



The Emergence of an Innovation Cluster in the Agricultural Value Chain along Colorado's Front Range

Innovators in an increasingly integrated Agriculture-Water-Food-Beverage-Bioenergy innovation ecosystem are gathering and growing along Colorado's Front Range, creating next-generation technologies and business models to nourish, refresh, and energize the world.

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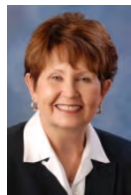
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Executive summary

Colorado has long embraced **agriculture** as central to its economy and **innovation** as an essential driver of economic growth. These two—**agriculture** and **innovation**—have been converging in Colorado for some time now, and the pace is picking up. This study proposes that a number of geographic, demographic, and economic factors are driving investment and engagement in innovation in the agricultural and food system, and the essential elements are in place along the Colorado Front Range for the emergence and growth of an innovation-led industry cluster in agriculture and food.

The objectives of this study

- To **recognize the emergence of an innovation-led industry cluster**, reframing conventional views of the industry to consider overlapping interests across the entire integrated value chain of agriculture.
- To **identify the geographic footprint** of this emergent innovation cluster, deriving it empirically from a landscape analysis of innovation data. This is important to update conventional notions of agricultural innovation as only involving rural areas.
- To **explore the fundamental factors that are favoring the Colorado Front Range** as a location for innovation in the agricultural value chain, including geographic, demographic, and economic factors.
- To **identify the main technology categories** in which Colorado firms and research institutions are innovating, as well as **their structural interrelationships** within the value chain.
- To **provide an inventory of companies and organizations** in Colorado that are engaged in innovation in the agricultural value chain, and their locations.
- To **recommend next steps** for encouraging growth of this emergent innovation cluster, such as cultivating talent, coordinating mechanisms for collaboration, and financing of innovation.

What is an innovation cluster? Why is it important?

An innovation cluster has been defined as “*a geographically proximate set of interconnected companies and associated institutions in a particular field*” where “*co-location of the various stakeholders accelerates knowledge sharing and development of new products and services.*” The emergence and growth of an innovation cluster has implications both for the industry and for the geographic region within which the cluster arises. **Companies benefit** from economic advantages of engaging within a cluster. **The region benefits** from increasing employment and tax revenues, resulting in better services and a higher standard of living. **The global economy benefits** too from the emergence of a regional ecosystem driving innovation.

The value chain of agriculture dictates the structure and scope of its innovation ecosystem

Understanding the full scope and structure of **the value chain of agriculture** is crucial to seeing the range of overlapping interests and thus the potential scope for clustering dynamics within what is effectively **an agricultural-water-food-beverage-bioenergy complex**. The value chain of agriculture can be understood to encompass *“the entire flow of inputs and outputs that enable agricultural enterprises to realize the value of their unique capital base by meeting the needs of final consumers.”* The value chain involves greater than 200 separate industry subsectors. These range from farm land, irrigation, labor, and other agricultural inputs, to commodity marketing and processing, food and beverage manufacturing, wholesale, and retail of food, beverage, and other agriculturally-derived products and services.

The global imperatives, or opportunities, for innovation in agriculture

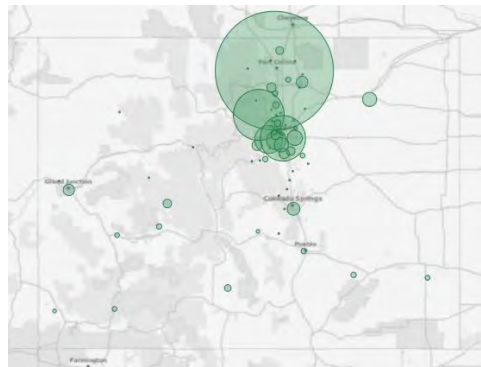
Globally, agriculture confronts a number of cross-cutting challenges. Global **growth in commodity prices** is a powerful indicator of the need—and the value proposition—for innovation in agriculture. Prices have risen at an average pace of 6 percent annually since 2000, after almost a century of real food prices declining by an average of 0.7 percent per year. A number of factors are driving **fundamental resource scarcity** in agriculture and food on both the demand side and the supply side. These scarcity factors can be interpreted as imperatives—or, conversely, as opportunities—for innovation.

Surveying the landscape of agricultural innovation in Colorado

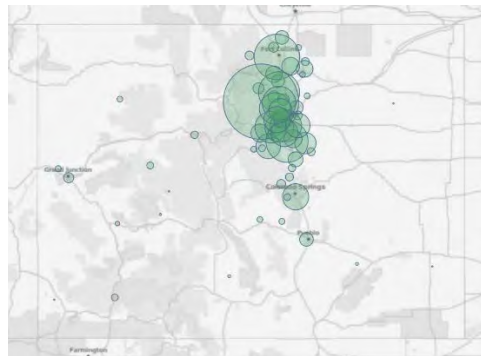
To understand who is innovating in the agricultural and food value chain within Colorado, and where, a **landscape analysis** mapping two R&D output proxies—scientific publications and U.S. patents—is conducted to provide a cross-sectional view of Colorado’s evolving science base and Colorado’s outputs of technological innovations.

Colorado’s science base in agriculture: Between 1990 and 2012, Colorado authors generated 14,913 scientific publications in the fields of science that encompass the industry’s value chain (including agriculture, agronomy, horticulture, plant sciences, water, soil sciences, entomology, veterinary health, and food science.) Of these scientific publications, 86 percent were by authors at public sector institutions (universities, public agencies, and nonprofits), 11 percent were by authors in industry, and a handful, just over 3 percent, were published jointly by authors at both (considered “public-private” collaboration). Overall, publication rates have grown steadily at 3.25 percent per year over the past two decades, from about 400 per year in 1990 to about 800 per year in 2012. Mapping where publications come from within Colorado, shows over 95 percent concentrated the northern Front Range and metro Denver. The single largest share is from Fort Collins.

Colorado's inventions in agriculture: During the same years Colorado inventors generated 2,548 patent applications and 2,455 granted U.S. patents in these fields of technology, for a combined total of 5,003 patent records. Of these, 10 percent were by public sector inventors at universities, public agencies, and nonprofit, 85 percent were by private sector inventors in industry, and a handful, just over 5 percent, were by inventors at both (considered “public-private” collaborators). Patenting grew at an average growth rate of 6.5 percent per year. A mapping of inventors within Colorado shows about 90 percent concentrated in the northern Front Range and Metro Denver. The single largest share is from Boulder.



a. Scientific articles published, by city of author's institutional affiliation



b. U.S. patents filed and granted, by city of inventor's residence

Some observations based on this landscape analysis:

- Colorado's R&D in agriculture and food is highly **concentrated geographically** within the relatively compact urban corridor including metro Denver and the northern Front Range.
- Colorado's R&D activities in agriculture and food have been **growing** two to four times **faster than the state's economy** overall, over the last two decades.
- Patenting activities have been growing two times faster than scientific publishing, over the last two decades, indicating that Colorado's **private-sector R&D** in agricultural and food technologies has been expanding relative to the state's already sizable science base.

Why the Colorado Front Range?

Several fundamental economic, geographic, and demographic factors that, together, are likely responsible for driving the emergence of an innovation cluster in the agricultural value chain along the Front Range:

Colorado has a long history of innovation in agriculture, food, and beverage:

The Front Range has given rise to such companies as Coors (founded in 1873), Monfort (1930), Leprino (1950), and Celestial Seasonings (1969). These companies have shaped the region's economy and created a culture in which agriculture and food entrepreneurs are seen as pillars of the community.

Colorado has become a nationally recognized center of innovation and entrepreneurship:

For example, in 2013 the U.S. Chamber of Commerce ranked Colorado number two for entrepreneurship and innovation, and in 2014 the Kauffman Foundation ranked Colorado number five for entrepreneurship. Such national comparative studies and indices are general indicators that the region has a good mix of conditions required to foster innovation in any industry.

The Front Range enjoys a quality of life that attracts and retains talent:

The most important factor, in any industry, for building innovation capacity is attracting and retaining talent. The region's quality of life makes it possible for the Colorado Front Range to attract and keep world class management and scientific talent from the coasts and from other major metro areas.

The major research institutions in the state are strategically co-located:

Rather than being dispersed widely around the state, the major research universities and federal research labs in Colorado are all situated within an hour's drive from one another. This relatively close co-location facilitates ongoing collaboration and exchange among these research institutions and companies in the region.

The Front Range has one of the highest regional concentrations of publicly-funded agricultural R&D in the nation:

In 2011, Colorado was third in the nation in federal agricultural R&D spending, exceeded only by California and Texas. Most of this funding was directed at the universities and USDA labs on the Front Range.

Close proximity between major production agriculture and a major urban corridor:

This proximity brings the agricultural infrastructure and workforce of northern Colorado into direct contact with an increasingly dense non-agricultural population, a growing high-tech urban and suburban business community, and increasingly sophisticated retail markets.

The sustainability challenges confronting Colorado agriculture are shared in many regions around the world:

The benefits from tackling the cross-cutting challenges endemic to Colorado are not limited to the region. The market for innovations that can solve Colorado's problems is decidedly global.

An inventory of Colorado innovators in the agricultural value chain

Who are the innovators in the agricultural value chain in Colorado? And what are the main technologies or industry sectors in which they are innovating? An inventory was taken of all private sector firms and public sector organizations engaged in innovation, based on (1) those companies and organizations generating the publications and patents identified in the landscape analysis, and (2) referrals from industry associations, networking events, interviews, news accounts, and other expert sources. The inventory includes 550 innovators, of which 460 are private-sector companies and 90 are public-sector (academic, non-profit, and government) organizations.

There appears to be a critical mass of innovating organizations active in Colorado within each of a dozen categories:

1. Innovators in **water** technology, infrastructure, analytics, and management
2. Innovators in **soil fertility** and **pest control**
3. Innovators in **plant genetics** and new crop varieties
4. Innovators in **animal** health, nutrition, and herd management
5. Innovators in **agricultural information systems**
6. Innovators in **sensors**, testing, and analytics for product quality and biosafety
7. Innovators in **bioenergy**
8. Innovators in commodity **processing** and food **manufacturing**
9. Innovators in dairy production and **dairy** product manufacturing
10. Innovators in **beer, wine, & spirits** production and marketing
11. Innovators in **natural, organic, and local** foods and marketing
12. Innovators in “**Fast & Fresh**” food service
13. Innovators in other emergent subsectors

Next steps

Based upon this analysis, several next steps are recommended for cultivating and capitalizing upon this economic growth opportunity.

0. ***As a prerequisite, realize the economic significance and technological sophistication of innovation activities occurring in the agricultural and food value chain.*** The economic significance of introducing game-changing innovations within agriculture, food, water, and bioenergy present real economic opportunity for Colorado.
1. ***First and foremost, develop and attract talent.*** Talent is identified, repeatedly, as the most important factor driving growth of an innovation cluster. The availability of skills is the factor most commonly cited by the executives interviewed for this study. Talent can be attracted to Colorado from other states based on the high

quality of life. To develop talent, it falls primarily to universities to supply the kind of high-quality professionals needed in the sciences, engineering, management, law, and finance to really drive the growth of an innovation cluster. For those in the farming and ranching community, there is opportunity for younger generations coming off the farm to combine their knowledge of agriculture with specialized skills in science, engineering, or business.

2. **Identify and support existing activities, and connect existing companies.** There is already much going on that has arisen in response to market forces and thus has real market potential. Growth of a cluster needs mechanisms to facilitate mixing and the spawning of collaborations. State government and the universities are in an excellent position to invite private sector innovators into networking events and thereby into deeper discussions.
3. **Exercise tolerance of different points of view.** Innovation is, by its very definition, a challenging of the status quo, and it requires a willingness to question how things are done. As a state, Colorado has recently been at the center of national debates, such as labelling of genetically modified organisms or cultivation of industrial hemp. Simply taking sides and defending ones interests is not helpful. Innovation requires listening to other's concerns, respecting others' intellectual and emotional responses to issues, and seeking common ground wherein solutions may lie.
4. **Coordinate vertically, to pilot locally, then sell globally.** Given the complexity of the value chain, vertical coordination is required for piloting many new technologies. The necessary upstream and downstream partners can be found in the Front Range. And, the region's market is large enough to grow within, before seeking to expand nationally and even globally.
5. **Develop financing mechanisms to assure access to risk capital.** There may be new opportunities for agricultural innovation by creating financing mechanisms that bring together the market knowledge of agriculturalists with the risk capital expertise of venture investors.
6. **Take the long view.** The cultivation of an innovation cluster is a long term effort, measured in decades. By some measures, innovation in the agricultural and food value chain has been mounting already in Colorado for at least two decades. Success may require another decade of dedicated effort.