with authoritative evidence, using country examples to show how agribusiness is learning to produce under a climate that is becoming less predictable.

Oceania: Australia and New Zealand

Managing exposure through knowledge and markets

In Oceania, climate is an unavoidable business variable. Australia and New Zealand are both sophisticated export economies, but their agricultural identities were built under markedly different natural conditions. Australia's broadacre grain, oilseed, beef, sheep, horticulture and wine systems operate across a continent where rainfall is highly variable and where drought, flood, heat and fire can alter the economics of an entire season. New Zealand's pasture-based dairy and red-meat systems benefit from a temperate maritime climate, yet face their own combination of floods, drought, erosion and biological emissions. In both countries, distance from major markets reinforces the need for reliability, productivity, and a clear value proposition. The innovation ecosystems observed across the region reinforce that local land availability, infrastructure and production management, shape not only which technologies are adopted, but also the pace and purpose of adoption.

Australia shows what happens when climate science becomes part of routine commercial decision-making. The national agriculture department reports that change in rainfall, temperature and extreme weather are already affecting productivity, water availability, soil, and the spread of pests, weeds, and disease. On farms, the response is visible in seasonal forecasting, water accounting, drought-resilient genetics, diversified rotations, and precision input use. These practices do not remove volatility, but they make exposure more measurable and create options before a crisis becomes irreversible. In a capital-intensive sector, the central question is not whether a farmer can eliminate climate risk, but whether management, insurance, infrastructure, and finance can absorb a sequence of difficult years without destroying productive capacity.

The Australian perspective is also shaped by national emissions policy. The Agriculture and Land Sector Plan released in 2025, places agriculture within the country's net-zero pathway and supports investment in measurement, emissions reduction and bioenergy. This creates opportunities for farmers of low-emissions food and fiber, but it also raises a practical challenge: climate credentials must be converted into farm value. The field experience in Queensland adds a concrete illustration.

Extensive livestock and feedlot systems reuse manure as biofertilizer, while irrigated cotton around Goondiwindi demonstrates how water management and technology can reshape a regional economy. Farm industry groups extend the model beyond farm gate by connecting and supporting supply chain – with characteristics into different Asian countries for noodle requirements or livestock preparation aligned with middle eastern religious markets. One farmer extended the model beyond the farm by transforming part of the cotton crop into a proprietary clothing brand with field-to-product traceability. The case shows that climate resilience and margin can be strengthened together when operational efficiency is connected to narrative, branding and consumer proximity.

Across the Tasman Sea, New Zealand demonstrates a different tension. According to Ministry of the Environment in New Zealand, agriculture accounts for more than half of national emissions, mainly from livestock methane, so adaptation and mitigation cannot be treated as separate agendas. The strategic task is to reduce biological emissions without undermining the competitiveness of pasture-based systems, although New Zealand already have a carbon footprint of 0.9 kg CO_2e/kg of milk, according to a study published at Journal of Dairy Science, compared with a global average about 2.4 0.9 kg CO_2e/kg of mil as reported by FAO. The field visit showed how a simple farming pasture-based cow dairy operation could be managed by two people, with once-daily milking and the farm integrated into other economic activities.

In the horticulture, the kiwifruit offers a contrasting but complementary model: the kiwi gold variety creates value through intellectual property, branding, pricing strategy, and value sharing across the chain. Together, these cases suggest that resilience does not always require more intensive production. It can also arise from simplicity, respect for natural limits, and deeper value-chain integration.

The lesson is that resilience grows when knowledge is operational. The Australia and New Zealand opportunities is not simply to develop more climate technologies, but to integrate weather intelligence, emissions measurement, animal and crop science, financial planning and market positioning into one management system. Australia contributes scale and risk discipline; New Zealand contributes pasture science, product quality and a close link between research and export reputation. Together they show that education is powerful when farmers can translate information into decisions and be valued within the international commodity supply chain.

Africa: Angola and Kenya

Resilience begins with the foundations of the value chain

In Africa, climate risk is inseparable from development, but it is rarely the first constraint that farmers encounter. Across much of the continent, low fertilizer use, limited access to improved seed and biotechnology, weak irrigation, rural roads, storage, cold chains, connectivity, extension and finance still constrain attainable yield before climate change becomes the dominant production risk. This does not diminish the importance of climate exposure. It changes the sequence of responses. A drought or flood acts on a production base that already has little buffer, while basic agronomic and infrastructure gaps limit the capacity to adapt. IPCC evidence indicates that climate change has already reduced agricultural productivity across Africa more than in any other region since 1961, yet the immediate resilience agenda must often begin with

soil fertility, water, knowledge and market access. The regional innovation perspective supports this interpretation: where conventional infrastructure is absent, digital tools may allow some stages to be leapfrogged, but technology cannot fully substitute for basic productive foundations.

Angola makes this sequence particularly visible. The country has around 35 million hectares of arable land, but approximately 6 million hectares are worked and only about 120,000 hectares are irrigated, according to the Ministry of Agriculture and Forest. Family farm agriculture dominates, representing around 90% of planted areas and 82% of output across the main crop groups. Fertilizer use remains low, while the country continues to depend on imported fertilizer and has limited domestic capacity in inputs, seeds and machinery. Under these conditions, nutrient availability, soil fertility, extension, irrigation, and logistics are not secondary issues within climate adaptation. They are prerequisites for establishing a productive base capable of absorbing climate shocks. Rainfall variability matters, but in many locations the yield gap created by basic agronomic and infrastructure limitations is still more immediate than the incremental effect of climate change.

The opportunity in Angola is not to import a complete agricultural model from another region or to begin with sophisticated climate technologies in isolation. It is to build connected production corridors where soil testing, appropriate fertilizer use, improved seed, water, extension, storage, processing and guaranteed demand reinforce one another. Irrigation and water harvesting can reduce seasonal exposure, but infrastructure alone will not transform farm results. Agricultural colleges, cooperatives, field-based extensions, and commercially disciplined offtake are needed to help farmers learn, invest, and market collectively. As this foundation improves, climate services, remote sensing and risk finance can add increasing value. The order matters: first strengthen agronomic capability and physical infrastructure, so finance is priority for those investments, then use climate intelligence to protect and optimize the productive system that has been created.

Kenya tells a more diversified story. Its high-potential crop regions, pastoral areas and horticultural export chains experience climate risk differently, yet everything depends on the timing and quality of rainfall. FAO’s assessment described exceptionally abundant long rains that supported planting while also increasing waterlogging and localized crop stress. This coexistence of benefit and damage illustrates an important point: climate risk is not synonymous with less rain. It is the loss of predictability, including rain that arrives too intensely, too late or in the wrong place. Perishable value chains add another layer because inadequate cold storage turns a production achievement into post-harvest loss. At the same time, Kenya demonstrates how innovation may take a different route when physical infrastructure is constrained. Mobile money and digital financial services have achieved wide everyday use, suggesting that asset-light digital solutions can sometimes leapfrog conventional stages, even though connectivity and technical training remain limiting factors in rural production.

At Ol Pejeta, a conservancy wildlife station, the climate narrative expands beyond crops to the management of a shared landscape, where livestock production and wildlife conservation are managed together through monitored grazing, predator-proof bomas, and real-time tracking. Approximately 6,500 roaming cattle herds are integrated into the landscape. The significance of the case is not the transfer of a single practice. It is the disciplined use of data to manage forage, animal health, predators, biodiversity, and community livelihoods as one system.

Africa's perspective from Angola and Kenya is therefore pragmatic. Climate resilience begins with the foundations that wealthier systems often take for granted: transparency, financial stability, knowledge, water, fertilizer, roads, extension, storage, energy, animal health and market access. Other technologies and climate services can accelerate progress, but adoption depends on visible economics, trusted intermediaries, and skills. The most durable opportunity is to build value chains in which farmers can retain enough value to invest in the next cycle.

Europe: Netherlands, Germany and Poland

Negotiating the transition between productivity and legitimacy

Europe's agricultural landscape is one of high productivity, dense infrastructure and strong institutions, but also intense public scrutiny. The climate debate is mediated through the Common Agricultural Policy, environmental regulation, consumer expectations, and increasingly detailed requirements for nutrients, water, biodiversity, and emissions. According to the IPCC report the crop losses caused by droughts and heatwaves across the European Union have tripled over the past fifty years, while agriculture remains both a source of emissions and a potential provider of carbon storage and ecosystem services. The European question is therefore not whether agriculture must change, but how the transition can occur without eroding farmer income, investment capacity or social legitimacy.

The Netherlands offers a striking example of productive intensity under physical constraint. Dairy, horticulture, potatoes, seed and food processing are concentrated within a small territory supported by exceptional logistics and knowledge infrastructure. Field observations included greenhouses designed with enough height for future vertical expansion and dairy operations run by only two people through automated milking. Artificial intelligence was already embedded in everyday horticulture, egg, pork, and dairy production. Wageningen's sustainability framework begins not with technology, but with priorities: identify material issues, establish measurable targets, translate targets into farm practices, combine interventions, and monitor progress. The Dutch paradox is that technological efficiency does not automatically guarantee sustainability. External inputs concentrated in confined areas can increase pressure on surrounding soils, while dependence on automation creates operational vulnerability when equipment, spare parts or specialist support fail.

Dutch controlled-environment agriculture shows the dual nature of adaptation. Greenhouses can protect production from rainfall and temperature volatility while using water and nutrients with precision. Yet the same system may transfer exposure from weather to energy prices, carbon intensity, and capital costs. The climate solution is therefore systemic: water reuse, renewable heat, efficient lighting, biological crop protection, long-term contracts, and credible sustainability premiums must reinforce one another. The Netherlands demonstrates that environmental ambition becomes scalable when public objectives are translated into a bankable farm or supply-chain proposition.

Germany approaches the transition through engineering and industrial capability. Its agricultural and food economy is connected to a powerful machinery sector, applied research institutions and an agtech ecosystem working on automation, biological inputs, connected growing systems and resilient infrastructure. A German best-

practice report from Strategy& study, point to the potential of robotics, precision agriculture, next-generation inputs and circular processing, while identifying unclear economics and regulation as barriers to scale. Germany's strength lies in bringing farmers, universities, trading and food processors into practical development partnerships. Its risk is that technically strong solutions may remain for pilots if capital requirements, permissions, or payback periods are not aligned with farm reality.

Poland shows another face of European adaptation. Its cereals, poultry, dairy, fruit and processing sectors range from small family farms to internationally competitive exporters. A warmer climate may lengthen growing seasons or alter crop suitability, but those possible benefits come with drought, heat, intense rainfall, pests and soil-moisture stress. Modernization must therefore deliver resilience, not only more equipment or inputs. Cooperative machinery, shared storage, digital advice, crop diversification, soil cover and landscape water retention can help smaller farms reach technologies and practices that would be uneconomic individually. European funds can accelerate this process when they are tied to measurable risk reduction and viable farmer income.

Europe's wider perspective from those countries is that climate transition is a negotiation among science, regulation, markets, and rural society. The Netherlands is trying to develop a governance and knowledge model, Germany an engineering model and Poland a modernization-at-scale model. In each case, the decisive issue is whether the farmer sees a coherent pathway from environmental target to operational practice and from operations to economic return.

Asia: China and Japan

Food security, technological sovereignty and disciplined execution

Asia brings climate risk into the sphere of national strategy. The continent combines enormous food demand, manufacturing scale, technological capacity and exposure to heat, flood, drought, typhoons, and water scarcity. Considering the continent concentrates almost 60% of global population with 4,8 billion people, according to United Nations report, for major importing countries, resilience is not only about stabilizing domestic production, but it is also about diversifying supply, controlling critical technologies, and reducing dependence on external shocks. This perspective changes the relationship with agricultural exporters: reliability, quality, traceability, and strategic optionality may become as important as price and volume.

China illustrates the power of coordinated scale. Field observations emphasized the alignment of long-term policy, applied science, manufacturing, and execution. The Jingwa Center, China Agricultural University and the China International Crop Protection Exhibition showed an ecosystem that places research, public policy, companies and markets close to applied problems. The Jingwa Center brings these actors together around dairy, greenhouse horticulture and orchards, including heat-stress management, carbon reduction, water-fertilizer systems and intelligent equipment. Maimai Technology connects crop models, the internet of things, artificial intelligence, remote sensing and traceability across production and consumption. In a system of China's size, incremental productivity gains can become strategically material when technology, management and policy are coordinated over the long term.

China’s natural constraints help explain the urgency. Limited arable land, regional water scarcity, salinity, degradation, floods, drought and heat meet the political priority of food security. Investments in genetics, gene editing, protected cultivation, and the adaptation of crops to saline or degraded soils can reduce biological and geopolitical exposure simultaneously, as demonstrated by government publication about the strategic objective to reduce soybean imports by 25% between 2026 and 2030. For Brazil, this is a reminder that an export market can be large and strategically vulnerable at the same time. The appropriate response is not to retreat from the relationship, but to broaden it toward product quality to be the commodity of preference. This is what Australia does, genetics, biologicals, machinery, traceability, branded products, and higher-value uses of soy, coffee, meat, and other agricultural products.

Japan offers a contrasting model based on precision, quality and labor-saving technology. Its food system combines small and fragmented farms, an ageing rural population, demanding consumers, and exposure to typhoons, heavy rainfall, and heat. Labor's scarcity makes technology essential, yet field observations showed that adoption may remain gradual, and that machines with embedded technology can still operate in isolation. Wagyu production illustrates how strict genetics, controlled systems and full traceability create value where quality matters more than volume. The Japanese case suggests that climate adaptation must respect accumulated knowledge and cultural continuity while opening the farm gate to greater connectivity, automation and succession solutions.

The Asian perspective therefore has two complementary lessons. China shows how state priorities, scientific institutions and industrial scale can accelerate deployment. Japan shows how precision, automation and quality can compensate for land and labor constraints. For exporters, both cases underline the danger of treating demand as permanent. Climate resilience must include commercial resilience, which means understanding the buyer’s food-security strategy, diversifying products and participating in innovation rather than remaining only a supplier of raw commodities.

Americas: Brazil and United States

Continental scale and systemic risk

In the Americas, the United States and Brazil anchor global supplies of grains, oilseeds, animal protein, bioenergy and agricultural technology. Their scale as the two major agricultural exporters magnifies both opportunities and consequences. A continental drought, flood or infrastructure disruption can affect domestic farm income, global trade flows, and food prices. Both countries also possess deep research capability, entrepreneurial farmers, and innovation ecosystems. The central challenge is to connect these strengths to financial and policy systems that recognize climate risk before losses occur, rather than only compensating them after the event.

The United States presents a highly differentiated risk map. Water scarcity and aquifer stress shape irrigated agriculture in the West and Plains; heat and storms affect the South; flooding threatens river basins; and pests and disease shift across production zones. The country’s distinctive advantage is the connection among agricultural science, biotechnology, digital technologies, crop insurance, futures markets and large-scale processing. Genetics, precision irrigation, weather analytics and variable-rate inputs can protect margins, while insurance and hedging distribute a portion of the

risk beyond the farm. Yet more correlated and severe losses can test these mechanisms, particularly when infrastructure, insurance, and production are affected at the same time.

The United States experience also shows how value addition and standardization can change the climate and market equation. Premium beef from Angus and Hereford cattle is scaled through certification, carcass control and quality protocols, while large dairy operations use standardized infrastructure to deliver consistent output. At the same time, direct-to-consumer products such as milk sold in returnable glass bottles show that scale and niche can coexist. Biofuels, green chemistry, and high-value soybean oils create further alternatives to a purely bulk commodity model. These cases reflect an innovation ecosystem in which adoption is strongly driven by cost-benefit logic, market incentives, and stakeholder coordination. The risk is unequal access. Data, machinery, genetics, and finance may improve resilience for well-capitalized farms while widening the gap for farmers unable to fund adoption.

Brazil's climate story is inseparable from the achievements of tropical agricultural science. Soybeans, corn, sugar, orange, coffee, beef, poultry, forestry and bioenergy expanded through the adaptation of genetics, soils and production systems to tropical conditions. The livestock substantial productivity gains and a long-term reduction in pasture area, alongside higher beef output. This narrative is strategically important because it shows the potential of intensification to spare land, but such claims gain credibility when methods and land-use outcomes are transparent and independently verifiable.

The same scale that supports Brazil's competitiveness creates systemic exposure. Drought, heat, excessive rainfall and fire can affect crops, pasture, animal performance, roads, storage, ports, and credit quality in the same cycle. Dependence on imported fertilizers and concentrated trade relationships adds geopolitical risk to physical climate risk. Deforestation and land-use concerns create another layer through reputation, finance and market access. Climate resilience in Brazil must therefore combine pasture recovery, integrated crop-livestock-forestry systems, biological inputs, precision digital agriculture, resilient genetics, infrastructure and credible traceability.

Finance is part of this transition, but its design matters. The climate-finance evidence that instruments aligned with climate objectives averaged US$2.6 billion per year from 2021 to 2023, with public programs playing a major role in loss compensation, according to Climate Policy Initiative publication. This underlines the need to shift more capital toward prevention, adaptation and measurable resilience, connecting credit conditions to soil recovery, water management, traceability and productivity rather than treating climate only as an emergency expense.

The commercial implication is equally important. The China reduction plan for protein imports will require that Brazil should also reduce its dependence on an undifferentiated commodity proposition by expanding meat, biofuels, high-oleic oils, biologicals, green chemistry, branded coffee and other value-added products.

Both countries demonstrate that the next frontier is not yielding alone, but resilient value creation across the full chain.

A shared perspective from the five continents

The journey across the five continents reveals that climate risk is always local in its expression but with systemic consequences. Temperate and tropical climates create different biological pressures, but infrastructure and financial tools determine how quickly production recovers; education determines whether science becomes practice; capital markets determine who can invest before a shock; and geopolitics determines which dependencies become strategic vulnerabilities.

Across these countries, the most transferable lesson is not a particular crop, machine or policy. It is a method and perspective: identify the material exposure, understand the local production and social system, connect the relevant institutions, create incentives that make adoption economically rational, and monitor whether the intervention improves resilience. Food security cannot be separated from farmer's viability, and productivity cannot be separated from soil, water, biodiversity, and infrastructure. The agribusinesses most prepared for a changing climate will be those that treat resilience not as a compliance chapter, but as a strategy for creating durable value.

The technology role in agribusiness climate resilience

Climate risk has moved technology from farming to the center of the agribusiness agenda. Across the value chain — crop and livestock inputs, farming, logistics, processing, finance and markets — volatility in rainfall, heat, drought, fire and pests now translates directly into yield loss, animal-performance decline, cost inflation, asset devaluation and market-access risk. In this context, technology is no longer only a productivity lever; it is resilience infrastructure. The evidence gathered for this study, combining scientific and market sources with field observation, is consistent: resilience depends less on any single tool than on the coordinated capacity of an innovation ecosystem to turn data into timely, place-specific decisions.

A brief context: from tropical revolution to digital resilience

Brazil's own trajectory shows that technology has always been the answer to environmental limits. The creation of Embrapa in 1973 launched a tropical-science revolution that turned the acidic, low-fertility soils of the Cerrado into one of the world's most productive agricultural frontiers, while biological nitrogen fixation, today covers around 80% of the national soybean area and saves an estimated US$10–25 billion a year in nitrogen fertilizer according to the Brazilian Forum on Tropical Agriculture, 2026. In the same study, the No-Till System, which completed 50 years in Brazil in 2022, covers roughly 36 million hectares, and was the first large-scale climate-adaptation technology: by keeping soil covered it reduced erosion by up to 90%, improved water infiltration and sequestered carbon. These milestones were about managing environmental risk long before climate risk had a name. What has changed is the nature of the toolkit: from mechanical and biological innovation to a data layer—sensors, satellites, models and artificial intelligence—that makes the modern farm a decision platform rather than only a physical asset.

The role of the innovation ecosystem in the climate challenge

The defining lesson of the last decade is that no single actor can manage systemic climate risk alone. Resilience emerges from open, networked, and collaborative innovation that connects corporations, startups, farmers, investors, and research institutions. PwC Agtech Innovation — one of the world's leading agri-food-tech hubs, based in Piracicaba — illustrates the model in practice, orchestrating a community of startups around real field challenges. Field-validated cases show how this ecosystem converts climate and resource pressure into scalable solutions: an example was a product built between a startup and a fertilizer corporate, to deliver real-time leaf-nutrition diagnosis to optimize fertilizer use; a soil-carbon project applies laser-based (LIBS) soil analysis to enable measurement, reporting and verification for regenerative practices and carbon credits; and international residents and membership startups from Germany and the Netherlands, bring real-time soil intelligence and automated farm data to Brazilian conditions. Crucially, this collaborative logic is already how leaders behave: 38% of Brazilian agribusiness CEOs report established partnerships with external players to accelerate innovation, according to PwC CEO Survey 2026.

How technology enables resilience under a changing climate

Technology builds resilience by making production more predictable, more efficient, and less exposed. Some transferable themes recur across every geography studied — water, soil health, genetics and digital intelligence — each amplified by AI and remote sensing. Precision digital agriculture and connected growing systems (sensor-guided irrigation, variable-rate inputs, satellite monitoring and farm-management software) reduce input waste and cushion the impact of weather extremes, while adaptive genetics and biological inputs lower the biological exposure of crops and herds. According to a study from Cherubin, 2026, soil health is the quiet foundation, as long-term Brazilian trials show that soil carbon can explain around 20% of soybean yield variation and enzymatic activity about 35% of its productive stability — the very definition of climate resilience — with diversified systems achieving water-use efficiency. The farmer response is real but uneven, although most of the Brazilian farmers already practice no-till system and adoption of regenerative practices that bring climate resilience in adverse years, yet the single biggest barrier is the difficulty of measuring impact. This measurement gap is precisely where digital Measurement, Report, and Verification (MRV), satellite analytics and low-cost soil sensing create disproportionate value, converting good practice into bankable, verifiable resilience.

Circularity and bioeconomy: future of agribusiness resilience

The next resilience frontier reframes from waste as a resource and biology as an industry. Circularity and the bioeconomy reduce dependence on imported, price-volatile inputs while generating new revenue and lowering emissions of intensity. Animal-waste biodigesters convert an environmental liability into biogas, biomethane and biofertilizer — Brazil surpassed 1,600 registered biogas units in 2024, with agriculture accounting for around 80% of installed plants — closing nutrient and energy loops on-farm, according to Brazilian Forum on Tropical Agriculture, 2026. Biological inputs, in which Brazil is the world's largest market, are expanding at roughly 21% per year, four times the global average, displacing fossil-based nitrogen and its potent nitrous-oxide emissions. New pathways can turn bioenergy carbon-negative, while environmental assets — decarbonization credits and voluntary carbon credits — let farmers monetize regeneration and finance the transition. These mechanisms matter because they align resilience with profitability: circular, bio-based systems are simultaneously more robust to climate shocks and more competitive in markets that increasingly price, sustainability and traceability.

Key trends and emerging developments, supported by data

It is possible to consider four data-anchored trends to define the near horizon. First, innovation has become a boardroom mandate: according to PwC Global CEO Survey, 63% of Brazilian agribusiness leaders consider innovation critical to strategy, and 43% now systematically embed climate-related risks and opportunities into core decisions, yet climate change ranks among the top threats (33%) alongside inflation and macroeconomic instability (35%). Second, digital maturity is rising but shallow: the Brazilian Digital Transformation Index (ITDBr) for agribusiness, in a scale 1 to 6, climbed from 3.1 to 3.6, matching the cross-industry average, but the technological-

frontier dimension collapsed to 1.8, exposing low adoption of emerging technologies. Third, value is migrating toward resilience-enabling segments: the Future of Food 2.0 publication from Strategy& estimates nine food-ecosystem growth areas will reach US$3.1 trillion by 2035, with the on-farm “How We Grow” cluster — next-generation inputs, connected systems and agri-infrastructure — quadrupling to US$400 billion, its trajectory determined largely by the adoption decisions of 608 million farmers, 84% of whom cultivate under two hectares. Fourth, the productivity headroom is scientifically quantified: the Yield Potential and Yield Gap Atlas show large, closable gaps between actual and potential yields, framing climate-smart intensification, not land expansion, as the resilient growth path.

Implications for decision makers amid rising climate volatility

For leaders, the strategic objective must shift from yield maximization to resilient value creation. It is important to treat climate intelligence as core infrastructure, embedding forecasting, remote sensing and MRV into routine farm and supply-chain decisions rather than compliance reporting. De-risk farmer adoption — the true bottleneck — through demonstration farms, cost-sharing, sustainability-linked credit, technical assistance and long-term offtake contracts, since adoption depends on trusted economics and visible field results. Invest in measurement, because verifiable data is the currency that unlocks cheaper capital, insurance and premium markets, and directly addresses the barrier of farmers. And connect to the ecosystem rather than building alone: partnerships, corporate venturing and hub participation share risk and close capability gaps that move faster than any single organization can. Financing instruments — blended finance, payments for environmental services and carbon markets — should be sequenced to each project's maturity, and concessional capital to the transition and commercial capital to scale.

A foresight outlook and key takeaways

In the future, the agribusinesses best positioned for climate volatility will be those that have made resilience measurable, financed, and collaborative. Expect AI-enabled decision agents, real-time soil and nitrogen intelligence, and satellite MRV to become standard, turning the current measurement gap into a competitive advantage; expect the bioeconomy — biologicals, biogas, biochar and bio-based materials — to move from niche to mainstream input strategy; and expect traceability and verified climate performance to become conditions of market access rather than optional differentiators. Brazil's opportunity is distinctive: it has already made the tropical transition once, by choice and ahead of obligation, and can now export not only commodities but the tools, genetics and technology know-how of climate-resilient tropical production.

Insights for agribusiness climate risk management

The climate has always been one of the primary risks to farming, but the central finding of this report is that the rhythms on which agriculture and livestock depend are themselves being reshaped. Within the increase in concentration of CO_2 equivalent in the atmosphere and the average global temperature, what was once a long-term scenario has become a structural determinant of agribusiness performance today, and the evidence gathered across different sources points in a single direction: climate risk is no longer a farm-gate concern but a systemic issue that propagates through the entire value chain.

Conclusions

Climate risk has become a systemic value-chain issue

The journey that structures this report demonstrates that climate risk moves from farming through five interconnected nodes — extreme events, productivity, logistics, cost structure and financial markets. Warming and variability erode both the average and the reliability of production; post-farm infrastructure is itself climate-exposed, so a single event compounds farm losses through logistics; the simultaneous inflation of insurance, credit, energy and freight squeezes margins across the chain; and, ultimately, capital, technology and talent flow toward climate-resilient assets, geographies and business models, reshaping competitive advantage. The material implication is unavoidable: resilience must be built across the whole system, not defended at the farm gate alone.

A shared perspective from five continents

Seen from five continents, similar global risk concern of increase in average temperature appeared in very different response. In Oceania, Australia and New Zealand showed that resilience grows when knowledge becomes operational, integrating weather intelligence, emissions measurement, animal and crop science, financial planning and market positioning into a single management system. In Africa, Angola and Kenya made clear that resilience begins with the foundations of the value chain — soil fertility, water, fertilizer, roads, extension, storage, energy, animal health and market access — before climate services can add their full value. In Europe, the Netherlands, Germany and Poland revealed a transition negotiated among science, regulation, markets and rural society, where environmental ambition becomes scalable only when public objectives are translated into a bankable farm proposition. In Asia, China and Japan placed climate risk within national strategy, joining food security, technological sovereignty and disciplined execution. And in the Americas, Brazil and the United States exposed how continental scale magnifies both opportunity and systemic risk, making resilient value creation across the full chain the true frontier.

Resilience emerges from a system, not a single solution

What connects these landscapes is the realization that climate resilience is not created by one technology or one policy. It emerges from the interaction of natural conditions, infrastructure, education, research, finance, public institutions, and market incentives.

Climate risk is always local in its expression yet systemic in its consequences: temperate and tropical climates create different biological pressures, but infrastructure determines how quickly production recovers, education determines whether science becomes practice, capital markets determine who can invest before a shock, and geopolitics determines which dependencies become strategic vulnerabilities.

Technology has become resilience infrastructure

Technology has become a resilience infrastructure rather than merely a productivity lever. Resilience depends less on any single tool than on the coordinated capacity of an innovation ecosystem to turn data into timely, place-specific decisions, organized around the themes — water, soil health, genetics and digital intelligence — and increasingly extended by circularity and the bioeconomy. The single greatest barrier remains in the difficulty of measuring impact, which is precisely why digital measurement, reporting and verification convert good practice into bankable, verifiable resilience. The overarching lesson is that the agribusinesses most prepared for a changing climate will be those that treat resilience not as a compliance chapter, but as a strategy for creating durable value.

Brazil's distinctive position of exposure and progress

Finally, Brazil occupies a distinctive position within this global picture. It carries high exposure, yet it also shows genuine progress, with an energy matrix that is 50% renewable and total net emissions that have fallen by 21% over three decades. Its tropical agricultural science, consolidated since the creation of Embrapa in 1973 through biological nitrogen fixation, the no-till system and integrated crop-livestock-forest models, expanded grain output by 496% while cultivated area grew only 116%, sparing an estimated 144 million hectares of native vegetation. Brazil, in short, has already made the tropical transition once, by choice and ahead of obligation, so now can export beyond commodities, the tools, genetics and technology know-how of climate-resilient tropical production.

Recommendations

From yield maximization to resilient value creation

If there is a single call to action arising from this study, it is that decision makers must shift their strategic objective from yield maximization to resilient value creation. That reorientation translates into four practical commitments. The first is to treat climate intelligence as core infrastructure, embedding forecasting, remote sensing and measurement, reporting and verification into routine farm and supply-chain decisions rather than confining them to compliance reporting. The second is to de-risk farmer adoption — the true bottleneck — through demonstration farms, cost-sharing, sustainability-linked credit, technical assistance and long-term offtake contracts, because adoption depends on trusted economics and visible field results. The third is to invest in measurement, since verifiable data is the currency that unlocks cheaper capital, insurance, and premium markets. The fourth is to connect to the ecosystem rather than build alone, using partnerships, corporate venturing and hub participation to share risk and close capability gaps faster than any single organization. All of them are connected, so climate will require even more attention in country like Brazil, where measurement remains difficult due tropical weather, also farmers need knowledge transfer from available technologies to transition for a more resilient farming system, and the importance to think in how create value beyond maximization commodity yield.

Each stakeholder has a clear role: farmers should test resilient practices with measurement of their outcomes to explore different markets; traders, cooperatives and processors should make supply chains the main channel for adoption through long-term offtake contracts, premiums for verified practices and co-funded technical assistance. Financial institutions should link credit lines and rural insurance to verified data. Through innovation hubs, multi-stakeholder programs could reduce the risk of new solutions through shared pilots. The challenge for Brazilian agribusiness is no longer to prove that resilient farming is possible, but to show, at scale and with verified data, that it creates more value than yield alone.

Redirecting finance toward prevention and adaptation

The design of finance is equally decisive. The recommendation is to shift more capital toward prevention, adaptation and measurable resilience, connecting credit conditions to soil recovery, water management, traceability and productivity rather than treating climate as an emergency expense. Blended finance, payments for environmental services and carbon markets should be sequenced to each project's maturity, with concessional capital to the transition and commercial capital to scale. The advancement of risk assessment based on farming system resilience is crucial to enhance financial capital for the sustainable projects.

Brazil already could use some the instruments in place, credit with lowers interest rates for farmers who adopt sustainable practices and banks should link to verified resilience outcomes. Trading companies and crop input suppliers should add resilience criteria to barter contracts and cooperatives combine smaller farmers into bankable projects. The resilient farming systems should be rewarded so that prevention costs less than recovery.

Building commercial and circular resilience

Resilience must also be commercial. An export market can be large and strategically vulnerable at the same time, as illustrated by China's plan to reduce soybean imports. The farmers should therefore reduce their dependence on an undifferentiated commodity proposition by expanding into higher-value products — meat, biofuels, high-oleic oils, green chemistry and branded coffee — while understanding the food-security strategies of their buyers. In parallel, circularity and the bioeconomy should move from niche to mainstream input strategy, with animal-waste biodigesters, biological inputs and bio-based materials aligning resilience with profitability by reducing dependence on imported, price-volatile inputs and lowering the intensity of emissions. In Brazil there are some initiatives such as for cotton traceability, but it needs to be extended to other crops and products, as the circularity can be a competitive advantage from the tropical region.

Each part of agribusiness value chain has a clear role in turning this resilience into competitive advantage. Farmers and cooperatives should diversify into value-added, such as grain-to-meat integration, corn ethanol and certified-origin coffee, also make biodigester and biological inputs standard practice. The cotton traceability model should be extended to soybean, corn, coffee and beef, and reward low-carbon origin through long-term offtake contracts. It is critical to prove commercial and circular resilience in one product line within a single crop cycle and report the results, demonstrating that resilient value creation pays.

A transferable method and a call to action

Above all, the recommendations are more related to a method rather than a single crop, machine or policy solution, as it was able to verity in every continent: identify the material exposure, understand the local production and social system, connect the relevant institutions, create incentives that make adoption economically rational, and monitor whether the intervention genuinely improves resilience. The agribusinesses best positioned for climate volatility will be those that have made resilience measurable, financed, and collaborative. For Brazil, the opportunity is uniquely its own: having already navigated the tropical transition, it can now export not only commodities but the tools, genetics and technology know-how of climate-resilient tropical production — turning the climate crisis from a threat to be managed into an opportunity to build fairer, more sustainable and more resilient agribusiness system.

The diagnosis is complete, and the time to act is now, every stakeholder must lead by example. Farmers must turn their farms into demonstration sites for no-till, biological inputs and integrated crop-livestock-forest systems. Traders and crop input suppliers must make contracts and financing conditional on verified environmental outcomes. Banks and insurers must reward resilience by pricing it into credit and insurance. Universities and research institutes must make tropical MRV accessible and at scale. Brazil has led the tropical transition once, and it must lead again by proving that climate-resilient agribusiness is the most profitable path forward.

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