Innovators and Innovations in the Agricultural Sector in the Province of Santa Fe, Argentina[1]

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Abstract

The agricultural sector in Argentina has undergone a profound transformation over the past fifty years, driven by a series of innovations aimed at enhancing productivity and quality. This paper focuses on the Province of Santa Fe, one of Argentina's main agricultural regions, and examines how innovation unfolded through the case of Federico Trucco, CEO of Bioceres, and the institutional networks that supported this process, particularly the Argentine No-Till Farmers Association (AAPRESID). Drawing on David Galenson's economic approach to creativity, which distinguishes between conceptual and experimental innovators, we analyze Trucco's trajectory, his investment in human capital, and the innovations he has led, notably the development of HB4 technology, the first commercially available GMO wheat in the world. Our findings highlight the role innovators and, more broadly, the importance of entrepreneurial talent, risk-taking, and institutional networks in fostering agricultural transformation. The case of Santa Fe illustrates that even in a traditional sector like agriculture, innovation can thrive and position a region at the global frontier.

JEL Codes: O31 Innovation and Invention: Processes and Incentives, O32 Management of Technological Innovation and R&D, Q1 Agriculture

[1] We thank participants at the 49th Meeting of The Association of Private Enterprise Education (APEE) 2025, Guatemala, for their comments.

Index

1. Introduction

“Those who say that indefinite growth is impossible, or at least unsustainable, in a world of finite resources are therefore wrong, for a simple reason: growth can take place through doing more with less” (Ridley, How Innovation Works, 2020)

Over the past fifty years, the Argentine agricultural sector has undergone a radical transformation. Although the country had been recognized as an agricultural powerhouse for over a century, between the 1970s and 1980s, it began to increase its production at an unprecedented rate. Argentina moved from producing approximately 10 million tons of cereals (mainly wheat, corn, and soybeans) per year in the early 1970s (FAOSTAT, 2023) to over 120 million tons by the early 2020s (Ministerio de Agricultura, Ganadería y Pesca, 2025). More importantly, while production increased twelvefold, the total agricultural land in use grew only by about four times, from roughly 7 million hectares in 1970 to around 30 million hectares today. This dramatic surge in productivity has positioned Argentina among the world's top agricultural producers.

How did this happen? A series of innovations throughout the agricultural value chain enabled Argentina to boost its output while expanding land use at a relatively moderate pace. The starting point was the adoption of no-till farming, a method that reduces soil erosion and costs, thereby paving the way for other significant advances. These advances include genetic improvements in seeds (especially GMOs), enhanced herbicides and fertilizers, more efficient crop rotations, and specialized machinery adapted to no-till techniques. Crucially, this transformation remains ongoing, as a vibrant ecosystem of agriculture-focused startups has emerged in recent years. In this paper we explore the innovation processes and the key innovators behind the remarkable gains in agricultural productivity, with a focus on the Province of Santa Fe and the case of the biotech company Bioceres and the innovator Federico Trucco.

The Province of Santa Fe lies at the heart of this innovative process. It has experienced productivity growth that outpaced the rest of Argentina—expanding from 4 million tons of cereals per year in the 1970s to around 30 million tons today, all while increasing agricultural land from 2.5 million to 5 million hectares (Ministerio de Agricultura, Ganadería y Pesca, 2025). Santa Fe is also home to several important industrial and technological hubs linked to agriculture, making it a compelling case study on how innovation can reshape an entire region. Rosario, one of the most important cities in Argentina and the largest in Santa Fe, is not only the epicenter of crop processing and grain exports but also hosts major companies and institutions dedicated to the scientific development of agricultural inputs and startup incubation.

Meanwhile, mid-size cities such as Las Parejas and Rafaela have become clusters for agricultural machinery and agribusiness networks.

Innovation is a key driver of economic growth, as highlighted by economists like Paul Romer and Robert Lucas. Romer's endogenous growth theory emphasizes that technological progress and human capital investments are central to sustained economic development. It shows how the generation of new ideas makes possible a continuous and unlimited economic growth in a world with finite resources. Similarly, Lucas's work underscores the importance of human capital in fostering economic growth.

As McCloskey observes, "ideas that people have for commercially tested betterment" are central to economic development. No other explanation convincingly accounts for the roughly 3,000% growth in per capita GDP in the developed world since the 1800s (McCloskey, Bourgeois Dignity: Why economics can't explain the modern world, 2010). McCloskey argues that the power of ideas and innovation can generate such a dramatic increase in GDP per capita in only two centuries by breaking the constraints of diminishing returns. In essence, innovation lets ordinary people develop new goods and services, satisfy the needs of their peers, and foster sustained economic growth.

Although significant progress has been made in understanding innovation, much remains to be explored. As Matt Ridley, the author of *How Innovation Works*, says, "The striking thing about innovation is how mysterious it still is. No economist or social scientist can fully explain why innovation happens, let alone why it happens when and where it does" (Ridley, How Innovation Works, 2020). In particular, Ridley attempts to explain the mechanisms of innovation by telling the untold stories of how ordinary people made extraordinary things, turning inventions into useful, marketable, and cheap innovations. Along the same line, we aim to learn about innovation through the cases of AAPRESID, and Federico Trucco and Bioceres, a central actor in the agricultural transformation of Santa Fe. Through their stories, we aim to explore the processes that led them to innovate, successfully develop their ventures, and generate positive economic and social impact.

We use David Galenson's economic approach to creativity as a framework to analyze these innovators. Galenson's work relies on case studies to explore how innovators develop their ideas and transform their fields. He distinguishes between two types of innovators: those driven by *motivated experimentation* and those driven by *conceptual execution*. The first group innovates by searching for and discovering solutions over time, often without a fully formed plan, and regularly revisiting their work to refine it. That implies that their most significant contributions tend to emerge later in their careers because they improve with the experience. In contrast, conceptual innovators begin with a preconceived vision and clear goals, seeking to break conventional paradigms. They usually develop their innovations early in their careers, since experience creates habits that impair their abilities to innovate (Galenson, 2006).

Galenson first identified this distinction among modern artists—comparing Paul Cézanne, Georgia O'Keeffe, and Jackson Pollock (experimental innovators) with Pablo Picasso, Andy Warhol, and Frida Kahlo (conceptual innovators). He later expanded the framework to other creative fields, from sculpture and poetry to economics and business. Recent research has also found the same pattern in the gastronomy and in the wine-making industry (Elías J. J., García Negro, Schling, & Mount, 2022) (Elías J. J., García Negro, Ferro, & Paolo De Salvo, 2020). This paper shows that Santa Fe's agricultural sector is also an excellent context for studying innovation and creativity. Moreover, the paper adds to existing innovation literature by highlighting the role of local institutions and entrepreneurial networks in stimulating transformation. In particular, it underscores how these support structures can accelerate both experimental and conceptual innovation in a traditional industry like agriculture.

The paper proceeds as follows. Section 2 presents data illustrating the remarkable rise in agricultural productivity in Santa Fe over the last 50 years**.** Section 3 introduces the conceptual framework that guides this paper's analysis of the individuals and organizations responsible for this transformation. Section 4 focuses on knowledge networks and institutions—in particular, AAPRESID, founded to disseminate the advantages of no-till farming. Section 5 applies Galenson's analytical framework to analyze the case of Bioceres and the innovator Federico Trucco. Section 6 concludes.

2. Recent Trends in Innovation in Argentina's Agricultural Sector

2.1. Evolution of No-Till Farming in Argentina: A Comparative Analysis with the USA and Brazil

Since the 19th century, Argentina has been renowned for its fertile agricultural lands. However, agricultural production stagnated severely in the 1950s and 1960s (Mundlak, Cavallo, & Domenech, 1991). Around that time, a group of entrepreneurs and institutions began to study and later promote an innovative production process that would revolutionize the sector: no-till farming. This method replaces the traditional practice of plowing the soil before sowing with direct sowing onto the stubble left from the previous crop. Although no-till farming had been implemented elsewhere, no country had yet adopted it on a significant scale comparable to its total available agricultural land.

Initially, convincing farmers to abandon their traditional production methods was challenging. Nonetheless, by the end of the 1990s, no-till farming in Argentina began to gain traction. In the 1989/1990 growing season, only 66,176 hectares were farmed using this method—just 0.4% of the total agricultural land at that time. A decade later, in the 2000/2001 season, the area under no-till farming had surged to 10 million hectares, covering around 44% of Argentina's cropland. By the 2016/2017 growing season, no-till practices extended over 33 million hectares, representing approximately 90% of the country's agricultural land (Asociación Argentina de Productores en Siembra Directa (AAPRESID), 2020).

In contrast, other major grain-producing countries, such as Brazil and the United States, did not experience a comparable transformation. In the 1993/1994 season, Brazil had about 3 million hectares under no-till farming—roughly 6% of its 51.3 million hectares of cropland. By the 2016/2017 season, this figure had risen to 33 million hectares or 52% of its 63.3 million hectares of cropland (Derpsch, Friedrich, Kassam, & Hongwen, 2010) (McNeely, 2022) (Worldometers, 2025). Similarly, the US implemented no-till farming on 15.7 million hectares in the 1993/1994 season; however, with a total cropland area of 184.1 million hectares then, no-till practices accounted for only about 8.5% of production. By 2016/2017, the US led in the absolute area under no-till farming—with 40.7 million hectares—but this still represented only about 25% of its total cropland, estimated at roughly 160.4 million hectares (No-Till Farmer, 2025) (USDA National Agricultural Statistics Service, 2019) (Worldometers, 2025) (see Figure 1).

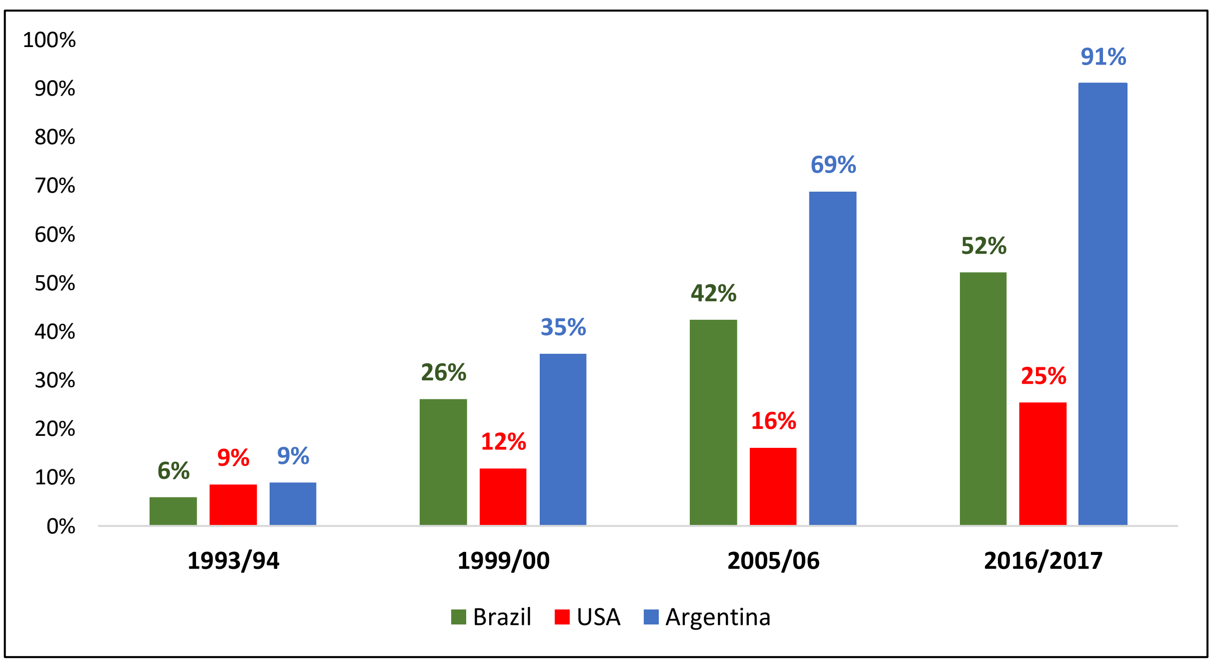

Figure 1. Area under no-till farming in percentage, by country

Roberto A. Peiretti offers evidence of the significant impact that no-till farming has had in Argentina (No-Till Farmer, 2023). His study reveals that from 1969 to 1994, Argentina's total cropland increased by 35%, while production grew by approximately 80%. However, since 1994, the expansion of cropland accelerated, rising by 85% by the 2019 growing season compared to 1994. In the same period, overall production surged by roughly 265%. Although many factors could have contributed to this dramatic increase in productivity, the timing of these changes strongly suggests that the adoption of no-till farming was a pivotal factor in this agricultural transformation.

Beyond boosting productivity, no-till farming offers other substantial benefits. Mainly among these are a significant reduction in soil erosion and lower production costs. Soil erosion is mitigated because crop residues left on the field after harvest form a protective layer that preserves soil moisture more effectively than bare, sun-exposed soil. Moreover, eliminating the need for one or two rounds of plowing before sowing reduces equipment usage, thereby cutting costs related to maintenance, fuel, labor, and other inputs. This enhanced efficiency not only minimizes operational expenses but also frees up time for other productive activities. In summary, no-till farming has increased productivity while simultaneously making the production process more ecologically sustainable and boosting farmers' profitability.

2.2. GMO Seed Adoption in Argentina: A Comparison with Brazil and the US

The rise in profitability enabled farmers to invest more in their operations. This, in turn, spurred demand for additional technologies closely linked to no-till farming. Among these innovations, GMO seeds have played a crucial role. In Argentina, these seeds were engineered not only for higher yields and improved herbicide tolerance but also specifically adapted to the country's soil. This strengthened Argentina's receptivity to GMO seed development, placing the country at the forefront of soybean, corn, and wheat biotechnology.

Figure 2 shows the adoption percentages of GMOs for the most important crops produced in Argentina, Brazil, and the US. As can be clearly seen, Argentina and the US were relatively quick adopters of GMO crops, while Brazil initially lagged behind. By 2017, however, all three countries had achieved near-complete GMO adoption. Notably, Argentina reached 100% adoption as early as 2012, suggesting that it has been much more receptive to biotechnology than its main competitors.

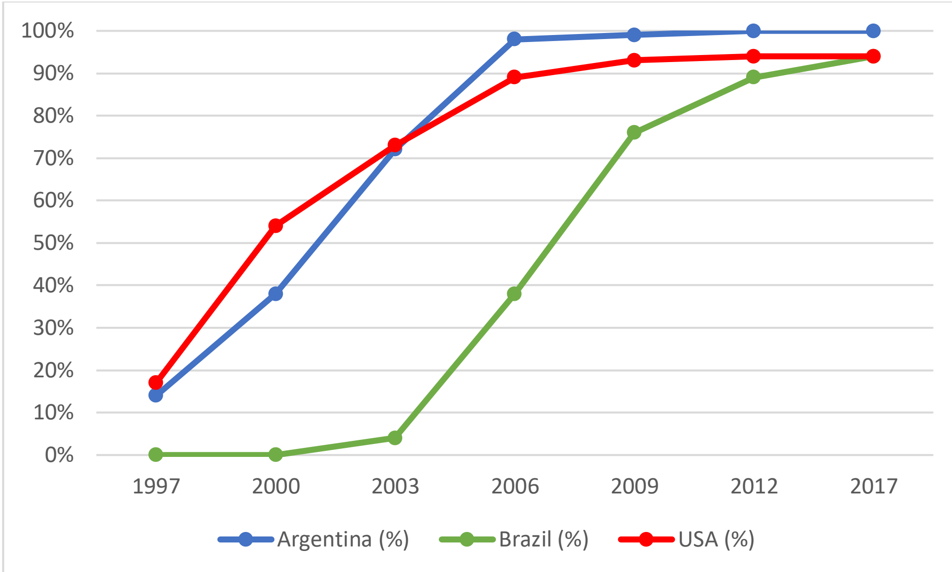

Figure 2. GMO seed adoption in percentage, by country

2.3. Agricultural Machinery Innovation: Patent Trends and the Santa Fe Cluster

Another area in which technologies related to no-till farming began to develop was machinery. The new production method altered the sowing process, creating a need to adapt sowing machines for no-till farming. As a result, various farming equipment manufacturers started improving their machines, adding specific accessories that further reduced costs and enhanced sowing precision.

As Beatriz Giraudo, former president of the Argentine No-Till Farmers Association (AAPRESID), explains:

"A new relationship with agricultural machinery began to emerge. It was necessary to develop all this technology associated with machinery that did not exist in Argentina or anywhere else in the world, and the metalworking industry drew inspiration from agronomists, from producers who used these technologies, and even from different types of soil, in order to carry out these developments. Even today, they remain in high demand worldwide, owing to the specialized knowledge associated with direct seeding technology" (Giraudo, personal communication, February 21, 2025).

Indeed, the growing interest in developing these new machines or accessories for no-till farming is evident in the Argentine national patent registry. Before the 1980s, no product had been registered in Argentina containing the words "*siembra directa*" [direct seeding (i.e. no-till farming)]. As early as 1985, a company requested permission to register "an improved agricultural implement for direct seeding." After that year, there were 18 new requests containing the words "*siembra directa*," with half of the applications submitted in the 1990s and granted in the 2000s. Most notably, 17 of these 18 patents were registered by farming equipment manufacturers (see table 1).

Table 1. Patents containing the words "direct seeding"

Year	Owner	About
1985	Airet, Omar Miguel y Airet, Ruben Lujan	An improved agricultural implement for direct seeding
1991	Dolbi Sociedad Anonima	A machine for direct seeding of agricultural crops
1993	Agrometal S.A.I.	Working device applicable to direct seeding machines
1994	Samaria, Carlos Enzo Evaristo	Medium drill seeder for direct seeding
1996	De Laudo, Juan Jorge, De Laudo, Raul Emilio, De Laudo, Andres Oscar	Direct seeding seeder
1998	Frattini, Oscar Hector	Set of furrow opener blades for direct seeding and localized fertilization
1998	Chinelli Roberto Santiago (H), Gorgojo Isaias, Naldini, Nolberto Luis	Improvements in soil marking devices applicable to direct seeding machines
1998	Chinelli Roberto Santiago (H), Gorgojo Isaias, Naldini, Nolberto Luis	Improvements in front blades of direct seeding machines
1999	Cervatte, Sergio Oscar, Rodriguez, Roberto Fermin	A device for direct seeding
1999	Giorgi, Hugo Hector	Train for location of seeds in direct sowing
2000	Baumer, Carlos Ricardo	Coupling and support device for variable accessories train, for direct seeding seeder for coarse and fine grains, fertilizers and agricultural machinery in general for soil treatment
2000	Bertini, Enrique	Discoidal tillage blade support structure applicable to direct seeding machine
2002	Romagnoli, Jorge Carlos Joaquin	Leveling wheel and covering wheel usable in direct seeding
2004	Chr.Hansen Argentina S.A.I.C.	Procedure for producing hard cheese with a granular texture using direct sowed crops; the crops used and the hard cheese with a granular texture thus obtained

2006	Guerriere, Jorge Omar	Provision for applying an inoculant diluted in water in a sowing furrow simultaneously with the implantation of seeds by direct or conventional sowing, application nozzle in the same, seeder and transport that include it
2010	Dow Agrosciences LLC	Protection from herbicide penoxsulam damage in rice field seeded in water, direct seeding and transplantation
2012	Vallesi, Hugo Pedro, De Alberto David Santiago	Direct seeding cart
2013	Hidraulica Tedeschi S.R.L.	Improvements in the layout of fertilization and direct seeding units on agricultural machines
2020	Romagnoli, Jorge Carlos Joaquin	Stubble sweeper and on-wheel stubble compactor applicable to direct seeding machines

Source: Own elaboration using information from the Argentine national patent registry

The province of Santa Fe, in particular, became the epicenter of many of these innovations. Early in the no-till farming revolution, a large cluster of manufacturers emerged in certain parts of the province, all dedicated to producing similar equipment and, crucially, sharing knowledge about this new production process. Being strategically located in the center of the Pampas proved essential for these companies; as of 2021, Santa Fe accounted for 44% of all agricultural machinery and agricultural parts manufacturers in Argentina (see Figure 3). Interestingly, Córdoba and Buenos Aires rank behind Santa Fe with 33% and 14% of machinery manufacturers, respectively, despite having larger cropland areas (Instituto de Estudios de la Realidad Argentina y Latinoamericana (IERAL), 2021)

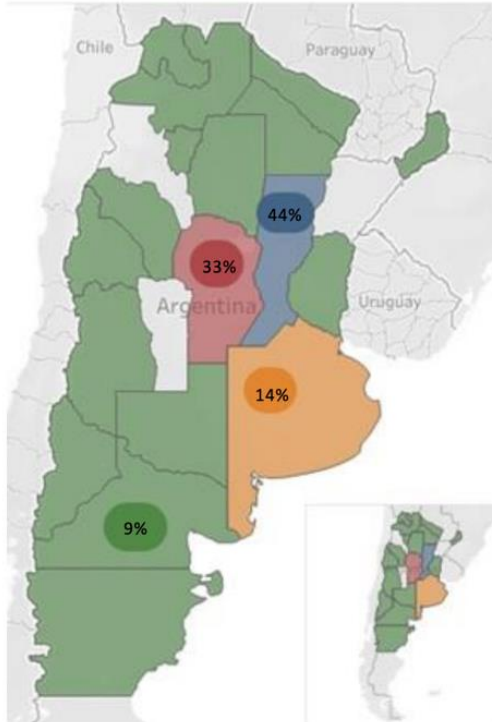

Figure 3. Distribution of agricultural machinery by province, in percentage (Instituto de Estudios de la Realidad Argentina y Latinoamericana (IERAL), 2021).

2.4. Growth in Agricultural Production: The Expansion of Extensive and Intensive Margins in Argentina and Santa Fe

As a corollary of these and several other related innovations, Argentina's agricultural sector—along with the province of Santa Fe—experienced an astonishing growth in both intensive and extensive production. Nationally, cereal output of the most important crops soared from about 10 million tons in 1970 to between 120 and 140 million tons by the early 2020s. Much of this expansion was driven by intensification: while total cropland increased from roughly 7 million hectares in the 1970s to about 30 million hectares today, production rose by a factor of 12 to 14 (FAOSTAT, 2023) (Ministerio de Agricultura, Ganadería y Pesca, 2025). Moreover, it is difficult to determine precisely how much of the new agricultural land came from marginal areas that were previously unused versus how much was converted from other types of production, particularly livestock. Nevertheless, the cost reductions associated with these innovations were so substantial that whether farmers opted to utilize marginal lands or switch from livestock to agriculture, their decision was likely driven by higher profitability (see Figure 4).

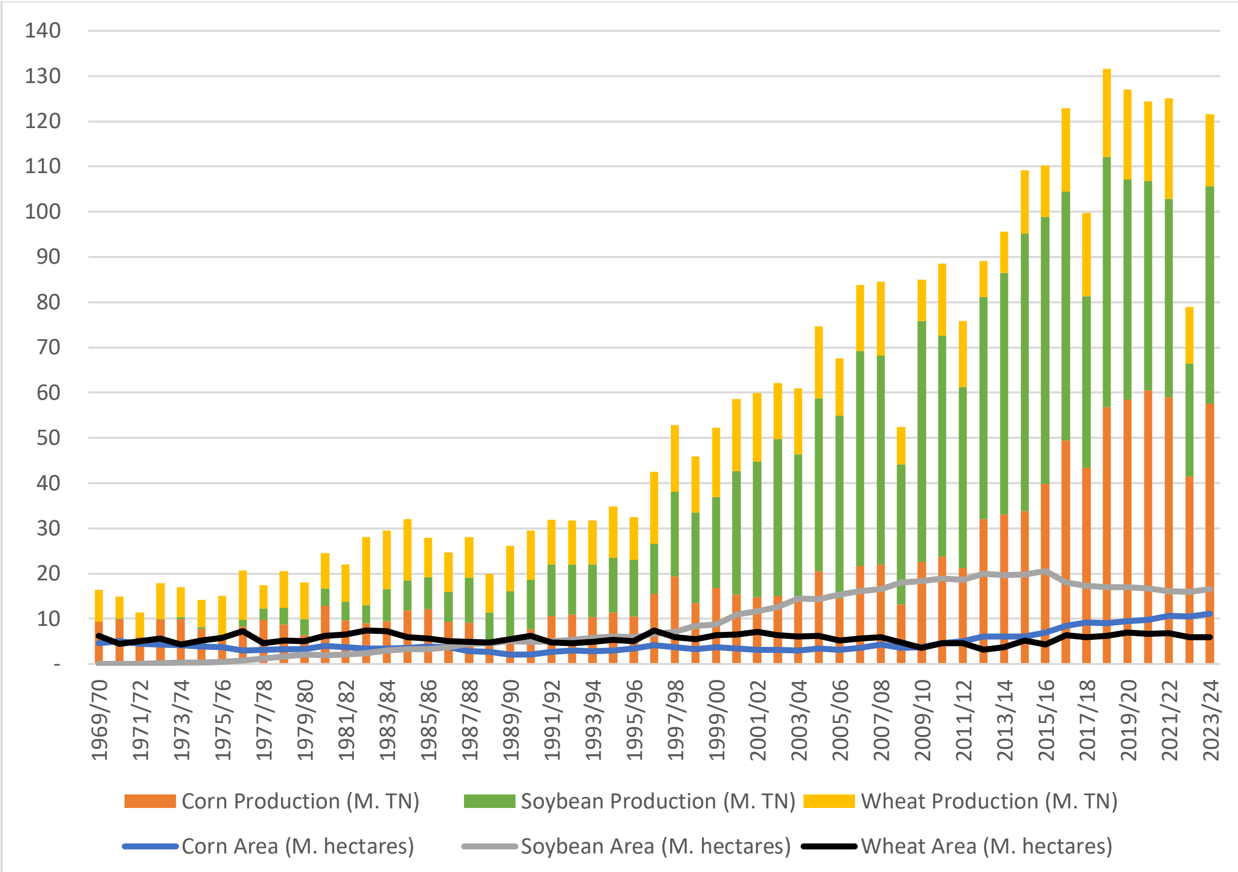

Figure 4. Argentina total cereal production and cropland, in millions metric tons and hectares.

The province of Santa Fe witnessed an even more dramatic expansion in both intensive and extensive production. In the 1970s, Santa Fe produced around 4 million tons of cereals on approximately 2.5 million hectares. By 2023, production had climbed to roughly 30 million tons on just 5 million hectares. This represents a seven-and-a-half-fold increase—275% more than the growth in cropland, which merely doubled (Ministerio de Agricultura, Ganadería y Pesca, 2025). Historically, Santa Fe was a major cattle-raising region; thus, part of its expanded agricultural footprint likely came from converting livestock areas to crop production, while some was derived from cultivating previously marginal lands (see Figure 5).

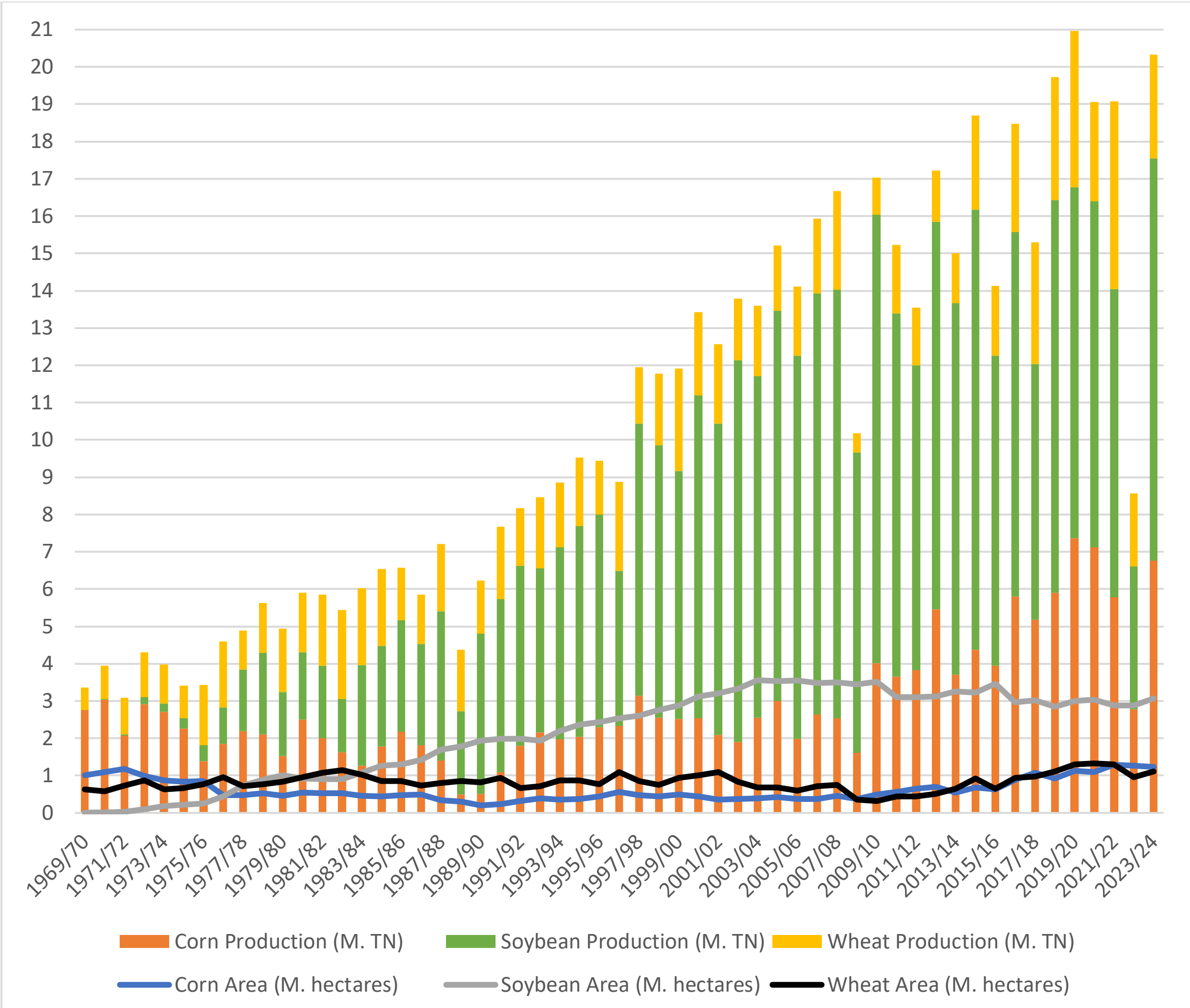

Figure 5. Santa Fe total cereal production and cropland, in millions metric tons and hectares.

3. Innovation and Creativity: A Conceptual Framework[2]

For Gary Becker (2005), the knowledge revolution consisted of systematic application of knowledge to business and economics. This led to a productivity explosion, fueled by advances in scientific and other knowledge relevant to economies. Galenson's economic approach to innovation is presented next. This approach will serve as a framework for analysis to understand how innovation developed and its mechanisms in the agricultural sector of the province of Santa Fe, and to structure the analysis of the case study of the innovator Federico Trucco, which is presented in Section 5.

[2] This section is based on Elías et al (2020, 2022).

3.1. Planners versus improvisers[3]

In *The Lego Ideas Book*, Lipkowitz (2011), points out that, on some occasions, to start a new project it is convenient to plan in advance, while, on others, it is better to start without a preconceived idea and to devise the new model on the go. The work clearly establishes two possible approaches to innovation, but immediately raises the question of what determines the convenience of one or the other approach. According to Galenson, the optimal strategy for innovating (planning or ideating from experimentation as you go) depends on the type of innovator you are.

In his quest to understand the creative and innovation process, David Galenson realized that art was an excellent laboratory to study creativity from the economic perspective. As in the case of researchers, artists are also innovators. Significant works of art contain substantial innovations. Regardless of the nature of the innovation, its relevance ultimately lies in its degree of influence on other artists. In art, as in all intellectual pursuits, only artists who influence their successors' practice are truly significant.

From detailed study of more than two hundred artists' careers, Galenson establishes that there are two very different types of art innovators: conceptual innovators, who minutely plan before making a work, and experimental innovators, who make important decisions about their work while they are making it.

Conceptual innovators use their art to accurately express ideas. The precision of their objectives allows them to plan their work and execute it decisively. Pablo Picasso, Andy Warhol and Frida Kahlo were great conceptual innovators.

Their conceptual innovations tend to be dramatic. In most cases, they consist of something completely different, which breaks the conventional rules of a discipline or activity. Their most radical new ideas, and consequently their greatest innovations, tend to come early in their careers.

For conceptual innovators, such as Pablo Picasso, the planning stage is essential in the innovation process. Picasso made hundreds of preliminary sketches and drawings to paint *Les demoiselles d'Avignon*. This fundamental work of modern art, which can be seen at the MOMA in New York, was made by him in 1907, at the age of twenty-six. "In my opinion, searching means nothing in painting. Finding is the thing" and "When I paint, my goal is to show what I have found, not what I am looking for" are some of Picasso's phrases that reveal him as a highly conceptual innovator.

[3] Based on Elías (2014).

In contrast, experimental innovators seek to record their visual perceptions and lack a clear goal. They proceed tentatively, through trial and error, gradually building their skills as they go about their work, and tend to make their greatest contributions late in their career. Paul Cézanne, Georgia O'Keeffe and Jackson Pollock are some examples of great experimental innovators.

In a sort of extreme experimental improvisation for his paintings, Jackson Pollock would spread out the canvas on the ground and splash and drip paint onto it using hardened brushes, wands and syringes. Pollock explained that only after a kind of recognition period did he see what he had achieved. He avoided preconception to such an extent that only in the final stage of his work did he decide on the size and orientation of the painting. Pollock was an extreme experimentalist.

Two of greatest artists from Rosario, Santa Fe, epitomize the two types of innovators. Antonio Berni exemplifies the conceptual innovator and Lucio Fontana the experimental innovator. Early in his career, in his twenties, Berni developed a deliberate vision rooted in social and political critique. His approach was guided by strong intellectual and ideological convictions, which he translated into idea-driven artworks. Unlike experimental innovators who refine their language gradually, Berni introduced transformative ideas early and maintained a conceptual focus throughout his career. He was remarkably versatile—working across painting, engraving, collage, assemblage, and even large-scale installations—but his thematic coherence remained consistent: a deep concern with inequality, exploitation, and the lives of the marginalized. His iconic characters, Juanito Laguna and Ramona Montiel, emerged as powerful symbols of urban poverty and consumerism, created through a novel use of found objects and discarded materials. Berni’s capacity to synthesize aesthetics and message demonstrates the hallmark of a conceptual innovator: the use art as a vehicle for clearly articulated ideas.

In contrast, Lucio Fontana was a late bloomer whose artistic language emerged through a long process of exploration, observation, and refinement (Galenson, 2014). His trajectory was marked by continuous experimentation—from his early engagement with Cubism, Futurism, and Surrealism to his most personal innovations, such as the “buchi” (holes) and “tagli” (cuts). These breakthroughs stem from an ongoing dialogue with materials, space, and visual experience. Fontana did not consider his works traditional paintings or sculptures, but rather “spatial concepts,” the result of a deeply visual and tactile practice. His work reflects a persistent exploratory impulse, who advance by accumulation rather than by rupture.

The categories of conceptual and experimental innovators do not apply exclusively to the world of art. Later studies have demonstrated that these same patterns are repeated in fields as diverse as literature, music, business, science, the fine wine industry, and gastronomy. In this study, we show that, just as in art, the agricultural sector serves as an excellent laboratory for learning about creativity through the analysis of its innovators.

In “The Innovator’s DNA”, Dyer, Gregersen, and Christensen (2011) identify five key skills shared by successful business innovators: associating, questioning, observing, experimenting, and networking. These skills can be directly linked to the two types of innovators defined by David Galenson. While both types value networking, they differ in how they excel at the other capabilities.

For experimental innovators, observing and experimenting are essential. These innovators behave like scientists or anthropologists: they closely observe common phenomena—particularly user behavior—and actively test ideas through prototypes or pilot projects. As Edison said, “I haven’t failed. I’ve simply found 10,000 ways that do not work.” Their process is cumulative, driven by experience and iteration.

In contrast, conceptual innovators stand out for their ability to associate ideas from different fields and to question established assumptions. Associating—the ability to connect seemingly unrelated questions, problems, or concepts—is at the core of innovative thinking. Conceptual innovators often generate breakthrough ideas from a clear and sudden vision, rather than through long processes of trial and error. They also cultivate diverse networks to expand their thinking, intentionally engaging with people from other disciplines, countries, and cultures to push the boundaries of their knowledge.

An example of a conceptual innovator is Steve Jobs, who in the entrepreneurial world claimed that “people don’t know what they want until you show it to them. That’s why I never relied on market research” (Isaacson, 2011). Regarding experience, he stated, “it’s wonderful to have a beginner’s mind,” reinforcing the idea that habits often deteriorate creative capacity.

In contrast, Sam Walton, founder of Wal-Mart, serves as an example of an experimental innovator (Galenson, 2022). In his memoirs, Walton wrote: “Somehow, over the years, people have gotten the impression that Wal-Mart was something I dreamed up out of nowhere when I was middle-aged, and that it was just one big idea that turned into an overnight success. It’s true that I was forty-four when we opened our first Wal-Mart in 1962, but the store was totally a product of everything we had been doing since Newport: another case of my inability to leave things as they are, another experiment. And like most overnight successes, it took about twenty years to happen.” This illustrates that his success was the result of a continuous process of trials and adjustments that took decades to consolidate.

Table 1 summarizes the objectives, methods, and nature of the results in each type of innovator and provides some examples.

Table 2. Galenson's innovation typology applied to artistic creation

Innovators	Objectives	Methods	Results	Examples
Experimental	Imprecise and evolutionary The objective is a theme or problem	Tentative and incremental Trial and error	Slow development of skills leads to a work body	Paul Cézanne Jackson Pollock Lucio Fontana
Conceptual	Specific and sudden (discontinuous) The objective is precise	Targets established beforehand Detailed preparatory plans	Systematically developed specific final work	Pablo Picasso Frida Kahlo Antonio Berni

Source: prepared by the authors, based on Elías and Ferro (2018))

4. Knowledge Networks and the Spread of Innovation

"We have the knowledge, the science, the experience available to leave future generations better soils and a better environment than the one we received, for the first time in the history of humanity." – Beatriz Giraudo (Martinez Dodda, 2024)

The generation of new ideas goes beyond investments in R&D. The knowledge and human capital of the inventor are crucial. The accumulation of knowledge over time through interactions with other innovators is key. Universities, companies, and research institutions facilitate these interactions. During the idea production process, inventors form research teams and create ideas of varying quality. These ideas improve technologies and products, driving economic development (Akcigit et al., 2018).

For example, in the case of art, Vincent van Gogh did not begin to assimilate the most innovative art of his time until 1886, when he arrived in Paris. It was then that he learned the techniques and motivations of contemporary art, interacting with and learning from other painters like Georges Seurat and Émile Bernard, who influenced his understanding of color and new forms of representation. This period in Paris was crucial, as it allowed him to absorb the ideas and techniques he would later reinterpret to make a significant contribution to advanced art (Galenson, 2006). Van Gogh achieved this remarkably quickly, as the most outstanding works of his career began to emerge in 1888, only two years after starting his true training as an advanced artist, and continued during the last two years of his life. Van Gogh's experience in Paris illustrates how knowledge communities, by bringing together artists and intellectuals, are fundamental in fostering innovation and enabling creators to make new contributions.

However, knowledge communities are not exclusive to the art world. The agricultural sector of Santa Fe also has an institution that connects farmers, entrepreneurs, and researchers and creates an innovative environment, which has been the key driver for the productivity growth that the province experienced in the last 50 years. The Argentine No-Till Farmers Association (AAPRESID) was established in 1989, coinciding with a rising interest in no-till farming. In order to understand AAPRESID's history and relevance, we conducted an interview with its former president, Beatriz Giraudo.

4.1. Argentine No-Till Farmers Association (AAPRESID)

Despite Argentina's longstanding reputation for exceptional agricultural productivity, by the 1950s and 1960s, the humid Pampas began showing signs of exhaustion (Mundlak, Cavallo, & Domenech, 1991). A group of farmers and researchers soon conjectured that the underlying issue was soil degradation. As Giraudo explains, these farmers were *"deeply concerned by the deterioration of the soil. They observed that, as the soil deteriorated, the capacity to retain water in a rainfed agricultural system became increasingly limited"* (Giraudo, personal communication, February 21, 2025). This concern spurred them to evaluate production methods from other regions, focusing on minimizing erosion.

During this process, they met Carlos Crovetto from Chile. After studying in the United States, Crovetto brought back knowledge from Kentucky about a novel process known as no-till farming—centered on zero or minimal tillage. This method involves sowing new crops directly onto the residues of the previous harvest, eliminating the traditional need for pre-sowing plowing and thereby reducing soil disturbance and erosion. Although this technique had not yet gained popularity in the US, it proved well-suited for Argentina. Following a period of investigation and testing, Victor Trucco and a group of farmers founded AAPRESID in 1989 in a small town south of Santa Fe (AAPRESID, n.d.).

This marked the beginning of a revolution in Argentina's agriculture. This transformation was remarkably ahead of its time since it addressed the dual challenges of increasing production while protecting the environment. However, the key factor that contributed to the massive adoption of no-till farming in Argentina was that it was economically more efficient. In the 1990s, with relatively low agricultural prices and rising production costs, some farmers' profit margins were minimal or even negative. In this context, the increased productivity and reduced fuel usage associated with no-till farming provided a compelling economic incentive.

Today, estimates suggest that yields can increase by up to 28% while fuel usage is reduced by almost 60% with no-till farming. Moreover, this revolution has yielded a range of unintended benefits beyond increased income and cost reduction. These include significant reductions in soil erosion, improvements in water productivity of up to 25%, increases in soil carbon capture of up to 200%, enhanced diversity and biological activity in the soil, reduced use of chemical fertilizers and herbicides, and decreases in CO_2 emissions by around 40% (AAPRESID, n.d.). In this regard, Giraudo states:

"If we quickly trace the sequence starting from the adoption of no-till farming and the process of increasing complexity and enriching the entire system, erosion was halted by over 90%, water use capture improved by more than 80%, and evaporation decreased by more than 70%. [...] The numbers are all quite striking" (Giraudo, personal communication, February 21, 2025).

Nonetheless, perhaps the most significant benefit of no-till farming is its ability to maintain—or even improve—soil quality despite intensive production. This technology provides a level of sustainability in farming that had not been achieved before and overcomes the limitations imposed by diminishing marginal returns. With no-till farming, it becomes possible to rejuvenate soils to a condition nearly as immaculate as their original state while simultaneously increasing production. As Giraudo observes, "this translates into [the remarkable fact] that soils under enormous production pressure, when managed with the right technology, are not very different from pristine soils" (Giraudo, personal communication, February 21, 2025).

In this sense, AAPRESID itself stands as a milestone in agricultural innovation. It transformed forever the production process of Argentina's agriculture. Moreover, it achieved this change through a bottom-up approach. There was no commander or planner directing what or how to do; the process was driven by farmers and researchers exchanging ideas, experimenting, and learning collaboratively. As Giraudo describes it, this was "an organizational innovation." She adds:

"[H]aving producers drive this demand is the real game-changer, because typically scientists, technicians, or policymakers define things and expect producers to put them into practice. No, that is a recipe for failure. So, the fact that producers are the ones driving it, producers exchanging ideas among themselves, and from that exchange arises a need that fuels scientific-technological demand, alongside changes in metal-mechanics—this is definitely a major milestone and an example of how to succeed with all these revolutions and massive adoptions" (Giraudo, personal communication, February 21, 2025).

Just as in the case of art in Paris, AAPRESID exemplifies a dynamic knowledge community that unites entrepreneurs and researchers to promote innovation. Over more than 25 years, the institution has created an ecosystem that continuously generates agricultural knowledge and insights. This environment has not only spurred the development of new practices—such as crop rotations, service crops, and enhanced certification and traceability—but also facilitated the emergence of a network of startups and companies dedicated to refining no-till farming methods.

One notable subsector that has greatly benefited from the AAPRESID community is the industry of genetic editing. In particular, AAPRESID played a pivotal role in the creation of Bioceres[4], one of Argentina's leading biotech companies. Founded in 2001 by a group of 23 farmers—many of whom were AAPRESID founders—Bioceres has experienced remarkable growth over the past decade, going public in 2019 and reaching a valuation of 500 million as of 2025. More importantly, the company has gained international recognition for its innovative HB4 technology, which provides drought and salinity resistance to various crops. After more than 20 years of research, Bioceres developed the HB4 wheat, the first commercially available GMO wheat in the world.

This case demonstrates that the collaborative network fostered by AAPRESID is highly effective in nurturing innovation. Numerous startups and companies have emerged and continue to evolve within this dynamic collective brain. Looking ahead, Giraudo identifies promising areas of innovation in the application of artificial intelligence, digitalization, and traceability in agriculture. She remarks:

"[E]verything related to AgTech gives us tremendous support in this mandate to produce more with less. So, anything that involves gathering information—whether site-specific or integrated—linking different parameters to compare and improve… In other words, we are truly moving forward, even with artificial intelligence, toward the best possibilities of technology use in a much simpler and faster way than we ever imagined. I think we have a huge opportunity to continue strengthening these systems, which on the one hand involve working with biotechnology, with gene editing, with all that knowledge, and on the other hand involve being able to process all that data and extract a great deal of information and many practices in a highly accelerated way" (Giraudo, personal communication, February 21, 2025).

In sum, AAPRESID's knowledge community represents a remarkable success story. The institution has not only introduced a novel production method that is applied in more than 90% of the Argentine territory but has also established an innovative ecosystem that could serve as a differentiation mechanism for the agricultural sector of Argentina, or Santa Fe. The province, in particular, is especially well-positioned to support this mission. As Giraudo concludes:

[4] See section 5.1

"I insist that the possibilities we have to direct the biomass we produce and make it specific for different markets, for different processes, to achieve different goals—of course, food for people and for animals, but also everything related to human health, construction industries, packaging, and energy—are truly limitless. […] And again, I point out that Santa Fe has a strong enough scientific and technological platform to provide substantial support for all this. The entire industrial sector in Santa Fe is also extremely important; it's agro-diverse, and even though it is a single province, it has remarkably varied conditions. […] We also have a very interesting institutional framework. So I think that having a distinctive seal—I can't help but think of it as a country brand, because we can achieve that, we're prepared for it, but I insist that since we don't have it yet, let's have it for Santa Fe, let's even have it for different productive activities based on all these foundations—could be the next steps, and not difficult to accomplish" (Giraudo, personal communication, February 21, 2025).

5. Innovator: Federico Trucco – Bioceres

"Every pebble is unique, but profoundly unique objects are rare. Wherever these are found (whether in nature or among the members of human society) they are interesting in themselves. They offer opportunity for intimate indwelling and for a systematic study of their individuality. Since great men are more profoundly unique than any object in nature, they sustain a far more elaborate study of uniqueness than any natural object can."

—Polanyi, 1959

"The problems that are valuable, the ones worth solving, are the ones that are most likely to fail. Doing marginally better than someone else is of little importance to humanity. Doing the difficult things is what is important for humanity."

Federico Trucco (CFI Argentina, 2023)

With the aim of understanding the innovation process in Santa Fe's agricultural sector, we conducted an in-depth interview with Federico Trucco, CEO of Bioceres. Guided by Galenson's approach (Section 3), the interview explored his beginnings, his investment in human capital, the type of innovator he represents (conceptual or experimental), the influences that shaped his career, and the innovations he has led. Finally, we asked him to select three things he would take with him if he had to spend a year on a deserted island.

Federico Trucco is the CEO of Bioceres, a biotechnology company focused on developing innovative crop solutions. Bioceres was founded in 2001 by Víctor Trucco (Federico's father) and 22 other farmers from Argentina, and since its creation maintains its headquarters in Rosario, Santa Fe. Under Federico Trucco's leadership, the company went public, listed on NASDAQ, in 2019 and, as of January 2025, has reached a market capitalization of nearly USD 500 million.

Bioceres is widely recognized for its HB4 technology, which confers drought and salinity tolerance in crops. This technology was first applied to soybeans and wheat, making Bioceres the first company to develop—and, more importantly, commercialize—genetically modified wheat worldwide. Regarding the global significance of this achievement, Trucco remarks:

Regarding the worldwide importance of this development, Trucco remarks:

"Not for its productive impact, but for what it means in terms of our capabilities to develop a transgenic crop, to approve it internationally, even in species where [everybody] said it was impossible. Think about it: there are three transgenic soybeans [in the world]. One is from Bayer because they bought Monsanto, the other is from Corteva, and the other is ours. It's not that there are hundreds of thousands of transgenic soybean crops. And in wheat, we are the only ones. Therefore, I believe that as a Santa Fe native, to be able to achieve this, [to be] at the forefront in these issues, that for me is important" (Trucco, personal communication, December 17, 2024).

Beginnings

Federico was born in Rosario, Santa Fe, in 1977 but spent his childhood in San Jorge, a small city in the countryside of the same province. His father, Víctor Trucco, was the third-generation descendant of Italian immigrants who had come to Argentina to work the fertile Pampas. Víctor was among the first individuals to earn a doctorate in Biochemistry at the University of Rosario. In the 1970s, due to a controversial political climate, Víctor decided to return to his hometown, which somehow limited his professional activities in Biochemistry.

Following his father's footsteps, Federico developed an early fascination with science. After some time, Víctor resumed his original scientific pursuits and started a biotechnology company that attempted to extract an enzyme from bovine blood. Although that project failed, Federico's enthusiasm for science grew as he observed his father's research in the laboratory. It was there that his passion for biochemistry truly took shape *(Elige Tu Propia Aventura, 2022)*.

Investment in human capital: Formal education

When Federico Trucco was 12 years old, he left home and attended high school as a boarder. After graduating, he decided to pursue a career in biochemistry. He chose to study in Louisiana in the United States for two main reasons. First, an undergraduate degree in biochemistry in the U.S. took only three years, whereas, in Argentina, it required six. Second, getting a degree in abroad was not very expensive at that time due to the strong appreciation of the Argentine peso in the 1990s.

While pursuing the biochemistry degree, a friend recommended he specialize in a particular area of biochemistry. He decided to complete a master's in weed zoology and plant pathology, followed by a doctorate (Ph.D.) in crop science, remaining in the United States for ten years. During his Ph.D. studies, he frequently spoke with his father on weekends about establishing Bioceres. The company was created in parallel with his professional training and ultimately became the place where he would work.

Investment in human capital: On-the-job training

In 2005, Federico Trucco returned to Argentina and began working at Bioceres. However, the initial stage of his professional journey was marked by frustration:

"I think that when one comes with a certain level of training, one considers oneself better than everyone else. Then, reality sets in— one sometimes has to interact with people that one does not fully value or one thinks that the decisions that are made are incorrect or delayed. I felt a deep sense of frustration initially, as if all the effort I had put into building my professional competitiveness was going to waste. I can´t ignore that feeling. At first, I thought: I am in Argentina for a variety of other reasons, but it is a shame that I am wasting my time on this" (Trucco, personal communication, December 17, 2024).

Trucco explains that he had to learn a profound lesson in humility. Though it was a difficult experience, he appreciates the value of that process. Eventually, he reached a pivotal moment when he was entrusted with greater responsibilities:

"At a certain point, an opportunity opened up where I could have a little more prominence. And I think that there was a turning point, which was when we began to connect with the international world, and there was an American company called Arcadia, with whom we were able to reach an understanding to develop the HB4 technology, which gave a high value to Bioceres. That is, there was a capitalization that they made, recognizing a value of the company that was orders of magnitude greater than what our shareholders thought they had. That generated credibility for me, it generated enthusiasm for me. It ended up empowering me because, after that transaction, I became the CEO of the company" (Trucco, personal communication, December 17, 2024).

Innovation

In 2012, Bioceres and Arcadia entered into a joint venture that generated significant synergies for both companies. According to Trucco, the most notable benefit was the increased credibility among existing shareholders and prospective local investors, which substantially boosted the company's valuation:

"It generated two or three times more local funding than what [Arcadia] put [...]. In other words, the only thing that was needed was to show that there was a third party outside willing to buy shares of a certain value so that our own shareholders or other local investors would buy three times that amount of funding and, at the end of the day we would end up buying back that share from [Arcadia]" (Trucco, personal communication, December 17, 2024).

Although Bioceres had been funding and researching the HB4 technology since the early 2000s, the partnership with Arcadia propelled the company onto the global stage. A year later, in 2013, Bioceres finalized another joint venture—this time with Florimond Desprez, a world leader in wheat genetics. Together, they created Trigall Genetics to launch HB4 varieties in Argentina, Brazil, Uruguay, and Paraguay (Capital Intelectual S.A., 2021). Trucco stresses the importance of external validation—having an external partner invest in the viability of HB4 was crucial: *"We told them why we thought this was worth it, and we got them to support us financially by investing dollar for dollar in this project. And that's how we built the reality"* (Trucco, personal communication, December 17, 2024).

However, overcoming the regulatory hurdles required to approve a genetically modified crop proved to be a major challenge. Between 2006 and 2015, several field trials for the technology failed. Nonetheless, in 2016, two key Argentine regulatory agencies—CONABIA and SENASA—approved HB4. Trucco recalls the aftermath: "*And well, once we overcame that in Argentina, we achieved the first milestone; everything else happened with a speed that is even greater than we had anticipated"* (Trucco, personal communication, December 17, 2024). Currently, the HB4 technology is approved for cultivation and consumption in Argentina, Paraguay, and the United States, and for consumption in Brazil, Australia, New Zealand, Colombia, Nigeria, Indonesia, South Africa, and Thailand.

Asked about this accomplishment, Trucco emphasizes:

"The important thing is not so much the drought tolerance in wheat and the possibility of developing it through the HB4 gene, but breaking paradigms. Saying, well, everything that you said could not be done, I'm going to say that it can be done. And understand that by doing that, regardless of the economic result of HB4, you are building a letter of introduction to the industry in which you were thinking of participating.

In some way, at the end of the day, the investor is looking for someone who will come and do something different or at least try to alter the status quo" (Trucco, personal communication, December 17, 2024).

Type of innovator: Conceptual

Trucco is best characterized as a conceptual innovator for several reasons. The first is his acknowledgment of the importance of careful planning. In the case of the HB4 technology, for example, he points out that Bioceres followed a well-defined roadmap. He explains:

"There was a strategy and a plan behind it, which is to say, if at the end of the day, we have to do this somewhere on the planet, I think that in Argentina we have a good chance. First, because that is where we are. Second, because there are precedents of already approved transgenic crops. Third, because the international markets that we would need to approve the Argentine wheat, which are our export markets, are few. Basically, we sell to Brazil, we sell to some Latin American countries, and eventually, depending on the level of production, we can sell to Asia or the Middle East, but that depends more on availability in Russia and Ukraine than on our own competitiveness. And much of what we sell far away has to do with wheat used for fodder and not human food. Therefore, for us, it was a more limited project, which did not require a global investment, but rather a more regional investment and which was, all things considered, manageable" (Trucco, personal communication, December 17, 2024).

Second, he prioritizes radical innovation over incremental improvements. He frequently speaks of redefining or revolutionizing established frameworks through scientific breakthroughs or disruptive innovation. For Trucco, the greatest accomplishment of HB4 was challenging traditional assumptions—including his own. Indeed, when his father told him that Bioceres would begin developing the HB4 technology, he responded: *"What a waste of money […]. This goes against everything I learned in college. They are trying to solve a polygenic problem in a monogenic manner, something that has already failed umpteen times."* (Capital Intelectual S.A., 2021) However, upon witnessing HB4's success, he now asserts:

"Sometimes the most surprising things in science are those that break those paradigms that one has, where you think that this type of solutions can only be obtained in one way and you would never have thought that you would get it in another way" (Trucco, personal communication, December 17, 2024).

Third, Trucco views innovation as incompatible with a mere assembly-line approach to repeatedly generate disruptive products. Reflecting on the largest biotechnology firms, he observes:

"Monsanto is what it is because of the RR[5], but it was never able to repeat it with the same level of force […]. Bayer because of the Aspirin. And it seems like trying to repeat that initial success, saying: Look, I learned certain things, and now I put them in a matrix of all the decisions, I can recurrently generate Aspirin 2, Aspirin 3, or Aspirin 4. And the truth is that there are no precedents of success in that sense of companies that can recurrently achieve disruptive products. At least in the bio world" (Trucco, personal communication, December 17, 2024).

Looking ahead, after developing and commercializing the world's first transgenic wheat, the next steps for Bioceres remain open-ended. When asked, Trucco replies:

"Is there going to be an HB5 or HB6 wheat? For me, it makes little sense. I think we validated that. Today, I am more interested in another type or things that are complementary or adjacent than in looking for HB5, HB6, or HB7. […] I think it's good to do it, it's good to have achieved it. Now, I think there are other investments that are more attractive for us" (Trucco, personal communication, December 17, 2024).

Instead, Trucco sees the HB4 technology as a scaffold for generating adjacent or related breakthroughs: *"Today, biotechnology brings you gene editing, which is something fantastic; you can achieve a reduction in gluten, increase fiver, whatever you want"* (Trucco, personal communication, December 17, 2024). In 2021, Bioceres launched an investment fund called SF500, which supports start-ups in Santa Fe. The fund's objective is to create 500 companies related to life sciences, potentially generating synergies with the scaffold Trucco envisions. He explains:

"*We are not in a race to create an enormous conglomerate that controls full value chains from end to end. What we want is to create an ecosystem of independent companies that dare to challenge the status quo […] If we can multiply the impact, if we can create 500 companies with a path similar to our own, I believe we will be even closer to producing a veritable cultural change"* (Capital Intelectual S.A., 2021)

In this way, Bioceres hopes to fulfill its mission of bringing environmental resilience to global agriculture.

Three products he would take to spend a year on a desert island

As a good planner and conceptual innovator, Trucco states:

"I would take something to write on so I could have a process of maintaining my mental health, and I suppose I would have much time to think. So, [...] something that I can use to organize that. Generally, paper and pencil are useful and then, I suppose that if I get a little desperate, at some point I could have

[5] Roundup Ready, Monsanto's line of genetically modifies crops.

music by Maria Helena Walsh or something that I listened to when I was a kid, that takes me to a space of comfort, of refuge, of protection" (Trucco, personal communication, December 17, 2024).

6. Conclusion

The agricultural sector of Santa Fe is an excellent field in which to study innovation. In the past 50 years, it has undergone a profound transformation driven primarily by a remarkable increase in productivity. Put simply, from 1970 to the present, production has grown by an astonishing 650% while using only 100% more land.

Innovation was the key for Santa Fe to produce more with less and overcome the constraints of diminishing marginal returns. It all started with the adoption of no-till farming, a radical method introduced in the 1970s. After that came GMO seeds, crop rotations, specific chemicals and fertilizers, and improved machinery. All of these contributed to Santa Fe's agricultural revolution.

We approached this innovative process through the lens of David Galenson's economic methodology for creativity. Drawing on Galenson's distinction between experimental and conceptual innovators, we applied it to the case of Federico Trucco, showing how his trajectory as a conceptual innovator exemplifies the role of human talent and entrepreneurship in Santa Fe's agricultural revolution.

Moreover, this paper contributes to the existing creativity literature by underscoring the importance of network communities in fostering innovation. AAPRESID is a model institution showing how farmers and researchers can come together, exchange ideas about theory and practice, and develop innovative processes, products, and services. The organization demonstrates how different people, each pursuing their self-interest to improve their own situation, can promote the interest of society and increase production while preserving the environment.

Finally, and most importantly, our paper emphasizes that innovation can thrive even in a traditional sector such as agriculture. Contrary to the notion that some sectors are innovative while others are not, agriculture in Santa Fe has proven to be just as advanced as other areas of the economy, like the software or internet industry. Indeed, not many subsectors can increase output 7.5 times while only doubling input in just 50 years. The agricultural sector of Santa Fe is an exceptional example of how innovation can transform the world.

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