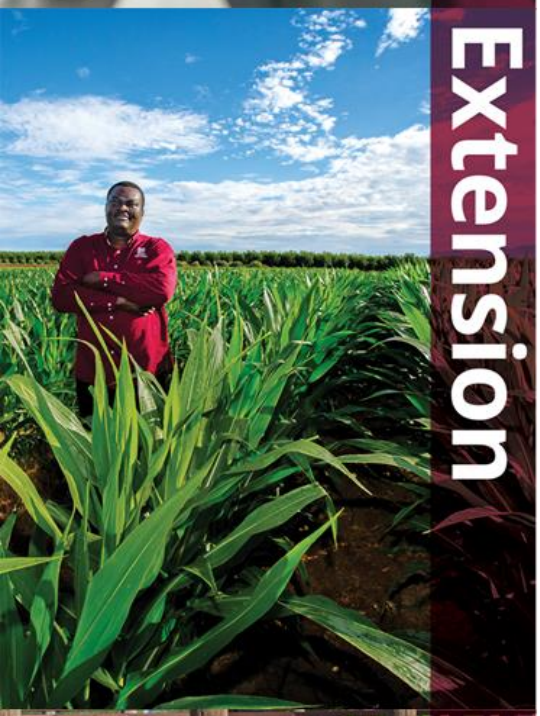

NM STATE UNIVERSITY

The Economic and Functional Impact of:

- **The College of Agricultural, Consumer and Environmental Sciences (ACES)**
- **The Agricultural Experiment Station System**
- **Cooperative Extension Service**

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TECONOMY PARTNERS LLC

Contents

EXECUTIVE SUMMARY

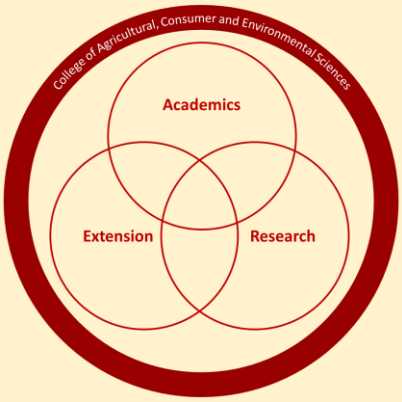
This report provides an in-depth review of the multifaceted economic and social impacts generated in New Mexico by the activities of the New Mexico State University (NMSU) College of Agricultural, Consumer and Environmental Sciences (ACES), its Experiment Station System, Cooperative Extension Service, and Academic Programs. This three-component NMSU ACES system provides higher education (at both the undergraduate and graduate levels), undertakes basic and applied research, and extends research-based knowledge and best-practices to benefit agriculture, value-added industries, communities and families across New Mexico. It is a unique and valuable resource for New Mexico.

The Importance of Knowledge

Today we live in what has been termed the "knowledge economy". It is knowledge, and its twin innovation, that are at the heart of modern economic and societal progress. Knowledge underpins both individual and collective prospects for success in an increasingly complex and competitive global economy. Knowledge of science, technology, engineering, social sciences, business, and other fields of inquiry critical to the economic success of the nation and its individual states, regions and communities, is built through research and imparted to individuals by education.

The NMSU ACES system forms a knowledge production and education system that not only serves the academic community and students enrolled at NMSU, but also one that rather uniquely applies its knowledge to benefit the broader economy, society, communities, families and individuals across New Mexico through the proactive work of Cooperative Extension. Every New Mexican can access NMSU ACES through Extension, gaining insight into diverse topics in farming, ranching, value-added industrial activity, natural resources, community development, economic development, family and consumer science, youth development, and a variety of additional fields of importance. Together, ACES, the Experiment Station System, Extension and academic programs represent a uniquely pragmatic system, designed to meet very real needs across the state for knowledge and actionable information and dedicated to imparting the skills required to put knowledge into action for the betterment of New Mexico's economy and society.

The three-part ACES system, comprising the Experiment Station, Extension and Academic Programs, works in unison to provide a holistic system of formal higher education, research-based knowledge generation, and extension-driven distribution of applied knowledge and know-how to benefit the economy and society of the State of New Mexico and beyond.



The Functional Role of NMSU ACES in New Mexico

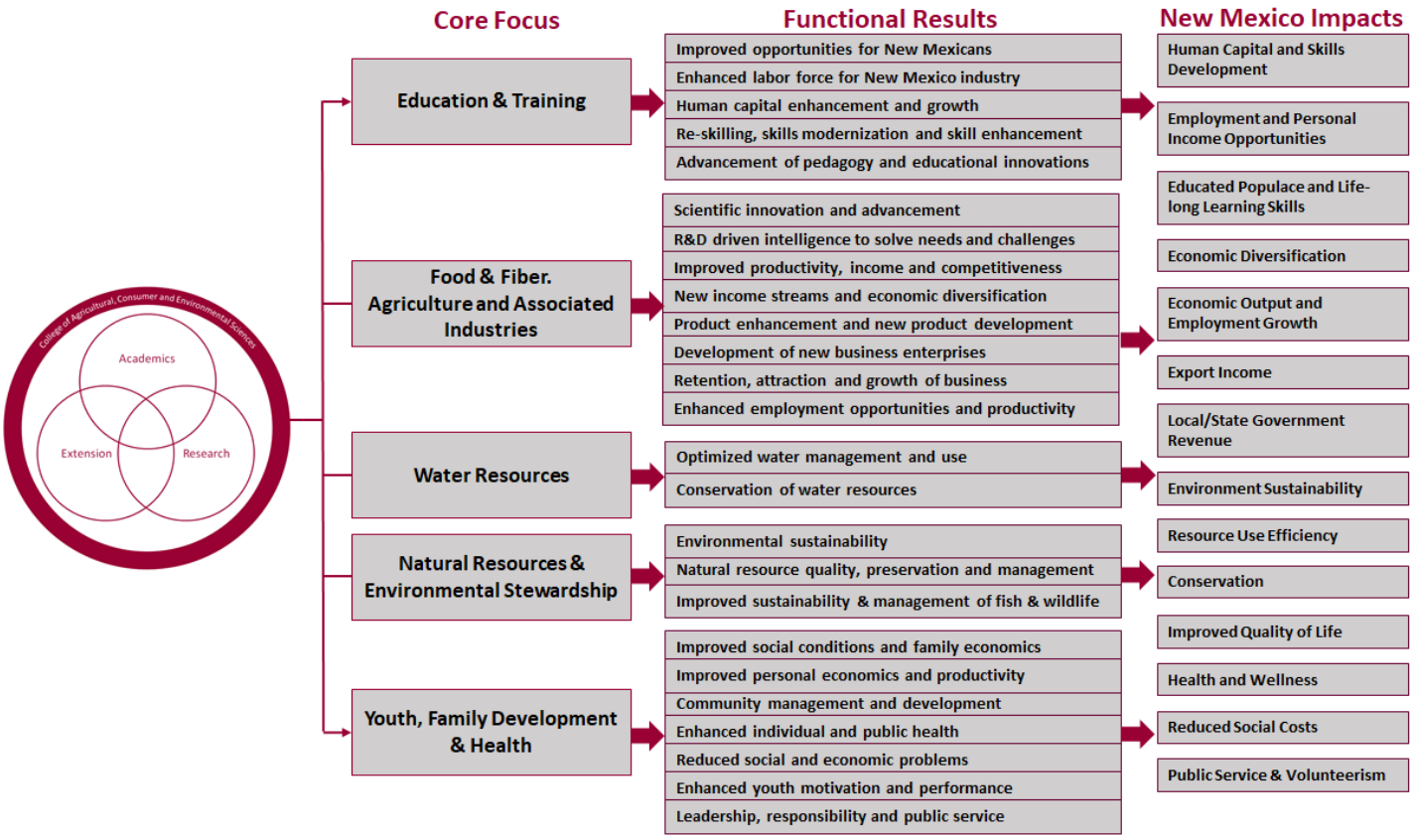
Through the three core elements of ACES, the College can deploy key services, including for example:

- Providing R&D based innovations and practice recommendations that enhance productivity across agricultural and associated industrial value-chains.
- Solving specific problems and challenges identified by producers, industry, and key stakeholders.
- Assuring a safe and secure domestically produced food supply.

- Catalyzing the development of the modern industrial bio-based economy to foster economic diversification, value-added product development, and energy independence.
- Managing New Mexico's crucially important water resources to optimize water use and long-term availability for future generations.
- Fostering ecological and environmental stewardship and natural resource management.
- Building stronger, healthier, economically-resilient rural, suburban, and urban communities.
- Developing the specialized human capital required to sustain economic growth and meet New Mexico's demand for well-educated, skilled and capable life-long learners.

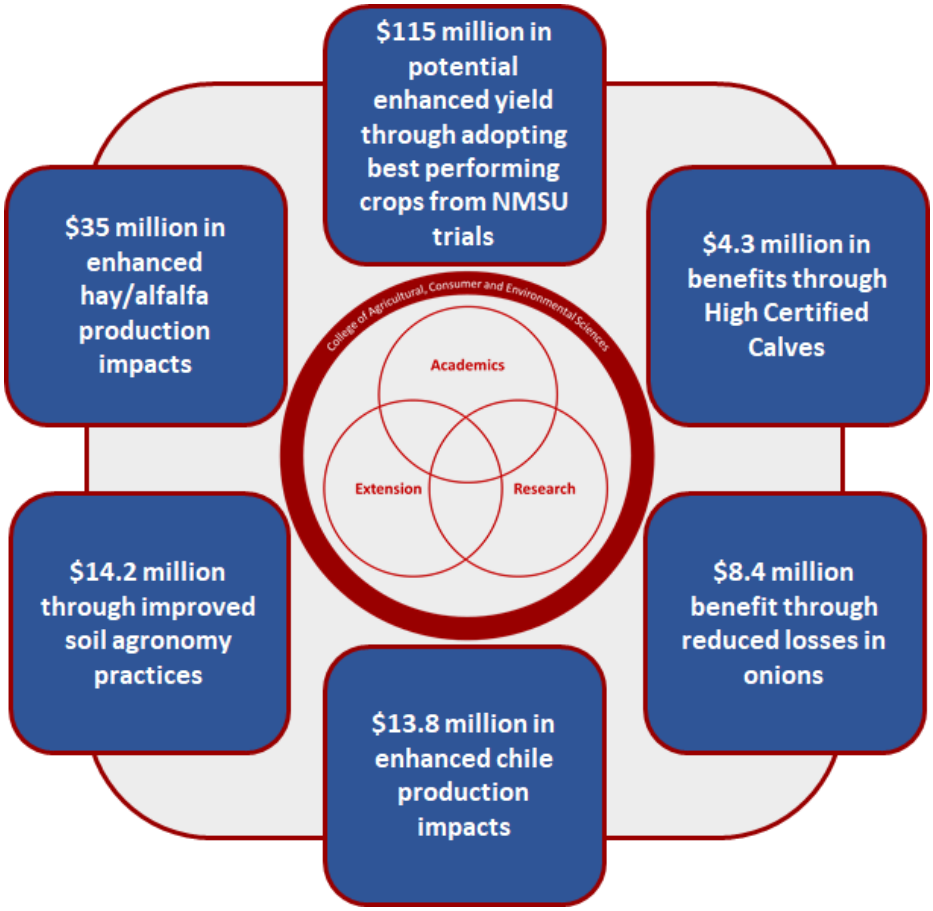
The work of the NMSU ACES system is pragmatically focused on developing positive functional impacts for New Mexico and New Mexicans. Although it is a complex challenge to depict the full range of activities undertaken by the system, Figure ES-1 provides a general overview of key areas of focus, the types of wide-ranging functional results being achieved, and serves to characterize the types of positive impacts being generated in New Mexico by NMSU ACES.

Figure ES-1: The Functional Impact of ACES, the Experiment Station System and Cooperative Extension in New Mexico



Providing a full accounting of each and every program and their multi-faceted impacts is impractically complicated, if not impossible to quantify, given that many of the functional benefits manifest themselves in educational gains, behavior changes, challenges or losses averted, and other benefits that do not lend themselves readily to economic impact assessment. What is possible, and performed within this report, is a description of key programmatic areas and the highlighting of specific impact area examples (with quantitative data where applicable, and narrative description of likely functional benefits where not). What is discovered through this process is that ACES has a significant impact on the state – with some examples illustrated in Figure ES-2 summarizing just some of the impact areas considered and highlighted herein in terms of the agricultural economy.

Figure ES-2: Case Studies in ACES Impact – Examples of Agricultural Impacts in New Mexico



These examples, which together combine to a positive estimated benefit exceeding $190 million for New Mexico annually, are just six of more than 70 program impact descriptions contained in this report.

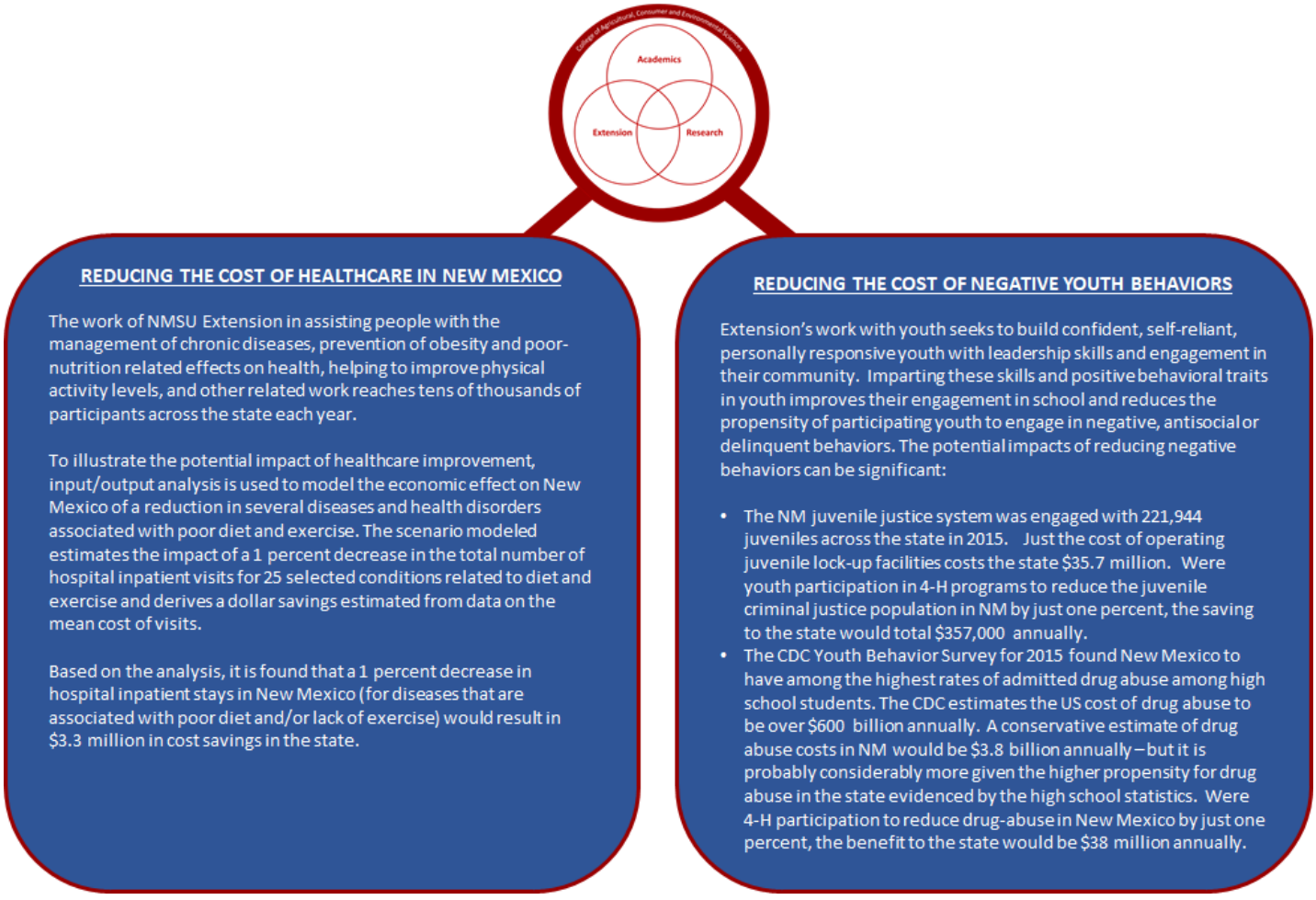
While the agricultural economy, and the rural society it supports, is highly important – NMSU ACES touches a much broader section of the economy and society. NMSU work highlighted herein demonstrates activities focused on:

- Conserving, sustaining and optimizing fresh water resources for New Mexico.
- Understanding, managing and protecting New Mexico's natural resources, ecosystems and wildlife.

- Preventing wildfires and preparing New Mexico for optimal response in the face of natural disasters and emergencies.
- Developing strategies and actions for community development and local economic development.
- Improving the socio-economic status of rural and urban communities.
- Helping to build stronger families.
- Providing education and activity programs to help realize the full potential of New Mexico's youth.
- Improving the health, nutrition and physical activity levels of New Mexicans and promoting public health.
- Helping new businesses develop, grow and succeed.
- Providing critical research-based input to public decision making processes and public policy.

To investigate the type of magnitude of impacts that can occur through diverse ACES activities Figure ES-3 highlights the impact of two areas: reducing anti-social and risk behavior in youth through Extension 4-H and reducing hospitalizations through work to improve the health of New Mexicans. Together, just these two examples save the state a potential $41.7 million annually.

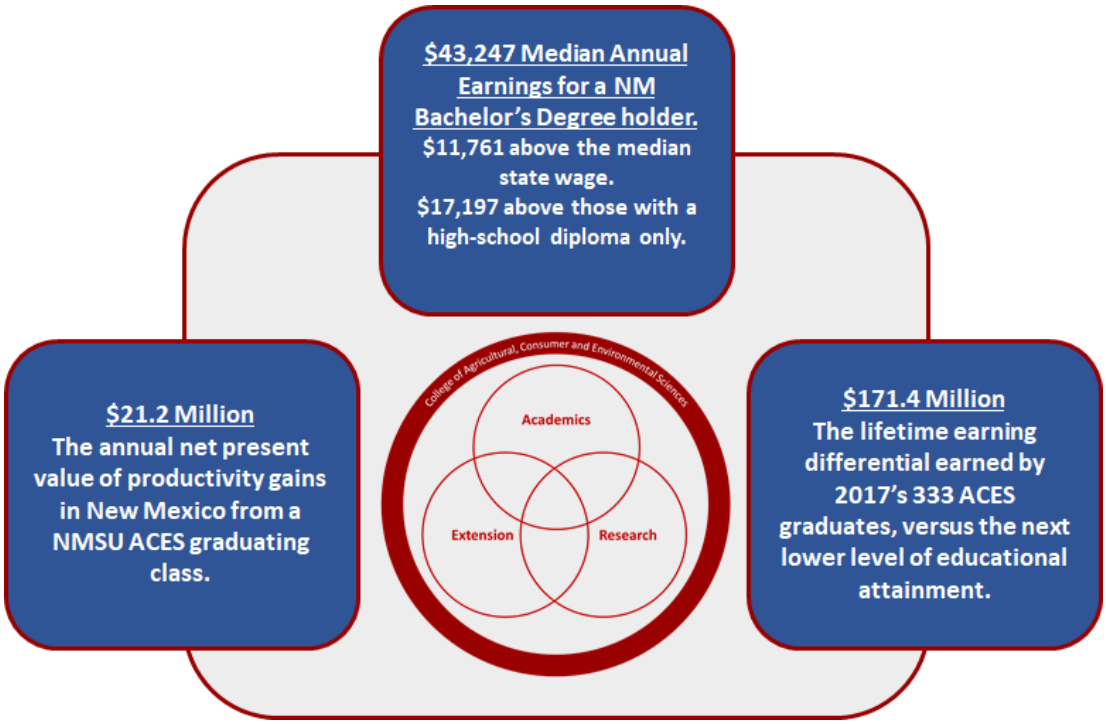
Figure ES-3: Case Studies in ACES Impact – Examples of Healthcare and Youth Programs



It is clear that the diverse work of NMSU ACES in research and the focused work to deploy research-findings into action across New Mexico undertaken by Extension is having large-scale and wide-ranging economic and societal benefits across the state.

NMSU ACES is also, of course, engaged in higher education – producing graduates that provide a broad range of benefits to individuals, to society at large, and to the State of New Mexico. Furthermore, the productivity in the New Mexico economy is boosted by the knowledge and skills that ACES graduates bring to the workplace – with some of these impacts summarized on Figure ES-4

Figure ES-4: Case Studies in ACES Impact –Economic Benefits of ACES Higher Education Credentials



While it is clearly very difficult to put a final dollar value on each and every program and activity undertaken, it is clear that the diverse work of NMSU ACES in research, the focused work to deploy research-findings into action across New Mexico undertaken by Extension, and the educational gains being made through ACES graduates is having large-scale and wide-ranging economic and societal benefits across the state. Given NMSU's long-standing Land-Grant track record in the agriculture and natural resource sectors and the dedicated resources ACES applies to improving and growing the agriculture and agribusiness sectors of the state economy, ACES's work has a powerful annual impact on state output in these sectors. A general perspective can be gained through modeling what the total impact would be for each one-percent boost in the New Mexico agricultural output. Utilizing the IMPLAN input-output analysis, the impact of each one-percent increase in agricultural production was calculated (Table ES-1).

Table ES-1: The Impact of One-Percent Incremental Increases in New Mexico Agricultural Output

Level of Increase in Agricultural Output	Impact on Total NM Economic Output	Number of Jobs Generated in the New Mexico Economy	Labor Income Generated in the NM Economy
1 percent	**$53,356,364**	**531**	**$15,185,419**
2 percent	$106,712,728	1,062	$30,370,838
3 percent	$160,069,092	1,593	$45,556,257
4 percent	$213,425,456	2,124	$60,741,676
5 percent	$266,781,820	2,655	$75,927,095

As shown on Table ES-1, every one-percent increase in New Mexico agricultural output has substantial benefits for the New Mexico economy, generating:

- **A total economic output impact totaling $53.4 million.**
- **Labor income generated for New Mexicans would be almost $15.2 million.**
- **531 jobs would be created in the state.**

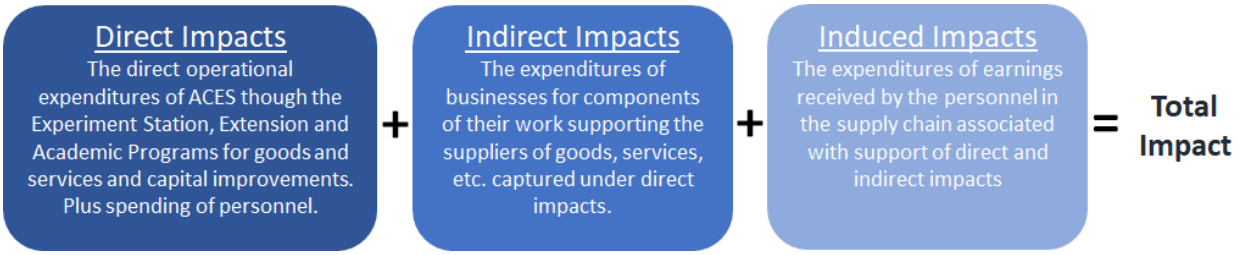
It is clearly challenging to determine what level of increase in state agricultural output may be allocable on an annual basis to the work of NMSU ACES. However, one can look across the many functional impacts to see what sorts of impacts are being generated through just some of the many NMSU ACES programs. Through this analysis, **it is clear that direct benefits from ACES programs for the agricultural sector considerably exceed the one-percent level – and more likely would be in the order of a five-percent or higher magnitude**.

It also should be noted that expanding the agricultural sector presents opportunities to benefit every county in the state. Agriculture and associated processing industries are highly diffused across every New Mexico county; therefore, the direct and indirect effects of expansion in the sector are felt much more widely than with narrower, geographically focused sectors. Other work of ACES is similarly wide in its geographic scope in the state, such as the work of the School of Hotel, Restaurant and Tourism Management within ACES that supports the statewide tourism industry.

The Economic Impact of ACES Expenditures

In addition to the mission-based functional impacts generated by ACES, there are also economic impacts generated in New Mexico via the operational expenditures of the Academic Programs, Agricultural Experiment Station and Cooperative Extension Service. While ACES does not exist simply to create economic stimulus in New Mexico via its expenditures, the impact of this is not insignificant. Over $23 million of the total budget for the ACES system comes from the Federal government, which is then almost all spent within New Mexico, thereby expanding the economy. To measure the impact of ACES expenditures, input/output analysis is used to measure direct, indirect and induced spending as shown on Figure ES-5

Figure ES-5: Components of the Economic Impact of Institutional Expenditures.



Together, ACES Academic Programs, the Experiment Station, and Extension had FY2016/17 expenditures totaling $70.6 million and employed 741.6 full-time equivalent (FTE) personnel. This level of employment and expenditures generated a total expenditure impact (output) in New Mexico of $132.3 million for FY2016/17 and supported 1,204 jobs with a labor income of $65.36 million (Table ES-2). NMSU Cooperative Extension expenditures are responsible for 451 jobs and $49.9 million of the economic output, while the Experiment Station system accounts for 551 jobs and $62.7 million in output.

Table ES-2: Expenditure-based Economic Impact of the ACES Agricultural Experiment Station, Cooperative Extension Service, and Academic Programs, Combined on the State of New Mexico ($ millions)

Impact Category	Employment	Labor Income	Output	State/Local Tax Revenue	Federal Tax Revenue
Direct Effect	741.6	$47.58	$70.60	$0.98	$8.77
Indirect Effect	150.9	$6.25	$21.92	$0.87	$1.50
Induced Effect	312.0	$11.53	$39.78	$2.33	$2.82
Total Impacts	**1,204.5**	**$65.36**	**$132.30**	**$4.18**	**$13.09**
Multiplier	1.62	1.37	1.87	--	--

Again, it should be noted that these impacts are based on the expenditures of the College only. Functional impacts for New Mexico, generated through the actual activities of ACES, the Agricultural Experiment Station, Cooperative Extension, and Academic Programs, are not included in these numbers, and are addressed under the functional impact discussion on previous pages.

Summary and Conclusions

While NMSU, as a Land-Grant University, has its origins in legislation originally written in 1862 (and the Agricultural Experiment Station in 1887, and Extension legislation in 1914), the Land-Grant vision embodied in the College of Agricultural, Consumer and Environmental Sciences (ACES), its Experiment Station System and Cooperative Extension Service is as relevant today as it has ever been. Research, education, and the ability to put knowledge into action to enhance the economy is absolutely key to economic success in a highly competitive global economy. As this study illustrates, the three-component ACES system at NMSU is on the frontlines in these arenas, working to secure New Mexico's current and future economic position, resiliency and success. At the same time, ACES is doing much more—undertaking work to protect New Mexico's water and natural resources, to help families and individuals reach their full potential, and build healthy and productive communities across the state. It is found that the ACES system, while headquartered at NMSU in Las Cruces, is truly a statewide asset – providing benefits to all in the state and great promise for many more benefits into the future. By supporting the College, the Experiment Station System and Extension Service, governments at the

federal, state and county levels are investing in the future sustainability, health and prosperity of New Mexico and New Mexicans, and this investment clearly demonstrates strong returns.

I. INTRODUCTION

A. The Importance of Knowledge

Benjamin Franklin's statement that "an investment in knowledge always pays the best interest" is a truism – as true and relevant today as it was in the late 1700's. Knowledge provides a platform upon which further discovery and innovation can occur, and knowledge empowers rational economic and social actions. Knowledge is the fundamental good upon which human progress and economic activity is built.

Franklin noted that acquisition of knowledge requires an investment. This is true in terms of the investment in time that it takes to learn and build a base of knowledge. It is also true in terms of actual investment of financial resources in funding the research inquiry that builds new knowledge and the formal education activity so important to imparting knowledge to individuals and equipping them for life-long learning.

In the U.S., as well as the rest of the developed world, investment in knowledge has come through public and private investment in institutions of research and education. In the western tradition no place embodies knowledge generation and transfer more comprehensively than universities. This tradition, formalized in Europe over 930 years[1] ago, set the path leading to the first U.S. higher education institutions – Harvard in 1636 and William and Mary in 1693. Today there are over 4,500 higher education institutions (colleges and universities) in the United States, and in the 2016/17 academic year over 20 million undergraduate students alone were enrolled in U.S. studies.[2]

Today we live in what has been termed the "knowledge economy". As the Organization for Economic Co-operation and Development (OECD) notes:

> *The OECD economies are increasingly based on knowledge and information. Knowledge is now recognized as the driver of productivity and economic growth, leading to a new focus on the role of information, technology and learning in economic performance. The term "knowledge-based economy" stems from this fuller recognition of the place of knowledge and technology in modern OECD economies.*[3]

Information, and the knowledge-required to turn information into meaningful intelligence for action, is at the forefront of driving the knowledge economy and economic and societal progress in general. As such, knowledge also underpins individual prospects for success in navigating and thriving in modern society and the world of work. Because of the higher-order knowledge that is increasingly required for success in the global economy (and the competitive advantages that accrue to innovation), the capacity, capabilities and sustainability of research universities has risen to the highest level of strategic importance for individual nations, states and regions.

B. Land Grant Universities: Centers of Knowledge Production and Transfer

The U.S. has a long history in investing in higher education and research. Within the United States an especially important investment was made in higher education capacity through creation of Land-Grant

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[1] The first European university, the University of Bologna, was established in 1088

[2] Statista.com. "College & University - Statistics & Facts." https://www.statista.com/topics/829/college-and-university/

[3] OECD, 1996. "The Knowledge Based Economy". Organization for Economic Co-operation and Development. OECD Publication OCDE/GD(96)102.

universities. The Morrill Act of 1862 provided public lands to the states that financed the creation of colleges to teach agriculture and mechanical arts. The resulting Land-Grant colleges provided a path for ordinary citizens to gain the higher education needed to advance their work, their communities and the economy. Research became embedded in the Land-Grants through passage of the Hatch Act in 1887 supporting research and innovation activity. This legislation funded the system of state Agricultural Experiment Stations, which were predominantly set-up under the Land-Grant colleges, providing assets for both general and location-specific research aimed at improving agricultural productivity and the economic value-chain dependent on it.

In 1914 the success of the Land-Grant colleges was further enhanced through far-sighted legislation forming Extension. The Cooperative Extension system was formed to assure that the expertise and research findings of the Land-Grant colleges and their experiment station systems was translated into action on the farm and in communities. Extension is paired with the word "cooperative" because it operates as a collaboration between the federal government, state governments and county governments in supporting knowledge transfer.

The Land-Grant college system tradition comprises a special cluster of higher education institutions purpose-designed not only to enhance education across the nation, but also to increase the national stock of knowledge through research and put knowledge to use through assuring its transfer from the academy to agricultural producers, industries, workers, community leaders and individuals. While initiated in 1862 the Land-Grant system is as relevant today as it has ever been – perhaps even more so given today's "knowledge economy" and the extreme complexity of industries like modern agriculture that draw upon wide-ranging areas of scientific inquiry and technological innovations. From humble beginnings, the 1862 Land-Grant universities have grown to become some of the World's largest and most prestigious research universities – but always embedded within them is the ethos of a knowledge generation and knowledge put-to-work translational mission.[4]

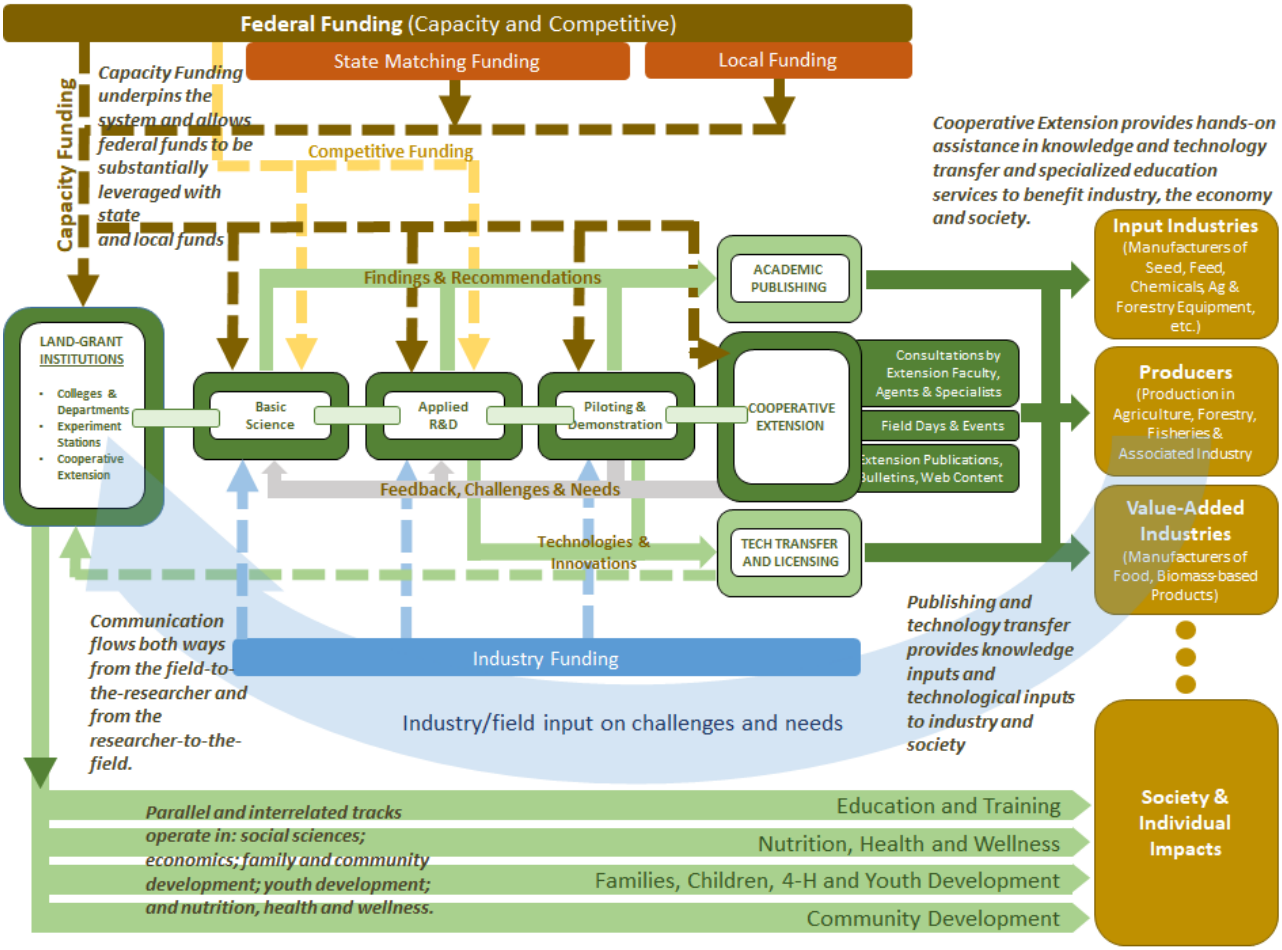
Figure 1: The Signature Structure of Land-Grant Universities.[5]

[4] Further federal legislation in 1890 and 1994 built upon the Land-Grant system to integrate historically Black colleges and universities and Native American colleges respectively.

[5] Adapted from original TEConomy graphic in Cummings D., Tripp S. and Grueber M., 2017. "A Quantitative and Qualitative Review of the Impacts of the University of Missouri Extension."

Figure 1 provides a simple illustration of the three-component mission of the Land-Grant universities. The actual structure and operation of such an important system, however, is rather more complex. Funding from federal, state and local (county) level government is engaged, together with funding from industry and other research funders (such as foundations) who seek to access the specialized expertise and infrastructure at the Land-Grant universities. Federal government funding comes in the form of mandated "capacity" funds provided under a congressionally-set formula to each state's Land-Grant institution(s), together with competitive grant funding. Funds feed into a system that is uniquely enabled, resourced and structured to understand both leading-edge scientific questions and the pragmatic needs and characteristics of agricultural production environments, economic value systems, communities and individuals. The Cooperative Extension component of the system assures that research findings and best practice recommendations are translated into use by those best able to use the knowledge and apply it to improve the economy and society. Figure 2 illustrates the structure of this system, which operates bi-directionally, with needs and challenges flowing in from the field, and discoveries, innovations and solutions to challenges being extended from the university to those stakeholders best positioned to put the new knowledge to work.

Figure 2: The Unique Land-Grant University System.[6]



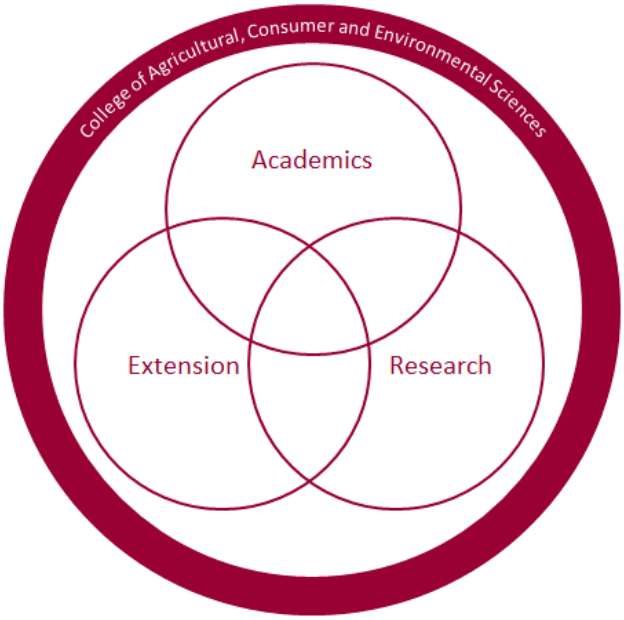
[6] Tripp S., et al. 2017. "National Evaluation of Capacity Programs." TEConomy Partners, LLC. Prepared for the National Institute of Food and Agriculture (NIFA)

C. New Mexico State University and the NMSU College of Agricultural, Consumer and Environmental Sciences (ACES)

New Mexico State University (NMSU) is one of the United States' signature Land-Grant Universities and a major public research university. Established in 1889, when the New Mexico territorial legislature authorized the creation of the College of Agriculture and Mechanic Arts, NMSU has grown to be a world-class provider of higher education (with a current enrollment exceeding 16,000 students) and a significant performer of academic research (with 2016 research expenditures exceeding $110 million). In addition to providing higher education and academic research services, as a Land-Grant university, NMSU is home to the high-profile mission of Cooperative Extension in New Mexico – working to provide the citizens of New Mexico with research-based, practical knowledge and applied educational programming.

NMSU's Land-Grant status and heritage is particularly embodied in the work of the **College of Agricultural, Consumer and Environmental Sciences (ACES)** and its research and extension missions – coordinated and delivered through the **NMSU Agricultural Experiment Station System** and the **NMSU Cooperative Extension Service.** The three-part College system, comprising academic programs, the Experiment Station and Extension systems (Figure 3), works in unison to provide a holistic system of formal higher education, research-based knowledge generation, and extension-driven distribution of applied knowledge and know-how to benefit the economy and society of the State of New Mexico and beyond.

Figure 3: Three Central Components of the College of Agricultural, Consumer and Environmental Sciences at NMSU



The NMSU **Agricultural Experiment Station System** comprises NMSU faculty, research scientists and staff undertaking basic through applied research on the NMSU campus in Las Cruces and at 12 agricultural science and research centers throughout the state. Research is focused across four broad themes, covering: "plants," "animals," "people," and "energy and the environment."

NMSU Cooperative Extension is organized to carry forward the know-how, knowledge and research findings of NMSU to benefit all New Mexicans. With a presence in all 33 counties, Cooperative Extension at NMSU is a large-scale organization with major initiatives and programs spanning the food and agriculture value-chain, the environment, energy and natural resources, economic development, health and family wellbeing, and youth education and development.

ACES addresses a multi-faceted mission through its operations in higher education, research and extension. As illustrated in Figure 2, as the leading Land-Grant mission focused component of NMSU, ACES operates cooperatively with federal, state and local government funders, together with industries in the state, communities and individual stakeholders to advance the agricultural, forest and natural-resource based industries of the state, downstream value-added industries, and the urban and rural community structures that enable economic activity to occur.

Through the three core elements of ACES, the College and the University are able to sustain key functions for New Mexico and New Mexicans, including for example:

- Providing R&D based innovations and practice recommendations that enhance productivity across agricultural and associated industrial value-chains
- Solving specific problems and challenges identified by producers, industry, and key stakeholders
- Assuring a safe and secure domestically produced food supply
- Catalyzing the development of the modern industrial bio-based economy to foster economic diversification, value-added product development, and energy independence
- Managing New Mexico's crucially important water resources to optimize water use and long-term availability for future generations
- Fostering ecological and environmental stewardship and natural resource management
- Building stronger, healthier, economically-resilient rural, suburban, and urban communities
- Developing the specialized human capital required to sustain economic growth and meet New Mexico's demand for well-educated, skilled and capable life-long learners.

The New Mexico Agricultural Economy

John Diemer, Terry Crawford and Michael Patrick, faculty specialists in Economic Development at NMSU Extension report that:

"The combination of agriculture and food processing is an important part of New Mexico's economy. Together the two broad industries accounted for $10.6 billion (roughly 12.3%) of New Mexico's $86.5 billion gross state product (GSP) in 2012. In addition, the two industries directly created 32,578 jobs and 18,308 jobs in related support activities for a total of 50,886 jobs statewide."

(NMSU Extension Circular 675)

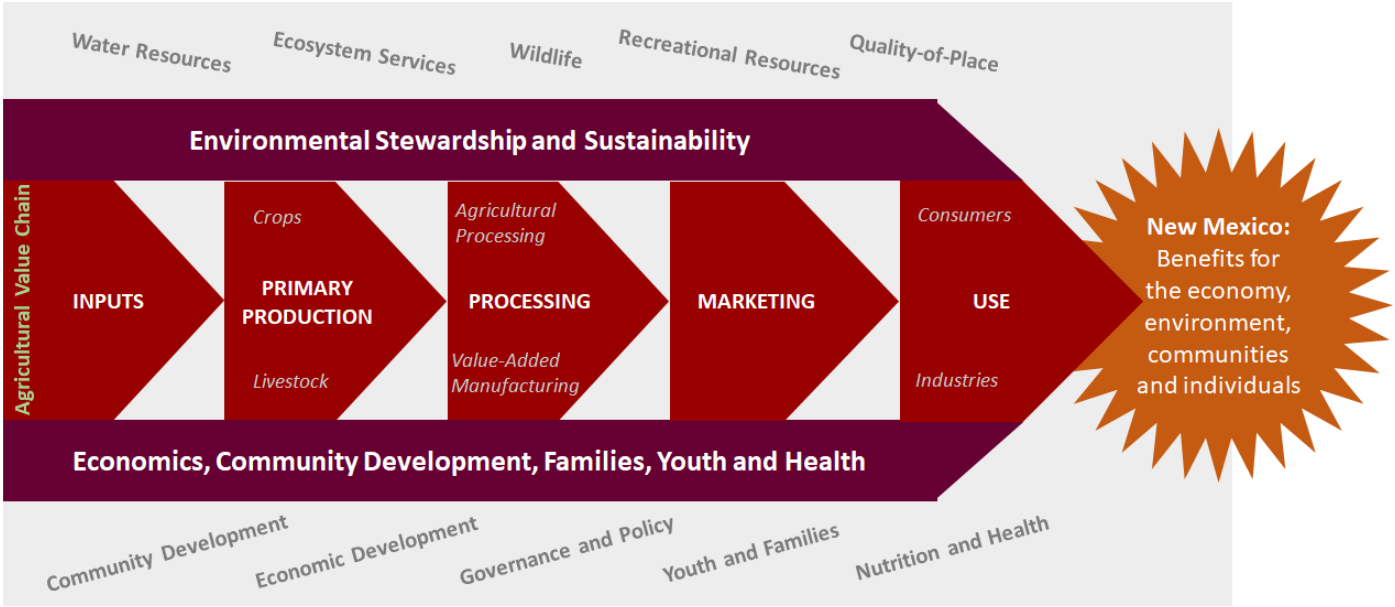
TEConomy notes that this level of economic performance does not occur via chance, especially not in the challenging New Mexico production environment. Rather, it results from the hard work of ranchers, farmers and processors, and is uniquely supported, advised, and enhanced by the publicly supported work of NMSU ACES in conducting agbioscience research, developing new technologies and practice innovations, and working proactively to disseminate knowledge and adopt innovations and best practices into applications across the industry value-chain. NMSU ACES is also providing education that powers human capital development to support the industry across the state.

The NMSU College of Agricultural, Consumer and Environmental Sciences, in combination with the Cooperative Extension Service and Agricultural Experiment Station represents a uniquely powerful

resource for sustaining and securing New Mexico's competitiveness and leadership in multiple arenas of major importance to the economy and society.

New Mexico's robust ranching and farming industry is a core, but not exclusive, component of the focus of ACES. On Figure 4, the dark red central arrows depict the agricultural value-chain activity spanning work across: agricultural inputs (developing seed, livestock varieties, water resources, agro-chemicals, livestock feed and animal health products used on farms and ranches); managing and optimizing the production environment; and, carrying farm and ranch output forward into value-added processing, marketing, distribution and use. Operating alongside and in support of the agricultural value-chain, is work by ACES, the Agricultural Experiment Station and Cooperative Extension Service to assure environmental stewardship, study and manage natural resources such as fish and wildlife, secure the natural recreation assets of New Mexico, and assure New Mexico continues to be balanced in sustaining economic progress and quality-of-place. In parallel the College of ACES also provides robust education, research and extension knowledge transfer activity focused on: enhancing the operations of business; agricultural and natural resource economics, and sustaining the community structures, family units and individual capacity-building needed to maintain a productive and healthy economy and society.

Figure 4: Education, Research and Extension –Working Together to Enhance New Mexico's Agriculture, Economy, Environment, Communities and Individual well-being



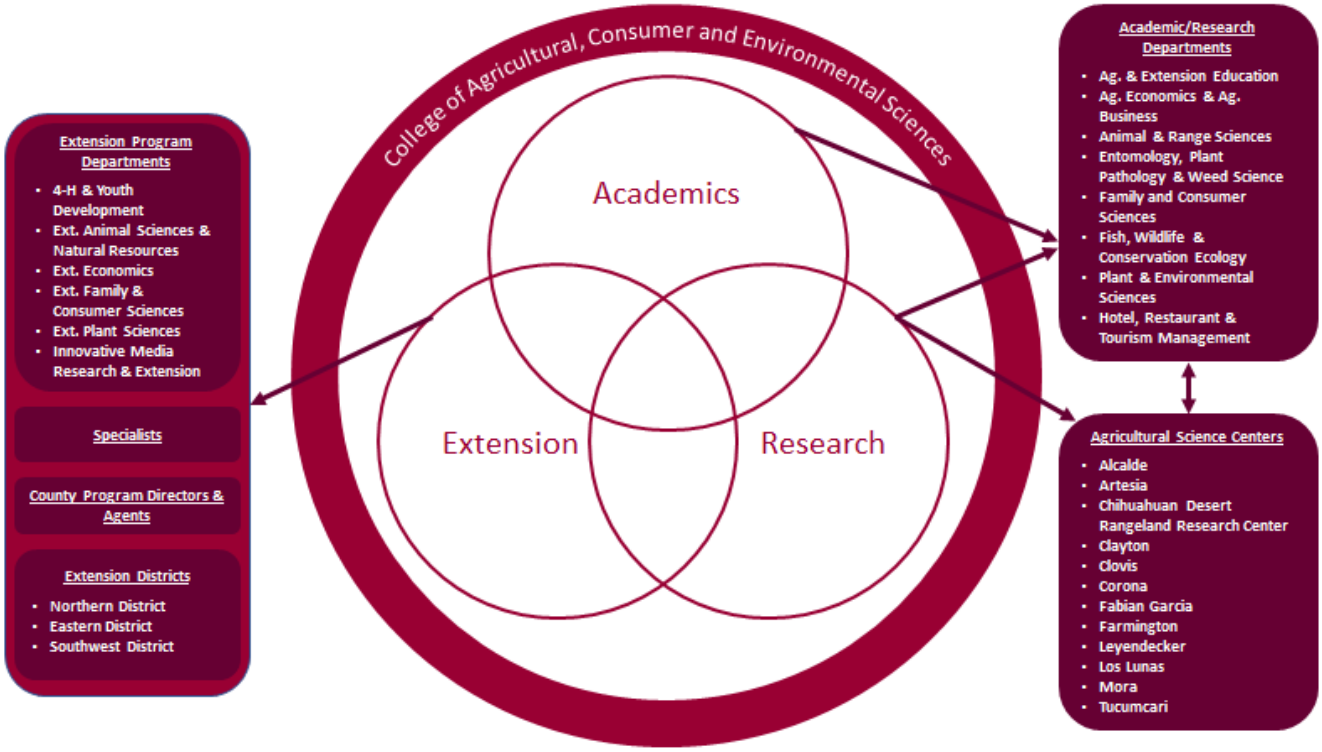
These functional activities of ACES are aptly captured in the College's mission statement:

> *The College of Agricultural, Consumer and Environmental Sciences at New Mexico State University is the Land-Grant college that provides comprehensive programs to New Mexicans in agriculture, family and consumer sciences, wildlife and natural resources conservation and management, community economic development, and hotel, restaurant and tourism. These programs are delivered through statewide, integrated efforts in teaching, research, and extension.*

D. Organizational Structure of ACES

As noted, ACES accomplishes its diverse activities through three primary organizing elements: academic departments, the Agricultural Experiment Station, and the Cooperative Extension Service. These three elements have specific departments, programs and research centers associated with them as shown on Figure 5. Higher education (including baccalaureate, masters and doctoral degrees) is delivered through academic departments under the College. The College contains seven academic departments plus the School of Hotel, Restaurant and Tourism Management.

Figure 5: Three Principal Components Under the College of Agricultural, Consumer and Environmental Sciences



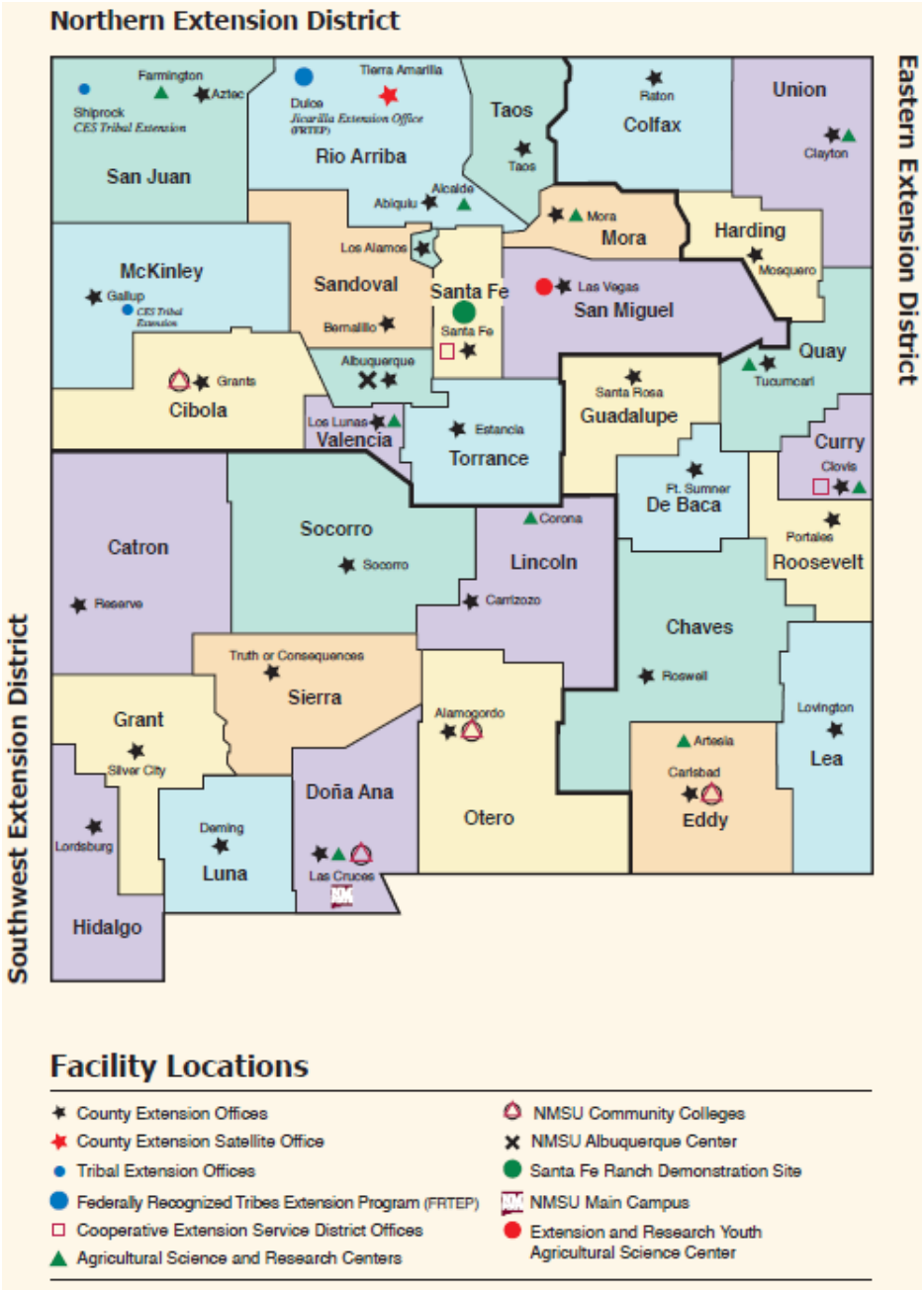
The departments are the academic home to the College's faculty, with most faculty having both teaching and research component to their appointments. Research within ACES is carried out by faculty and personnel at the main campus of NMSU in Las Cruces and also at the 12 NMSU Agricultural Science Centers located throughout New Mexico (Figure 6).

Extension similarly contains departments, with Extension "Program Departments" organized along similar disciplinary lines to the academic departments, with faculty holding majority Extension appointments. Additionally, some academic department faculty hold joint Extension appointments. Faculty in the Extension Program Departments form the core of the team of Extension Specialists – faculty with specific areas of focused expertise specific to subject matter covered by Extension. Extension in addition is divided into three Districts within the state and has offices in each of the 33 counties in New Mexico and tribal areas allowing for local needs and issues to be addressed.

This structure allows ACES to maintain within Las Cruces the key faculty, teaching facilities and infrastructure required for teaching undergraduate and graduate students and for delivering programs

of research focused on faculty and departmental interests. Crucially, it also provides geographic coverage across New Mexico, down to the individual county level, enabling research teams to gain insight and key research questions from local stakeholders. This enables the development of research programs that bring innovations, practice enhancements and other benefits to farmers, ranchers and communities across the diverse geography and climate zones of the state. Supporting this geographic coverage are the 12 locations of the Experiment Station System (green triangles on Figure 6), which allow research programs to take place in specific environments of relevance and for important research and educational interactions to take place with farmers, ranchers, foresters and other professionals working in these regions of the state.

Figure 6: NMSU ACES, Experiment Station (Science Centers) and Cooperative Extension Service System



E. Evaluating the Economic and Functional Impacts of ACES Agricultural Experiment Station, Cooperative Extension Service, and Academic Programs

The complex and multifaceted mission areas of ACES, the Agricultural Experiment Station, Cooperative Extension Service and Academic Programs (which work together across an overlapping suite of service areas) can make it difficult to explain ACES and its critically important role in sustaining and supporting New Mexico's environment, farms, ranches, forests, and urban and rural communities. To evaluate ACES and explain the impacts it is generating for New Mexico and New Mexicans, the College approached experts in economic and functional impact analysis at TEConomy Partners (TEConomy) to commission an independent study and report on College impacts across its key mission areas.

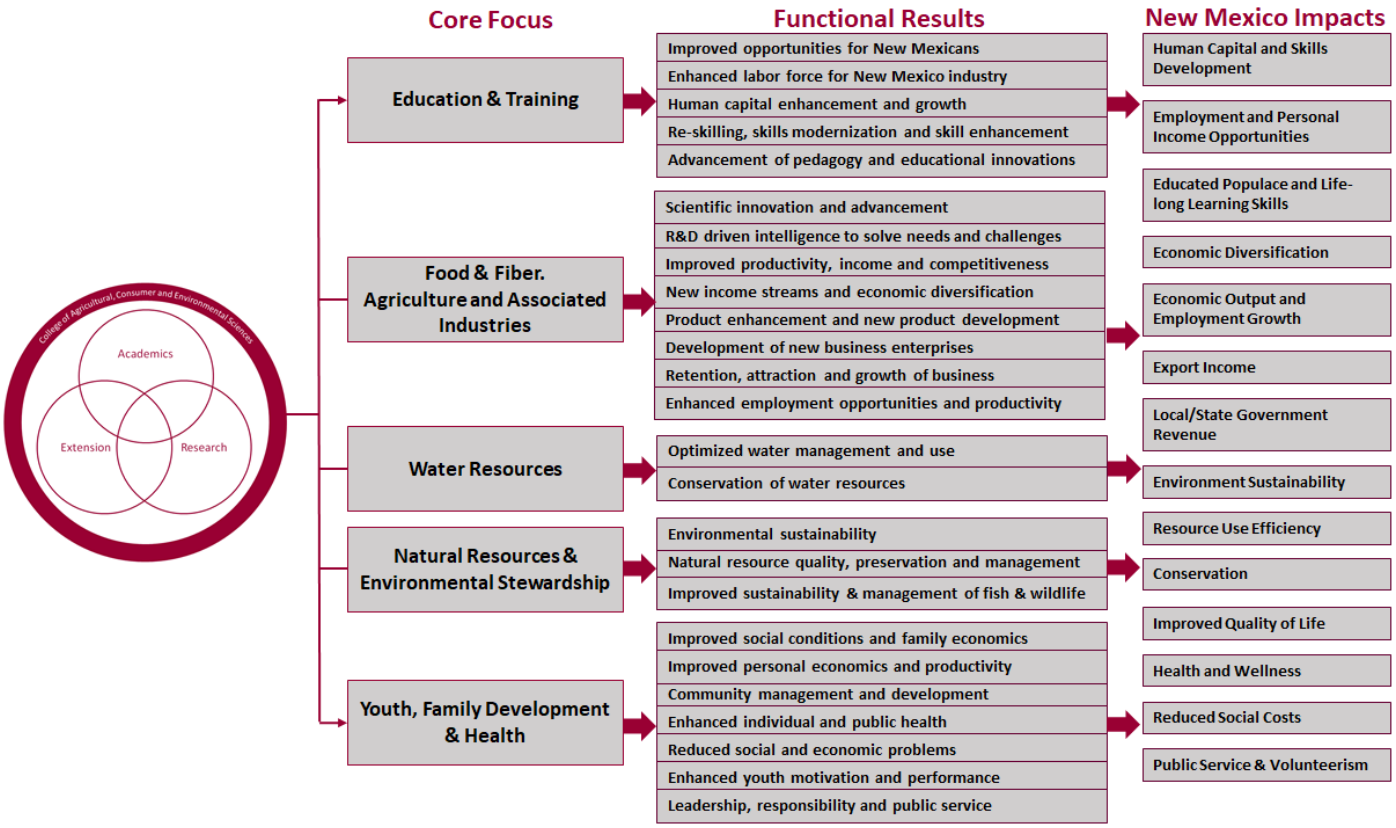
TEConomy has performed national program evaluations for the USDA's National Institute of Food and Agriculture (NIFA), assessments of the role and functions of experiment stations and extension services throughout the North Central and Southern Regions of the U.S., and multiple individual impact assessments and research projects for individual Land-Grant universities across the United States. TEConomy thus has the in-depth knowledge of the structure and function of higher education, research and extension activities required to undertake an in-depth independent assessment for NMSU.

In performing evaluations of the impact of universities and their associated programs, the impacts are typically evaluated along two pathways. Figure 7 outlines these pathways. The primary, and most important pathway, comprises the **functional impacts** (the red boxes on Figure 7). These functional impacts are the reason for the existence and operations of ACES, the Experiment Station, Cooperative Extension and Academic Programs. **They comprise the core programmatic activities focused on producing specific benefits for New Mexico's economy, communities, and families.** Regional economists typically term these functional impacts "forward-linkage impacts."

In addition to the functional impacts, ACES also generates economic activity in the economies of New Mexico and the individual counties and communities where ACES, Science Centers and Extension offices have a physical footprint. Operational expenditures of ACES and the expenditures of ACES faculty, staff and student employees generate these expenditure impacts. The direct and indirect economic impacts of these expenditures on New Mexico's business volume (output), employment, and personal incomes generated by these expenditures are typically termed "backward-linkage impacts." ACES obviously does not exist simply to create economic stimulus through expenditures, but this is not an insignificant area of impact within New Mexico—primarily because a large proportion of the funding for ACES research and extension activities comes from external funding (federal and grant sources) that then are spent in operations across New Mexico.

The expenditure impacts (backward linkage impacts) of ACES are measured herein using the standard regional economic analysis technique of Input-Output (I/O) analysis. Measurement of ACES impacts are made using the IMPLAN I/O model for New Mexico. I/O analysis examines the financial transaction relationships among the subject entity (ACES and its employees) and its final consumers. For the IMPLAN analysis, operational data consisting of employment, wage and benefit figures, and revenue and expense figures were provided by ACES covering operations of the College together with Extension and the Experiment Station systems. The resulting analysis quantifies the direct, indirect, and induced impacts of College-associated expenditures on employment, labor income, output, and tax revenue within New Mexico.

Figure 7: The Functional (Forward Linkage) and Expenditure (Backward Linkage) Impacts of the College of Agricultural, Consumer and Environmental Sciences (ACES) on the State of New Mexico.



The functional impacts generated by the actual research, education and extension activities of ACES represent the unique impacts generated by specific work undertaken by faculty and staff across the College's Academic Programs, Cooperative Extension Service, and Agricultural Experiment Station systems. It is the functional impacts that are most important to document (although both functional and expenditure impacts are documented herein).

With 741.6 FTE faculty and staff, and hundreds of research and Extension projects occurring at any given time, it is not feasible to quantify the impacts generated by each and every program activity. The diversity of activity undertaken also means that impacts are generated in multiple ways and are complex to measure. For example, work to improve forage for cattle may result in direct yield gains for ranchers, while activity aimed at preventing the spread of cattle diseases works to stop losses from occurring. One impact is a tangible monetary gain, while the other is a hypothetical loss-avoided. Also generating measurement challenges are the many sociological, behavioral and human performance changes sought through research, education and training performed by the College and the educational programing provided to various populations via Extension. Measuring behavioral change, or the impact of knowledge increases across thousands of impacted individuals and hundreds of educational programs, is impractical. TEConomy's approach to functional impacts instead relies on narrative pertaining to the characteristics of impacts generated, documented with data when available and illustrated by case studies and illustrative examples. It should be noted that the case studies and associated functional impacts highlighted represent just some of the examples of the functional impacts of ACES, the

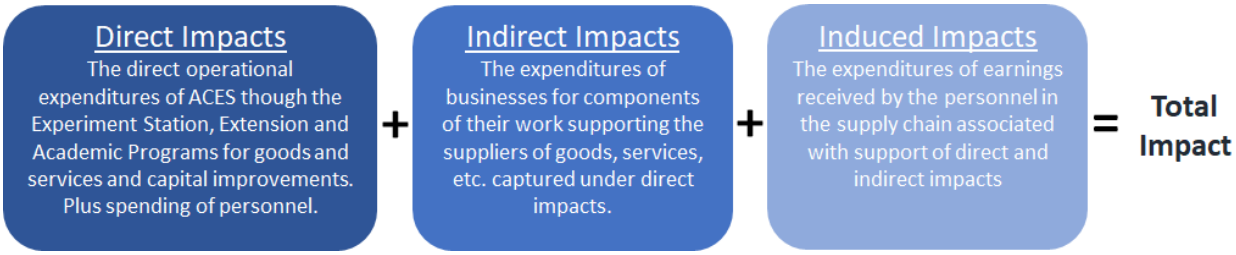
Experiment Station System and Extension and, therefore, not a holistic accounting of all activity. Because if this, the functional impacts reported likely significantly undercount the full functional impact of the higher education, research and extension activity performed by New Mexico State University. The goal with the functional impact analysis is to provide the reader and key stakeholders with a sound understanding of broad range of activities undertaken and the breadth and depth of economic, social and individual impacts being generated across New Mexico.

II. EXPENDITURE BASED ECONOMIC IMPACTS OF ACES

As noted in Chapter I, the main impacts of ACES, the Experiment Station System and Cooperative Extension result from the functional activities undertaken by the organization and its faculty and staff. Each day, NMSU researchers, educators and extension professionals are working with students, communities, farmers, ranchers and other key stakeholders to enhance knowledge, improve productivity and economic progress, and improve the quality-of-life of New Mexicans. These are functional impacts and they are addressed in Chapters III, IV and V.

From a traditional economic perspective, however, ACES, the Agricultural Experiment Station and Cooperative Extension Service have an "economic impact" on New Mexico through their direct operational expenditures and the expenditures of faculty, other staff, and service providers. These are components of backward-linkage economic impact noted in the discussion of Figure 7 in the previous chapter. The measurement of expenditure-based impacts comprises three main components as shown on Figure 8:

Figure 8: Components of Expenditure-Based (Backward Linkage) Economic Impacts of ACES, the Agricultural Experiment Station and Cooperative Extension Service



A. Expenditure Impact Modeling

Estimation of the economic impacts shown in Figure 8 makes use of an input-output model which models the interrelationships and transactions between economic sectors. Input-output multipliers are based on the flow of commodities between industries, consumers and institutions in the state economy. The findings reported in this chapter are derived from using the New Mexico-specific input-output model developed by IMPLAN. The IMPLAN model is the most widely used model in the nation and is based on the U.S. Bureau of Economic Analysis (BEA) national accounts data, supplemented with state level employment data from the U.S. Bureau of Labor Statistics (BLS) and other economic data from the U.S. Bureau of the Census. The analysis calculates three categories of impacts as shown on Figure 8:

- **Direct Impacts** – the specific impact of the direct expenditures of the institution
- **Indirect Impacts** – the impact of suppliers to the institution
- **Induced Impacts** – the additional economic impact of the spending of employees and supplier employees
- **Total Impact** = the sum of the three above impact categories.

In effect, the input-output analysis models the "ripple effect" (also known as the multiplier effect) that originates from NMSU ACES, the Agricultural Experiment Station and Cooperative Extension Service operations and associated expenditures in the economy of New Mexico.

The IMPLAN input/output model is used to derive estimates for four types of impacts:

- **Output** (also known as production, sales, or business volume) is the total value of the goods and services produced in the economy. For public/non-profit organizations "expenditures" are the most appropriate measure of this economic activity to use.
- **Employment** is the total number of jobs created and includes the direct employment at ACES across the Agricultural Experiment Station, Cooperative Extension Service, and Academic Programs and the indirect and induced employment impacts.
- **Labor Income** is the total amount of income, including salaries, wages and benefits, received by university employees and others in the supply-chain.
- **Government Revenues** includes estimates of revenues generated for federal and state/local governments through the economic activity measured.

In performing the impact assessment TEConomy produced separate models for operations of the Agricultural Experiment Station, Cooperative Extension Service and Academic Programs of the College. The impacts for these three entities are also modelled in aggregate to derive a total impact of the combined three organizations.

B. Combined Expenditure Impacts of ACES Agricultural Experiment Station, Cooperative Extension Service, and Academic Programs.

The expenditures of the three-part system of the ACES College (Agricultural Experiment Station, Cooperative Extension Service, Academic Programs) are, as anticipated, substantial. Table 1 shows expenditures by primary category and revenues from principal source for FY 2016/17:

Table 1: Expenditures and Revenues for the ACES Agricultural Experiment Station, Cooperative Extension Service and Academic Programs Combined

Expenditure Categories	Expenditures ($ millions)
Compensation (741.6 FTE personnel)	$47.58
Operational Expenditures	$23.02
Total Expenditures	**$70.60**

Revenue Categories	Revenue ($ millions)
Public: State and County-Based Revenue	$32.34
Public: Federal-Based Revenue	$23.15
Private: Grants, Sales and Services	$4.92
Total Revenue (Restricted and Unrestricted)	**$60.41**
Academic Revenue	$8.89
Total Combined Revenue	**$69.29**

The direct, indirect and induced economic impact of the total expenditures and employment highlighted on Table 1 combine to create the impacts shown on Table 2. The three-part system (Agricultural Experiment Station, Cooperative Extension Service, and Academic Programs) generated an FY2016/17 combined expenditure-based economic impact for New Mexico (as measured by output) totaling $132.3 million. In total, the expenditures of the combined entities generated over 1,204 jobs in New Mexico paying a combined $65.36 million in labor income (an average labor income of $54,263 per job).

Table 2: Expenditure-based Economic Impact of the ACES College, (Agricultural Experiment Station, Cooperative Extension Service, and Academic Programs) Combined on the State of New Mexico ($ millions)

Impact Category	Employment	Labor Income	Output	State/Local Tax Revenue	Federal Tax Revenue
Direct Effect	741.6	$47.58	$70.60	$0.98	$8.77
Indirect Effect	150.9	$6.25	$21.92	$0.87	$1.50
Induced Effect	312.0	$11.53	$39.78	$2.33	$2.82
Total Impacts	**1,204.5**	**$65.36**	**$132.30**	**$4.18**	**$13.09**
Multiplier	1.62	1.37	1.87	--	--

Again, it must be noted that these impacts are based on the expenditures of the ACES system only. Functional impacts for New Mexico, generated through the actual activities of ACES Agricultural Experiment Station System, Cooperative Extension Service and Academic Programs, are not included in these numbers, and are addressed in subsequent chapters.

The expenditure impacts generated by Cooperative Extension Service, the Agricultural Experiment Station and Academic Programs in the college of ACES are detailed respectively in sections C, D and E below.

C. The Expenditure Impacts of Cooperative Extension

Table 3 details FY2016/17 expenditures by primary category and revenues for the NMSU Cooperative Extension Service.

Table 3: Expenditures and Revenues for NMSU Cooperative Extension

Expenditure Categories	Expenditures ($ millions)
Compensation (287.8 FTE personnel)	$18.76
Operational Expenditures	$9.86
Total Expenditures	**$28.61**

Revenue Categories	Revenue ($ millions)
Public: State and County-Based Revenue	$15.76
Public: Federal-Based Revenue	$10.03
Private: Grants, Sales and Services	$1.58
Total Revenue (Restricted and Unrestricted)	**$27.37**

The expenditures and employment highlighted on Table 3 combine to create the expenditure-based economic impacts for Extension shown on Table 4. NMSU Cooperative Extension generated, in FY2016/17, a combined expenditure-based economic impact for New Mexico (as measured by output) totaling over $49.9 million and generated over 450 jobs in the state with labor income totaling $24.9 million.

Table 4: Expenditure-based Economic Impact of NMSU Cooperative Extension on the State of New Mexico ($ millions)

Impact Category	Employment	Labor Income	Output	State/Local Tax Revenue	Federal Tax Revenue
Direct Effect	287.8	$18.76	$28.61	$0.39	$3.46
Indirect Effect	44.2	$1.73	$6.18	$0.33	$0.42
Induced Effect	118.7	$4.39	$15.14	$0.89	$1.07
Total Impacts	**450.8**	**$24.88**	**$49.94**	**$1.60**	**$4.95**
Multiplier	1.57	1.33	1.75	--	

D. The Expenditure Impacts of the Experiment Station System

Table 5 details FY2016/17 expenditures by primary category and revenues for the NMSU Experiment Station System.

Table 5: Expenditures and Revenues for the NMSU Experiment Station System

Expenditure Categories	Expenditures ($ millions)
Compensation (328.9 FTE personnel)	$20.26
Operational Expenditures	$12.84
Total Expenditures	**$33.10**

Revenue Categories	Revenue ($ millions)
Public: State and County-Based Revenue	$16.57
Public: Federal-Based Revenue	$13.13
Private: Grants, Sales and Services	$3.34
Total Revenue (Restricted and Unrestricted)	**$33.04**

The expenditures and employment highlighted on Table 5 combine to create the expenditure-based economic impacts for the NMSU Experiment Station System shown on Table 6. The Experiment Station System generated, in FY2016/17, a combined expenditure-based economic impact for New Mexico (as measured by output) totaling $62.7 million and generated 551 jobs in the state with labor income totaling $29.1 million.

Table 6: Expenditure-based Economic Impact of the NMSU Experiment Station System on the State of New Mexico ($ millions)

Impact Category	Employment	Labor Income	Output	State/Local Tax Revenue	Federal Tax Revenue
Direct Effect	328.9	$20.26	$33.10	$0.42	$3.73
Indirect Effect	83.6	$3.71	$11.85	$0.39	$0.86
Induced Effect	138.9	$5.13	$17.71	$1.04	$1.26
Total Impacts	**551.4**	**$29.10**	**$62.67**	**$1.84**	**$5.85**
Multiplier	1.68	1.44	1.89	--	--

E. The Expenditure Impacts of Academic Programs

Table 7 details FY2016/17 expenditures by primary category and revenues for the College's academic education operations.

Table 7: Expenditures and Revenues for Academic Programs

Expenditure Categories	Expenditures ($ millions)
Compensation (124.9 FTE personnel)	$8.56
Operational Expenditures	$0.33
Total Expenditures	**$8.89**

Revenue Categories	Revenue ($ millions)
Total Revenue	**$8.89**

The expenditures and employment highlighted on Table 7 combine to create the expenditure-based economic impacts for the College's educational operations shown on Table 8.

Table 8: Expenditure-based Economic Impact of Academic Programs on the State of New Mexico ($ millions)

Impact Category	Employment	Labor Income	Output	State/Local Tax Revenue	Federal Tax Revenue
Direct Effect	124.9	$8.56	$8.89	$0.18	$1.58
Indirect Effect	23.1	$0.81	$3.88	$0.15	$0.23
Induced Effect	54.3	$2.01	$6.93	$0.40	$0.49
Total Impacts	**202.3**	**$11.38**	**$19.70**	**$0.73**	**$2.30**
Multiplier	1.62	1.33	2.22	--	--

F. Summary

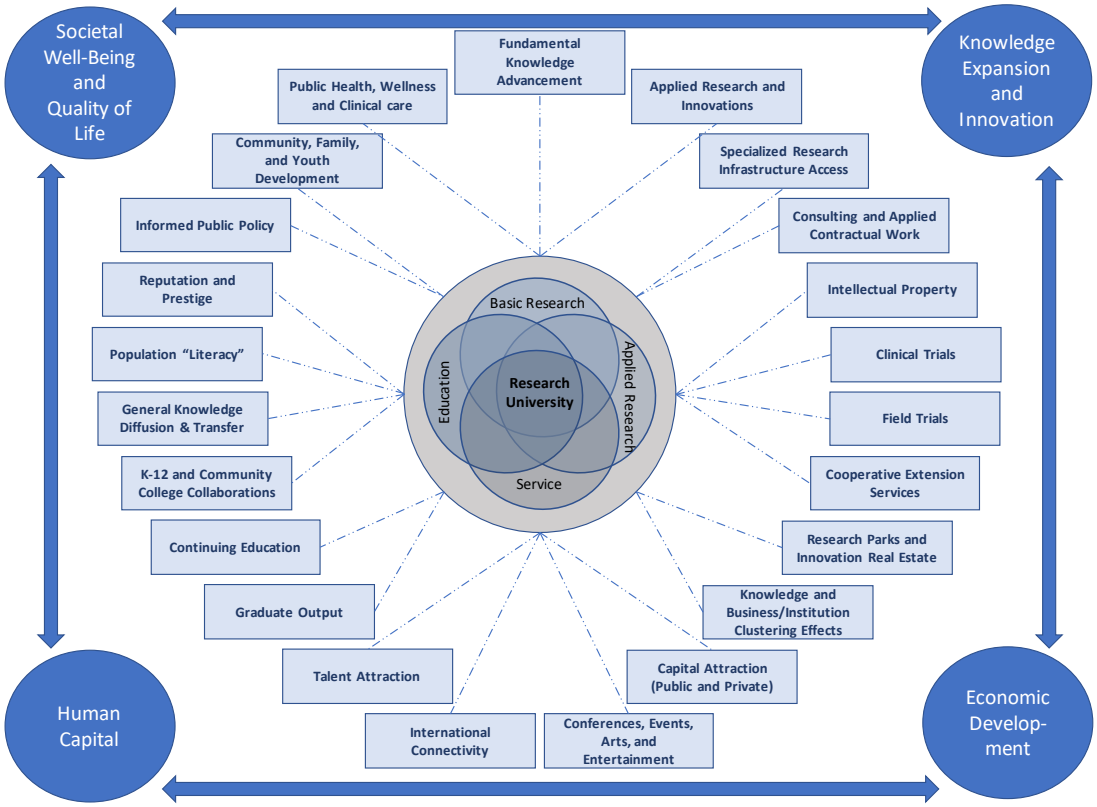
The expenditure impacts illustrated in this Chapter are significant for New Mexico, accounting for over 1,200 jobs that pay good family-sustaining wage levels and generating $132 million in economic output impact in the State. This expenditure impact of ACES Agricultural Experiment Station, Cooperative Extension Service and Academic Programs is especially notable in that a substantial portion of the funds generating this impact come to New Mexico from outside of the state in the form of capacity and competitive grant funding provided to NMSU by the federal government (primarily through USDA NIFA).

III. INTRODUCTION TO FUNCTIONAL IMPACTS.

Chapter II highlighted the significant economic impacts that occur in New Mexico via the operational expenditures and personnel expenditures of ACES Cooperative Extension Service, the Agricultural Experiment Station and Academic Programs. These expenditure impacts are certainly of significant benefit to New Mexico and the locations where ACES has operations across the state. However, as noted previously, ACES Agricultural Experiment Station System, Cooperative Extension Service and Academic Programs do not exist to generate expenditure impacts (that is a side benefit of their presence in New Mexico), rather **they exist to generate wide-ranging mission-specific impacts through the provision of higher education, research and extension programing**. These mission-based impacts are termed functional impacts and are the true signature benefits generated.

A recent project by TEConomy provided a comprehensive overview of the multi-faceted beneficial impacts generated by research universities (the macro category of universities in which NMSU resides overall).[7] As shown on Figure 9, the "*Importance of Research Universities*" project found that research universities, such as NMSU, generate functional impacts in four principal domains: 1) knowledge expansion and innovation; 2) economic development; 3) human capital development, and 4) social well-being and quality-of-life (at both a national and local level). These domains incorporate 23 individual areas of functional impact driven by the education, research and service missions of research universities.

Figure 9: Functional Impacts of Research Universities

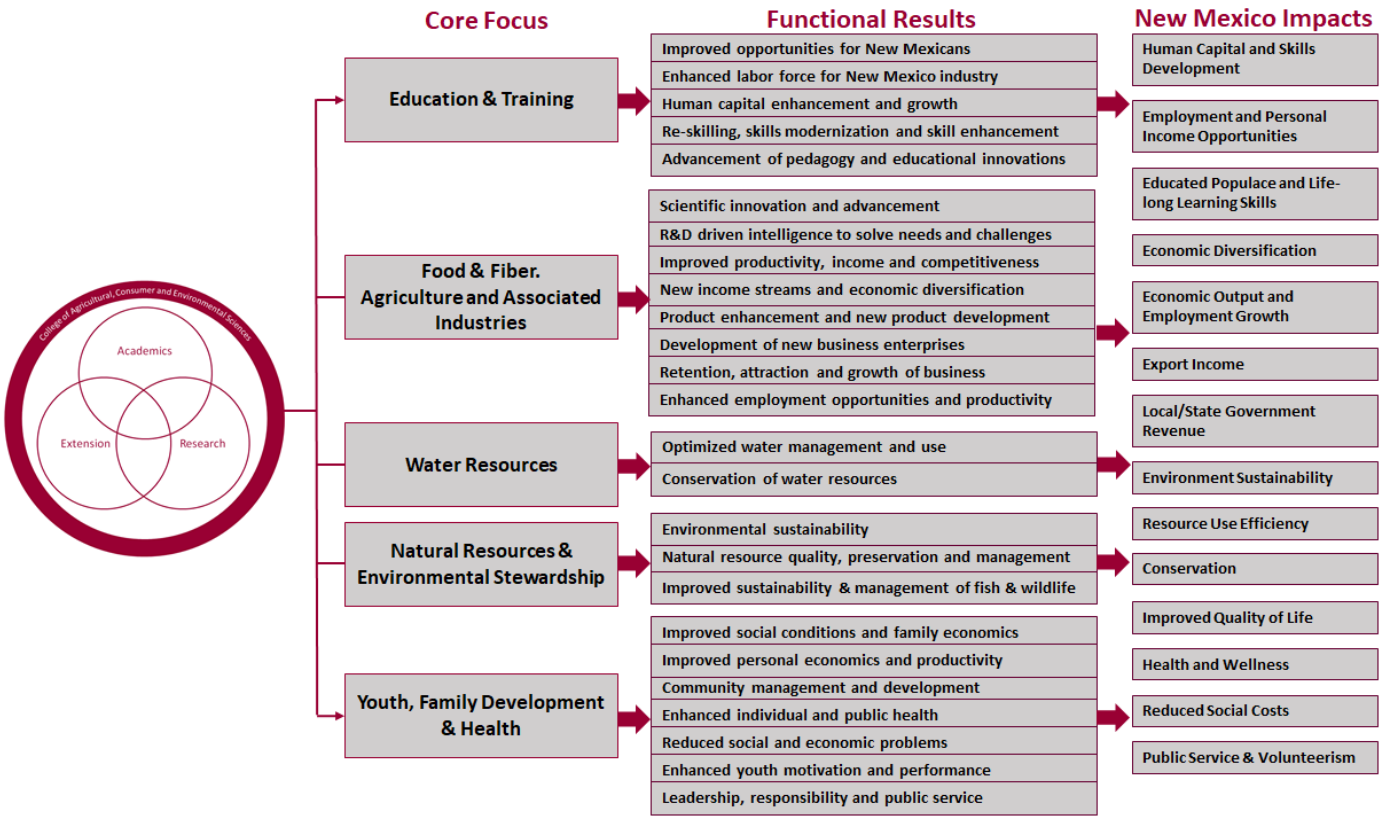


[7] Tripp, S., Helwig, R. and Yetter, D. 2017. "*The Importance of Research Universities*". TEConomy Partners, LLC. for BioCrossroads Indiana and the Central Indiana Corporate Partnership. Funding by the Lilly Endowment.

New Mexico State University is fully engaged across this broad spectrum of research university impacts. The key difference with NMSU versus research universities in general is that NMSU is one of a special subset of research universities, the Land-Grant universities that carry forward applied and translational research and education programing through the Cooperative Extension Service at a high-level of intensity for their home states. As noted in Chapter I, as home to the Experiment Station System, NMSU operates a research enterprise not only present on campus in Las Cruces, but also deliberately dispersed to provide dedicated research locations in varying New Mexico environments. Also, as home to Cooperative Extension, the University has a presence in every county in the state and is able to be highly proactive in carrying its knowledge, solutions to challenges, new discoveries, practice innovations and other advancements out into the field and into the hands of those who can put the knowledge to work. **Taken together, the missions of education, research and extension, embodied within ACES at NMSU, provide a powerful knowledge-based economic and social development engine for New Mexico.**

Figure 10 illustrates the robust suite of focus areas and associated functional impacts that result from the work of ACES Cooperative Extension Service, Agricultural Experiment Station, and Academic Programs system. The analysis of functional impacts performed for ACES by TEConomy uses this graphic as an organizing element for analysis and the discussion of case studies. In Chapters IV, V and VI these functional impacts are examined for the research, extension and higher education missions at the College respectively.

Figure 10: The Functional Impacts of the College of Agricultural, Consumer and Environmental Sciences (ACES), the Experiment Station System and NMSU Cooperative Extension Service.



IV. THE ECONOMIC AND FUNCTIONAL IMPACTS OF RESEARCH AND THE NMSU EXPERIMENT STATION SYSTEM

As a Land-Grant university, research is thoroughly embedded across the NMSU ACES enterprise. Research stands alone as a specific functional activity, but it is also very much integrated with higher education (with engagement of students, especially graduate students, in research projects and programs) and in Extension which feeds research questions into the research system, transfers useful research findings to application in the field, and actively participates in the research itself through Extension specialist faculty and other engaged personnel. **In effect, research is a functional mission area of ACES that is interwoven across the entire College structure.**

Why Research Matters

The National Governors' Association, in its guidance to governors on State Leadership in the Global Economy, explains: *World class research is a passport to success in the global economy. Industry can no longer compete by selling standard products made with standard processes and that could be produced anywhere in the world at lower cost. Businesses must constantly innovate to raise the quality of production, introduce new product lines or services, and add greater value to their outputs. For this reason, states must create an environment that supports continuous innovation. This requires investment in cutting-edge research, facilities and equipment.*[8]

Indeed, the evidence on the importance of research universities to advancing technology-based economic development is overwhelming:

- The Milken Institute notes that research centers and institutes are "indisputably the most important factors in incubating high-tech industries." In a widely cited study, they found that 65% of the difference in economic success for regions from 1975 to 1998 is accounted for by the presence and growth of high-technology industries.[9]
- According to a study prepared for the U.S. Small Business Administration, "Research universities and investment in research universities are major factors contributing to economic growth in the labor market areas in which the universities are situated."[10]
- Studies by the Office of Technology Policy and others have found that all areas of technology-based economic development in the United States have strong concentrations of both university and private research.[11]
- A long term longitudinal study of the relationship between the stocks of knowledge from academic publications and industrial productivity found a significant and large impact.[12]
- An industry survey by Carnegie Mellon University found that university and government laboratory research importantly affect industrial R&D across much of the manufacturing sector, equally through suggesting new projects and contributing to the completion of existing projects and that the influence of research on industrial R&D is disproportionately greater for larger firms as well as start-ups.[13]

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[8] National Governor's Association, "A Governor's Guide to Trade and Global Competitiveness," 2002, page 5.

[9] Milken Institute, *America's High-Tech Economy,* 1999.

[10] Bruce Kirchhoff, "The Influence of R&D Expenditures on New Firm Formation and Economic Growth," Maplewood, N.J.: BJK Associates, 2002.

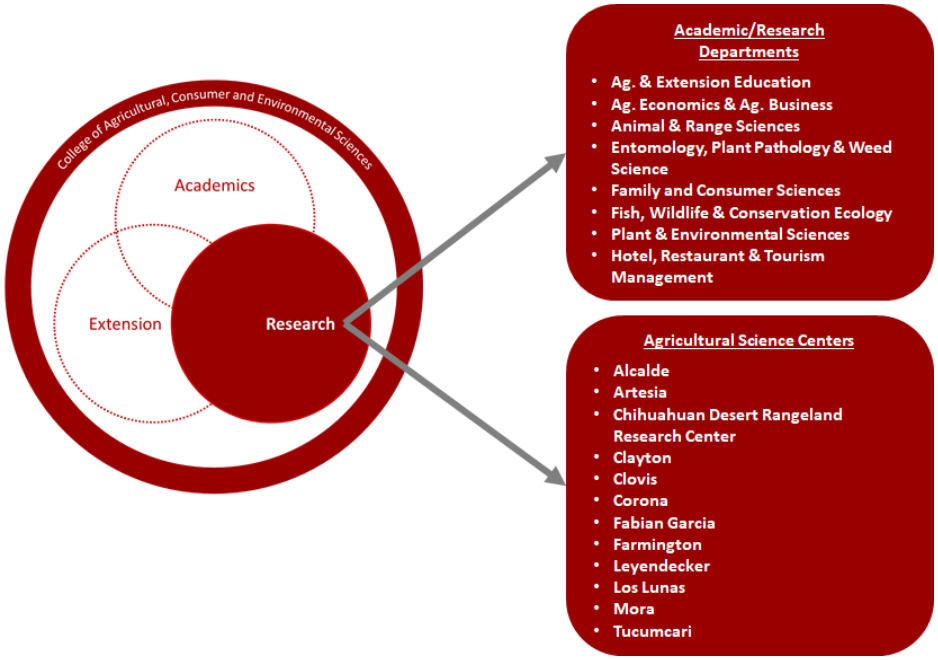
[11] U.S. Department of Commerce, Office of Technology Policy, *The Dynamics of Technology-based Economic Development: State Science and Technology Indicators*, Washington, D.C., 2000.

[12] James D. Adams, "Fundamental Stocks of Knowledge and Productivity Growth, Journal of Political Economy, 98:673–702

[13] Cohen, Nelson and Walsh, "Links and Impacts: The Influence of Public Research on Industrial R&D, Management Science, January 2002, Vol. 48, No 1.

Figure 11 highlights two of the core organizational structures within which research is undertaken at ACES. As with nearly all universities, faculty have a home academic department and this department structure provides a resource base and community of intellectual capacity in focused disciplinary areas. For example, in the Department of Animal and Range Sciences a faculty member leading a research program in cattle nutrition can work with colleagues in the Department who will have complementary expertise in cattle physiology, reproductive biology, livestock genetics and behavior, etc. that enhance the research. Similarly, faculty in one department can access their colleagues in other departments within ACES and across the university to create transdisciplinary teams to facilitate research or simply tap-in to a necessary niche area of specialized knowledge. For example, the researcher working in cattle nutrition within the Department of Animal and Range Sciences can access the expertise of plant scientists specializing in forage crops contained in the Plant and Environmental Sciences Department.

Figure 11: Key Components of the ACES Research Enterprise



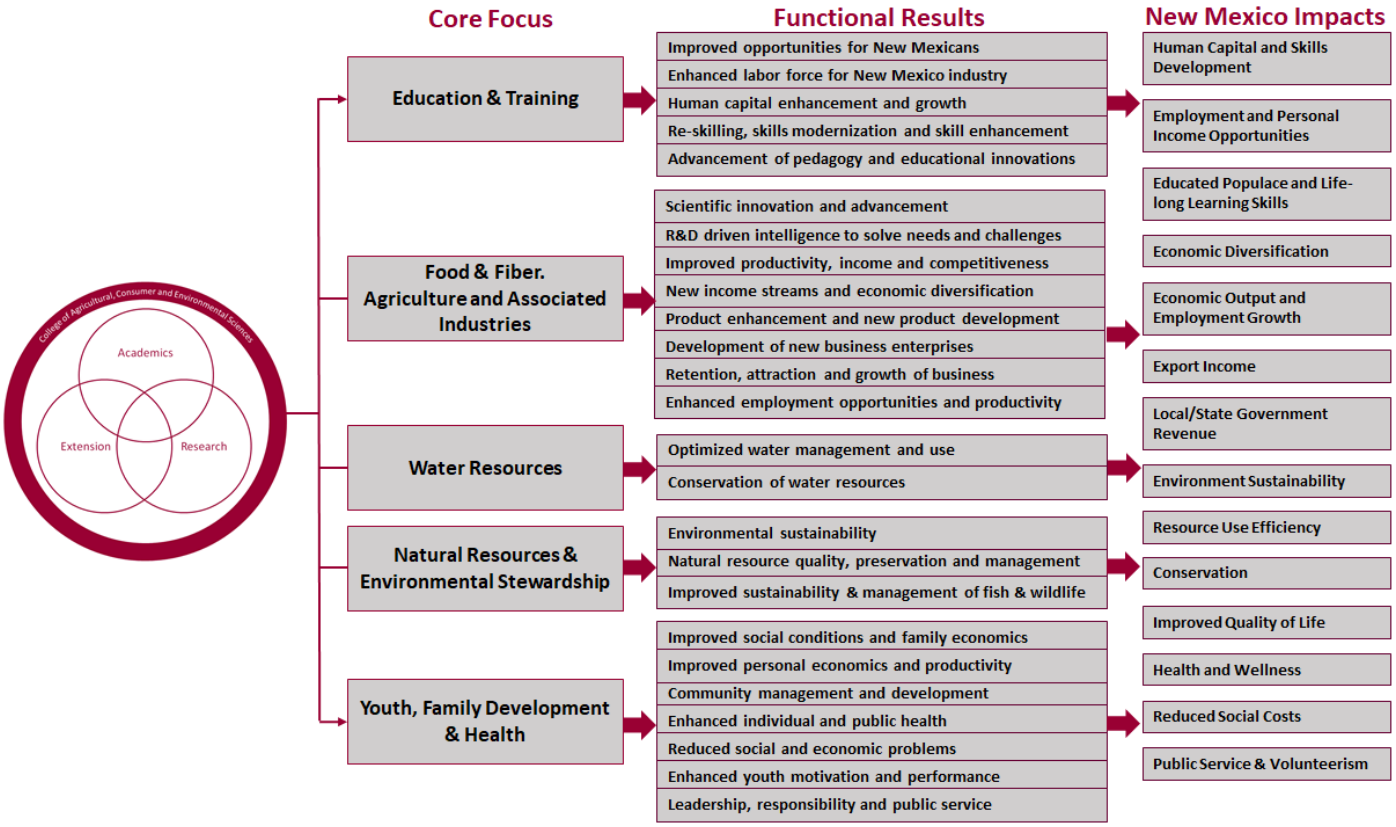
One of the key characteristics of agriculture as an industry is that it is (largely) an outdoor activity, with a production environment that can differ greatly from one geographic location to another. Soils, climate, pest profiles, water resource access, etc. each impact farm and ranch production and are spatially variable. Reflecting this reality, ACES operates the Experiment Station System, with 12 locations across the state. These Agricultural Science Centers (ASCs) facilitate research in specific environments of relevance to the farmers and ranchers operating in the regions where the ASCs are located. Through the characteristics of the land, the specialized knowledge of the ASC personnel, and specific research infrastructure located at the ACSs, NMSU research is able to target research to the right location, undertaking, for example: rangeland and livestock research (at centers such as Clayton Livestock Research Center, the Corona Range and Livestock Research Center and the Chihuahuan Desert Rangeland Research Center); and Forestry research in Mora at the John T. Harrington Forestry Research Center. Crops of significant economic importance to New Mexico (such as alfalfa, onions, pecans, corn, etc.) can be studied and improved through research at multiple NMSU Agricultural Science Centers able to duplicate farmers' field conditions.

A. Focus Areas for NMSU ACES Research

The functional impact diagram for ACES (Figure 12) highlights five primary macro areas of focus for the work of the College, four of which are research intensive:

- **Food and Fiber (Agriculture and Associated Industries)** – Working to improve farm, ranch and forest productivity and quality of output and enhance value-added processing opportunities in food, fiber and industrial biomass utilization across New Mexico.
- **Water Resources** – Performing research on key aspects of New Mexico's critically important water resources.
- **Natural Resources and Environmental Stewardship** – Seeking to sustain, conserve and leverage New Mexico's environment and natural resources to benefit the state and its citizens.
- **Youth, Family Development and Health** – Focused on the social and economic systems that provide opportunity, stability and well-being for communities, families and individuals across urban and rural environments and socio-economic boundaries.

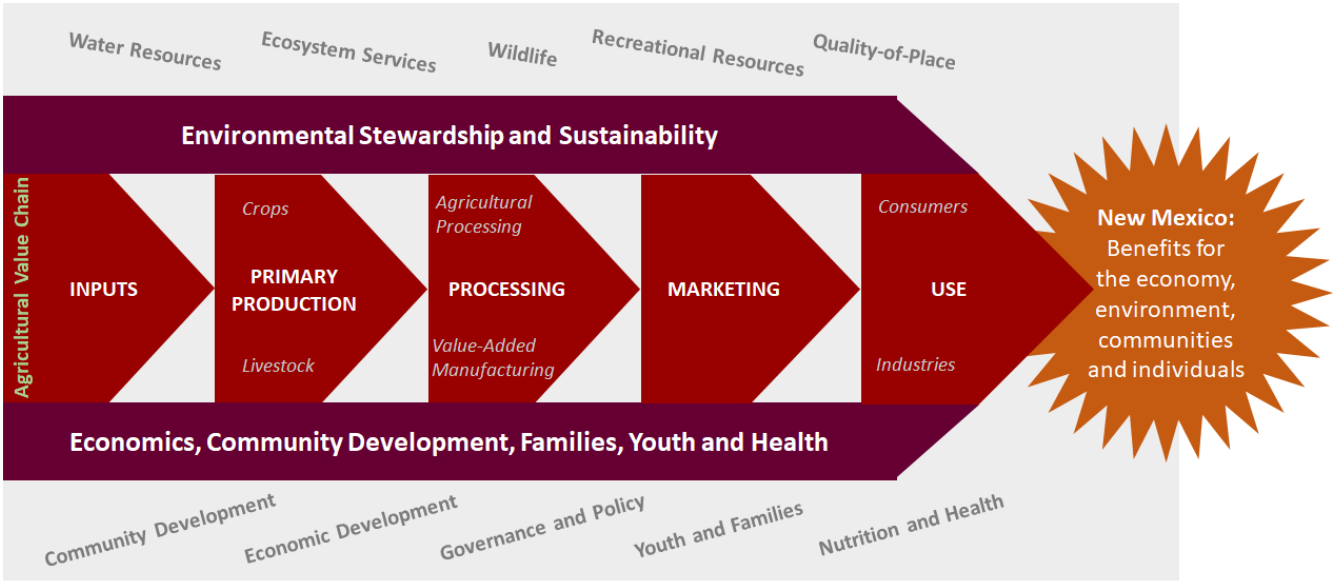
Figure 12: Functional Impacts of ACES Research



The research at ACES is effectively very much focused towards optimizing economic development from the agricultural and natural resource assets of the state, informing sustainable environmental stewardship across the state, and researching the social and economic aspects of community and family life in New Mexico to assure a quality-of-life for which New Mexicans can be proud. In recent communications, ACES has been describing its focus as being on "Four Pillars for Economic and Community Development", categorizing the four pillars as: 1) Food and Fiber Production and Marketing, 2) Water Use and Conservation, 3) Health of New Mexicans, and 4) Environmental Stewardship. These

are quite similar to the categories developed by TEConomy in Figure 12 to profile the functional impacts of ACES, except TEConomy expands the Health of New Mexicans to more broadly reflect the activities of the College not only in health but also in youth, family and community development. Research within ACES is effectively working to address the key areas shown on Figure 13:

Figure 13: Areas of Research at ACES



These key focus areas for research are considered below, with examples and case studies used to illustrate the types of important functional impacts for New Mexico being achieved through the work.

B. ACES Research in Action: Food and Fiber (The Agricultural Value Chain)

The agricultural production and food processing industry in New Mexico is a major industry category for the state, comprising 12.3% of gross state product (GSP) when studied in 2012.[14] To put 12.3% of GSP into context, the GSP of tourism in Florida (the industry that state is most associated with) was 10% in 2016.[15] **Agriculture is clearly big business for New Mexico and almost 51,000 jobs are supported in the state because of agriculture and associated business activity.**

In most industries the research that improves products and productivity is conducted by the industry itself. In aerospace, the automotive sector, metals, software, electronics, etc., industry research that is conducted by the producers themselves dominates. This is not the case in agriculture. As noted in a recent report for USDA NIFA:

[14] John Diemer, Terry Crawford and Michael Patrick. 2012. "*Agriculture's Contribution to New Mexico's Economy*." NMSU College of Agricultural, Consumer and Environmental Sciences. Circular 675. Accessed online at: http://aces.nmsu.edu/pubs/_circulars/CR675/welcome.html

[15] Visit Florida data. Reported in article in the Tampa Bay Times titled "*Tourism brought in record $112 billion to Florida in 2016."* January 17, 2018.

- *"Unlike most other manufacturing or technology industry sectors, agriculture is almost entirely composed of small and midsize business enterprises in terms of primary production. Whereas the global automobile industry, for example, comprises circa two dozen or so major manufacturers, agricultural output in the United States alone stems from the work of 2.1 million individual farms. The national U.S. agricultural industry's output is the net result of literally hundreds of millions of individual decisions made by farmers across their growing seasons, with those decisions having to take into account an exceptional number of variables (weather, soil fertility, pathogens, pests, commodity prices, global competition, etc.) and the potential deployment of multiple technologies and solutions (such as specific crop varieties and cultivars to use, livestock health products to employ, type of tillage to deploy, and capital investments in new farming equipment, to name just some). The fact that American farmers and the R&D system that supports these farmers have together achieved [large scale] productivity increases in the face of the variable production environment and multivariate decision-making environment in which farmers operate is a splendid American success story, but one that goes under recognized and underappreciated… Importantly, unlike many other industries, the primary production sector in agriculture, being made up of millions of small and midsize enterprises, has only a limited internal R&D capacity. Instead, innovations and productivity increases predominantly depend on R&D and knowledge transfer from agricultural inputs suppliers, the United States Department of Agriculture (USDA) Agricultural Research Service (ARS), and America's unique system of Land-Grant universities and Cooperative Extension Services.*[16]

Achieving performance gains in agriculture is no easy task. As noted in a recent report for USDA NIFA:

"Unlike almost every other industry, the agricultural industry operates within a production environment that has great year-to-year and season-to-season variability. It is (largely) an outdoors industry dependent on weather and open to the pressures of naturally occurring diseases and pests. Factors both abiotic (rainfall, sunlight, frost, etc.) and biotic (plant and livestock diseases, crop-damaging pests, etc.) are variables that substantially affect production but cannot be assured in advance. New diseases are emerging, and existing diseases and pests are expanding in their geographic range, spurred in part by human activities and the reactions of the biosphere and climate to them. The dynamic production environment, and the challenges associated with it, represent a unique signature of the agricultural industry."

Tripp S., et al. 2017. "National Evaluation of Capacity Programs." TEConomy Partners, LLC. Prepared for the National Institute of Food and Agriculture (NIFA).

The above observations certainly hold true in New Mexico where 61% of 24,721 farm and ranch operations were found in 2012 to be "small" by USDA standards, with annual sales of less than $250,000.[17] <u>These types of farms and ranches do not have R&D budgets and thus very much depend on the R&D performed by others to sustain their productivity in the face of changing competition and market forces</u>. **In New Mexico the research performed by NMSU ACES is especially important because many of the crops and agricultural specializations in the state are niche crops (e.g. pecans, chiles, etc.)**

[16] Tripp S., et al. 2017. "*National Evaluation of Capacity Programs*." TEConomy Partners, LLC. Prepared for the National Institute of Food and Agriculture (NIFA)

[17] John Diemer, Terry Crawford and Michael Patrick. 2012. "Agriculture's Contribution to New Mexico's Economy." NMSU College of Agricultural, Consumer and Environmental Sciences. Circular 675.

and are not subject to large scale research projects by major agbioscience companies. ACES is, in effect, the research and development arm for these thousands of New Mexico agricultural producers.

Producers have make-or-break decisions to make each year in terms of what to produce, how to produce it, and the timing for activities throughout the year, and the NMSU Experiment Station System is there to figure out what works in New Mexico's varied environments, and Extension is there to work with the producers directly in transferring research knowledge and relaying their concerns and challenges from the field. It is a unique and elegant system of support for a key New Mexico industry that helps meet the needs of all New Mexico residents every day and sustains an active export market. Several examples serve to show ACES work in this regard in action:

1. Research in Support of the Ranching and Dairy Industries in New Mexico

As of the first of January 2018, New Mexico had a cattle and calf inventory of over 1.5 million head. Beef cattle are by far the largest component of the state's livestock industry with the next highest inventory being in sheep and lambs at 96,000 head. In cattle, New Mexico operates largely at the front end of the beef supply chain – working to produce the calves and provide cattle grazing prior to the shipment of cattle for finishing and harvesting outside of the state. As such, NMSU research for the ranching industry focuses on relevant needs in the cow/calf production and grazing environment.

Multiple areas stand-out as a focus of R&D activity within ACES in relation to the ranching industry. These do not represent all research undertaken at ACES focused on New Mexico's ranching industry, but those listed below do provide good examples of the types of impacts being generated:

> The increasing productivity of U.S. agriculture, and the growth of the large-scale value-added industry chain that benefits from it, has not occurred by serendipity. Rather, it has resulted from the intense and deliberate application of scientific research and technological development across a broad-range of disciplines and research challenges. Research-driven advancements in animal science, veterinary medicine, genetic marker-assisted livestock breeding, and advanced nutrition formulations, for example, have led to widespread gains in the output of the livestock and poultry sectors. Likewise, in crop agriculture, innovations in agronomic techniques, soil science, plant biology and breeding, molecular genetics, pest and disease management technology, and agricultural equipment engineering have led to similarly far-reaching increases in on-farm production. Today, revolutionary new technologies in biotechnology, genomics, precision equipment guidance, robotics, computerized decision support systems, and other technological fields are finding direct application in expanding agricultural production and efficiency. At the same time, rural sociologists, family and consumer science researchers, education and communications specialists, agricultural economists, and other allied academics and professionals have worked, and are working, to understand and sustain the economic and social fabric of rural, small town, and urban America that supports much of the progress in national farm, forest, and natural resource industries. In other words, research drives increasing productivity in agriculture and associated industries and works to sustain the societal, family, workforce, public policy, and other necessary pillars that support a sustainable agricultural economic ecosystem.
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> *Tripp S., et al. 2017. "National Evaluation of Capacity Programs." TEConomy Partners, LLC. Prepared for the National Institute of Food and Agriculture (NIFA).*

a. RESEARCH: Rangeland Management and Grazing

New Mexico's semi-arid rangeland environment, and the quality of natural forage within this environment, are significant factors influencing the productivity of animal agriculture across the state. Preserving the quality of fragile rangeland while improving the productivity of range herds requires finely tuned expertise and programs of specialized research to provide scientific findings and recommendations able to enhance the New Mexico livestock economy and the deeply embedded ranching cultural heritage of New Mexico. NMSU has deep expertise in warm season low-input grazing systems, and a broad range of programs dedicated to research for improving rangeland management and grazing. As noted previously, research programs are specially enhanced by NMSU operating several agricultural science centers focused on improving this important component of the New Mexico economy. Some limited examples of high impact work at NMSU serve to illustrate some of the important activities taking place (Table 9):

Table 9: Examples of Impacts in Rangeland Management and Grazing

Integrated Pest Management (IPM) of non-crop ecosystems	Grazing cattle on natural rangeland has the benefit of limiting the amount of arable land used to produce forage and feed. Rangeland however, as an open and natural environment, carries with it risks to livestock health. One of these risks endemic to New Mexico is the prevalence of poisonous rangeland plants, such as locoweed. In New Mexico it has been found that locoweed causes 25% of the range herd to become moderately intoxicated and 7% to be severely poisoned. The resulting reduction in the health of the cattle causes an estimated loss of between $75 and $282 in value per head, depending on severity equivalent to negative impact $18 million in the State. NMSU ACES research has now identified specific fungal species that are responsible for producing the locoweed toxin. This has resulted in NMSU ACES scientists developing biomarkers to pinpoint toxicity levels, develop recommended control measures, and develop grazing management guidelines to reduce negative impacts on ranch operations. The work on locoweed is just one example of the IPM teams work to research solutions to weeds across New Mexico's rangeland.
Range Improvement Task Force (RITF)	The RITF (an integrated CES and AES organization unique to New Mexico) provides an impartial, science-based resource for resolving volatile and controversial issues in the use of rangeland natural resources across New Mexico. The RITF utilizes NMSU ACES expertise in conflict mediation, research and education, to seek solutions that balance productivity for livestock operations with maintaining the long-term viability of the New Mexico production environment. Much of the rangeland in the State is on the margins in terms of being productive and sustainable, and the RITF provides an exceptionally valuable resource for resolving issues that emerge in managing a vulnerable production system that is of great economic and cultural value for the state. When issues emerge, they are often urgent and the RITF has been structured for rapid response – providing advice on rangeland management, conflict resolution, and public policy (at a local, state and federal level). A quantitative rapid assessment methodology has also been developed and deployed, accepted by both federal land management agencies and grazing permittees providing a transparent system for decision making. A crucial benefit of this NMSU operation is provision of well-researched, factual information to inform natural resource management

	decisions and combat prevalent misinformation and scientifically-indefensible decision making. Some examples serve to show the impacts generated through such work: • 2013 RITF research at Mountainair Ranger District, across multiple allotments, helped reverse a U.S. Forest Service decision that would have forced 32 allotment owners to sell or find alternative pasture for 1,346 head of cattle. The cost savings to these allotment holders totaled between $435,000 and $888,000. Similar work in the Santa Fe National Forest preserved production across 586,000 acres for 116 family ranchers. • The Dunes Sagebrush Lizard was proposed as a candidate for an endangered species listing – potentially impacting the ability for rangeland production within its areas of habitat. Scientific review by RITF was partially responsible for a decision that placement on the candidate list was not warranted, thereby helping maintain the availability of the full environment for grazing.
Genetic Selection	Cattle have been gradually improved by humans for centuries, using selective breeding methods. Slow and steady increases in the health, feed conversion efficiency, rate of weight gain, beef quality characteristics, and other desirable factors have been achieved through these traditional, but time consuming methods. Today, the speed and accuracy of breeding for desirable traits has been greatly accelerated through the application of molecular biology, modern genetics and genomics analysis technology. The research tools help researchers to more efficiently improve productivity and reduce production costs for livestock producers. New Mexico's rangeland grazing environment places stress on cattle in terms of the distances they must traverse to access sufficient natural forage and water. NMSU ACES scientists have been using modern genetic techniques to identify the genetic traits of cattle that are best suited for the challenging NM production environment, including taking the fascinating approach of seeking traits associated with cattle that are more "adventurous" in terms of braving steeper terrain that has been under-grazed or cattle presenting a willingness to travel further afield from their water source in search of forage. Through identification and breeding of cattle with these positive traits, rangeland can be more evenly and sustainably grazed, and stocking rates potentially increased. Furthermore, water quality in NM surface waters will be improved by cattle being less concentrated close to water sources. NMSU ACES researchers are using genomics in combination with GPS tracking and geographic information systems technologies to advance this research. Early results from the research program suggest that low cost DNA tests will be usable to detect desirable traits in bulls to sire progeny with "adventurous" traits, enabling ranchers to positively impact grazing distribution, reduce overgrazing of riparian areas, and potentially increase stocking rates by as much as one-third.

b. RESEARCH: Cattle Reproduction

Successful livestock operations require an efficient re-stocking of animals harvested, and thus they are significantly impacted by their achieved rates of successful conception and the carrying of livestock progeny to a successful birth. Similarly, livestock operations also depend on having new-born livestock that are healthy and possessing of characteristics that will enhance their productivity in the specific production systems in which they will be deployed – and it is increasingly evident that fetal development conditions and maternal nutrition characteristics will influence such downstream productivity. NMSU faculty and research teams are actively pursuing work in livestock reproductive biology to advance productivity across New Mexico's livestock operations.

Reproductive biology work in ACES is having cross-over benefits into human biomedical sciences. Research work in placental development is seeing findings relevant to cancer, while work focused on bovine reproduction and estrogen has similarly led to findings applicable to human medicine.

Table 10: Examples of Impacts in Cattle Reproduction

Reproductive Success in Livestock	Reproductive efficiency is a key variable in determining profitability of livestock operations. Improving rates of conception, maintenance of pregnancy, maternal and fetal health, and the potential reproductive longevity of livestock species each can have a significant effect on the viability and profitability of livestock operations. Indeed, livestock reproduction failure is noted by the Animal and Range Sciences program at NMSU as being the cause of the second largest area of losses for livestock operations. NMSU ACES sustains a significant area of expertise in basic science investigation of livestock reproductive biology, including pioneering work in comparative biology of tumors and placental development – which are found to share multiple developmental characteristics. A key advantage here is that the national Institutes of Health have invested huge levels of funding in the study of tumor biology, producing results that NMSU is able to translate into reproductive biology advancements. NMSU researchers are also making fundamental advancements in knowledge of immune system regulation and angiogenesis in enabling placental growth during early pregnancy. This fundamental reproductive biology research is working towards the goal of reducing the large number of livestock pregnancies that fail to advance beyond a 20-week gestation period due to failures in implantation and placentation. With calving rates currently at 30% for a single fertilization in dairy cattle and 60% in beef, the potential benefits of improving scientific understanding of how to enhance reproductive success are significant. NMSU work in this regard is a testament to the importance of basic science research and how the advancement of basic scientific knowledge can lead to tangible and translatable results for agriculture.
Fetal Programming	NMSU ACES researchers have found that the ability of cattle to digest low-quality forages that can predominate in NM grazing environments is effectively "programmed" into a fetus during its gestation. Further, it is found that the make-up of the feed consumed by the dam impacts this fetal programming. These findings have profound implications for downstream productivity in New Mexico ranching by leading to feed and feed supplement recommendations for

	cattle during pregnancy to promote the birth of calves better able to achieve better health and weight gain from natural low-quality forage in New Mexico's dry rangeland environments.

2. Research in Support of Farming in New Mexico

In addition to the production of livestock and the state's significant dairy industry, New Mexico's farms are also engaged in substantial crop production. USDA data for 2017 show the market value of New Mexico crops totaling almost $617 million. In terms of acreage, the largest crop commodities are: hay and silage (including alfalfa); wheat; corn for silage; and pecans. New Mexico is quite diverse in terms of its crops produced. Unlike the rather monolithic production profiles of Midwest states (in corn and soybeans particularly), New Mexico produces a diverse range of row crops and horticultural crops (vegetables, fruits and nuts). NMSU maintains active research programs in support of crop farming in the state, incorporating programs focused on plant breeding and crop improvement, crop protection research, and research on alternative crops and cropping systems suited to a New Mexico production environment. Several examples of NMSU R&D work in these areas are highlighted below. Again, these do not represent all research undertaken at ACES focused crop farming in New Mexico but do provide robust illustrative examples of the types of impacts being achieved.

a. RESEARCH: Plant Breeding and Crop Improvement

Land-Grant universities, including NMSU, have a long-standing history of major contributions to plant breeding and crop improvement. One of the core reasons why the United States has been able, consistently over many decades, to sustain increasing yields from its agronomic land has been the work of Land-Grant university plant scientists and plant breeders identifying positive phenotypic traits in crops, then selecting them to create high performing crop varieties. Traditional breeding techniques have been complemented, more recently with advanced molecular and genetic analysis and plant transformation techniques that have accelerated the identification of positive genetic traits and their introduction to improved crop varieties through conventional breeding or genetic modification techniques. Currently, modern gene-editing technology (Such as CRISPR-Cas9) is showing great promise as a further tool for advancing crop performance.

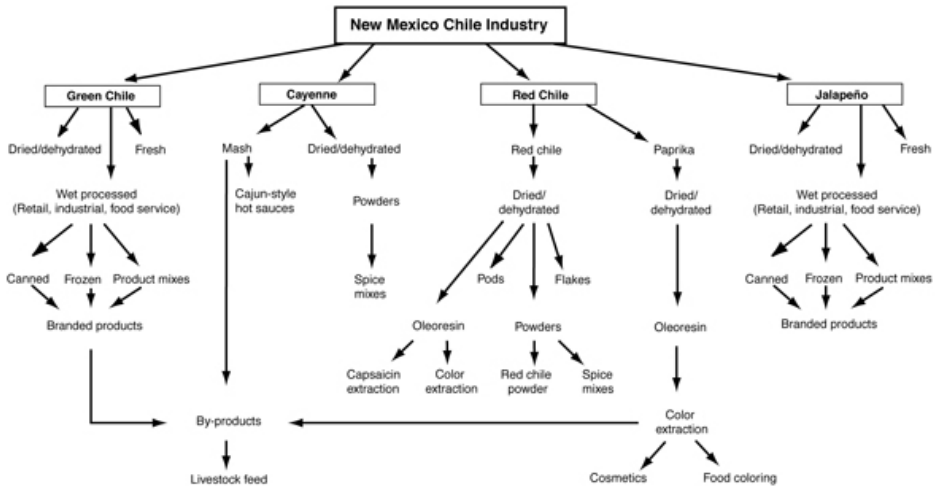
NMSU plant scientists use both conventional breeding and modern molecular breeding techniques to enhance a broad range of crops of economic importance to New Mexico. Programs operate in crops of core significance to NM production, including in alfalfa, onions, pecans, cotton, chiles and many others. In addition to NMSU-developed crop lines grown in New Mexico, NMSU-originated germplasm is also found in many of the commercially developed and sold seed marketed and grown in the state.

The Agricultural Science and Research Centers operated by NMSU ACES across New Mexico provide a valuable resource in terms of crop development research. These facilities enable research to take place in field conditions of direct relevance to the regional conditions experienced by New Mexico farmers. These regional science centers play an important role, not only as development sites for NMSU breeding and crop improvement programs, but also as sites for NMSU testing of commercial crop varieties. Through crop trials, NMSU scientists are able to validate and quantify the performance of various crop variety options available to New Mexico farmers and provide reliable, independent recommendations to producers as to the varieties best suited for high-performance on their farms.

Crop variety testing by NMSU is a key contributor to NM agricultural productivity. Trials have documented benefits of a 25% yield gain through NMSU developed recommendations based on quantitative field evaluations**. Impact analysis shows that implementing NMSU recommendations drives a $115 million annual increased benefit in terms of state output versus the trial mean.**

Some examples of the variety of work undertaken in plant breeding and crop development at NMSU are provided in Table 11:

Table 11: Examples of Impacts in Plant Breeding and Crop Improvement

Chile Peppers	Chile peppers are an iconic part of New Mexico agriculture, with deep cultural significance. They have also historically been an important crop economically. Currently approximately 9,000 acres of land is cultivated for chiles in New Mexico with a production value of $44.6 million for 2017. Unlike many crops produced in the state, chiles are also part of a vertically integrated value-added food processing industry in the state with Chile processing representing a circa $500 million industry for the state. The figure below provides an overview of the industry structure and its products in the state.[18]  Research at ACES has made important contributions to the industry and the university has a well-established reputation as the leading institution in chile breeding and

[18] T.Y. Hall and R.K. Skaggs. "New Mexico's Chile Pepper Industry: Chile Types and Product Sourcing." New Mexico Chile Task Force Report 8. College of Agricultural, Consumer and Environmental Sciences, New Mexico State University.

	genetics. Indeed, chile breeding has a 125 year history at NMSU, with selection and development of **the widely-grown New Mexico pod type** (also known as "long green" or "Anaheim") begun in 1894. Today, NMSU ACES research work continues to improve the genetics of pepper germplasm for New Mexico growers. A key area of focus of the chile breeding and improvement program is on improvement in three main areas: high yield, resistance to pests and diseases, and the development of heat and drought tolerant chile cultivars. A recent research breakthrough pertains to Verticillium chile wilt which has been a major issue for growers. NMSU identified molecular markers for resistance to the disease and has published these markers so that seed companies can use the information to improve commercial varieties. NMSU has also been developing new cultivars to provide growers with new marketable products. A recent example of this work is the NuMex R. Vince Hernandez paprika-type cultivar which has proven to have **a 30% higher dry yield, helping growers to expand revenue by greater than $1 million.** Another important project (see write-up in the Extension section of this report) is focused on developing green chile varieties suited to mechanical harvesting methods.
Alfalfa	Alfalfa hay is an important crop for New Mexico which, like chiles, is part of a vertically integrated production chain. New Mexico alfalfa had a production value of $171 million in 2017, and comprises a key input providing feed for the large-scale livestock and, especially, dairy industry in the state (with just the milk production side of the dairy industry having sales of $1.34 billion in 2017). As with chiles, NMSU ACES sustains an active alfalfa improvement program. The NMSU ACES-developed NuMex Bill Melton variety, a drought tolerant variety, for example, can sustain high yielding fields under reduced application of scarce irrigation water. **Commercial marketing of the variety began in 2015 and is generating $500,000 in annual hay sales**. Innovative research in alfalfa at NMSU ACES has been developing transgenic alfalfa containing a maize gene that encodes an enzyme for carbon metabolism that is demonstrating a two-times increase in growth rates – providing benefits not only in terms of yield, but also additional cuttings. NMSU ACES is also participating in a program testing 250 new alfalfa experimental breeding populations for a 3-year field evaluation (planted in 2017) in collaboration with two private industry sponsors. Overall, the work of NMSU ACES in water management strategies, alfalfa improvement and recommendations for seed and fertilizer application rates, has been found to increase production efficiency by more than 25%. **A conservative gain of $100 per acre for producers results in a large $35 million economic impact for the state.**
Onions	NMSU ACES maintains one of the few public breeding programs in onions, and the production of onions in the state has expanded, supported by NMSU-developed sweet onion cultivars. As noted in an NMSU Circular "during the months of June and July, New Mexico supplies more than 50 percent of onions consumed in the United States (USDA 2000). Each year, New Mexico grows 7,000 to 8,000 acres of onions, producing 160,000 to 180,000 tons at a value of $40 million to $55 million."[19] The NMSU ACES onion breeding program has released multiple varieties grown by producers, including: NuMex Starlite; NuMex Dulce; NuMex Mesa; NuMex Sweetpak, and NuMex Luna. Importantly, each of these NMSU varieties has good to excellent performance against the endemic organism causing pink root. Onion germplasm developed at NMSU also

[19] Christopher S. Cramer. "New Mexico Onion Varieties." NMSU College of Agricultural, Consumer and Environmental Sciences (ACES). Circular 567. http://aces.nmsu.edu/pubs/_circulars/CR567/

	demonstrates reductions in Iris yellow spot virus and experiences lower levels of thrips crop damage. These latter characteristics are estimated (via impact analysis) to reduce up to $210 million in U.S. onion losses and reduce pesticide applications by $13 million per year. 2016 data[20] show New Mexico produced 4% of U.S. onions, so **ACES developed savings from reduced pesticide use would equate to a $520,000 benefit for New Mexico farmers, while the reduction in onion losses based on NMSU germplasm improvements would be a benefit of $8.4 million.**
Pecan Cloning	USDA data show the importance of pecans as a core crop for New Mexico farmers, with a 2017 production value totaling $220.8 million.[21] Improving pecans has been challenging because traditional breeding techniques are slow given the slow maturation rate for trees. **NMSU ACES researchers have, however, made a key breakthrough for the pecan industry through the first successful cloning of pecan trees.** By growing in tissue culture and then successfully transferring to soil, new variety development can be accelerated substantially. Cloning also allows ACES to supply pecan tissue cultured trees that are free of diseases that affect the crop (such as leaf scorch caused by Xylella fastiidiosis). ACES researchers are also engaged in developing salt tolerant pecans and pecans with improved nutritional profiles.
Peanut	NMSU research resulted in the release of NuMex-01, which is a high oleic and high yielding cultivar. Demonstrating a 13% higher pod yield versus existing cultivars, NuMex-01 has the potential to increase peanut production value in New Mexico by $500,000 annually.
Cotton	Glandless cotton produces cottonseed that is valued for food and aquaculture feed. This provides additional income for New Mexico cotton producers. Researchers at NMSU ACES have developed and released the Acala 1517-18 GLS glandless cotton cultivar and have also identified two cotton breeding lines demonstrating resistance to Fusarium wilt.

b. RESEARCH: Crop Protection

Next to water availability, pests are often the most limiting factor on crop yield and crop protection research is essential to dealing with current and emerging threats from biotic stressors (plant pathogens, insects, weeds and other pests). NMSU has been a leader in bringing together the necessary academic disciplines to pioneer integrated pest management (IPM) approaches – and has a combined department containing plant pathology, entomology and weed science. Understanding the complex field interactions of plant pathogens, insects, weeds and other pests in a holistic, systems approach enables ACES research and Extension personnel to make more informed recommendations for IPM practices for New Mexico farmers and ranchers. This approach has enabled NMSU to build a particular reputation and special expertise in wild-type organisms and their ability to directly and indirectly impact agricultural crops (building on understanding the interactions between, and among, complex life-cycles of, insects, weeds and diseases).

[20] National Onion Growers Association. https://www.onions-usa.org/all-about-onions/where-how-onions-are-grown

[21] United States Department of Agriculture, National Agricultural Statistics Service. "2017 State Agriculture Overview, New Mexico."
https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NEW%20MEXICO

Table 12: Examples of Impacts in Crop Protection

Chile Peppers	As noted above, chile peppers are an economically and culturally important crop in New Mexico. Keeping fields productive in the face of weed growth has been a particular challenge, with hand weeding costing upwards of $300 to $400 per acre. Research at NMSU ACES has developed a novel approach called a "stale seed bed weed" prevention strategy that first allows weed seeds present in fields to germinate and begin their growth cycle and then be destroyed by herbicide prior to then planting the field with chile peppers. The potential impact of this approach is significant – substantially reducing hand weeding costs and also preventing the 76% reduction in chile yields that can occur if mid-to-late season weeds go unchecked. Another challenge to NM chile production is the southern root knot nematode which reduces yield, stunts the growth of the chile plant (and by stunting the growth of chile plant enables endemic weeds such as spurred anoda and yellow and purple nutsedge to grow faster – reducing chile yields even further). The nutsedge weeds also present a challenge in that their rooting system tends to protect nematodes from nematicide applications. NMSU ACES has performed research on this vexing challenge and developed a crop rotation management strategy whereby nematode-resistant alfalfa is grown breaking the cycle of nematode infestation. Given that nematode infestation can cause 25% to 31% yield losses in New Mexico chile fields, the new NMSU ACES-developed approach has the potential to preserve significant economic value in this iconic crop. **With the NM chile crop totaling $44.6 million for 2017, the potential direct impact value through increasing chile yield through these ACES innovations could total as much as $13.8 million.** The ACES nematode quarantine facility is a key asset for ACES researchers in being able to research nematodes, nematode impacts and effective anti-nematode chemicals and strategies.
Alfalfa	As with chile peppers, alfalfa production in New Mexico is negatively impacted by endemic weeds. Broadleaf and buckhorn plantain weeds are particular challenges to manage. AES researchers and Cooperative Extension Specialists have an active research program examining and testing herbicides and combinations of active ingredients that are proving more effective for weed control in alfalfa production systems.
Fast reaction to issues found (pecans and onions)	One of the keys to preventing widespread breakouts of plant diseases and pests is early detection and diagnosis of the causative agent. Researchers and Extension professionals at ACES are able to work hand-in-hand with the New Mexico Department of Agriculture to provide a rapid-response team, able to get to the site of an emergent disease in the state within one-day and establish rapid quarantine and treatment procedures. Two examples serve to show this rapid-response in action. In the first case pecan weevil (historically a problem in Texas but not in New Mexico) was reported in a New Mexico county on the border with Texas. The NMSU response team was able to get to the site on the same day, quarantine the county, and prevent shipment of pecans (except back into Texas). In the second case a similarly fast turnaround was achieved when a backyard grower's garlic crop displayed symptoms of stem and bulb nematode – a nematode with potential to

	cause substantial damage to the state's important onion crop. NMSU received a sample from the grower at 4pm, had conducted tests by 6pm confirming the infestation, enabling a response team to rapidly be deployed to put in place effective quarantine measures. **It is, of course, hard to put a number on the hypothetical losses prevented to important New Mexico crops by this fast-reaction team at NMSU – but with pecans a $220.8 million crop in 2017, and onions up to a $55 million crop, large-scale potential negative impacts were averted.**
Strategies for interrupting life cycles of parasites and vector-borne diseases	Basic sciences research, examining fundamental questions of disease and vector interactions and movement in agronomic systems is being pursued at NMSU. By developing an understanding of the systematic processes involved in processes such as insects carrying viruses between crops, or weeds hosting and promoting the growth of damaging nematodes, NMSU Aces researchers are able to better identify opportunities to break the symbiotic cycles that promote crop damage. This fundamental work is also being applied to understanding arthropod vector systems in terms of disease transfer between mammalian systems of relevance to both livestock and human health.

c. RESEARCH: Alternative Crops and Cropping Systems

ACES helps producers across New Mexico by working to improve and protect crops. University research is also helping to enhance the New Mexico farming economy by introducing new value-added crops (especially those suited to water-constrained production environments) and new cropping systems designed to enhance yield and conserve environmental resources. Some examples of this work follow (Table 13):

Table 13: Examples of Impacts in Alternative Crops and Cropping Systems

Modeling Tools	Advanced digital technologies provide NMSU ACES researchers with sophisticated tools to understand environmental dynamics and forecast conditions for optimal farm and ranch decision making. ACES researchers are, for example, using computer modeling and geospatial analysis tools to simulate various management approaches and weather pattern their effects on soil management and agronomic productivity. Large areas of New Mexico have lacked adequate soil, hydrology and ecosystem dynamics data necessary for optimized land-use planning. ACES researchers are working to resolve this data shortfall by using advanced machine learning algorithms to digitally characterize and map soil properties (both physical and chemical) to provide land managers with information for planning purposes.
Alternative Field Production Techniques	**Example 1:** Water run-off from agricultural fields is a problem from two primary dimensions. First, in water scarce New Mexico, the loss of water to run-off means the water was wasted in terms of not being available for use by the crop in the field. Second, run-off from fields carries with it valuable soil materials, nutrients and agrichemicals – negatively impacting the production capacity of the field and flushing nutrients and chemicals into surface waters. Since much of the irrigated land in New Mexico uses center pivot irrigation, ACES researchers have been developing a system of concentric circle buffer strips whereby strips of grasses separate concentric circles of crops. The dense buffer strips serve as a barrier to

	water run-off, helping to significantly improve soil moisture and preserve soil nutrients. **Example 2:** Research at the ACES Tucumcari Science Center has been evaluating alternative conservation tillage techniques – including testing of conservation tillage strips alternating between cotton and corn. **The work shows strong prospects for success in NM production conditions, with analysis demonstrating a potential $14.2 million yield advantage versus traditional practices (based on 2016 prices and acreage in the state).** The conservation tillage techniques being recommended also have the advantages of reducing farm energy expenditures, reducing soil erosion, and enhancing water and nutrient use efficiency.
BioEconomy development	Microalgae can be rich in lipids (oils) and chemical compounds useful for industrial and nutritional applications. NMSU ACES researchers have been investigating New Mexico's arid and semi-arid soils in search of novel strains of microbes that may have economic potential in a bio-based industrial economy – as fuels, chemical raw materials, soil remediation and stabilization agents, or health products. This work has resulted in NMSU ACES algae strain collection increasing from 300 to 500 strains, with 12 new genera and 32 new species described. While early in applied development, the discovery and characterization of algae strains provides an expanded toolkit for NMSU ACES researchers seeking to build a bio-industrial economy base in the state.
New crops	Change is inevitable in New Mexico agriculture. As water resources become increasingly constrained, as climate change creates challenges in the production environment, as consumer preferences and markets evolve – there is a distinct need for NMSU ACES to be researching not only how to keep current crops productive, but to also seek new value-added crops for production in the state that are suited to current and forthcoming conditions. Some examples of work by ACES in evaluating and promoting the introduction of new crops for New Mexico include: • Guar (also known as cluster bean) is a legume native to the Indian subcontinent. The crop has been explored for New Mexico given relatively low water use and drought tolerance characteristics. One of the applications being explored for the crop is the use of guar gum as a natural fracking additive for the oil and gas industry that would be considerably more environmentally benign than the synthetic chemicals used currently. • Other water efficient crops, such as winter canola and safflower, are being researched for their production potential in NM agronomic conditions. Winter canola and safflower are subjects of investigation. • Blue corn is found to have improved protein and oil content versus the typically cultivated commodity corn varieties. Suited for use in value-added food products, the blue corn landrace seed has been distributed to small farms in northern and southern regions of the state to develop the market. • Jujube is a small tree, in the buckhorn family, that produces a small date-like edible fruit. Popular in China and other Asian markets, over 400 cultivars of jujube have been selected. The tree prefers hot weather yet survives frosts and thus has suitability in New Mexico's environment. Currently only 6 cultivars of jujube are commercially grown in the US. ACES Sustainable Agriculture Science Center at Alcalde has been evaluating 50 different

	characteristics, extended maturation dates, and which will sell at a premium price. The crop is starting to gain momentum now with 10 commercial growers in NM as of early 2018 compared to no growers 5 to 10 years ago. • New Mexico, like many states, has been experiencing significant growth in specialty beer brewing and micro-brewery operations. The New Mexico Brewers Guild now has 65 brewery members. Recent research identifies the industry having a $340 million annual economic impact in the state and producing 85,230 barrels of craft beer annually.[22] Responding to industry demands, NMSU researchers have been researching hops and malted barley varieties and planting at multiple test locations. ACES has also acquired two mechanical hops pickers for evaluation. It is intended that the inclusion of New Mexico ingredients, in terms of barley and hops, will help with the value-added branding of "New Mexico True" for locally produced beers and provide new crops for farmers to cultivate in New Mexico.

As can be seen from the above examples, ACES research is actively focused on improving agricultural productivity in New Mexico and improving the profitability of New Mexico's farms and ranches. Improving yield, protecting farmers from crop and livestock losses, and introducing new high-value crop options for New Mexico producers serves to grow and protect the key agriculture sector of the New Mexico economy.

3. Research on New Mexico's Water Resources, Natural Resources, Wildlife and Ecology

Arid and semi-arid ecosystems are inherently fragile, with plants and animals surviving by occupying distinct niches in an extreme environment. Balancing the use of New Mexico lands for agriculture and other economic uses with the need for conservation of diverse habitats for New Mexico native species is part of the highly important work undertaken at ACES.

a. RESEARCH: New Mexico Water Resources

One of the key areas of focus for NMSU ACES in terms of natural resources, wildlife and ecology in the state is water. Water is a scarce and precious resource for New Mexico, necessary for the survival of every natural species in the state and underpinning human economic activity. Multiple approaches are being taken to conserve fresh water resources in the state – with some examples shown in Table 16:

Table 16: Examples of Impacts in New Mexico Water Resources

Using brackish water to replace or supplement fresh water	Most of the crops and forage planted in New Mexico require irrigation, either from surface waters or from aquifers (which are largely experiencing long-term lowering water levels). Most crop plants are not tolerant of moderately elevated levels of salt in soil and water, but there are certain species (called halophytes) demonstrating salt tolerance or thriving in salty conditions that may provide an alternative and sustainable crop for the production of livestock fodder. NMSU ACES has been evaluating various plants (Triticale, Switch grass and Atriplex) for their potential economic use and has also been examining the degree to which salt-uptake in the plants may prove beneficial in reducing a need for

[22] Shelby Perea. April 3, 2017. "NM craft beer continues to grow, says new report." Albuquerque Business First. https://www.bizjournals.com/albuquerque/news/2017/04/03/nm-craft-beer-economic-impact-growing-says-new.html

	supplemental salt in livestock diets. Being able to use brackish water will effectively make a resource out of a very much underutilized water source.
Using municipal wastewater for energy crops	Another project to use an underutilized water source in New Mexico has focused on the use of treated municipal wastewater as an irrigation source for energy crops. ACES research, using a greenhouse-based study, found that the use of this water type does not cause any yield loss in three energy crops tested (energy sorghum, switchgrass and canola) and showed an advantage in terms of improving soil organic carbon content in salt affected soil. Based on the positive findings the research has progressed from the greenhouse to field trials.
Controlling invasive plants	Biological control is being tested as a management approach by ACES to the spread of saltcedar, an invasive tree introduced to the U.S. from Asia. Saltcedar presents a current and expanding threat to water resources in New Mexico with a single saltcedar tree able to absorb 200 gallons per day. Now established along the Gila, Salt, Pecos, Colorado, and Rio Grande rivers, the trees cause considerable ecological and hydrological harm. The tree is fast reproducing, very fast growing (up to 12 feet in a single season) and hard to kill (recovering rapidly from being cut down or from fire). The tree name reflects another harmful characteristic in that saltcedar deposits salt above and below the ground, forming a saline crust that inhibits other plants from growing in the area. It is clearly an imperative for New Mexico to halt and reverse the spread of this invasive plant and ACES has been researching various approaches. Current research at ACES is evaluating the saltcedar leaf beetle (Diorhabda elongat), an insect that can aggressively defoliate a saltcedar tree as a biological control agent. While the beetle has proven effective in destroying the trees, ACES is taking care to study the ecological effects and assure there is not unintended collateral damage that may occur via the release of the insect.

b. RESEARCH: Fish and Wildlife

New Mexico's varied aquatic and terrestrial habitats are home to a broad diversity of fish and wildlife. Adapted to habitat niches in New Mexico's arid, semi-arid and mountain areas there are multiple rare and endangered species threated by competing human land-use and environmental change. ACES undertakes a wide range of research programs focused on understanding New Mexico's fauna and approaches to stewardship of wild species in the state.

Table 17: Examples of Impacts in Fish and Wildlife

Management of game species	Hunting and fishing is an important recreational industry in New Mexico – providing pleasure for state residents and attracting tourists into the state. The harvesting of game species has to be appropriately managed, however, to assure populations are sustainable. NMSU researchers engage in studies that provide important input to fish and game management decisions. For example: • Research to measure the numbers and spatial density of black bears in the state by NMSU ACES researchers provided input to decisions to revise the harvest limits for the species. • Assessing the long-term sustainability of Rio Grande cutthroat trout and strategies to remove non-native invasive fish species that impact trout habitat and barriers that can prevent future invasion.

	• Evaluation of forest restoration practices and the response of game species such as mule deer, elk and black bear.
Evaluating risk of livestock predation by Mexican Wolves.	The Mexican wolf, a subspecies of the grey wolf, has a natural range that extends into southern New Mexico. By the mid 1970's the wolves had almost disappeared in the southwest US and New Mexico, the result of a targeted eradication program under the auspices of protecting livestock and game species from wolf predation. With better, research-based understanding of the roll of apex predators in healthy ecosystems, efforts began to help Mexican wolves become reestablished across their natural range. Not surprisingly livestock producers have concerns over livestock depredation and associated economic losses. NMSU ACES has been working with state and federal agencies to take a proactive technology-driven approach to predict areas where there is a higher propensity for wolf presence, thereby helping ranchers protect their livestock and relocate them to lower risk areas. ACES has helped develop dynamic risk mapping that uses artificial intelligence algorithms and knowledge of wolf behavior.
Advanced quantitative methods in evaluating land capacity	The above cited predation mapping is just one example of multiple applications of advanced quantitative methods to wildlife studies at NMSU. NMSU ACES researchers are developing techniques and applications of advanced statistical and mathematical modeling to assess the carrying capacity and population density of various New Mexico ecosystems. Using information theory, capture-recapture modeling, matrix population modeling and Bayesian statistics provides NMSU researchers with sophisticated methods to quantitatively investigate complex questions.
Exploration of species natural history and movement using advanced technology	In addition to the advanced statistics and mathematics based algorithms noted above, ACES wildlife researchers are pioneering work in the state using advanced digital technologies for tracking wildlife movement within and across ecosystems. By using radio tagging, GPS monitors, satellite telemetry and imaging, and even stable isotopes, NMSU researchers are able to track wildlife movement and use the resulting data to evaluate movement ecology and the use of, and contribution to, ecosystem resources by various species.
Endangered Species Research	New Mexico's diverse, and often harsh, landscape is home to some unique and highly specialized animals that have evolved to occupy specialized environmental niches. Property development, expanding communities, farming and livestock grazing, construction of energy and transportation infrastructure, etc. can impact the habitats of natural species to the point where their population sustainability becomes at risk. NMSU ACES faculty and researchers have engaged in multiple research programs to understand the threats and risks to individual species and develop recommendations for policies or adaptive mechanisms. ACES work on burrowing owls, for example, has examined the effectiveness of relocation of owl populations threatened by urban encroachment. Similarly, recent work has been focused on understanding the habitat needs of Bendire's Thrashers, a bird native to arid land in New Mexico. NMSU ACES expertise is also being used to advise on infrastructure installations, such as solar or wind power ventures, to avoid conflict with rare and endangered wildlife. It is also important to note that NMSU ACES research has also provided the independent analysis necessary to quantify wildlife species populations that have led to certain species being delisted or not-

	listed as endangered or threatened – thereby avoiding unnecessary management actions and associated costs.

4. Research for New Mexico's Economic and Community Development

ACES recognizes that a large part of its work is focused on sustaining and improving the economics of agriculture and the rural economic and community development ecosystems that support it. Whether working towards improving primary agriculture, developing downstream value-added agriculture and food products, or managing the key resources (such as water) that support this economic ecosystem, multiple faculty with ACES focus on key questions pertaining to economic and community development.

Table 18: Examples of Impacts in Economic and Community Development

Evaluating the financial feasibility for NM value-added food products	Researchers at NMSU ACES in the Agricultural Economics and Agricultural Business Department at ACES perform a range of studies and analyses to assess the market for, and financial feasibility of, value-added food development projects. The expertise of the department has been applied to analysis across a wide-range of value-added product opportunities for New Mexico, including, for example: pecan flour and oil; malt production for the brewing industry, and new crop introductions (such as jujube and guar).
Water Shortage Management	Management of water resources has always been crucially important in New Mexico, and into the future it is likely to become an even more important issue as climate variability and drought impacts are felt, aquifers are drawn down, and urban development and other actors influence watersheds. Research is highly important in understanding these issues and working towards solution, and the development of research tools goes hand-in-hand with this work. ACES agricultural economists have been working with other ACES colleagues to inform public policy and have developed software-based cost-benefit analyses systems that will give stakeholders a research-based tool for testing scenarios. With the system, analysts and stakeholders can project the cost of water shortages, test different policy actions and work towards a shared understanding of the best pathways forward in managing New Mexico's scarce and changing water assets.

5. Research Focused on New Mexico Families, Youth, and Health

A report for the directors of Cooperative Extension services in the north central region of the U.S. noted that:

> *While the United States provides its people with many opportunities and represents the largest and most diverse economy among nations, there is no hiding the fact that it is also a country where tens of millions of residents face significant problems and challenges. Over 45 million Americans presently live in poverty, and U.S. life expectancy is just 42nd among all nations. Almost 79 million Americans are obese, and more than 117 million residents have one or more chronic health conditions. Over 87 million in the nation are worried about having enough money each month to pay their regular monthly bills, and 17.6 million U.S. households are food insecure. We have the highest incarceration rate of any nation, and, if presented with this*

report, more than 32 million adult Americans would be unable to read it because they are illiterate.[23]

These and similar issues are felt acutely in New Mexico, where persistent poverty, poor health and other socio-economic challenges continue to affect large numbers of New Mexicans. The need for solutions to these vexing human challenges is acute, since:

- The state has the second highest poverty rate in the nation[24]
- 31% (157,000) New Mexico children, live at or below the poverty line (compared to the national child poverty rate of 22%)[25] New Mexico leads the nation with the most children under age 5 living in poverty – 36.2 percent.[26]
- The sixth highest rate of drug overdose deaths in the nation.[27]
- 28.8% of new Mexicans are obese and 22.6% physically inactive.[28]
- 46% of New Mexicans have a literacy level of 2 or lower, holding them back from participating in the 64% (and rising) percentage of jobs that require literacy beyond this level.[29]

Researchers at NMSU ACES, and colleagues in NMSU Cooperative Extension, are on the frontlines in terms of research focused on understanding these socio-economic and health challenges and developing actionable programs to effect positive change. As would be expected given the breadth and scope of these human challenges, the work undertaken at NMSU is similarly wide-ranging. Some examples, below, help to illustrate just some of the diversity of research work taking place:

Table 19: Examples of Impacts on New Mexico Families, Youth, and Health

Bed Bugs	Since 2004 there has been a rather dramatic rise in bed bug infestations across the U.S. and these infestations show a relationship with people living in poverty. It has been hypothesized that both a reduction in pesticide use and an increase in bed bugs demonstrating resistance to common pesticides are contributing to the challenge. Entomology research at NMSU ACES has been focusing on multiple questions pertaining to bedbugs, including: bed bugs as an incubating vector for Chagas Disease; pesticide resistance, bed bug behavior in terms of host seeking, and identifying effective non-chemical controls for bed bugs. Bed bug research is part of broader NMSU ACES entomology research focus on tackling urban pests. New research in the development of insect chemical attractants and repellants is being facilitated by recent investment by ACES in an electroantennogram which can assist in the study of insect response to odors, pheromones or environmental chemical signals.

[23] Battelle Memorial Institute, Technology Partnership Practice. 2015. "Analysis of the Value of Family & Consumer Sciences Extension in the North Central Region." http://www.nccea.org/app/download/7241418760/Battelle_FCS_Executive_Summary_11-2015.pdf
[24] Trust for America's Health. "Key Health Data About New Mexico." http://healthyamericans.org/states/?stateid=NM
[25] Nicole Knight Shine. 2016. "Report: Child Poverty Rate Highest in New Mexico." New Mexico Voices for Children. https://www.nmvoices.org/archives/6332
[26] Rick Nathanson. 2017. "New Mexico now worst in nation for child poverty." Albuquerque Journal. September 19th, 2017. https://www.abqjournal.com/1065961/nm-overtakes-mississippi-as-state-with-most-children-in-poverty.html
[27] Trust for America's Health. Op.Cit.
[28] Ibid
[29] New Mexico Coalition for Literacy. "Where New Mexico Stands in Terms of Literacy Skills." https://newmexicoliteracy.org/literacy-facts/

Nutrition	Within the NMSU Department of Family and Consumer Sciences (FCS), the program in Human Nutrition and Dietetic Sciences performs research on dietary choices, diet quality and its implications for chronic disease development and obesity. Research is multidisciplinary, able to draw upon the expertise from other FCS faculty in Family and Child Sciences, Family and Consumer Sciences Education and Food Science and Technology to research ways to improve diet and educate individuals and families in making healthy dietary and lifestyle choices. Work in this regard integrates with the SNAP-Ed work of ICAN under Extension.
Novel Food Safety research	Crossing college boundaries at NMSU, and using NMSU IMPACT funds to support the work, ACES faculty and faculty in the Department of Chemistry have been performing collaborative research into the development of novel detection systems for foodborne pathogens. Current levels of detection are problematic, requiring a number of pathogens to be grown in culture over days in order for detection to occur (and at that point food may be reaching market or beginning to spoil in storage awaiting shipment. Faster detection is needed. The NMSU research is working towards a real-time detection system using a system that would allow a food inspector to take a sample, insert it into a device and get immediate results. While NMSU's research in this area is still relatively recent, success is occurring with systems in the prototype development stage and applications for patent protection are being considered.

V. THE ECONOMIC AND FUNCTIONAL IMPACTS OF NMSU COOPERATIVE EXTENSION SERVICE

A. The Importance of Research-Based Information

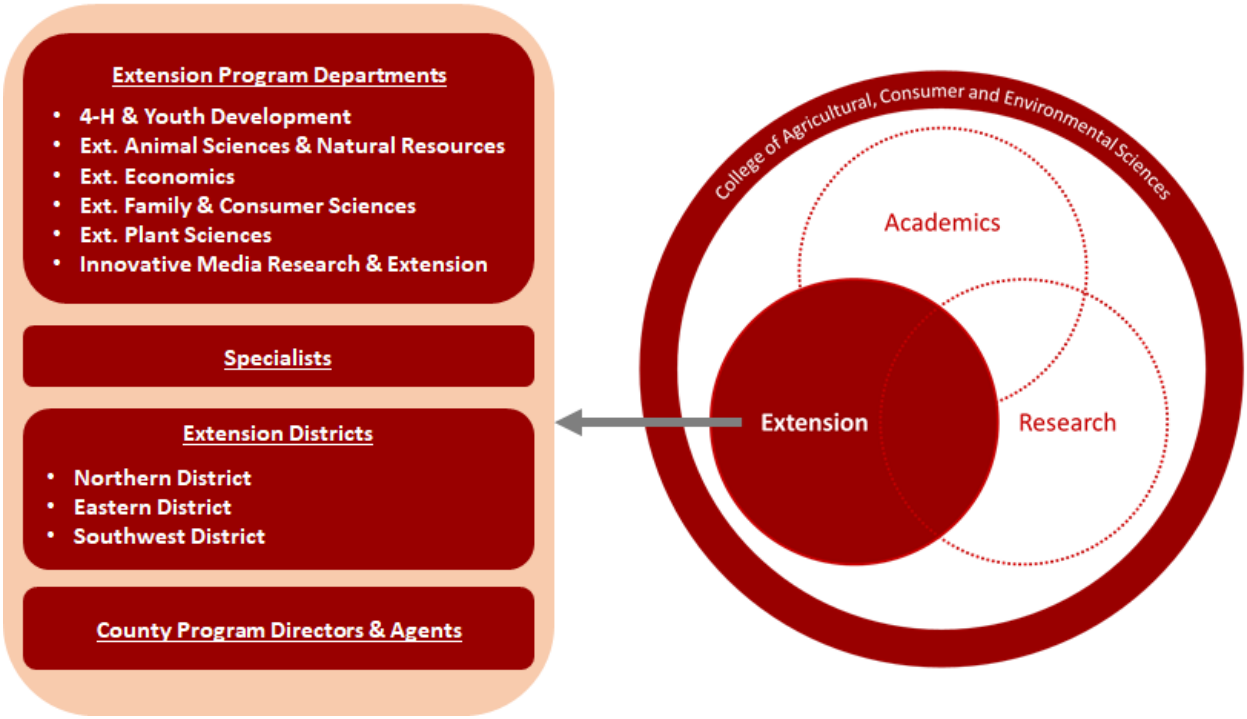
We live in an increasingly complex world. The ongoing proliferation of technologies, products, innovations, information and recommendations from a multiplicity of sources provides an overwhelming set of options and opportunities to choose from. Making rational decisions against a background of overwhelming choice is no easy task. This modern challenge is complicated further by the sheer amount of unvetted and unmoderated "information" contained online. Rife with misinformation, disinformation, biased marketing messaging, opinions of self-professed "experts", and pushing of vested interests, we each face the challenge of sorting through what is true, truly useful and actual "knowledge". How do we know what is real, reliable, trustworthy, and best suited to our needs and applications?

For agricultural and natural resource industry professionals, rural and urban communities, families and individuals a well-proven solution to the "reliability of information challenge" is Cooperative Extension. Since 1914, New Mexico has benefited from Cooperative Extension Service as a trusted, research-driven, reliable knowledge resource. In today's knowledge-driven economy, Cooperative Extension's value as an independent provider of scientifically-assessed valid solutions is perhaps as relevant and necessary as it has ever been. Via education events and field days, one-on-one consultations, publications and research-bulletins, advisories and published practice recommendations (available on paper and via Extension's web presence), Cooperative Extension Service provides a truly trusted source of knowledge, know-how and research-based solutions to challenges.

ACES Cooperative Extension serves as a gateway to the research and associated subject matter expertise discussed in the previous chapter, and also as a moderator and aggregator of best-practices. It also serves a hands-on role, working in the field to evaluate on the ground issues and needs as requested by New Mexicans, and Extension is highly proactive in terms of initiating educational events, workshops and field days across the state to highlight best-practices, modern methods, and practical solutions to producer, community and family challenges.

Cooperative Extension delivers its programs and activities through the system structure shown on Figure 14. There are three Extension Districts in the state that serve a coordinating role to assure work is focused on the distinctive needs of each region, and there is the front-line of Extension located at the county level, with county program directors and agents available to meet the specific local needs. This system of County Extension Agents is backed-up by Extension Specialists – faculty at ACES who have specific subject matter expertise and, therefore, an ability to dive deeply into identification of the best practice and solutions for specific challenges and questions. The specialists are organized under respective Extension Program Departments which have broad alignment with academic departments within ACES and access to the faculty in those departments. The Extension Program Departments include: 4-H and Youth Development; Extension Animal Sciences and Natural Resources; Extension Economics; Extension Family and Consumer Sciences; Extension Plant Sciences, and Innovative Media Research & Extension Department.

Figure 14: The Structure and Organization of NMSU Cooperative Extension



B. The Functional Impacts of Extension

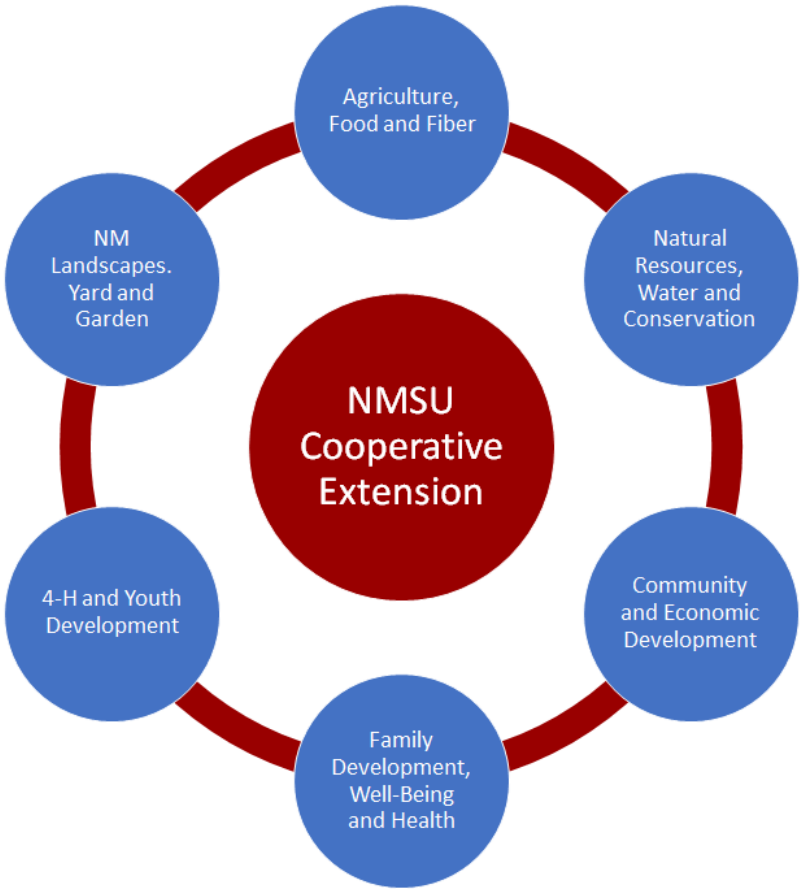
The USDA's National Institute for Food and Agriculture (NIFA) provides a good topline summary of the function of Extension, noting that:

> *Extension provides non-formal education and learning activities to people throughout the country – to farmers and other residents of rural communities as well as to people living in urban areas. It emphasizes taking knowledge gained through research and education and bringing it directly to the people to create positive changes.*[30]

While this provides a very general description of the function of Extension, it does not do justice to the full scope and scale of NMSU Extension activities – which are both extensive and intensive. In 2016 NMSU Extension programming reached over 600,000 individual stakeholders across the state, including over 45,000 individual youth. Extension conducted over 400 events across New Mexico in 2016 and developed 120 publications. To provide illustration of the range and scope of functional benefits for New Mexico and New Mexicans provided by Extension, summaries and examples of Extension work are provided herein, grouped by the following impact themes (Figure 15):

[30] National Institute for Food and Agriculture. https://nifa.usda.gov/extension

Figure 15: Functional Impacts Themes of NMSU Extension



1. EXTENSION: Agriculture, Food and Fiber

As noted in Chapter I, agriculture and its downstream value-added processing industries (such as food processing) represent a significant component of the New Mexico economy. These industries, together, are responsible for supporting almost 51,000 jobs statewide and generate 12.3% ($10.6 billion) of NM's gross state product (2012 data).

What is critically important to understand is that much of this production occurs outside, in a natural environment. Sustaining productivity and output increases in agriculture is an ongoing challenge given the unique characteristics of the industry and its operational environment. Farming and ranching in New Mexico comprise 24,700 individual farm/ranch operations.[31] The sector thus comprises thousands of small and midsize business enterprises that have to work in a uniquely variable and challenging production environment. Indeed, New Mexico represents a particularly challenging environment, especially in regard to access to water resources and the fragile nature of its semi-arid production environments.

Farmers and ranchers in New Mexico have to make a large-number of decisions each year than can make-or-break their profitability. It is fair to say that no other category of business faces such a variable

[31] 2017 State Agricultural Overview for New Mexico. USDA NASS. Accessed online at: https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NEW%20MEXICO

and risky series of decisions that must be made and repeated each year. Examples of just some of the questions that producers must address are noted in a report for USDA NIFA[32] and are shown on Figure 16.

Figure 16: Annual Farm and Ranch Decision Making in a Complex Variable Environment

As small and midsize enterprises, the majority of New Mexico's farms and ranches must seek the answers to these and other crucial questions from outside parties. As noted in Chapter IV, producers do not have the budgets or time to conduct their own research, experiments, and investigations of best practices. Similarly, the complexity of modern life sciences, technological innovations, and the research literature covering these, is such that it takes specialized (often scientific) knowledge to convert the findings of research into practical use. Recognizing these facts helps to bring clearly into focus the importance to farmers, ranchers and others in the food and fiber value-chain, of having the NMSU ACES Cooperative Extension Service to turn to for reliable advice, recommendations and verified information.

[32] Tripp S., et al. 2017. "National Evaluation of Capacity Programs." TEConomy Partners, LLC. Prepared for the National Institute of Food and Agriculture (NIFA)

Cooperative Extension Service provides a known and trusted access point to NMSU professionals who can provide advice and pragmatic solutions to production and other challenges.

Discussing every project and program undertaken by Cooperative Extension Service for New Mexico farmers and ranchers would lead to an excessively long report. Rather than providing a laundry list of activities, a series of examples are presented herein as case studies illustrative of the high impact work of Cooperative Extension Service in support of agricultural production.

a. Examples of NMSU Extension Support for the Ranching and Dairy Industry

Table 20: Examples of Extension Impacts in the Ranching and Dairy Industries

Trichomoniasis Control	Trichomoniasis is a venereal disease of cattle that can cause producers major losses by causing infertility, low pregnancy rates, an extended calving season, and occasional abortions in pregnant cows. It can be a costly challenge to eradicate from a herd. In 2005, Trichomoniasis became reportable in New Mexico due to a break-out of the disease in the north-central region of the state. The NM State Veterinarian asked Extension to lead development of a Trichomoniasis control education program to raise awareness of the disease, promote testing and teach control measures. Initiated in 2006 the extension work has helped reduce disease incidence to the point that only 1.5% of 16,000 bulls tested positive for the diseases in 2017. **Reducing the burden of this disease is a critically important contribution by Extension to the NM ranching industry.** Impact analysis shows the following negatives associated with the disease: • Trichomoniasis positive ranches in NM experienced a 37% drop in weaned calves when the disease is present • Conception rates dropped from 90.5% in disease free ranches, to 64.5% in ranches exposed to the disease • Trichomoniasis impacts were found to cost $400 per cow (in terms of overall negative economic impact) in tested livestock enterprises.
High Certified Calf Program	Cooperative Extension Service provides a third-party verification program for calf vaccination, weaning programs, and adherence to Beef Quality Assurance practices. The program helps NM ranchers secure premium prices for their calves at market. ACES calculated that **if just 10% of the 610,000 NM calves marketed in 2017 were in the ACES High Certified Calf Program the premiums achieved would result in approximately $4.3 million in new revenue increase for the producers (an average value increase of $70.49 per calf).**
U.S. Dairy Education and Training Consortium	Modern dairies are intensive and sophisticated operations requiring skilled operational and management staff. Cooperative Extension Service has been responsive to the demand for trained personnel to staff the industry, leading a consortium of universities in delivering a capstone six-week practical dairy summer course in Clovis (developed and delivered in collaboration with area dairies). **Over its now 10-years of operations, the summer course has taught 427 students. Tracking of students now shows that fully 4 out of 5 graduates of the course received employment in agriculture and 2 out of 3 were employed in the dairy industry.**
Nutrient Management.	Intensive animal agriculture generates large-scale volumes of manure. The New Mexico dairy industry is home to 325,000 cows, producing over 6.8 million tons of

	manure annually (equivalent to each dairy cow producing 20.9 tons of manure annually). The manure produced by the industry contains nutrients useful to improving agricultural soils and so most of the manure is applied, together with wastewater, to farm fields in New Mexico. An environmental challenge is created, however, when nutrients from the manure applications leach into and pollute groundwater – and this is a challenge for New Mexico where approximately two-thirds of the groundwater-monitoring wells located near dairies have been exceeding the 10ppm nitrate-nitrogen state standard limit. When limits are exceeded dairy operators are mandated to use expensive remediation technology costing circa $32,000 per acre-inch of water. Cooperative Extension is helping alleviate the problem by providing dairy operators and dairy consultants with soil test software that helps optimize manure application within allowable limits. By having this Extension resource, dairies are now able to avoid the extremely high costs that would be incurred were they to be required to perform remediation. Data from California, at the upper limits of remediation cost, show that water treatment for a 2000 cow dairy, treating 112 acre-inches of water could cost up to $43 million per year.

b. Examples of NMSU Extension Support for New Mexico Crop Production

Table 21: Examples of Extension Impacts in New Mexico Crop Production

Agronomy Consultations and Advising	**Example 1:** Extension provides a valuable service in helping farmers through agronomy consultations that help farmers select the best crop species and variety for their production environment, fine-tune their fertilizer and agro-chemical inputs, and optimize their use of water resources. Research at NMSU indicates that in just one crop (hay), university-developed recommendations can save producers $100 per acre. Extension, working with farmers, is translating the research into tangible productivity gains and costs savings for producers. The potential benefits of this work are large scale when translated across the production industry in the state. New Mexico produces 1.2 million tons of hay and 2.4 million tons of silage, with a combined value exceeding $365 million per year. **Overall, impact estimations show implementation of these Extension solutions for hay and silage production having the potential to exceed $35 million annually for the state agriculture sector.** **Example 2:** Another example of Extension agronomy consultation in action is working to improve sustainable farming techniques in northern New Mexico. The northern area region of the state has a short growing season that is difficult to extend due to low temperatures. Greenhouses would be one solution but tend to be prohibitively expensive for the predominantly small-scale farmers in the region. Extension has been demonstrating the feasibility of using hoop houses and/or high tunnels as an alternative to expensive greenhouses – enabling producers to have an extended growing season for high value cash crops. NMSU Extension has now helped over 1400 New Mexico producers introduce hoop houses and high tunnel systems on their farms – helping these small producers increase their crop production and annual income.

Plant Diagnostic Clinic and Extension Plant Pathology	**Example 1:** Getting an early and accurate diagnosis of plant pathogens or stresses is critically to avoid losses and maximize yields across New Mexico. Cooperative Extension Agents are the frontline "troops" working with producers to identify plant diseases and other stresses impacting crops, backed up by Extension specialists in plant pathology, and the Plant Diagnostic Clinic at NMSU. Samples tested at the Diagnostic Clinic that are sent via Extension Agents are analyzed free of charge for producers. This Extension/Diagnostic Clinic system is in constant use, providing over 2000 diagnoses annually. The system is also on the frontlines in making sure new diseases are identified and rapidly addressed – which is a very real threat given, on average, the Clinic finds and identifies 5 new diseases each year. **Example 2:** Early identification of abiotic and biotic issues in crops is also a biosecurity issue. Cooperative Extension makes a substantial commitment to making sure producers and other frontline agriculture professionals across the state are educated and trained to be "first detectors." Reaching over 1,600 persons annually, the Extension first detector training has now provided training to over 16,000 New Mexicans and certified over 4200 personnel. The Cooperative Extension website is also a key resource for those with questions on plant diseases and other biotic and abiotic stresses impacting crops. Disease fact sheets covering a variety of crops and diseases are included on the website, together with other publications and information resources to quickly equip producers to recognize problems and consider solutions.
Introducing Improved Crops for NM production	**Example 1:** As noted above, the selection of the optimal crop variety to plant for a given field and anticipated field-conditions is one of the most important decisions a farmer makes each growing season. With considerable choices of varieties and cultivars on the market, the decision has the potential to be overwhelming without the coordinated testing and advisory services provided by NMSU Experiment Station testing and the Extension service consultation system. NMSU performs crop variety testing across a range of critically important crops for New Mexico agriculture, including for example alfalfa, corn, cotton, sorghum, and wheat. University performed variety trials have been identifying varieties with an average 25% performance gain versus trial mean varieties, and Extension Agents and Specialists are then able to carry these results to benefit farmers across the state. **The estimated economic impact benefit of adopting the recommended varieties, based on ACES variety trials, is $115 million annually.** **Example 2:** ACES is not only testing crop varieties but is also actively engaged in research and breeding programs to improve crops. An important crop for New Mexico that has been the focus on ACES research is pecans, which represent an expanding crop for New Mexico (with the state now producing 27% of U.S. pecan output). ACES maintains a proactive Extension program in support of pecan production, including having a dedicated pecan specialist. Combining research and Extension activity, ACES is working to improve root stocks of existing cultivars for NM production and is using genetic tools (under a USDA specialty crop grant) to improve pecans. **Example 3:** Glandless cottonseeds bring a significant price premium in the market. Extension has been proactive in reaching out to cotton growers in New

	Mexico to provide education regarding the agronomic and management practices required for successful cultivation of a glandless cotton crop. Post-educational surveying of producers shows that 90% of producers gained appropriate knowledge to be successful cultivating the crop after their Extension education participation. While still new, and an emerging market, since 2015 glandless cotton has been produced on over 100 acres in the state, receiving a price of $800 per ton of cottonseeds versus just $250 per ton for conventional varieties.
Controlling Weeds and Pests	Weeds and pests are an ongoing challenge for farmers. According to the USDA, pests, crop diseases, and post-harvest losses reduce crop yields by 20-25% each year in the United States.[33] At ACES Extension and research work hand-in-hand to find and introduce and optimize Integrated Pest Management (IPM) processes protocols and recommendations for New Mexico farmers. Some examples, below, serve to illustrate just some of the range of projects that Cooperative Extension is engaged in: **Example 1:** Alfalfa is the largest crop (in terms of total cash receipts) grown in New Mexico, producing annual gross income for farmers of circa $158 million per year. Alfalfa weevils are one of the most significant insect pests in alfalfa in New Mexico, with Cooperative Extension noting that "each year, producers report significant economic losses due to this pest, particularly on first cuts."[34] Biological Control methods have been developed as an alternative to chemical pesticides and have been successfully used and well-proven by ACES in control of alfalfa weevil over many years of trials. Similarly, biological control is being found to be effective for pests impacting sorghum and pecans in New Mexico**. NMSU calculations show the developed biological control system in alfalfa saving growers over $2 million per year. Replicating these results across alfalfa, sorghum and pecans are estimated to save growers up to $6.5 million statewide**. Extension Weed Control has also been working in alfalfa to find solutions to infestations of late-season perennial weeds. Such weeds are quite difficult to control with current management options lowering forage quality and yield and making the crop more susceptible to disease and insect damage. Extension has been engaged in evaluating various herbicides and combinations of active ingredients to help growers better manage difficult-to-control weeds in alfalfa (such as broadleaf and buckhorn plantain). **Example 2:** Pesticides are an important tool for farmers in protecting their crops and sustaining competitive yield. However, they must be used carefully to avoid spill-over environmental impacts and applied in a manner that assures no adverse health effects for workers performing the applications. NMSU Extension's Pesticide Safety Education Program teaches the correct and safe use of pesticides through educational resources and training**. Covering a broad range of topics on human safety and environmental issues, the Extension program reaches over**

[33] United States Department of Agriculture, National Institute of Food and Agriculture. 2015. "Global scientists meet for integrated pest management idea sharing." https://nifa.usda.gov/blog/global-scientists-meet-integrated-pest-management-idea-sharing

[34] Jane Breen Pierce and Mark Marsalis. "Alfalfa Weevil Control Options in New Mexico." NMSU Cooperative Extension Service, Guide A-338. http://aces.nmsu.edu/pubs/_a/A338.pdf

	500 individuals each year (350 for recertification and 150 new license holders). Pesticide applicators earn an average salary in New Mexico of $34,570 – with each year of recertification/new certification supporting personnel with a total of $17.3 million in annual wages. **Example 3:** New Mexico's rangeland supports the large ranching industry in the state. Natural rangeland is, however, subject to the pressures of invasive brush and weeds that reduce the quantity of forage available and thus the carrying capacity of the land. Cooperative Extension operates a Rangeland Brush and weed Management Program focused on giving ranchers and land managers the knowledge and training they need to take appropriate control measures. In 2017 the program performed 500 teaching events reaching 500 people across New Mexico.
Vegetable and Fruit Production	**Example 1:** Vegetables are an important crop for New Mexico and can be an enabling crop in meeting the high value farm-to-table and local food sectors of the market. NMSU Extension has been providing vegetable production training events that have seen strong demand and good results in terms of 87% of participants responding to follow-up surveys noting that the training led to them producing more vegetables. Data provided by participants growing tomatoes as a result of their training showed an increase in local production by: 5,250 lbs. in Bernalillo County; 1,980 lbs. in Sandoval; 1,860 lbs. in Taos; 1,110 lbs. in Chaves; 1,830 lbs. in Grants; 1,650 lbs. in Los Alamos, and 4,290 lbs. in Valencia County. Overall, only counting surveyed counties, the vegetable production training resulted in 17,970 additional pounds of locally grown tomatoes in the state. **Example 2:** Chiles are an iconic and culturally important crop for New Mexico, and also feed into a value chain that includes downstream chile processing plants in the state. A key challenge for production is the need for hand-labor to harvest chiles, and competition from cheaper labor producers in Mexico has made it harder for New Mexico producers to compete. Cooperative Extension sees development of mechanicalized harvesting as a solution to regrow the industry and is doing work not only in the testing of potentially suitable equipment and equipment use procedures but is also taking the novel approach of using ACES chile breeding expertise to breed green chile cultivars that will be particularly well suited to mechanized harvesting. The potential impact for New Mexico producers is likely to be highly significant. Extension notes that **if only 10% of green chile acreage lost since peak production is returned to production as a result of mechanization, $19 million in additional state crop receipts would be generated annually.** **Example 3:** Cooperative Extension is also working to bring new fruit and vegetable crops to New Mexico that are suited to the state's challenging production environment. One of the new crops starting to gain traction is jujube. ACES has been testing varieties and developing recommendations to help producers avoid late-frost damage. Extension has held workshops, field days and promoted publications that are gaining momentum for this new product in New Mexico. There are now 10 commercial fruit growers that have established jujube production, and hundreds of home gardeners have planted jujube trees as a source of home grown fruit.

Soils	The arid soils of the western United States are a valuable but fragile resource. Cooperative Extension promotes understanding of statewide soil characteristics and best-practices for soil conservation and improvement. One of the unique assets of the Cooperative Extension is the Innovative Media Research and Extension Department which is nationally recognized for excellence in the development of multimedia education and training materials optimized for the multiple audiences Extension has to reach. The Innovative Media Research and Extension Department has developed a special program called "Understanding Western Soils" which provides educational animations and video content focused on key western soil properties and techniques for sampling and testing arid western soils. A series of 15 videos highlight topics of concern to Western producers. **Extension reports that survey results from viewers showed 60% reporting a 75-100% knowledge increase and 40% reported a 25-50% knowledge increase. NMSU Extension has now made the video content from the program available over YouTube with the result that videos have been viewed more than 32,000 times.**

c. NMSU Extension Support in Economics and Agricultural Business Management

Table 22: Example of Extension Impacts in Economics and Agricultural Business Management

Rural Agricultural Improvement and Public Affairs Project (RAIPAP)	New Mexico has several defining historic, cultural, political and socio-economic characteristics that influence its agriculture. The large presence of federal public lands, for example, makes for ranching and farming dynamics that are different in NM versus other agricultural states. In New Mexico 34.7% of total state land acreage is in federal government ownership, compared to just 1.8% in Texas, 1.6% in Oklahoma, 0.6% in Kansas and 0.3% in Iowa for example.[35] Also, the Native American heritage and population of New Mexico brings traditions in Pueblo and tribal cultures that influence agricultural practices and land use. New Mexico also has many farms that are extremely small in comparison to national averages – although this fact is masked in USDA statistics due to the very large size of ranches for cattle grazing in the state. The Sustainable Agriculture Science Center at Alcalde notes that the average size of farms they work with is just 3 acres. Unlike most states, the number of farms is increasing in New Mexico – but it is because of cultural practices whereby farmers may divide their land between their heirs. The Extension RAIPAP program is an organizational and programmatic response to these unique, defining characteristics of the NM agricultural environment. It brings ACES expertise to bear in training beginning farmers and ranchers – providing guidance in production, marketing, management and financing. It works with tribes and pueblos to achieve economic success for farmers while sustaining sensibilities to traditional practices and beliefs. The RAIPAP project covers 15 counties, predominantly in northern New Mexico, working to assure best practices for sustainable agriculture are utilized while respecting the unique cultural heritage of farming and ranching in the region.

[35] Jackie Icken. 2014. "From 0.3 to 81.1: What percentage of each state is owned by the federal government?" Deseret News.

	RAIPAP has trained over 160 Native American beginning farmers and ranchers within the northern and southern pueblos, thus increasing farm income and maintaining cultural values and tradition. RAIPAP also have assisted over 1400 New Mexico producers in building high tunnel/hoop house units and by extending the growing season, thus improving annual income through additional crop production.

2. EXTENSION: Natural Resources, Water and Conservation

Perhaps nothing is more important to the future of New Mexico as sustaining access to fresh water and assuring the long-term sustainability of New Mexico's scarce water resources. The majority of crops produced in the state require irrigation to achieve commercially viable yields and water availability represents the primary limiting factor in expanding agricultural production in the state.

NMSU ACES operates a multi-disciplinary Water Task Force comprising research, teaching and Extension faculty and scientists working together to use research and Extension expertise to respond to water resource issues and needs in New Mexico. The Water Task Force team has identified six important areas in which New Mexico's Water issues lie, including:

- Drought
- Hydrology
- Ecology
- Watershed Management
- Water Policy
- Conservation
- Water Quality

Through the coordination of the Water Task Force, NMSU develops and shares research information relating to specific water issues and promotes the optimal mediation of water use for the state of New Mexico. NMSU work in water is further advanced by the NMSU Agricultural Science Center at Farmington which has a long-standing track-record in irrigation research, testing and demonstration for both agricultural crops and landscape plants.

In water, and other areas such as wildfire management and wildlife assessments, NMSU Extension works with land owners, land managers and public officials across New Mexico to assure the states valuable land and natural resource assets are managed using research-based insights and knowledge.

Table 23: Examples of Extension Impacts in Natural Resources, Water and Conservation

Managing Water Quality	**Example 1:** Periodic rains, low flow streams, and other factors in New Mexico's semi-arid environment can lead to pollutants becoming more concentrated in water resources than they would in states with more favorable hydrologic conditions. With water crucial to human, livestock, wildlife and general ecosystem health, maintaining water quality is of extreme importance. Cooperative Extension has developed a range of programming, resource materials and events that reach out to diverse audiences across New Mexico – ranging across agricultural professionals and pesticide applications, Master Gardeners and the home gardeners they serve, and New Mexico children. The

	Extension Aquatic Ecology Specialist notes that persons being reached by these Extension programs who have been surveyed, confirm the effectiveness of the programming – with 94% reporting that they changed their attitudes toward personal practices than can conserve water quality. **Example 2:** NMSU Extension and Research faculty were first responders in evaluating and monitoring the impacts of the 2015 Gold King Mine spill into the Animas River. Because of the well-established and trusted relationship between NMSU faculty and the Navajo people, NMSU was able to sample farmland and irrigation ditches during the emergency response as EPA responders were being expelled. Data from these samples is showing that heavy metals like lead are below regulatory limits and outreach is helping producers to have confidence in resuming their farming activities. In addition, the research data being generated is making huge contributions into the scientific body of knowledge regarding farm-land downstream of a legacy mining district.
Managing Water for Economic and Community Development	The ability to sustain economic and community growth in New Mexico has a limiting factor – scarce water resources. Growth in agriculture, industrial activity, residential developments, etc. each come with demand for water resources. The optimal management of water resources to support both long-term sustainability and economic and community growth is a multi-variate, complex challenge. ACES has been applying quantitative analysis and computer modeling and simulation expertise to develop information systems to support water resource decision making. This expertise has been extended to support public policy decisions in the state. An example of this in action was an assessment of the feasibility of additional water storage development in the Gila River Basin – showing that additional storage could increase community farm income across the region by 30%, with some sub-regions in the area able to increase incomes up to 900%. Similar work has been performed to evaluate irrigation capacity improvements for the Rio Grande and Canadian River basins. The tools and analysis enabled by this research are designed for use by various stakeholders across New Mexico in managing the states climate-stressed river and aquifer systems.
Turfgrass Water Management Practices	Maintaining turfgrass (for lawns, sports fields, gold courses, etc.) in arid and semi-arid environments requires the use of scarce water resources for regular irrigation. NMSU Extension's turfgrass program provides a range of resources and programming aimed at helping those with turfgrass optimize irrigation and avoid irrigation management practices that waste water to evaporation or run-off. Now Extension is going further with research that is examining novel chemical management strategies that may reduce water consumption in turfgrass applications. Chemicals being tested include plant growth regulators, surfactants and products that activate a plant's defense mechanisms by affecting stomata conductance. Turfgrass is challenged at varying drought levels using treated and untreated test plantings to assess the potential for successful irrigation water use reductions. The program has successfully demonstrated the water-conserving benefits of drip-irrigation for turfgrass areas. Data collected from a pilot project in Albuquerque indicated that the drip irrigated parks in Albuquerque used 30% less water, with no drop in visual appearance. Albuquerque hopes to install subsurface systems in other parks in 3 to 5 years, which could save up to $1 Million annually in water costs

Benefits of Prescribed Fire	Recent wildfires across the western states have all too visibly shown the dangers of allowing brush wood, scrub, forest understory and other highly flammable biomass to build-up. Past management practices allowed the build-up of this biomass by deliberately excluding fire from the landscape – when in fact it is a natural "control agent" if allowed to occur and keep biomass from accumulating to levels leading to catastrophic large wildfires. Today in New Mexico's forests and other landscapes, large and severe fires are a very real threat to lives, to property, wildlife, ecosystems and the health of watersheds. NMSU Extension is providing training for landowners in the use of controlled "prescribed" fire – designed to reduce the build-up of dangerous levels of fuel. The Extension work has started to gain traction, within the past three years, 500 acres of land have been appropriately managed with prescribed fires. The professional training, and the skills and knowledge provided by Extension is critically important to assure prescribed fires are used appropriately and that unintended fire damage is avoided. Post-program surveying by Extension has shown good results for the training, with 87% of participants demonstrating improved knowledge and skills, and 98% reporting that they intend to pursue additional burning opportunities on their land.

3. EXTENSION: Community and Economic Development

Cooperative Extension is highly active in work to plan, promote and support economic and community development in New Mexico. Work addresses development in both urban and rural areas of the state and is highly interdisciplinary – bringing together ACES researchers and Extension Specialists expertise in economics, business planning, value-added food products, education, governance and public policy. Much of the work in these areas is coordinated by the Community Resources and Economic Development Program under NMSU Cooperative Extension which deploys research-based knowledge and information, education programs and professional training programs to empower community and economic development leaders to achieve positive results on the ground. Examples of several key areas of Extension work in these areas are provided below:

Table 24: Examples of Extension Impacts in Community and Economic Development

New Mexico EDGE	The NMSU Cooperative Extension "NM EDGE" program focuses on the education and training of public and elected officials in best practice administrative, management and professional processes and strategies. EDGE stands for "**E**ducation **D**esigned to **G**enerate **E**xcellence" for the public sector. Through NM EDGE, NMSU Extension acts as an umbrella organization to manage and deliver the County College (founded with the NM Association of Counties), the NM Certified Public Manager® Program, and other continuing education certification programs. The program has been proactive in establishing curriculum committees that help Cooperative Extension identify knowledge and education gaps across the public administration sphere. NMSU faculty and Extension professionals are then able to design the custom curricula needed for imparting best practice knowledge and skills to fill the gaps. Cooperative Extension also operates an active program in local government finance advising and support. Training and education provided for persons in

	pubic financial administration positions in counties, cities, and towns throughout New Mexico.
Entrepreneurship and Entrepreneurial development	Cooperative Extension has been particularly focused on filling an identified need for rural entrepreneurship, serving the 22.6%[36] of New Mexican's classified as residing in rural areas. A key focus on Extension work in this regard is focused on developing resources and tools that support the successful work of rural economic development practitioners – helping practitioners understand best practices and what works in terms of providing support services for rural entrepreneurs and start-up business enterprise.
Helping Small Farms with Value-Added Opportunities	Small farms can have a challenging time sustaining profitability if only supplying into large, price constrained commodity markets. Without economies-of-scale in production, smaller farms are at a disadvantage. Cooperative Extension works actively with small farm producers to examine alternative crop opportunities, niche market opportunities (such as farmer's markets, local food opportunities, etc.) and to help with advice regarding value-added food production and other entrepreneurial endeavors on the farm. The Extension Small Farms Program looks for opportunities for adding value to farm commodities in diverse ways, including for example: organic and specialty markets, direct marketing of products, community supported agriculture, and agri-tourism.
Rural Education Support	As discussed in the next chapter, the education and skills of human capital are the most significant assets for communities, regions and states seeking to compete in the highly competitive global knowledge-economy. Sustaining high quality education is crucial for rural areas to participate in the modern economy, providing opportunities for personal advancement and the talent needed to grow and sustain local economies. Cooperative Extension runs the Rural Education Program that seeks to bring the deep expertise of the university in education and the community and family expertise of Extension to build robust and productive connections and relationships between schools, parents, students and communities.
Stronger Economies Together and Strategic Planning	The Stronger Economies Together (SET) program has been developed by the USDA Rural Development program. SET operates with Land-Grant universities in each state, and in New Mexico, Cooperative Extension leads the work. The aim of the program is to significantly enhance rural economic development through professionally developed strategic plans at a regional (multi-county) level – bringing together resources to achieve projects at a significant and effective scale. In New Mexico the work of Extension has established nine SET regions to undertake the strategic plan development work (with 32 of New Mexico's 33 counties included). Alongside the SET program, Cooperative Extension's expertise in strategic planning is also made available to individual communities and other groups throughout the state. Extension provides assistance with community visioning, strategy and action development rooted in identified best-practices, and strategy implementation assistance. As communities work on their plans, Extension

[36] University of New Mexico. Bureau of Economic Research. 2016. "How Rural is New Mexico." https://bber.unm.edu/blog/?p=364

	support is available to assist with asset mapping, data analysis, and the gathering of community input and surveys.
Supporting the Growth of New Mexico Food Processing	Agriculture is a traded industry, building wealth and exports for New Mexico. While the primary production of livestock and crops from ranching and farming are fundamental and of considerable value to the New Mexico economy, their value to the economy and economic development can be expanded through downstream value-added processing industries. Value-added industries in cheese and chile processing show the benefits to New Mexico jobs and income generation, and NMSU Extension is active in providing support for increased value-adding opportunities. Extension has developed, for example, the New Mexico Food Industry Resource Guide providing guidance to entrepreneurs and new business developers seeking to start food processing ventures. The guide provides education and guidance in multiple core areas of activity, including: regulations for the industry; good manufacturing practices; building a food processing facility, and packaging. Extension also provides marketing information and advice to assist with the promotion of value-added food products. Cooperative Extension also supports the existing food processing industry with continuing education and training programs covering processing technologies and procedures. An example of this is the Better Processes Control School for Acidified Foods, a certification course for managers and supervisors of food processing operations for low-acid and acidified canned foods.
Southwest Border Food Protection and Emergency Preparedness Center (SWBFPEPC)	Protecting our food supply and keeping the foods we consume safe is critically important work. The Centers for Disease Control (CDC) reports that each year roughly 48 million people get sick from a foodborne illness, 128,000 are hospitalized, and 3,000 die.[37] The SWBFPEPC is an Extension/New Mexico Department of Agriculture program that is engaged in food protection, food safety and food defense/security. The program helps protect the national and New Mexican agricultural industry and food supply against multiple threats such as foodborne pathogens, agro-terrorism or supply chain disruption events. The SWBFPEPC is proactive in providing training to agricultural producers, first responders, public health officials and others on the frontlines in securing a safe and secure agricultural value chain. The program also maintains stocked emergency response trailers around the state for rapid response to events that may arise.

4. EXTENSION: Family Development, Well-Being, and Health

Extension faculty at ACES are engaged in both research and education focused on helping individuals, families, and communities reach their full potential. Extension's family and consumer science programs are pragmatic and proactive, focused on achieving tangible results for families and individuals, with an active focus on nutrition, physical activity, health and well-being, human development, and personal financial management.

[37] Centers for Disease Control and Prevention. "Foodborne Illnesses and Germs." http://www.cdc.gov/foodsafety/foodborne-germs.html

Table 25: Examples of Extension Impacts in Family Development, Well-Being and Health

Interventions for Chronic Conditions	The management of chronic disease conditions in New Mexico represents a substantial challenge to state finances and the economy moving forward. The Partnership to Fight Chronic Diseases notes that 1.2 million people in New Mexico had at least one chronic disease in 2015 and 490,000 had two or more chronic diseases.[38] The financial cost of chronic disease treatment and associated lost labor productivity is projected to average $5.1 billion per year in New Mexico. Following current trends, chronic disease and lost productivity is expected to cost New Mexico $8,300 per resident by 2030. NMSU Extension, recognizing the challenge, has multiple programs and initiatives aimed at promoting research-based interventions at a community level. Extension, supported by funding from the NM Department of Health, works statewide to increase access and adoption of chronic disease self-management programs. In addition, NMSU Extension is using community workshops to "train the trainers." For 2018 Cooperative Extension has reintroduced the well-proven National Diabetes Prevention Program (NDPP) to the state. Under the program, Extension will be seeking to help people with this chronic condition improve their weight loss, nutrition and physical exercise levels. With research showing that people with prediabetes taking part in such structured programs can reduce their risk of developing diabetes by 58**%, the program has the potential to help significantly reduce both the life challenges associated with this chronic condition and society and the state reduce the financial burden of the disease (estimated at $2 billion annually).** NMSU Extension also works with diabetics and their families to teach healthy cooking skills. Partnering with the NM Department of Health and 21 other organizations, Extension has conducted cooking schools that so far have had 470 participants, with 79% of participants reporting that they are following three or more of the major recommended eating practices covered by the program. A contributing and exacerbating factor in chronic conditions is stress. Managing Stress and Building Resiliency is a program developed by Cooperative Extension that has so far been delivered to 1,000 New Mexicans. Evaluations show participants demonstrated significant increases in knowledge, skills, and motivation to better handle stress.
Helping New Mexicans Manage Debt	Excessive debt and inadequate debt management skills can be an extreme form of hardship for families and individuals. Plus, many people with poor or no health insurance can see just one trauma or disease push them into a difficult debt situation. Cooperative Extension's Debt Elimination Program focuses on helping individuals and families appropriately manage their spending, reverse their debt trajectory, and start the process of paying-down their debt. Impact assessment conducted by Extension saw fully 100% of participants improving their skills, knowledge and attitudes regarding debt reduction and elimination, with 93% focusing on eliminating their debt as soon as possible.

[38] Partnership to Fight Chronic Diseases. "What is the impact of chronic disease on New Mexico?" https://www.fightchronicdisease.org/sites/default/files/download/PFCD_NM_FactSheet_FINAL1.pdf

ICAN, New Mexico's Snap-Ed Program	The Supplemental Nutrition Assistance Program (SNAP), (formerly known as the Food Stamp Program) is the nation's largest anti-hunger program and a cornerstone of the nation's support for individuals and families with limited financial resources. To help SNAP recipients make informed, healthy choices, the federal government includes funding for the Supplemental Nutrition Assistance Program – Education (SNAP-Ed). SNAP-Ed is a research-based federal nutrition education and obesity prevention program that is frequently delivered by experts at Land-Grant universities. In New Mexico SNAP-Ed is delivered through NMSU Extension and its ICAN (Ideas for Cooking and Nutrition) program. ICAN in NM reaches over 80,000 families annually – providing classes, face-to-face nutrition education, coaching on healthy lifestyles and a range of development initiatives such as community gardens and healthy food in schools. Evaluations show that **84% of ICAN participants eat healthier after their ICAN education, providing a pathway to healthier and more productive lives for New Mexicans and reduced healthcare costs for New Mexico. ICAN operates in 23 counties across New Mexico, providing approximately 40 job opportunities to local citizens, and contributing $1.7 million to the state's economy in salary and benefits.**

The Functional Economic Impact of NMSU Extension Work to Enhance the Health of New Mexicans

The work of Cooperative Extension Service in assisting people with the management of chronic diseases, prevention of obesity and poor-nutrition related effects on health, helping to improve physical activity levels, and other related work reaches tens of thousands of participants across the state each year. As noted above, the ICAN program alone serves, on average, over 80,000 families annually. Improving the health of new Mexicans has an obvious benefit for the quality of life of people across the state, but it also generates tangible savings in terms of reducing healthcare costs.

To illustrate the potential impact of healthcare improvement, TEConomy used input/output analysis to model the economic effect on New Mexico of a reduction in several diseases and health disorders associated with diet and exercise. The scenario modeled estimates the impact of a 1 percent decrease in the total number of hospital inpatient visits for 25 selected conditions related to diet and exercise and derives a dollar savings estimated from data on the mean cost of visits. Data are derived from state statistics from HCUP State Inpatient Databases [2014], recorded by the Agency for Healthcare Research and Quality (AHRQ).

Based on the analysis, TEConomy finds that a 1 percent decrease in hospital inpatient stays in New Mexico (for diseases that are associated with poor diet and/or lack of exercise) would result in $3.32 million in cost savings in the state.

5. EXTENSION: 4-H and Youth Development

4-H is delivered by Cooperative Extension, providing education and development programs where young people learn by doing. As noted by the national 4-H organization:

> *Kids complete hands-on projects in areas like health, science, agriculture and citizenship, in a positive environment where they receive guidance from adult mentors and are encouraged to*

> *take on proactive leadership roles. Kids experience 4-H in every county and parish in the country—through in-school and after-school programs, school and community clubs and 4-H camps.*[39]

As noted in a recent report for the University of Missouri Extension:

> *4-H Youth Development seeks to instill integrity, service, leadership, a sense of duty, and personal growth in the youth it serves. It is in these efforts that the 4-H Center for Youth Development can be seen to build a basis for positive personal and societal economic impacts. Specific life skills development activities are built into 4-H Youth Development projects, activities, and events with the goal of helping youth become contributing, productive, self-directed members of society. 4-H Youth Development projects are designed to be in-depth learning experiences for 4-H members.*[40]

4-H is found to be a highly effective and beneficial program. The National 4-H Impact Assessment Project identified the following beneficial impacts for youth engaged in 4-H programs:[41]

- The opportunity to value and practice service for others
- An opportunity for self-determination
- A positive relationship with a caring adult
- A physically and emotionally safe environment
- An inclusive environment
- Engagement in learning
- Opportunity for mastery
- An opportunity to see oneself as an active participant in the future.

As noted in the previously cited University of Missouri Extension study:

> *Research shows convincing evidence that participation in 4-H Youth Development programs engenders positive self-esteem, personal responsibility, and an engagement with and responsibility toward community. Participants from at-risk backgrounds who achieve such positive outcomes through 4-H Youth Development programs are, of course, less likely to succumb to external peer pressures and the low self-esteem issues that so often lead to antisocial and self-destructive behavior.*[42]

Building more self-confident, responsible, educated and community-focused children and youth for New Mexico represents a core investment in the future human potential of the state. The programing undertaken by NMSU Extension in this regard is diverse and intensive and it would take a study all its own to do full justice to all the work

NMSU 4-H Extension, on an annual basis, includes:

- >40,000 youth
- > 4,000 volunteers
- 200+ projects available

[39] National 4-H Council Website. "What is 4-H." https://4-h.org/about/what-is-4-h/

[40] Deborah Cummings, Simon Tripp and Martin Grueber. 2017. *"A Quantitative and Qualitative Review of the Impacts of the University of Missouri Extension."* TEConomy Partners, LLC. for the University of Missouri Extension.

[41] Prepared and Engaged Youth Serving American Communities: National 4-H Impact Assessment Project, http://www.national4-hheadquarters.gov/about/impact/impact1.pdf.

[42] Cummings, Tripp and Grueber. Op. Cit.

undertaken. However, the following examples provide an illustration of the type of breadth and scope of work.

Table 26: Examples of Extension Impacts 4-H and Youth Development

Enhancing Public Education	Agricultural Science is a STEM discipline that integrates life science, physical science, engineering, economics and other disciplines. It is an applied field that very much helps students understand STEM content in the context of something real that they can associate with and understand. Cooperative Extension leverages the power of agricultural science to improve the performance of New Mexico's public education for children and youth. Through the NMSU Extension and Research Youth Agricultural Science Center, youth are provided educational opportunities in agricultural sciences related STEM disciplines taught through hand-on activities in the production of food. Approximately 750 New Mexico students are engaged in the Agricultural Science Center program each year and evaluations performed show very positive results being obtained. Participating students are found to score significantly higher on state mandated science assessments. The Cooperative Extension Service also provides 30 NMSU undergraduates with Extension summer internships. Internships provide undergraduate students with the opportunity for participatory learning and working with local communities. This program also improves the retention rate of undergraduate students. In addition, the program may increase student interest in Extension careers and help to provide a well-trained, experienced, Extension workforce.
New Mexico 4-H Home Economics School	The 4-H Home Economics School is designed for 4-H members ages 9 through 13 with curricula focused on building individual skills and leadership abilities through family and consumer science activities. Through the program, older children are engaged as "Junior Instructors" for younger participants, building skills in leadership, communication and teamwork. Tangible skills are taught and learned in areas like weaving, cooking, and jewelry making all with a goal of enhancing self-confidence and teamwork.
Educational and Training Technology Using Innovative Media	Innovative Media Research and Extension at ACES are recognized leaders in the development of multimedia and digital applications to enhance education and training. With expertise in the development of animations, games, interactive media, and apps, Innovative Media Research and Extension are able to design, develop and test the latest technologies for Extension education. Growing up with modern media and digital technology, the Innovative Media work is particularly appealing and relevant to education and outreach with children and youth. Some examples of the developed programs and applications include: • *Math Snacks* – targeting middle-school youth, testing math concepts through games and animations. • *Virtual Labs* – which uses interactive modules in food science as a basis for training high school and college students in basic laboratory techniques. • *Ninja Kitchen* – which uses electronic gaming to teach food safety principles • *Night of the Living Debt* – using gaming to help participants understand

	personal finance and debt. Cooperative Extension's work is facilitated by having The Learning Games Lab which is a development studio, a user-testing research space, and an exploratory environment for playing and evaluating games and educational tools. The Lab leverages "youth consultants" who assist in the testing of animations, and interactive educational gaming apps – hosting 60 youth for sessions in 2017.

The Functional Economic Impact of Reduced Youth Antisocial Behavior and Crime in New Mexico

Extension's work with children and youth, including but not limited to the work of NMSU 4-H, seeks to build confident, self-reliant, personally responsive youth with leadership skills and engagement in their community. Imparting these skills and positive behavioral traits in youth improves their engagement in school and reduces the propensity of participating youth to engage in negative, antisocial or delinquent behaviors. Research into 4-H impacts has found that "across Grades 5 to 8, trajectories reflecting higher school engagement (for 4-H youth) were positively associated with grades and negatively associated with delinquency, depression, and substance use."[43] The potential impacts of reducing negative behaviors can be significant:

- The NM juvenile justice system was engaged with 221,944 juveniles across the state in 2015.[44] Just the cost of operating juvenile lock-up facilities costs the state $35.7 million.[45] **Were youth participation in 4-H programs to reduce this population by just 1% the saving to the state would total $357,000 annually.**
- The CDC Youth Behavior Survey for 2015 found New Mexico to have among the highest rates of admitted drug abuse among high school students. NM has the second highest percentage among US states in terms of high schoolers taking cocaine and ecstasy, ranked fifth for methamphetamines and eighth for heroin use. In comparison, NM ranks 36th in the size of its school population. Just the cost of a juvenile case processed through the New Mexico Drug Court is $21,800 per juvenile, while the cost of rehabilitation and provision of healthcare services related to drug abuse represent a considerably higher burden.[46] The CDC estimates the US cost of drug abuse to be over $600 billion annually. With New Mexico home to 0.64% of the U.S. population a conservative estimate of drug abuse costs in the state would be $3.8 billion annually – but it is probably considerably more given the higher propensity for drug abuse in the state evidenced by the high school statistics above. **Were 4-H participation to reduce drug-abuse in New Mexico by just one percent the benefit to the state would be $38 million annually.**

[43] Richard m. Lerner, Jacqueline V. Lerner, et al. *"The Positive Development of Youth: Comprehensive Findings from the 4-H Study of Positive Youth Development."* Tufts University. Institute for Applied Research in Youth Development.
[44] State of New Mexico. Juvenile Justice Services Bureau. 2016. "Juvenile Justice Services (JJS) Annual Report." https://cyfd.org/docs/FY16_JJSAnnualReport.pdf
[45] Olivier Uyttebrouck. 2016. "Juvenile lockup costs escalate despite fewer incarcerated youth." Albuquerque Journal. September 11, 2016.https://www.abqjournal.com/842790/juvenile-lockup-costs-escalate-despite-fewer-incarcerated-youth.html
[46] New Mexico Legislative Finance Committee. Program Evaluation Unit. 2017. "Program Evaluation: Update on New Mexico Drug Courts." Report #17-03https://www.nmlegis.gov/Entity/LFC/Documents/Program_Evaluation_Reports/Program%20Evaluation%20Update%20on%20New%20Mexico%20Drug%20Courts.pdf

6. EXTENSION: New Mexico Landscapes – Yard and Garden

Cooperative Extension Service expertise in plant sciences, horticulture, turfgrass, irrigation and low-water use landscaping is a valuable resource for communities, families and individuals in New Mexico looking to improve and beautify their property, produce home-grown fruits and vegetables, and assure environmentally responsible use of their land. Extension has a long-standing track-record in supporting landscaping and home garden development, with Extension and Extension-trained volunteers providing the latest research-based knowledge to benefit New Mexico residents. Perhaps the best known of the NMSU extension programs in this regard is the Master Gardeners Program, a well-used and important program, but the wide-ranging resources of NMSU ACES researchers and Extension Specialists are available to New Mexicans to answer questions, provide information resources, diagnose plant health issues, help avoid introducing invasive plants, and other core activities.

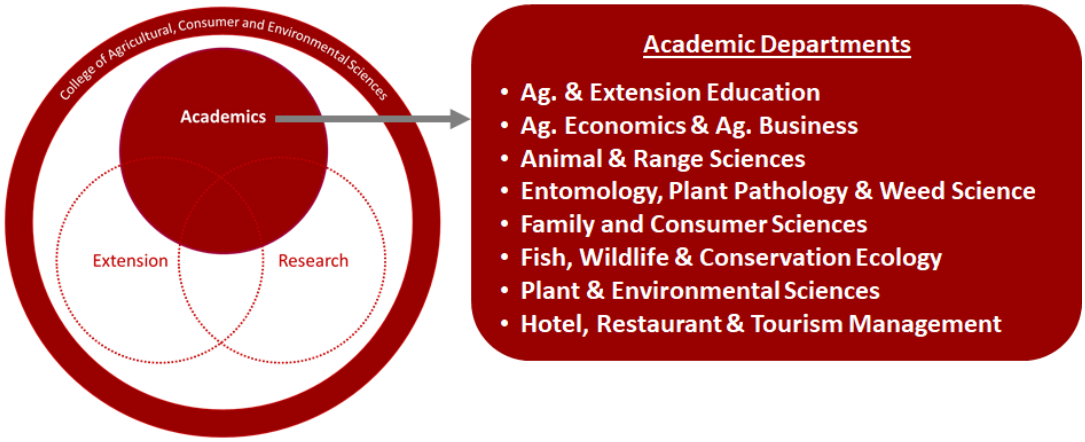
Table 27: Examples of Extension Impacts in New Mexico Landscapes, Yard and Garden

Master Gardener Program	The Master Gardener Program at NMSU Extension is a powerful example of how a "train-the-trainers" approach can leverage volunteers to create a large-scale base of expertise to serve the needs of diverse communities. In the 2015-16 program year, Extension had 1,278 Master Gardeners active and these volunteers provided over 61,000 hours of service to New Mexicans. Were ACES to have to hire its own Extension agents to perform the work conducted by Extension-trained Master Gardeners it is calculated that the University would need to hire 29 full-time additional Extension agents at a cost of $1.4 million annually). In addition to working one-on-one, as needed with New Mexico property holders and family gardeners, Master Gardeners are also engaged in collaborative projects comprising multiple community members. A good example of this is the "Seed2Need" program where Master Gardeners provided consultation support to students who contributed 2,882 hours in Sandoval County to prepare, plant and harvest food in gardens. In 2017 the program in Sandoval County harvested over 61,000 pounds of produce that was donated to food pantries serving an average of 70,000 New Mexicans each week.
Southwest Yard & Garden Weekly Newspaper Column.	Providing reliable fact-based research-driven information is at the heart of Extension work. One of the time-tested methods used to deploy Extension information for home gardeners has been The Southwest Yard & Garden weekly column. The column has been published in New Mexico for over 28 years by NMSU Extension Horticulturalists, is carried by multiple local newspapers across the state, and circulation over the last year has increased by 47% to 387,117 readers.

VI. THE ECONOMIC AND FUNCTIONAL IMPACTS OF ACES HIGHER EDUCATION

NMSU's College of Agricultural, Consumer, and Environmental Sciences (ACES) provides degree programs at the Bachelor's, Master's and Doctoral level. The College and its academic departments provide diverse programs of study – producing graduates to meet the needs of the farming and ranching industries, value-added industries, government agencies, the tourism and hospitality industry, community and economic development organizations, and other needs for highly educated individuals within New Mexico. Figure 14 shows the academic departments within ACES.

Figure 14: Academic Departments in the NMSU College of Agricultural, Consumer and Environmental Sciences



Higher education is associated with large-scale benefits for individuals and society.[47] For individuals, the achievement of higher education credentials is found to bring financial benefits in terms of significantly enhanced income and employment benefit levels, and additional personal benefits including enhanced job satisfaction, happiness, health and longevity. Government, industry and society similarly benefit directly from higher education through enhanced economic productivity of an educated workforce, associated economic growth and increased government revenues, and through reductions in social program costs and negative externalities (such as crime). Society also benefits by having a more highly educated populace in terms of higher levels of civic engagement, volunteerism, improved child welfare and a broad variety of other factors. **The evidence is extremely strong that an investment in higher education has a strong return – for individuals, for the economy and for society overall.**

A. The Importance of Higher Education

As the U.S. seeks to retain a competitive edge within a highly competitive global economy, it has become increasingly clear that **the most valuable asset for the nation and individual states is a well-educated, skilled populace and workforce able to be productive, technologically-savvy, innovative and adapt to change**. In our modern, knowledge-driven economy people need to be equipped with the solid educational fundamentals necessary to meet increasingly complex job requirements and the ability to participate in life-long learning to upgrade their skills as the world of work changes and evolves.

[47] See for example: Walter W. McMahon. 2009. "Higher Learning, Greater Good: The Private and Social Benefits of Higher Education." The Johns Hopkins University Press.

Today and into the foreseeable future it is hard to overstate the importance of education, especially higher education, to New Mexico's economic and societal progress. Higher education facilitates productivity and efficiency gains across the economy, and it also provides a positive return on investment for individuals and society, thereby adding additional economic benefits. The following statements by researchers examining the importance of higher education ably make these points:

- "An educated populace is a key source of economic growth both directly, through improved labor productivity, and indirectly, by spurring innovation and speeding the diffusion of advanced technologies."[48]
- "The most important elements in the quest for a competitive advantage in commerce, be it at the micro, or firm, level or at the macro, or national, level, are the skills and initiative of its workforce."[49]
- Higher education provides extensive benefits to students, including higher wages, better health, and a lower likelihood of requiring disability payments. A population that is more highly educated also confers wide-ranging benefits to the economy, such as lower rates of unemployment and higher wages even for workers without college degrees. A postsecondary degree can also serve as a buffer against unemployment during economic downturns. Those with postsecondary degrees saw more steady employment through the Great Recession, and the vast majority of net jobs created during the economic recovery went to college-educated workers.[50]

"The face of American agriculture is changing. Nearly 10 percent of U.S. jobs are related to agriculture and the increasingly complex nature of production requires more training and education in science, technology, engineering and mathematics—the STEM fields—to stay competitive and meet the needs of a growing world for food, fuel and fiber. This is a great opportunity for smart, young people to start careers in a field that addresses some of the world's most pressing challenges."

Former U.S. Agriculture Secretary
Tom Vilsack

Economist Lester Thurow notes that in a global economic climate, where natural resources, machines, and technology are made highly mobile, and thus relatively less important, the importance of education has significantly expanded. Thurow comments that "people will move, but more slowly. Skilled people become the only available sustainable source of competitive advantage."[51]

Baum and Ma[52] note that the benefits of higher education for individuals are both monetary and nonmonetary, including the following:

[48] Claudia Goldin and Lawrence Katz. 2009. "The Future of Inequality: The Other Reason Education Matters so Much." The Milken Economic Review.
[49] Kenneth Gray and Edwin Herr. 1998. "Workforce Education: The Basics." Allyn & Bacon, Needham Heights, Massachusetts.
[50] Diane Whitmore Schanzenbach, Lauren Bauer, and Audrey Breitwieser. 2017. "Eight economic facts on higher education." The Brookings Institution. Washington, DC.
[51] Lester Thurow. 1992. "Head to Head: The Coming Economic Battle Among Japan, Europe, and America." Morrow & Company, New York.
[52] Sandy Baum and Jennifer Ma (2007). *Education Pays: The Benefits of Higher Education for Individuals and Society.* Trends in Higher Education Series. College Board.

Individual Higher Education Benefits *(Baum and Ma, 2007)*

- *There is a positive correlation between higher levels of education and higher earnings for all racial/ethnic groups and for both men and women.*
- *In addition to earning higher wages, college graduates are more likely than others to enjoy employer-provided health insurance and pension benefits.*
- *The income gap between high school graduates and college graduates has increased significantly over time. The earnings benefit is large enough for the average college graduate to recoup both earnings forgone during the college years and the cost of full tuition and fees in a relatively short period of time.*
- *The considerable nonmonetary rewards of a college education include better health and greater opportunities for the next generation.*
- *Any college experience produces a measurable return when compared with none, but the benefits of completing a bachelor's degree or higher are particularly large.*

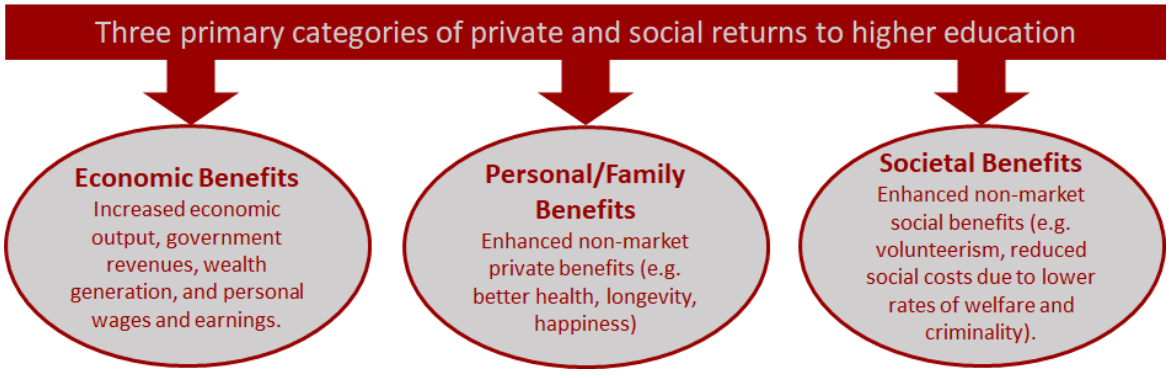
Baum and Ma[53] also note that the benefits of higher education for society as a whole are both monetary and nonmonetary, including the following:

Societal Higher Education Benefits *(Baum and Ma, 2007)*

- *Higher levels of education correspond to lower unemployment and poverty rates. So, in addition to contributing more to tax revenues than others do, adults with higher levels of education are less likely to depend on social safety-net programs, generating decreased demand on public budgets.*
- *The earnings of workers with lower education levels are positively affected by the presence of college graduates in the workforce.*
- *College graduates have lower smoking rates, more positive perceptions of personal health, and healthier lifestyles than individuals who did not graduate from college.*
- *Higher levels of education are correlated with higher levels of civic participation, including volunteer work, voting, and blood donation, as well as with greater levels of openness to the opinions of others.*

Research thus ascribes three categories of primary private and social returns to investment in higher education.[54] These may be summarized on Figure 15.

Figure 15: Macro Categories of Private and Social Returns to Higher Education



[53] Sandy Baum and Jennifer Ma (2007) *Education Pays: The Benefits of Higher Education for Individuals and Society*. Trends in Higher Education Series. College Board.

[54] See for example: Walter W. McMahon. 2009. "Higher Learning, Greater Good: The Private and Social Benefits of Higher Education." The Johns Hopkins University Press.

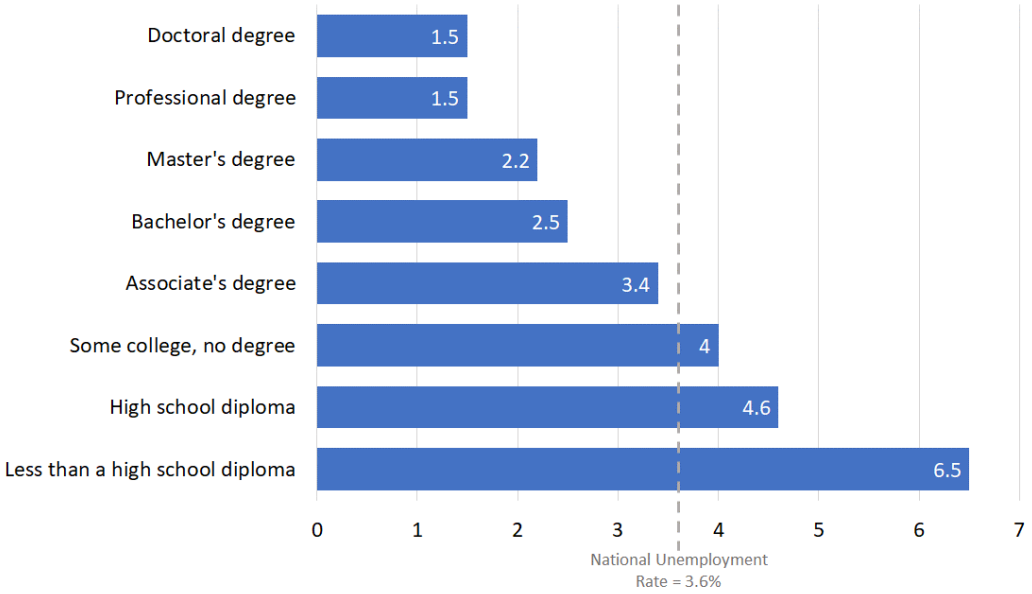
In the narrative and analysis that follows, TEConomy examines the private and social benefits of higher education generally and in relation to specifics at NMSU ACES.

B. ECONOMIC BENEFITS: Personal Economic Benefits of Higher Education

1. Lower Levels of Unemployment

While unemployment is currently low nationally (3.9% for the U.S. in March 2018) it is a more persistent problem in New Mexico (5.6% for New Mexico in March 2018[55]). Achieving higher education significantly reduces the likelihood of experiencing the challenges of unemployment. There has long-been, and continues to be, a significant disparity in unemployment rates between those in the U.S. who have higher education qualifications and those who do not. Bureau of Labor Statistics (BLS) data for 2017 provide a clear illustration of this trend[56], showing the benefit of increasing levels of higher education in terms of propensity to find employment (Figure 16).

Figure 16: Unemployment Rates by Educational Attainment



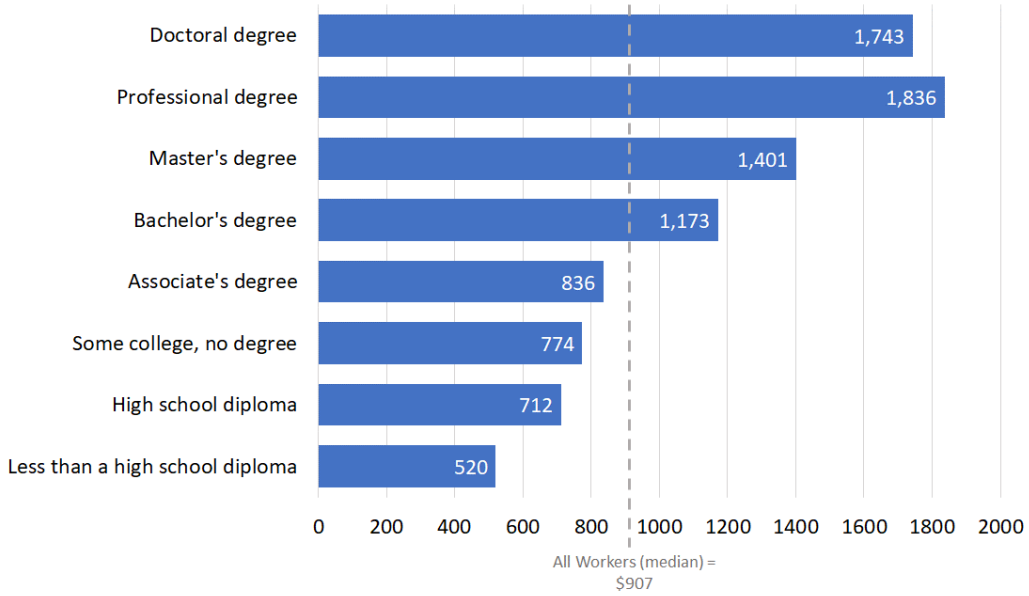
2. Higher Levels of Job Income

Not only do an individual's prospects for employment rise with education, so too do their prospects for experiencing higher levels of income. There are clear financial rewards to investing in attaining higher education, and thus the inverse holds true, that there is a financial penalty incurred by those who do not so invest. The relative differential in earnings that accrues to increasing levels of education is clear in recent national BLS data[57] (Figure 17). Those having less than a Bachelor's degree earn less than the

[55] Source: Bureau of Labor Statistics
[56] https://www.bls.gov/emp/chart-unemployment-earnings-education.htm
[57] Ibid

median income for all workers in the nation, while those with a Bachelor's or higher degree earn significantly more.[58]

Figure 17: Median Usual Weekly Earnings ($) by Educational Attainment



Writing in 2009, Walter McMahon noted that the "64 percent of the population that has only finished high school has seen no increase in their real earnings since 1980, whereas the real earnings of college graduates continue to rise sharply."[59] It is also evident that the substantial income divide in favor of college graduates continues to increase.

The Income Benefits of Higher Education are Strong and Growing

College graduates, on average, earned 56% more than high school grads in 2015, according to data compiled by the Economic Policy Institute. That was up from 51% in 1999 and is the largest such gap in EPI's figures dating to 1973. Since the Great Recession ended in 2009, college-educated workers have captured most of the new jobs and enjoyed pay gains. Non-college grads, by contrast, have faced dwindling job opportunities and an overall 3% decline in income, EPI's data shows. "The post-Great Recession economy has divided the country along a fault line demarcated by college education," Anthony Carnevale, director of Georgetown University's Center on Education and the Workforce, said in a report last year.

College grads have long enjoyed economic advantages over Americans with less education. But as the disparity widens, it is doing so in ways that go beyond income, from homeownership to marriage to retirement. Education has become a dividing line that affects how Americans vote, the likelihood that they will own a home and their geographic mobility.

The dominance of college graduates in the economy is, if anything, accelerating. Last year, for the first time, a larger proportion of workers were college grads (36%) than high school-only grads (34%), Carnevale's research found. The number of employed college grads has risen 21% since the recession began in December 2007, while the number of employed people with only a high school degree has dropped nearly 8%.

Christopher S. Rugaber, The Associated Press.
"Pay gap between college grads and everyone else at a record."
Published in USA Today. January 12, 2017.

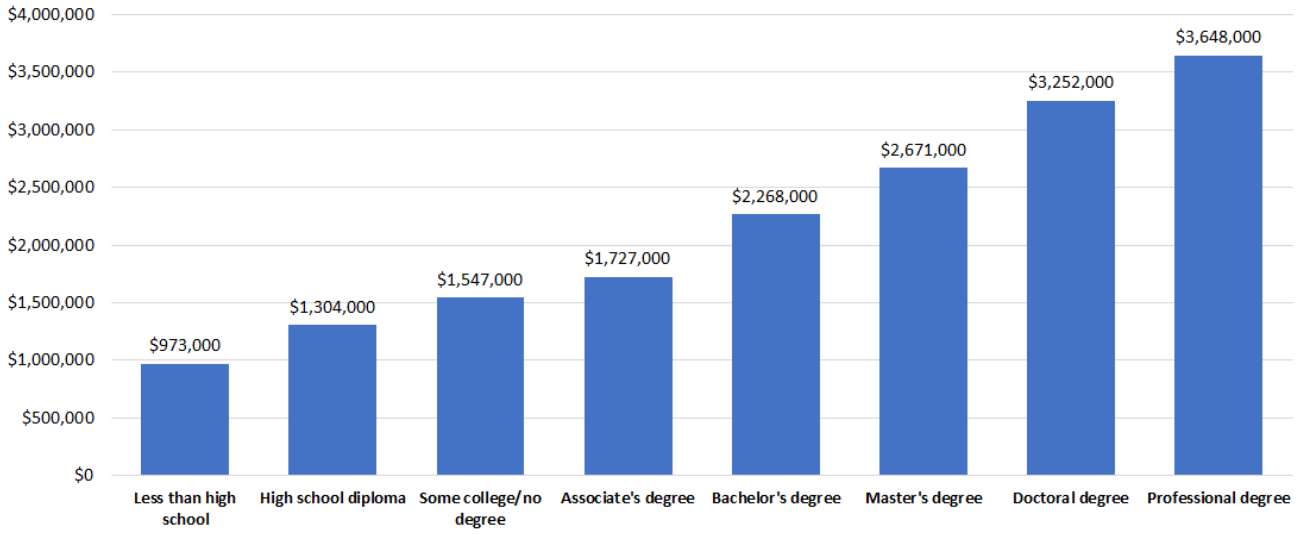
[58] The same holds true for New Mexico. See Figure 17.
[59] Walter W. McMahon. 2009. "Higher Learning, Greater Good: The Private and Social Benefits of Higher Education." The Johns Hopkins University Press.

c. Increased Lifetime Earnings

Because of the increase in earnings power of college graduates there is a strong lifetime financial benefit to achieving higher education credentials. Considering the investment in time to get a degree (which includes an opportunity cost in terms of not working during that time and therefore associated income foregone) and the investment in personal or family funds to pay for the education, higher education has a strong payoff over a lifetime of work. A recent in-depth study of the relationship between lifetime earnings and educational attainment, performed by researchers at Georgetown University, concluded the following:

> *This report examines lifetime earnings for all education levels and earnings by occupation, age, race/ethnicity, and gender. The data are clear: a college degree is key to economic opportunity, conferring substantially higher earnings on those with credentials than those without. A 2002 Census Bureau study estimated that in 1999, the average lifetime earnings of a Bachelor's degree holder was $2.7 million (2009 dollars), 75 percent more than that earned by high school graduates in 1999. Today, we find similar numbers — but since 1999, the premium on college education has grown to 84 percent. In other words, over a lifetime, a Bachelor's degree is worth $2.8 million on average.*[60]

Figure 18: Median Lifetime Earnings by Highest Educational Attainment (2009 Dollars)[61]



ACES is focused on a broad range of education programs—programs leading to Bachelor's degrees (22 degree programs), Master's degrees (13 programs) and Doctoral degrees (ACES College directs two Doctoral degree programs and collaborates with other Doctoral Degree programs in the College of Business and College of Arts and Sciences). With more than 1,600 students enrolled in these degree programs at any given time, ACES is a significant higher education provider for New Mexico.

ACES data for the numbers of graduates across the College's degrees for 2017 are shown on Table 28, and these figures allow the use of the above median lifetime earnings figures for these levels of degree

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[60] Anthony P. Carnevale, Steven J. Rose and Ban Cheah. *"The College Payoff: Education, Occupations, Lifetime Earnings."* The Georgetown University Center on Education and the Workforce.

[61] Ibid (Georgetown University analysis of U.S. Bureau of the Census data).

to derive an estimate of the increased personal income potentials that are likely to accrue to persons graduating from ACES degree programs.

Table 28: Projected Lifetime Earnings Differential for 2017 Graduates of ACES Higher Education Programs[62]

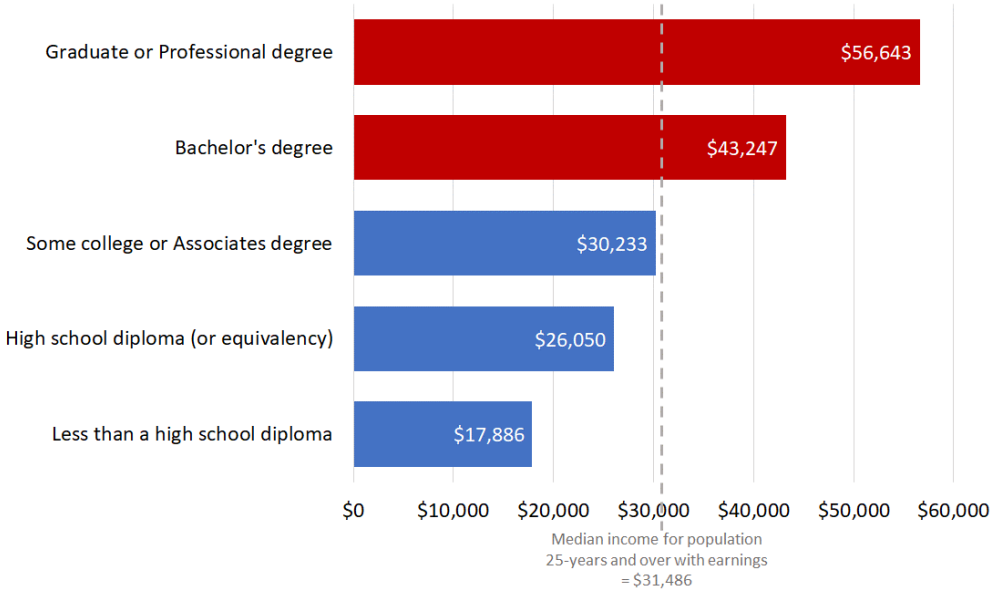
Qualification	2017 ACES Graduates	Median Work-Life Earnings (National Data)	Lifetime Differential Versus Next Lower Level of Education*	ACES 2017 Graduates Combined Lifetime Earnings Using National Data	ACES 2017 Graduates Combined Differential **(Value Realized from ACES Qualification** – Projected from National Data)
Doctoral Degree	6	$3,252,000	$581,000	$19,512,000	**$3,486,000**
Master's Degree	65	$2,671,000	$403,000	$173,615,000	**$26,195,000**
Bachelor's Degree	262	$2,268,000	$541,000	$594,216,000	**$141,742,000**
Associate's Degree	--	$1,727,000	$	--	--
	333			$787,343,000	**$171,423,000**

Table 14 shows the results of calculating earnings differentials based on the ACES graduating classes for 2017 (333 students across all undergraduate and graduate degree programs). These findings show that the ACES graduating class, across all College degree programs will, as a result of their education, increase their combined lifetime earnings by an estimated $171.4 million per graduating class (an average of $514,784 per graduating student). With both STEM and social science disciplines incorporated across ACES degrees, it is likely that the median values from the Georgetown University national study represent a reasonable approximation of expected earnings for ACES graduates overall.

The above estimates of work life earnings are, as noted, based on national data. Some specific New Mexico data are available through the U.S. Census Bureau 2012-2016 American Community Survey data estimates, and these data confirm the progressive increase in median earnings that are experienced in New Mexico at successively higher levels of educational attainment. Figure 19 summarizes the latest data release estimates for New Mexico confirming that those attaining a Bachelor's degree, or higher, experience median annual earnings considerably higher than the median for all working adults 25 years and older. These data indicate that workers with a Bachelor's degree will experience 1.66 times the level of income realized by those with only a high school diploma (or equivalent) while for those with a graduate or professional degree the figure is 2.17 times.

[62] Notes on Table 14: Financial data used are from Figure __. Doctoral Degree and Professional Degree – The differential level used is a master's degree. Master's Degree – The differential level used is a bachelor's degree. Bachelor's Degree – The differential level used is an associate degree.

Figure 19: Median New Mexico Annual Earnings by Educational Attainment



The Brookings Institution's "Hamilton Project" has also performed in-depth analysis of federal data on median lifetime earnings by college major (collected through the American Community Surveys from 2009 through 2012).[63] These data allow an examination of the strong financial return to attaining a Bachelor's degree in several of the disciplines relevant to degrees awarded by ACES. Tracking median lifetime earnings, the Hamilton Project analysis shows the results on Table 29 for degree categories relevant to ACES.

Table 29: Lifetime Earnings at the 50th Percentile of Earnings Distribution for Selected Bachelor's Degrees Versus Lower Levels of Educational Attainment (in current dollars).

Education Level/Discipline	Lifetime Earnings in Current Dollars	Increased Lifetime Earnings vs. HS Diploma Only	Percent Gain in Lifetime Income vs. HS Diploma Only
Agricultural Economics	$1,270,000	$690,000	119%
Environment and Natural Resources	$1,140,000	$560,000	97%
General Agriculture	$1,100,000	$520,000	90%
Hospitality Management	$1,080,000	$500,000	86%
Animal Sciences	$1,010,000	$430,000	74%
Family and Consumer Sciences	$810,000	$230,000	40%
High School Diploma/GED	*$580,000*	--	--

The above U.S. data are for bachelor's degree holders only, and do not include data for those continuing onwards to gain post-graduate qualifications (for whom research indicates even higher lifetime earnings). They show a robust return to the types of Bachelor's degrees that may be attained through ACES – ranging from a 40% increase in lifetime earnings for a Bachelor's in Family and Consumer

[63] Brad Hershbein and Melissa S. Kearney. "Economic Analysis. Major Decisions: What Graduates Earn Over Their Lifetimes." The Hamilton Project, Brookings Institution, Washington D.C. http://www.hamiltonproject.org/papers/major_decisions_what_graduates_earn_over_their_lifetimes

Sciences over a high school diploma only to a high of a 119% increase for a Bachelor's in Agricultural Economics.

Beyond an individual's working life, it is also notable that better financial benefits in retirement are also associated with higher levels of education. Baum and Ma find that the likelihood of a person being covered by an employer-provided pension plan increases significantly with higher levels of educational attainment.[64] Census Bureau data analyzed for 2009 showed that only 30% of persons without a high school diploma are covered by employer-provided pension plans, while fully 65% of those having an Associate's degree are so covered, and 70% for those with a bachelor's degree or higher.

C. ECONOMIC BENEFITS: Meeting Labor Demands in the New Mexico Economy

The fact that graduates of degree programs experience lower levels of unemployment and substantially greater levels of job income is a reflection of demand for their skills in the labor market. Recent studies point to skills in agricultural sciences and associated disciplines being particularly robust in terms of demand. Indeed, there is concern nationally that the output of graduates in these fields is insufficient to keep pace with rising demand for specialized agbioscience and associated agriculture-related higher education graduates.

> "College graduates with expertise in food, agriculture, renewable natural resources, and the environment are essential to our ability to address the U.S. priorities of food security, sustainable energy, and environmental quality. Graduates in these professional specialties not only are expected to provide answers and leadership to meet these growing challenges in the United States, but they also must exert global leadership in providing sustainable food systems, adequate water resources, and renewable energy in a world of population growth and climate change."
>
> Purdue University and USDA
> *Employment Opportunities for College Graduates in Food, Agriculture, Renewable Natural Resources, and the Environment, United States, 2015–2020*

Recent research shows that the United States faces the challenge of a skilled agricultural workforce shortfall. According to a recent report from the U.S. Department of Agriculture (USDA) supported by analysis from Purdue University, there will be nearly 58,000 job openings in the U.S. food and agriculture industry each year (from 2015 to 2020) for college graduates from across the country.[65] Over this same period, only 35,400 new U.S. graduates with degrees in food, agriculture, and natural resources will be available, leaving almost 40 percent of the available jobs open. Against this background, NMSU ACES undergraduate and graduate degree programs are a critically important part of the solution for New Mexico.

[64] Sandy Baum and Jennifer Ma (2007) *Education Pays: The Benefits of Higher Education for Individuals and Society*. Trends in Higher Education Series. College Board.

[65] Purdue University and USDA, Employment Opportunities for College Graduates in Food, Agriculture, Renewable Natural Resources, and the Environment, United States, 2015–2020. See: https://www.purdue.edu/usda/employment/.

Against this background of need and demand for graduates of Colleges of Agriculture, the importance of NMSU ACES as a key supplier of in-demand talent for this large sector of the New Mexico economy comes clearly into focus:

- 14 of ACES's 22 undergraduate degree programs are unique to NMSU, not offered at any other college or university in New Mexico.
- The College operates two PhD and 13 Master's programs. The College collaborates with other Doctoral Degree programs in the College of Business and College of Arts and Sciences.
- Student enrollment in the College has increased by approximately 3% over the past 3 years. ACES is the only College at NMSU Main Campus to have demonstrated an increase in enrollment during this period of time.
- Combined programs within ACES account for greater than 1,600 students at both the undergraduate and graduate levels.
- ACES has a retention rate for students that is significantly higher that the state average and national average. ACES experienced a 78% retention rate for 2016, versus a national average of 71% and a New Mexico statewide average of 65%.

ACES Undergraduate Degree Programs

- Agricultural Biology
- Agricultural Economics & Agricultural Business
- Agricultural & Extension Education
- Agriculture & Community Development
- Agronomy
- Animal Science
- Clothing, Textiles & Fashion Merchandising
- Conservation Ecology
- Environmental Science
- Family & Child Science
- Family & Consumer Sciences Education
- Food Science & Technology
- General Agriculture
- Genetics
- Hotel, Restaurant & Tourism Management
- Horticulture
- Human Nutrition & Dietetic Sciences
- Natural Resource Economics & Policy
- Rangeland Resources
- Soil Science
- Turfgrass Science & Management
- Wildlife Science

A recent report examining the need for graduates from colleges of agriculture noted that:

> *In addition to needing more agriculture professionals, the United States also needs professionals with broader training that integrates agricultural sciences and other science, technology, engineering, and mathematics (STEM) disciplines. Agriculture is a fundamentally interdisciplinary endeavor, and agriculture professionals rely on a range of specialties that necessitates a broad education. Plant breeders, for example, draw upon entomology, plant pathology, agronomy, soil science, and microbiology, and need to integrate the tools of genetics, bioinformatics, statistical modeling, and robotics. Without an interdisciplinary workforce, the pace of technological innovation in agriculture may slow, and critical global challenges may not be addressed.*[66]

NMSU is being responsive to this national need by encouraging cross-disciplinary training and enabling students to take courses across college and school boundaries. Multiple interviews with faculty at NMSU noted the transdisciplinary and collaborative environment that exists across the campus.

[66] TEConomy Partners, LLC. 2016. "Ensuring an Agbioscience Workforce for Indiana's Future." AgriNovus Indiana.

D. ECONOMIC BENEFITS: Public Economic Benefits Via Enhanced Workforce Productivity Attributable to Higher Education

Economics research shows that public economic benefits are realized through higher levels of educational attainment within a state population. These gains principally occur through enhanced levels of economic productivity allocable to knowledge and skills enhancement acquired via higher education.

A 2006 study performed by Impact Economics LP projected the productivity returns from education allocable to graduates from an expanded University of Minnesota Rochester.[67] The study used productivity gain functions adopted by the Office of the Comptroller in the State of Texas[68] and originally developed by Black and Lynch[69] at the National Bureau for Economic Research who used data from a large-sample survey to derive a measure that a 10 percent increase in the average educational level of workers results in a 5.9 percent to 12.7 percent increase in nonmanufacturing industries' productivity.

> Society as a whole also enjoys a financial return on the investment in higher education. In addition to widespread productivity increases, the higher earnings of educated workers generate higher tax payments at the local, state, and federal levels. Consistent productive employment reduces dependence on public income-transfer programs and all workers, regardless of education level, earn more when there are more college graduates in the labor force.
>
> S. Baum and J. Ma
>
> *Education Pays: The Benefits of Higher Education for Individuals and Society*

The State of Texas study used the lower productivity gain levels of nonmanufacturing workers to derive a conservative estimate of impacts, and their analysis takes into account the costs involved in gaining higher-education credentials, concluding that the net present value (to the economy via productivity enhancement) per student per year of higher education amounts to $39,000. The Impact Economics study for the University of Minnesota used the same $39,000 value figure. Given that the original $39,000 figure was derived through analysis performed in 1995, and the fact that productivity has increased within the economy in subsequent years, TEConomy has adjusted the figure in-line with basic inflation experienced over the 1995-2018 period. Adjusting for inflation the value rises to $64,383 (with cumulative inflation across the 24 years of 65.1%).

Using the $64,383 figure for estimate potential net productivity gains via an additional year of education in the New Mexico economy allocable to ACES graduate output results in an estimate of a net present productivity increase value of $21.2 million for the 2017 ACES graduating class (Table 30).[70] It is likely that this represents a very conservative estimate of the productivity gains allocable to ACES education. ACES graduates have highly practical STEM and social science skills which, when applied in the workplace, likely have impacts in excess of an average productivity gain figure.

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[67] S. Tripp, Impact Economics, LP (2006). "Projections of Economic Impact: The Role and Impacts of a Signature Research University in Southeast Minnesota." Performed for the Rochester Higher Education Development Committee.

[68] C. K. Strayhorn (2005). "The Impact of the State Higher Education System on the Texas Economy." Office of the Comptroller of Texas: Special Report.

[69] S. Black and L. Lynch (1995). "Beyond the Incidence of Training: Evidence from a National Employers Survey." Working Paper No. 5231, National Bureau of Economic Research (Cambridge, MA).

[70] It should be noted that the present productivity gain will be realized in the state where the graduate chooses to work. Many NMSU ACES students will choose to live and work in New Mexico, but not all.

Table 30: Net Present Productivity Increase Value for 2017 ACES Graduating Students (Undergraduate and Graduate Degrees Combined).

Number of 2017 ACES Graduates	Net Present Productivity Value of Additional Education Year	Net Present Productivity Increase Value for This Volume of Students Each Year of Education
333	$64,383	**$21,182,007**

A 2013 research report by Berger and Fisher[71] evaluated the link between higher education attainment in a state and state prosperity. Since the wealth of a society can only increase if the economy becomes more productive, the researchers sought to understand the effect that investment in education has on productivity. Their major findings support the hypothesis that higher levels of educational attainment create public economic benefits by improving productivity across the economy. Berger and Fisher use rising incomes as a proxy for productivity increase under the rational argument that to "achieve rising incomes for average people, two things need to happen: productivity needs to increase (creating more income overall), and new income generated from their increased productivity needs to be returned to workers in the form of higher wages." Their analysis shows that states that increase the level of education across their workforce see greater productivity – finding that between 1979 and 2012 "states in which the share of adults with at least a college degree experienced greater increases in productivity, measured as gross state product per hour worked." They also found that this greater productivity is associated with higher wages, noting that "states with larger increases in productivity experienced larger increases in median worker compensation."

ACES Education Focused on Needs in the State

The role of ACES in meeting specialized needs for education in New Mexico is embedded across the degree programs at the College. The responsiveness of the College to meeting particular needs for New Mexico can be seen in the two examples below:

Example 1: The School of Hotel, Restaurant and Tourism Management prepares students for management positions in New Mexico's economically important hospitality and tourism industry. NMSU provides the only Bachelor's degree in NM in the field, and teaching a broad hospitality curriculum, with an applied business focus. Tourism represents a large and expanding sector of the NM economy, supporting 8.4% of statewide employment and having a total economic impact of $9.03 billion in 2016 (data from Tourism Economics). NMSU ACES is making sure the sector has the well-educated and skilled human capital required for management and leadership positions across this important state industry.

Example 2: The Department of Agricultural and Extension Education at NMSU ACES offers two degree paths in "Agricultural and Extension Education" and "Agricultural and Community Development" – two areas of specialized education required to advance rural development and the agricultural industry. It is being found in NM, that the skills of these graduates across a broad range of life science, physical science and social science content (in combination with an understanding of rural needs and communities) produces graduates who are highly valued as science teachers in NM's rural K-12 school districts – filling a distinctive need for science teachers in the state.

E. Personal and Societal Benefits

As shown above, there are clearly substantial personal and economy-wide benefits associated with increasing levels of higher education attainment achieved through ACES in New Mexico. Researchers

[71] Noah Berger and Peter Fisher. 2013. "A well-educated Workforce is Key to State Prosperity." Economic Analysis and Research Network (EARN). Washington, Dc.

have found, however, that the full scope of benefits realized through increasing levels of higher education are significantly broader. These broader benefits are largely, but not exclusively non-monetary, and have been the subject of study, including longitudinal studies of student outcomes. Some examples of the benefits confirmed include:[72]

- Higher education attainment is correlated with enhanced health outcomes, through graduates being less likely to smoke, more likely to exercise, and less prone to depression.
- Have higher levels of engagement in their communities, being more likely to vote and participate in volunteer activities.[73]
- Demonstrating more positive attitudes towards diversity and equal opportunities, such as on race and gender equality issues.
- Are more likely to be very satisfied with their jobs

Important for consideration by the State of New Mexico, increasing levels of educational attainment are also associated with reduced demand for public assistance (thereby reducing costs for provision of costly public support through welfare, Medicaid, and unemployment compensation) and demonstrate lower crime rates (thereby reducing criminal justice system costs).

F. Conclusion

The education of students by ACES provides a broad range of monetary and non-monetary benefits to the individual, to society at large, and to the State of New Mexico. Graduate earnings exceed, by a considerable margin, the median income for a worker in New Mexico, and the state economy realizes significant productivity gains across the economy from each graduating class. The state will realize revenue gains via increased levels of income tax realized by ACES graduates, and via increased commercial (e.g. corporate income tax) revenues realized through productivity gains in the economy. Multiple studies suggest that the state will also benefit through graduates placing low demands on public assistance and associated benefits, and through graduates being engaged citizens in their state and community.

[72] Walter W. McMahon. 2009. "Higher Learning, Greater Good: The Private and Social Benefits of Higher Education." The Johns Hopkins University Press. See also: Beyond the Financial Benefits of a Degree." 2005. Accessed online at: http://ww2.prospects.ac.uk/cms/ShowPage/Home_page/Labour_market_information/Graduate_Market_Trends/Beyond_the_financial_benefits_of_a_degree__Autumn_05_/p!eXeLcmm. See also: Sandy Baum and Jennifer Ma (2007) Education Pays: The Benefits of Higher Education for Individuals and Society. Trends in Higher Education Series. College Board.

[73] Institute for Higher Education Policy. 2005. "The Investment Payoff: A 50-State Analysis of Public and Private Benefits of higher education." Washington, DC.

VII. RECOMMENDATIONS: OPPORTUNITIES TO ENHANCE ACES IMPACTS

While ACES is generating strong impacts across its research, education and extension domains, that does not mean there are not additional opportunities to expand these positive impacts for New Mexico. TEConomy has had the privilege of working with multiple Land-Grant universities and colleges of agriculture across the United States and some themes we are seeing across the nation could well be a fit to enhancing impacts within New Mexico. Four opportunity areas stand out for consideration by ACES:

1. Transdisciplinary Initiative for Digital and Prescription Agriculture
2. Transdisciplinary Initiative for New Mexico Agri Value-Chain Enhancement
3. Transdisciplinary Agricultural Literacy Initiative
4. Transdisciplinary Initiative for Youth Development via on-line learning and STEM programming.

It is by design that each of the above potential initiatives is labelled "transdisciplinary". The frontiers of agricultural, natural resource, environmental and social sciences are expanding rapidly, and considerable dynamism is being observed at the intersections between disciplines, where the phenomena of "convergence" is bringing together practitioners across multiple fields of inquiry to innovate systemic and holistic solutions to major challenges. In this new research environment, traditional academic departmental silos are being revisited, and opportunities for multi-disciplinary research and educational programs pursued. These include initiatives that may span not only multiple departments, but also multiple colleges within a university.

TEConomy finds that colleges of agriculture are particularly suited to understanding multi-disciplinary science and transdisciplinary[74] research activity. Built around an inherently pragmatic and applied Land-Grant ethos and mission, colleges of agriculture and their associated experiment station and extension service systems have evolved to direct intellectual and educational resources towards finding solutions to complex, multi-dimensional challenges. This has often brought faculty from multiple academic disciplines to work together in finding solutions to challenges and market-facing needs – for example:

- Bringing entomologists, microbiologists, plant pathologists, soil scientists, ecologists and others together under an "Integrated Pest Management" structure – an effective and environmentally sensitive approach to pest management that uses comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with deep understanding of available pest control methods, is used to reduce or prevent pest damage by the most economical means while limiting hazards to people and the environment.
- SNAP-Ed, bringing together expertise in consumer and family sciences, health and nutrition, education and communications to provide holistic education-based solutions to improving the health and wellbeing of low and moderate income families and individuals.

[74] While the terms multi-disciplinary, inter-disciplinary and trans-disciplinary have separate meanings, the colloquial use of these terms is often interchangeable. TEConomy uses the term "transdisciplinary" generally to refer to an environment of science in which multiple scientist/faculty work together on a common team to advance a research initiative, and an environment in which these faculty may come from multiple academic colleges, departments and individual academic disciplines. Elizabeth Pain, in *Science*, provides a concise description of the semantic differences in terms, noting that: "*Multi-(or pluri-) and interdisciplinary research are often used interchangeably, but originally they referred to different approaches. When experts from different fields work together on a common subject within the boundaries of their own discipline, they are said to adopt a multidisciplinary approach. However, if they stick to these boundaries they may reach a point where the project cannot progress any further. They will then have to bring themselves to the fringes of their own fields to form new concepts and ideas--and create a whole new, interdisciplinary field. A transdisciplinary team is an interdisciplinary team whose members have developed sufficient trust and mutual confidence to transcend disciplinary boundaries and adopt a more holistic approach."* http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2003_01_03/nodoi.16570029665485298080

Several major Land-Grant institutions are developing, or have developed, significant transdisciplinary initiatives targeting areas of need that have the potential to generate large-scale positive impacts for the economy and society. A notable example of this is the North Carolina Plant Sciences Initiative (NC PSI), which implicitly recognizes that transdisciplinary teams of scientists will be required to work on advancing major initiatives in plant sciences. The NC PSI, funded by the State of North Carolina, The Golden Leaf Foundation, and other key stakeholders, is building a state-of-the art transdisciplinary plant science building on the NC State Centennial Campus specifically to accommodate interdisciplinary approaches to plant science challenges and opportunities (including industry labs and collaborations). Purdue University has adopted a similar approach (also called the Plant Sciences Initiative), and the University of Missouri is likewise developing transdisciplinary approaches to enhancing post farm-gate value-added manufacturing in the state.

ACES has already embraced transdisciplinarity in an approach to research and education that is built around thematic areas rather than single traditional academic discipline silos. This is evident, for example, in the organization of academic programs under the eight themes (seven departments and one school) of:

- Agricultural and Extension Education
- Agricultural Economics and Ag Business
- Animal and Range Science
- Entomology, Plant Pathology and Weed Science
- Family and Consumer Sciences
- Fish, Wildlife and Conservation Ecology
- Plant and Environmental Sciences
- Hotel, Restaurant and Tourism Management.

ACES views its stated mission of achieving “economic and community development” for New Mexico through a thematic lens – with a focus on four transdisciplinary “pillars” as depicted in ACES’ illustrative diagram (Figure 20).

Figure 20: ACES Pillars for Economic and Community Development

As noted, ACES has been forward looking in terms of adopting an organizational framework conducive to modern transdisciplinary work. However, in reviewing areas of research, education and extension activity performed by ACES, some gaps were observed (perhaps better termed "opportunities") in thematic areas likely to be of significant importance to New Mexico, these included:

- **A very limited portfolio of work in the fast moving area of digital agriculture/precision agriculture.** This is one of the areas in agricultural science where transdisciplinary convergence is most evident – integrating agricultural sciences, digital sciences and engineering to achieve enhanced yields and substantial gains in input use efficiencies.
- **Only moderate work to develop an enhanced value-added processing industry for post farm-gate processing of agricultural food, feed and biomass products.** A number of leading Land-Grant universities in the U.S. are seeking ways to enhance economic and community development through research innovations and education focused on downstream value-added product and industry development.
- **Opportunities to leverage ACES expertise in extension education and modern media to address the issue of misinformation and disinformation impacting consumers and the agricultural value-chain.**
- **Opportunities to leverage ACES expertise in agricultural education, youth development, and on-line learning tools to address shortfalls in STEM education opportunities found across the state.**

Each of these areas would need further study to assess the feasibility of ACES engaging in focused transdisciplinary initiatives, and the potential impact of such initiatives on New Mexico. Below, TEConomy puts forward a brief prospectus of each of these three opportunity areas:

Opportunity	1. Transdisciplinary Initiative for Digital and Prescription Agriculture
Description	The primary global challenge of "how to increase agricultural production without pressing more land into agricultural use" is a key driver of innovation in agriculture. Striving to increase yield from every square foot of existing farmland, researchers are increasingly using digital and engineering-based technologies to create a "precision agriculture" industry. Precision agriculture systems deploy highly precise global positioning systems, advanced sensors, and data analysis technologies to provide the tools and information farmers need to optimize and customize the timing, amount, and placement of seed, fertilizer, pesticides, irrigation, and other inputs – all towards the goal of producing maximum yield at the lowest cost. Given New Mexico's more fragile production environment and limitations of water resources, precision and digital agriculture holds significant promise for enhancing state agriculture. *The Economist* views precision agriculture as "the biggest change to agriculture in rich countries since genetically modified crops."[75] Precision agriculture represents the "digitalization" of production systems and is inherently transdisciplinary. It requires the incorporation of an emerging set of technologies in sensing and data analytics to gather, track, and analyze agricultural data, usually in conjunction with other systems such as harvesting, planting, or field-input application machinery. Integrating multiple hardware and software technologies, precision agriculture engages not only traditional agricultural equipment manufacturers, but also includes companies engaged in information- or computer-oriented technologies, including agricultural decision support software, sensors and monitoring systems, GPS and mapping systems, predictive modeling technologies, and unmanned aerial surveillance (UAS) and imaging technologies.

[75] Schumpeter, "Digital Disruption on the Farm," The Economist, May 24, 2014.

Issues for ACES and NMSU	Engaging in a digital and precision agriculture initiative at NMSU would require the facilitation of transdisciplinary inquiry not only within ACES but also reaching into other NMSU colleges – most notably into the College of Engineering. At the present time, NMSU has only limited activity in the discipline of Agricultural Engineering, with a minor in the field under the Department of Civil Engineering within the College of Engineering. Appropriately addressing opportunities in prescription and digital agriculture would require collaboration across Colleges and Departments with areas outside of ACES likely needing to be engaged in: • The College of Engineering: Civil/Ag Engineering; Chemical and Materials Engineering (particularly in regard to sensor systems); Electrical and Computer Engineering, and Industrial Engineering. • The College of Arts and Sciences: Computer Science; Geography, and Mathematical Sciences. Within ACES such an initiative would be likely to draw from faculty across four primary department areas: Plant and Environmental Sciences; Entomology, Plant Pathology and Weed Science; Agricultural Economics and Ag Business, and Animal and Range Science. Agricultural and Extension Education would likely have potential for engagement also.
Potential Impact Benefits	• Development and introduction/testing of digital and precision agricultural technologies for the improvement of farming and ranching yield and profitability in New Mexico. • Optimization of inputs application with associated cost and environmental benefits. • Water use efficiencies. • Enhanced collection of field data for ongoing research and the improvement of New Mexico agriculture. • Enhanced preparation of students for entering production environments that will increasingly see adoption of modern digitally enabled technologies in order to sustain competitiveness. • Potential development of commercializable technologies leading to entrepreneurship opportunities and new business development.

Opportunity	**2. Transdisciplinary Initiative for New Mexico Agri Value-Chain Enhancement**
Description	Multiple states have worked to increase economic output through encouraging the post-farmgate manufacturing of value added food products and/or downstream value-added products from biomass (such as biobased chemicals, fuels, or fiber products). Universities, especially Land-Grant universities, have been playing an important R&D and education role in this movement, with institutions such as Iowa State University, the University of Nebraska, and The Ohio State University investing in R&D centers equipped with testing equipment, pilot plant equipment and other resources required to advance university-innovations and bring university expertise to bear on industry challenges and needs. The development of value-added small-scale farm enterprises provides individual farmers or groups of farmers with an opportunity to supplement and diversify their incomes. The development of value-added processing of New Mexico produced farm and ranch products also can reduce the outflow of commodities that leave the state with limited or no value-added and substitute for currently imported processed food or biomass-based products.
Issues for ACES and NMSU	ACES currently has relatively limited activity in the value-added space. Most of the activities in food processing at ACES are more focused around biosecurity related issues and on the education side on training personnel in safe food handling procedures. There is also some educational activity by ACES to support entrepreneurs trying to start new value-added ventures, but it is relatively limited at the present time. ACES does, however, have assets that may be applied to a larger-scale transdisciplinary initiative focused on identifying and developing value-added production in the state. In addition to having a Food Science and Technology education track within the Department of Family and Consumer Sciences, ACES also

	benefits from the signature capabilities of the School of Hotel, Restaurant and Tourism Management. ACES has been proactive in working to introduce new crops to the New Mexico production environment, and there is opportunity to tie the introduction of such crops to new processing ventures that would help secure a supply and demand environment for producers and processors.
Potential Impact Benefits	• Additional value-added to New Mexico produced farm and ranch output • Diversified income streams for producers • Potential processor and producer contractual relationships helping to decouple producers from the significant fluctuation in unpredictable commodity market prices • Reduced importation of value-added products produced elsewhere to meet New Mexico market demands.

Opportunity	**3. Transdisciplinary Agricultural Literacy Initiative**
Description	When TEConomy representatives have met with major agbioscience companies, commodity groups, producers and other key stakeholders in the agri-food value-chain a fairly consistent issue has been raised by industry – misinformation and disinformation impacts on market development. The challenge is significant, growing and global with the Internet and social media able to rapidly spread misinformation and facilitate the dissemination of deliberately misleading or false information by special interest groups. Misinformation is false or inaccurate information that is spread unintentionally. Disinformation is intentionally false or inaccurate information that is spread deliberately. Both misinformation and disinformation can have significant impact on domestic and worldwide opinions and shape public and regulatory policies. Agriculture has been on the receiving end of a wide-range of mis/dis-information challenges with, for example: • Urban consumers increasingly distanced from the food production system and lacking an informed understanding of the farming and value-added systems that supply their food. • A lack of consumer understanding of the modern techniques used to improve crops and livestock, and a tendency towards fear of transgenics, gene-editing and other genetically modified agricultural techniques. • A growing belief that all farming in the U.S. is operated by large-scale corporate farming and that the small family farm hardly exists. • Disinformation regarding the health impacts of common agricultural chemicals and an expanding misperception that “organic farming” uses no such inputs. The above examples represent just a few of many challenges related to communications and mis/dis-information impacting agriscience and agribusiness.
Issues for ACES and NMSU	ACES may have the ability to launch a transdisciplinary communications initiative focused on both combatting mis/dis-information and providing an outlet for communicating scientific consensus on agricultural production practices and their contributions to domestic and global food security and food affordability. In addition to the usual expertise contained across faculty and extension, ACES has some rather unique signature programs and resources that could be applied to this opportunity – for example: • The Department of Agricultural and Extension Education • The Innovative Media Research and Extension Team. These represent robust research and education programs at ACES, containing expertise in ag-related communication to audiences ranging from school children to science-savvy producers. Such a transdisciplinary initiative could also incorporate NMSU expertise from outside the ACES College – with relevant expertise likely to be found in:

	• The College of Arts and Sciences: Creative Media Institute; Department of Communication Studies, and the Department of Journalism and Mass Communications. • The College of Business: Department of Marketing • The College of Health and Social Services: Public Health Sciences Department.
Potential Impact Benefits	• Potential to attract significant financial resources from USDA, the agriscience industry, commodity groups and other stakeholders seeking to improve public understanding of the science of agriculture and food production. • Long-term improved consumer demand conditions for food products produced using modern molecular crop-improvement technology that enhances yield and producer profitability and sustainability.

Opportunity	**4. Transdisciplinary Youth Development Initiative**
Description	The importance of receiving a solid base of STEM (Science, Technology, Engineering and Mathematics) Education as part of the overall development of youth can not be overstated. According to the U.S. Department of Commerce, STEM occupations are growing at 17 percent, while other occupations are growing at less than 10 percent. STEM degree holders have a higher income than non-STEM careers. These careers play a key role in the sustained growth and stability of the economy and are a critical component to helping any region prosper in the future. STEM education creates critical thinkers, increases science literacy, and enables the next generation of innovators. Innovation leads to new products and processes that sustain our economy. Innovation and science literacy depend on a solid knowledge base in the STEM areas. It is clear that most jobs of the future will require a basic understanding of math and science. Unfortunately, as the importance of STEM education continues to grow, the nation falls further and further behind. Out of the 35 members of the Organization for Economic Operation and Development (OEDC), the US ranked 30th in math achievement and 19th in science achievement. Only 36 percent of all high school graduates are prepared to take a college-level science course. As a result, according to the Department of Labor, U.S. universities are expected to produce only 29 percent of the number of graduates required to fill anticipated job openings in the coming five years. If leaders within the agbioscience community do not feel these statistics impact the field, they would be wrong. According to a report from the U.S. Department of Agriculture (USDA) supported by analysis from Purdue University, there will be nearly 58,000 job openings in the U.S. food and agriculture industry each year (from 2015 to 2020) for college graduates from across the country. Over this same period, an average of 35,400 new U.S. graduates with degrees in food, agriculture, and natural resources will step in to fill these positions, potentially leaving almost 40 percent of the available jobs open. The transdisciplinary challenges referenced above, that can effectively be solved through advancements in agbioscience innovation, are thus occurring at a time when there are not enough skilled individuals entering the workforce.
Issues for ACES and NMSU	ACES has the ability to launch a transdisciplinary youth development initiative focused on both enhancing in-person STEM education throughout the State of New Mexico as well as through on-line tools and resources. In addition to the usual expertise contained across faculty and extension, ACES has some rather unique signature programs and resources that could be applied to this opportunity – for example: • The Department of Agricultural and Extension Education • 4-H Extension Team • The Innovative Media Research and Extension Team.

	These represent robust research and education programs at ACES, containing expertise in youth development focused on both school children as well as their teachers. Such a transdisciplinary initiative could also incorporate NMSU expertise from outside the ACES College – with relevant expertise likely to be found in: • The College of Education, School of Teacher Preparation, Administration and Leadership • The College of Education, Learning Design & Technology Degree Programs • NMSU STEM Outreach Center.
Potential Impact Benefits	• Potential to attract significant financial resources from USDA, the agriscience industry, commodity groups, school systems, civic leaders, and other stakeholders seeking to improve the development of youth as the future pipeline of talent for both the agbioscience industry as well as other STEM-related careers. • Long-term improved talent pipeline for the agbioscience industry and other innovation-driven industries that will lead to economic prosperity for the state and its citizens.

In addition to the above, it is also recommended that ACES direct more internal resources to assuring that faculty build reliable impact tracking and associated metrics into their research programs. TEConomy found that some ACES faculty have diligently tried to measure the effects of implementation of their research – providing data on increased yields, adoption of new technologies, potential losses prevented, number of persons served, etc. There is great variability, however, in availability of such information across ACES programs, and only a few of the research, education and extension initiatives undertaken by ACES have robust impact metrics, with dollar impacts or other metrics, associated with them. Given the, largely, applied nature of ACES work across New Mexico, it would behoove the College to continue to standardize expectations for annual reporting of research impacts and for establishing a selected number of long-term impact tracking projects in areas anticipated to be particularly significant in their benefits for New Mexico.

VII. CONCLUSIONS

The multifaceted economic and social impacts generated in New Mexico by the activities of NMSU ACES, including its Agricultural Experiment Station, Cooperative Extension Service, and Academic Programs, are significant. This three-component NMSU ACES system provides higher education (at both the undergraduate and graduate levels), undertakes basic and applied research, and extends research-based knowledge and best-practices to benefit agriculture, value-added industries, communities and families across New Mexico. It is a unique and valuable resource for the state.

In terms of ACES, the Agricultural Experiment Station and Cooperative Extension Service expenditure impacts alone, the expenditures generate $132 million in annual state output, supported 1,204 jobs, realizing $65 million in personal income for New Mexicans. The full impact of the mission-driven programs and activities, however, greatly eclipses these institutional expenditure impacts.

The programs and activities of NMSU ACES and its Agricultural Experiment Station within basic and applied R&D drives innovations in New Mexico that sustain and expand agriculture and agribusiness, while Cooperative Extension works proactively to assure these innovations are diffused and of maximum benefit to the New Mexico economy. Finally, the talent generated by the college through new graduates helps ensure the agbioscience industry in New Mexico remains globally competitive, and that the education of students provides a broad range of benefits to the individual, to society at large, and to the State of New Mexico.

Case studies, performed by TEConomy, to assess the impact of just some of these initiatives find many positive benefits for the New Mexico economy that run into the hundreds of millions of dollars. What is discovered through this review is that the ACES system is having a powerful impact on the state – with some examples illustrated in Figures 21 through 23 summarizing just some of the impact areas considered and highlighted herein.

Figure 21: Case Studies in ACES Impact – Examples of Agricultural Impacts in New Mexico. $190.7 Million from 6 Example Initiatives.

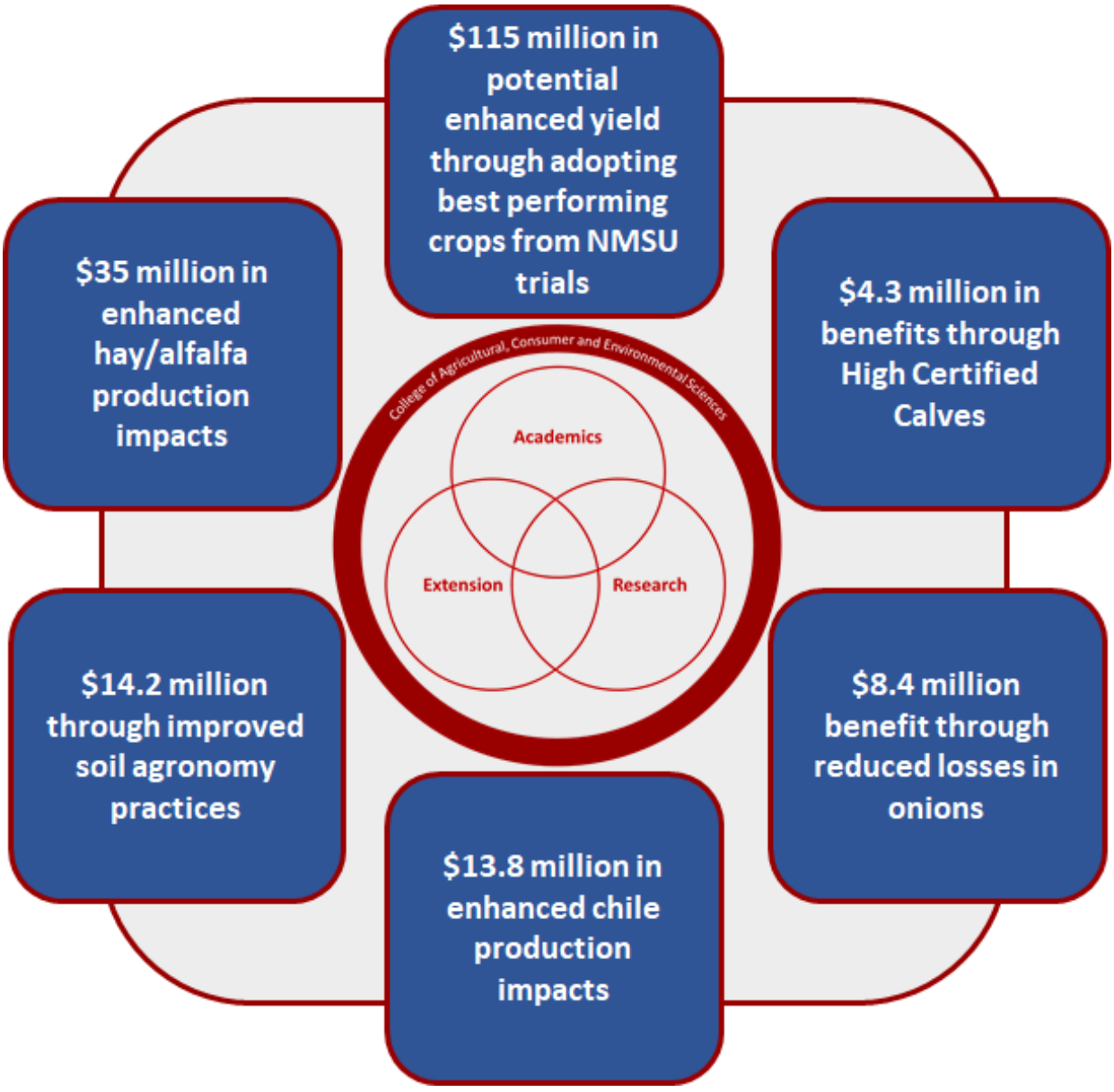


Figure 22: Case Studies in ACES Impact – Examples of Healthcare and Youth Programs

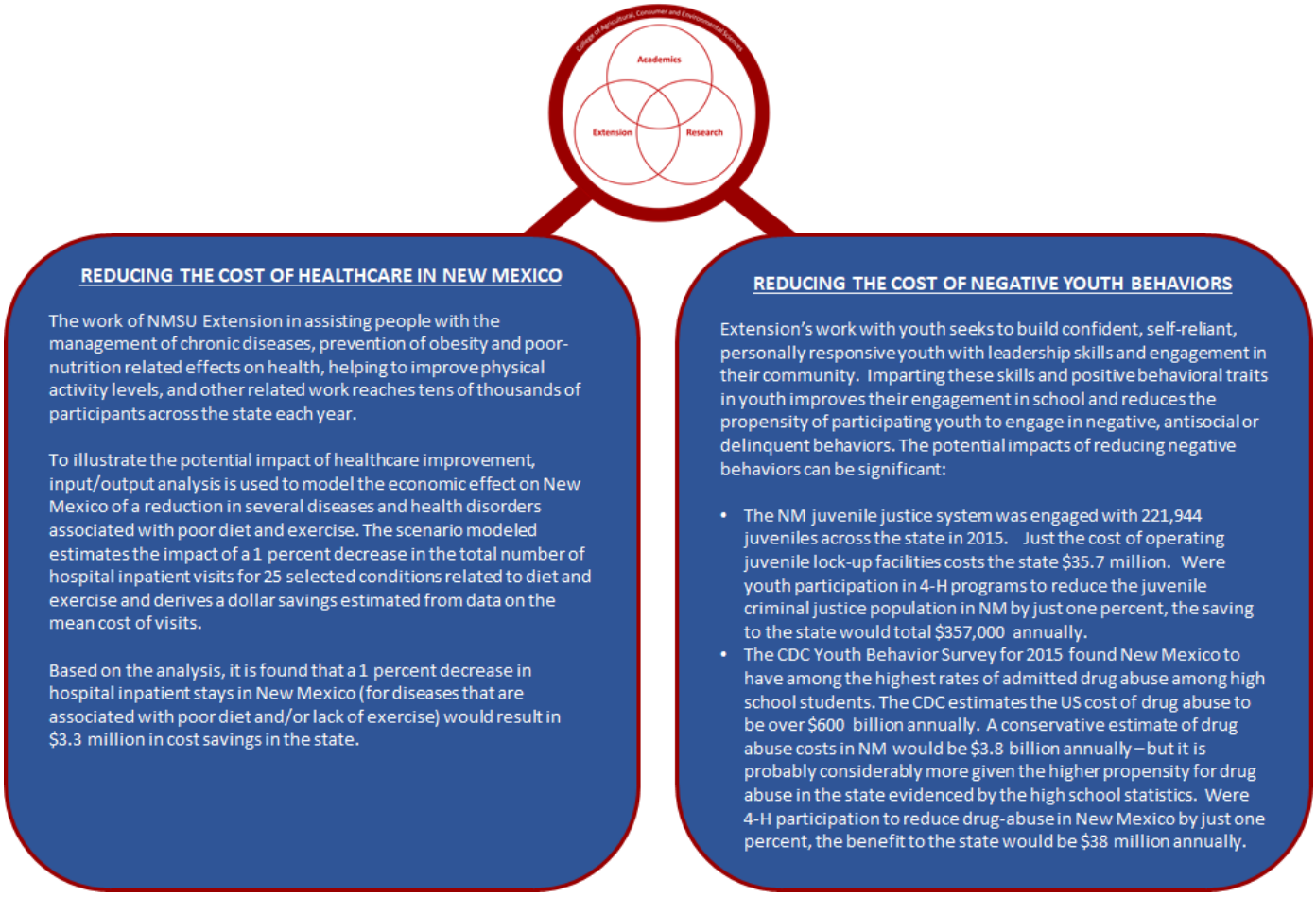
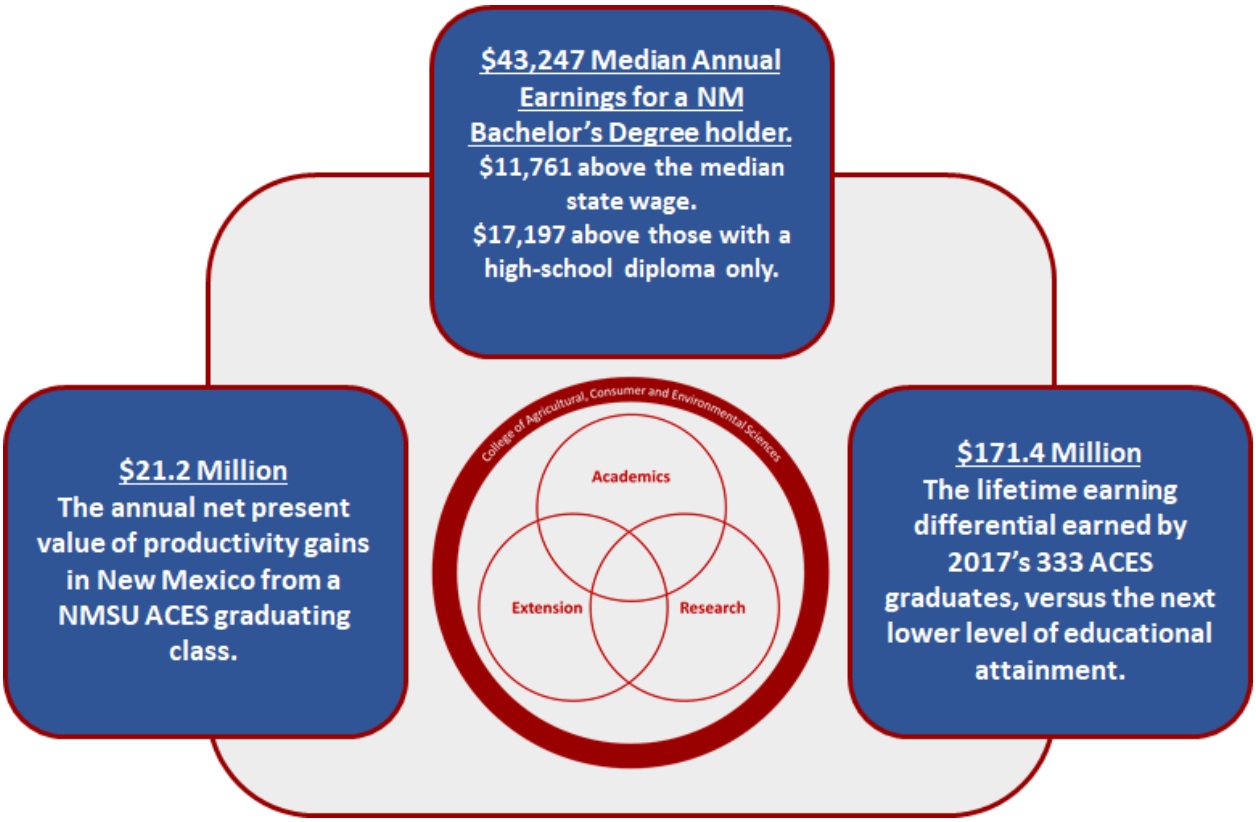


Figure 23: Case Studies in ACES Impact –Economic Benefits of ACES Higher Education Credentials



While it is clearly very difficult to put a final dollar value on each and every program and activity undertaken, it is clear that the diverse work of NMSU ACES in research, the focused work to deploy research-findings into action across New Mexico undertaken by Cooperative Extension, and the educational gains being made through ACES graduates is having large-scale and wide-ranging economic and societal benefits across the state. Given NMSU's long-standing Land-Grant track record in the agriculture and natural resource sectors, and the dedicated resources ACES applies to improving and growing the agriculture and agribusiness sectors of the state economy, ACES's work has a powerful annual impact on state output in these sectors. A general perspective can be gained through modeling what the total impact would be for each one-percent boost in the New Mexico agricultural output. Utilizing the IMPLAN input-output analysis, the impact of each one-percent increase in agricultural production was calculated (Table 31).

Table 31: The Impact of One-Percent Incremental Increases in New Mexico Agricultural Output

Level of Increase in Agricultural Output	Impact on Total NM Economic Output	Number of Jobs Generated in the New Mexico Economy	Labor Income Generated in the NM Economy
1 percent	**$53,356,364**	**531**	**$15,185,419**
2 percent	$106,712,728	1,062	$30,370,838
3 percent	$160,069,092	1,593	$45,556,257
4 percent	$213,425,456	2,124	$60,741,676
5 percent	$266,781,820	2,655	$75,927,095

As shown on Table 30, every one-percent increase in New Mexico agricultural output has substantial benefits for the New Mexico economy, generating:

- **A total economic output impact totaling $53.4 million.**
- **Labor income generated for New Mexicans would be almost $15.2 million.**
- **531 jobs would be created in the state.**

It is clearly challenging to determine what level of increase in state agricultural output may be allocable on an annual basis to the work of NMSU ACES. However, one can look across the many functional impacts to see what sorts of impacts are being generated through just some of the many NMSU ACES programs. Through this analysis, **it is clear that direct benefits from ACES programs for the agricultural sector considerably exceed the one-percent level – and more likely would be in the order of a five-percent or higher magnitude**.

It also should be noted that expanding the agricultural sector presents opportunities to benefit every county in the state. Agriculture and associated processing industries are highly diffused across every New Mexico county; therefore, the direct and indirect effects of expansion in the sector are felt much more widely than with narrower, geographically focused sectors.

While NMSU, as a Land-Grant University, has its origins in legislation originally written in 1862 (and Extension legislation in 1914), the Land-Grant vision embodied in ACES, its Agricultural Experiment Station, and Cooperative Extension Service is as relevant today as it has ever been. Research, education, and the ability to put knowledge into action to enhance the economy is absolutely key to economic success in a highly competitive global economy. As this study illustrates, the three-component ACES system at NMSU is on the frontlines in these arenas, working to secure New Mexico's current and future economic position, resiliency and success. At the same time, ACES is doing much more—undertaking work to protect New Mexico's water and natural resources, to help families and individuals reach their full potential, and build healthy and productive communities across the state. It is found that the ACES system, while headquartered at NMSU in Las Cruces, is truly a statewide asset – providing benefits to all in the state and great promise for many more benefits into the future. By supporting the College, the Agricultural Experiment Station and Cooperative Extension Service, governments at the federal, state and county levels are investing in the future sustainability, health and prosperity of New Mexico and New Mexicans, and the investment demonstrates very strong returns.