Enabling Precision Agriculture in North Carolina
USDA RBDG

Professor Nicholas Didow, PI
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University of North Carolina
Chapel Hill, NC 27599-3490

Final Report

Period of Performance: October 1, 2020 – September 30, 2021

Project Abstract: Farmers across Eastern North Carolina are becoming increasingly dependent on precision agriculture technologies to control costs, sustain profit, and compete nationally and globally. The agriculture sector has embraced telematics and other automated data centric analytical tools within the general descriptive name "precision agriculture" to increase farming efficiencies and reduce operating costs. Yet, none of these benefits can be realized without access to reliable and robust broadband in the field or farm office. Today, the majority of growers in Eastern North Carolina have either intermittent or no access to high-speed wireless broadband connectivity due to a lack of coverage and speed on the farm. This project seeks to:

1. Conduct on a farm in Lenoir County a field-test of an innovative way to provide an affordable, reliable, and robust high-speed 5G mobile broadband network in rural North Carolina by leveraging existing underutilized tower infrastructure;
2. Perform a ten county market analysis of the broadband coverage needs and economic benefits to farm businesses and the other businesses that benefit directly and indirectly from PA adoption enabled by broadband access; and,
3. Develop a sustainable business and marketing plan for an innovative ten-county 5G mobile broadband network service for farms, businesses, families, community anchor institutions, and individuals in the ten county area.

Many times over the past 12 months I have said I was thrilled, excited, and appreciative to receive this amazing USDA RBDG grant for such a worthwhile project. To design and conduct an ambitious largely field project like this is certainly challenging even in the best of circumstances, but to do it during the COVID-19 pandemic was unbelievably challenging. When the award was announced and as the project started on October 1, 2020, I began daily to watch the status of the COVID-19 pandemic, ever hopeful that we would quickly return to normal. That has not yet happened even today as the project is concluded and as I write the final report, but we have successfully planned and conducted this project and accomplished all deliverables at high quality and with major impact. As you would expect, this entire project was conducted in accordance with federal and state COVID-19 protocol guidelines with respect to vaccinations, masks, indoor gatherings, and outdoor gatherings including limitations on crowd size and physical spacing for both indoor and outdoor gatherings. To say that COVID-19 made for a particularly challenging project journey is an understatement; but, I appreciate all the teamwork, partnerships, encouragement, and support from everyone who made this project successful -- and I would do it again without question.

The project journey is largely chronicled in the four quarterly performance reports attached to this document as Appendix A. As acknowledged in these quarterly performance reports, this project was conducted and accomplished by a dedicated team of individuals with me as the Principal Investigator.

My core project team included:

- Professor Jason Ward, Biological and Agricultural Engineering, North Carolina State University
- Jessica Zufolo, FCC Precision Agriculture Task Force
- Jack McNairy, President, Harvey's Farms and Harvey Enterprises
- Steven Warwick, Connected Devices
- Christine Korowajczuk, CelPlan Technologies, Inc.
- Ian Moore, Alaska Map Science
- Alex Freylekhman, TelRad Networks
- Karen McFarland and Tammy Moravansky, Kenan-Flagler Business School, University of North Carolina

We also collaborated and coordinated many aspects of the project with Chinmay Soman, CEO and Founder, EarthSense; Steven Swain, Quality Equipment, John Deere; Kenneth Sherin, Broadband Access and Education Coordinator, NC Agriculture Extension; Natalie Rivera, Internet Connectivity Project Coordinator, NC Farmworker Health Program, NC Department of Health and Human Services; and, Jeremy Collins, NCDIT Office of Digital Equity and Literacy, Office of the Governor, State of North Carolina.

This project final report is organized by the three major deliverables identified above in the Project Abstract and by the major basis for determining project success according to the project narrative. The major basis for determining project success is whether the project results in the establishment of a new broadband network and service across the ten county region which provides affordable, reliable, and robust high-speed broadband connectivity in the field and farm office for PA applications and PA benefits, and in the home and business settings for others across the region. All three major project deliverables have been met, and the project itself has contributed significantly to new initiatives currently underway to deploy affordable, reliable, and robust high-speed broadband connectivity across unserved and underserved areas of rural Eastern North Carolina.

First Major Deliverable – Create Connectivity to Enable PA

The first major deliverable was to ***Conduct on a farm in Lenoir County a field-test of an innovative way to provide an affordable, reliable, and robust high-speed 5G mobile broadband network in rural North Carolina by leveraging existing underutilized tower infrastructure.***

We met the first major deliverable by successfully deploying a TelRad wireless broadband network using CBRS spectrum on an existing RTK tower located in a Harvey's Farms field outside Kinston and using this connectivity to enable several precision agriculture field applications and technologies, as well as to provide Internet connectivity to the fields, farm offices, and employee housing facilities at the site. We also hosted a precision agriculture field day demonstration event at the farm site on August 19, 2021.

TelRad network systems and CBRS spectrum have advantages over other technologies and other spectrum in their ability to provide connectivity in non-line-of-sight circumstances, as well as in line-of-sight conditions. Non-line-of-sight in Eastern North Carolina farm locations are more frequent than line-of-sight due mostly to tree lines and other dense foliage.

We also obtained and installed a Sentek Arable Mark II field monitor and a HOBO greenhouse monitor to add to the PA applications available for our demonstrations and field tests enabled by deploying the TelRad network using underutilized RTK tower infrastructure.

On the morning of April 6, 2021, the TelRad network was effectively deployed by Steven Warwick and his Connected Devices team at an elevation of 50 feet on the existing RTK tower located on Harvey's Farms off Bill Smith Road outside Kinston in Lenoir County. The network provided wireless connectivity to existing agriculture PA applications across the farm and to the Sentek Arable Mark II field monitor and HOBO greenhouse monitor. We also deployed a TelRad CPE (Consumer Premises Equipment) at the employee lodging facility located about a half mile from the RTK tower and provided connectivity to the migrant workers residing in that facility. We continued to periodically field-test different PA applications on site at the farm using the connectivity we had effectively established.

Below are some pictures of the TelRad network being deployed by a tower climber 50 feet up on the existing RTK tower, a point-to-point microwave mounted on the side of the farm building to provide Internet backhaul for the network on the RTK tower, and the TelRad antennae and base station equipment installed on the tower.

These next pictures show Jack McNairy and Jason Ward opening and assembling the HOBO greenhouse monitor and the Sentek Arable Mark II field monitor which we also used to field test effective connectivity from the deployed wireless network.

We decided that the best way to field test this innovative way to provide affordable, reliable, and robust broadband connectivity and the benefits from precision agriculture that connectivity enables would be to host a field day demonstration August 19 on the farm site outside Kinston. Priority attendees we would invite from the region would include farmers, farm business owners, FFA and 4H leaders and members, NC Agriculture Cooperative Extension directors, and state and local elected officials.

We established an agenda for the day and finalized commitments from several precision agriculture and broadband connectivity leaders to provide field PA demonstrations and to speak in "Tent Talks" about innovations and benefits from connectivity enabled PA technologies. A program from the Precision Agriculture Field Day Demonstration Event is included as Appendix B of this report.

The event participants included:

- Alex Freylekman, TelRad Networks, CBRS spectrum innovations in agriculture using RTK towers
- Steven Swain, Quality Equipment and John Deere
- Jason Ward, NCSU, HOBO greenhouse monitoring and UAVs
- Travis Daniels, Harvey Farms, drones and data analysis
- Jason Ward, NCSU, Arable Mark II soil sensor
- Chinmay Soman, EarthSense, real time field data collection and analytics with robotics
- Jeremy Collins, NCDIT and Hometown Strong Office of Digital Equity and Literacy
- Natalie Rivera, NC DHHS Farmworker Health Program
- Kenneth Sherin, NC State Ag Extension, Broadband Access and Education Coordinator

We distributed printed and electronic invitations to attend the precision agriculture field day event through all our networks, communication channels, and with flyers I distributed when I attended the Blackland Farm Manager's Tour on August 4. We also made arrangements to host everyone outside on August 19 under a large tent for shade, with clean porta-johns, BBQ, and ice cream during lunch.

Our planning target for the number of attendees was 40 +/-. We quickly saw the number of registrants pass that figure, and ended up with 70 to 75 attendees outside on the farm in 98 degree sunshine and under the tent for conversation, networking, lunch, and talks.

About 40 of the attendees were farmers or from farm businesses in the region, 20 were NC Ag Cooperative Extension agents and staff, and 15 or so were media, interested citizens, and public policy advocates.

Our original plan was to offer the PA field day demonstrations several times on different days. However, due to the ongoing COVID-19 situation and state and federal guidelines, we decided to video and audio record all the demonstrations and talks and post these resources on a website available to everyone at www.ncprecisionag.org and other public places.

Several Agricultural Extension directors also made video and audio recordings for them to use at a later date with other interested audiences, as did Jason Ward for use at NCSU.

Here are some pictures of the August 19 event. The pictures show the large tent where people gathered, networked, ate lunch, and listened to brief "Tent Talks"; some pictures of the field demonstration sites; and, the John Deere Precision Agriculture Mobile Classroom.

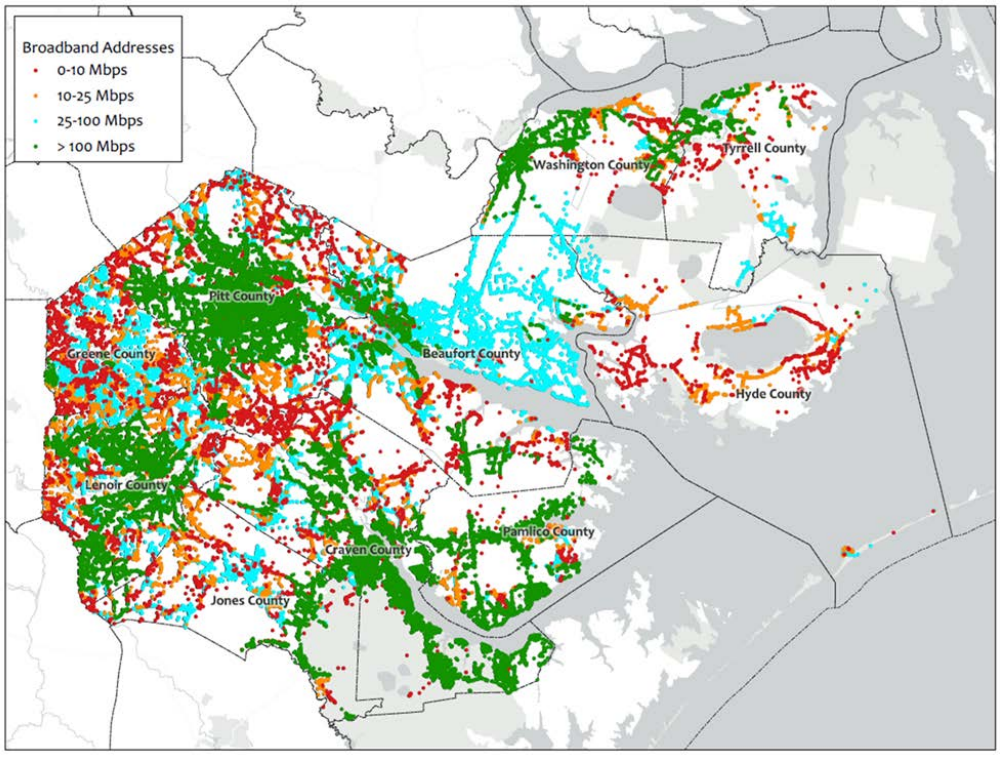
As a result of our creativity, patience, thoughtful planning, and thorough implementation, we successfully accomplished the first major deliverable for this important project.

Second Major Deliverable – Estimate PA Benefits

The second major deliverable was to ***Perform a ten county market analysis of the broadband coverage needs and economic benefits to farm businesses and the other businesses that benefit directly and indirectly from PA adoption enabled by broadband access.***

We successfully met the second major deliverable by developing and distributing a White Paper titled, "Broadband Coverage Needs and Economic Benefits to Farm Businesses from Precision Agriculture Adoption in Eastern North Carolina." The White Paper is included as Appendix C in this final report. The strategy we used to estimate the economic benefits from PA adoption was to extrapolate the economic benefits from PA adoption found in major research studies in other US rural areas to farm businesses in Eastern North Carolina. The White Paper in Appendix C provides much greater detail than the summary herein.

First, we confirmed the broadband coverage needs for this region through interviews and analysis of state and federal data bases. The following map is a typical representation of the extent to which the region is unserved or underserved.



The green dot areas are the locations of the four major towns in the region – Kinston, Greenville, Washington, and New Bern – non-rural areas with only occasional farms where legacy providers claim to offer high-speed service, although most is by copper cable and some by fiber. The red, yellow, and blue dot locations are generally farm lands that are underserved or unserved, and the rest – the white areas – are almost entirely farm areas that are completely unserved. State and USDA surveys confirm that PA

adoption throughout the rural geography of this region is minimal as reliable, affordable connectivity is lacking or nonexistent.

As reported in the White Paper, the table below shows the number of farms in each of the ten counties; the acres of land in farms; the market value of sales; the percent of sales from crops; the percent of sales from livestock, poultry, and products; and, the percent of farms that sell directly to consumers as reported in the USDA's 2017 *Census of Agriculture*.

Counties	**Farms**	**Acres land in farms**	**Mkt value sales**	**% sales crops**	**% sales livestock, poultry, products**	**% farms sell directly to consumers**
Washington	141	79,680	$49,046,000	88%	12%	6%
Tyrrell	68	52,946	$43,561,000	NR	NR	6%
Hyde	138	124,874	$117,383,000	NR	NR	2%
Beaufort	310	139,457	$112,038,000	65%	35%	6%
Pitt	478	186,412	$242,458,000	42%	58%	7%
Greene	207	83,322	$242,483,000	29%	71%	2%
Lenoir	386	113,708	$311,373,000	24%	76%	7%
Jones	177	65,649	$213,623,000	14%	86%	12%
Craven	245	81,360	$71,606,000	51%	49%	11%
Pamlico	100	43,262	$23,373,000	98%	2%	8%
TOTAL	**2,250**	**970,670**	**$1,426,944,000**			

According to the USDA 2017 *Census of Agriculture*, these ten counties in Eastern North Carolina include a total of 2,250 farms on 970,670 acres of farm land, with an average farm size of 431 acres. The total regional annual market value of farm sales is $1,426,944,000 for an average annual market value of farm sales of $634,420. Although they vary from one county to another, overall across the region these market sales are split rather evenly between crop sales and sales of livestock, poultry, and products. Only a small percentage of farms sell directly to consumers.

The total regional annual market value of farm sales is about 10% of the entire State of North Carolina annual market value of sales and the average farms sales of $634,420 in this region is over twice the state average of $277,924.

The White Paper then summarizes the estimated economic benefits from PA adoption using four sources and extrapolates these benefits to estimate the incremental annual economic benefit to the 2,250 farms in this ten county Eastern North Carolina region. The following table shows this analysis.

Source	Estimated Economic Benefit from PA Adoption	Incremental Annual Economic Benefit to 2,250 Farms in Ten County Eastern NC Region
USDA -- *A Case for Rural Broadband*	4.85% average increase in annual value row crops and livestock and dairy	$69,206,784
John Deere	additional $40/acre economic value	$38,826,800
Farms.com	additional $45/acre in revenue	$43,468,150
Pope and Sonka	$90/acre average net benefit	$87,360,300
AVERAGE		**$59,715,509**

Our analysis finds the average economic benefit for farms across the entire region from PA adoption is estimated to be $59,715,509 per year, and the annual benefit for each of the 2,250 farms would average $26,540 or roughly $62 per acre.

This White Paper admittedly focuses only on the potential direct economic benefits to farms and does not include multiplier effects to estimate indirect benefits, nor does it include other considerations such as environmental benefits; telehealth, medical emergency, and other health care benefits; nor migrant labor and other employee benefits. Therefore, this White Paper significantly understates the direct and indirect benefits to farms from PA enabled by access to affordable and reliable wireless broadband. Even with this shortcoming, these results provide strong support for the economic argument from agriculture and broadband advocates who champion affordable and reliable broadband deployment throughout rural America to finally close the Digital Divide as doing so makes possible the adoption of transformational initiatives such as precision agriculture possible, affordable, and beneficial to all stakeholders.

The White Paper is available to the public and has been distributed through various channels including UNC, NCSU, and NC Cooperative Extension.

This successfully accomplishes the second major deliverable for the EPA in NC project.

Third Major Deliverable – Plan for Sustainable Broadband Service

The third major deliverable was to ***Develop a sustainable business and marketing plan for an innovative ten-county 5G mobile broadband network service for farms, businesses, families, community anchor institutions, and individuals in the ten county area.*** We successfully accomplished this deliverable using publically available industry and market data and present our detailed plan in Appendix D titled, “Bringing Connectivity to Rural Eastern North Carolina”. This detailed White Paper is excerpted and summarized below.

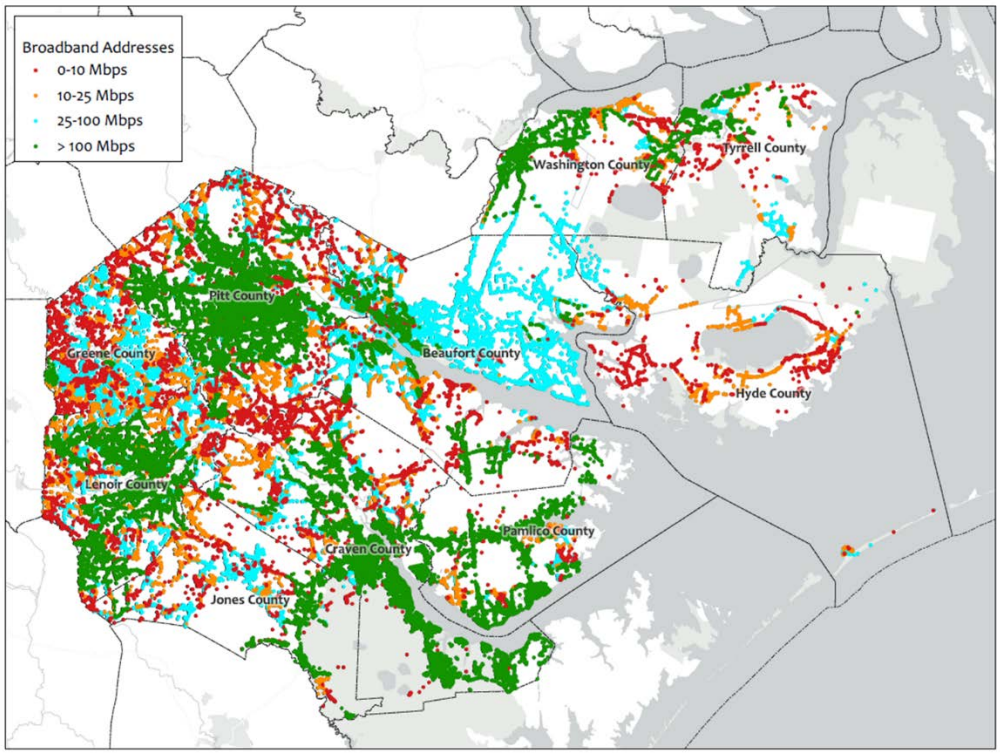
We find it is possible to sustainably offer broadband service to currently unserved and underserved rural areas of these ten Eastern North Carolina counties, particularly when a significant portion of the CAPEX deployment cost is covered by a local, state, or federal grant.

The US Census Bureau's 2019 *American Communities Survey* estimates the total population of the ten counties at 449,569 individuals residing in 179,017 households, for an average household size of 2.5 persons. The following table summarizes the county size in square miles, 2019 population estimate, 2017 estimated number of farms, and 2019 estimated number of businesses for each of the ten counties in the service area:

Counties	**Square Miles**	**Population**	**Farms**	**Businesses**
Washington	424	11,580	141	222
Tyrrell	594	4,016	68	72
Hyde	1,424	4,937	138	164
Beaufort	958	46,994	310	1,084
Pitt	655	180,741	478	3,659
Greene	266	21,068	207	261
Lenoir	403	55,949	386	1,173
Jones	473	9,419	177	132
Craven	774	102,139	245	2,158
Pamlico	567	12,726	100	237
TOTALS	**6,538**	**449,569**	**2,250**	**9,162**

NTIA estimates 26.5% of these 449,569 individuals residing in 179,017 households currently have no Internet access and 18.9% have no Computer, no Smartphone, nor Tablet. However, based on a review of broadband service providers throughout the ten county region and local information, broadband service availability varies dramatically from the "good side" of the Digital Divide wherein several Internet providers operate and offer service in the four major towns of Greenville, Kinston, New Bern, and Washington to the "bad side" of the Digital Divide in the rural areas surrounding these four major towns. Based on Internet access data reported in FCC Form 477 (June 30, 2020) and on local community knowledge, 53% of these 119,427 households, 2,250 farms, and 1,374 businesses are estimated to currently have access to no service or less than 10/1 Mbps service, 35% have access to 10/1 Mbps to less than 25/3 Mbps, 9% have access to 25/3 to less than 100/20 Mbps, and 3% have access to greater than 100/20 Mbps.

Using these federal data sources, the map below shows broadband access by speed tiers across the ten county region. Note that the faster available speed tier locations are all located proximate to the four largest towns in the region – Kinston, Greenville, New Bern, and Washington. In summary, the more rural the location, the slower the broadband that is available, if at all.



There are also a total of 9,162 "employer establishments," or businesses, in the ten counties as reported by the 2019 US Census Bureau's *QuickFacts*. These range in number from only 72 in Tyrrell County to 3,659 in Pitt County.

About 85% of these "employer establishments" are located within the four major towns of Greenville, Kinston, New Bern, and Washington and therefore are not included in the planned service area. The remaining 15%, or 1,374 businesses are within the planned service area.

The region also includes four major National Parks and Wilderness Areas that total 674 square miles. These parks and areas are the Alligator River National Wildlife Refuge and Reserve, Lake Mattamuskeet, Croatan National Forest, and Hofmann Forest.

Adjusting the service area to remove the 84 square miles, 153,283 population, the 7,788 businesses located within the four major towns of Greenville, Kinston, New Bern, and Washington, and the 674 square miles of parks and wilderness areas results in a net planned service area of 5,780 square miles with a population of 298,567 individuals in 119,427 households, 2,250 farms, and 1,374 businesses. It is logical that the percentage of households without Internet access in the planned service area is much greater than the NTIA ten county estimate of 26.5% as the four major towns are currently served by several existing broadband companies.

Using available industry data and cost estimates, it is possible to estimate the CAPEX costs to deploy a fixed wireless broadband service network across the entire 5,780 square mile ten county net planned service area, excluding the square miles for the four major towns and the park and wilderness areas.

Two additional key data points are the square miles of effective coverage per tower and the CAPEX cost per tower.

Industry data and RF network modelling conservatively suggest that multiple sectors deployed at a reasonable height on vertical structures – commercial towers, water towers, or grain silos -- in these Eastern North Carolina counties should provide effective connectivity to at least 80% of the desired locations within a 3 mile radius of the vertical structure on which they are deployed. A 3 mile effective radius per tower equals coverage of roughly 28 square miles per vertical structure, calculated using the formula for the area of a circle *Area = pi X radius squared*, or in this instance, Area of 28 square miles = 3.14 X (3 miles X 3 miles).

So if the average effective coverage per tower is 28 square miles and the net planned service area is 5,780 square miles, then the number of tower or vertical structure deployments needed is 5,780/28 = 206 towers.

Current available industry cost estimates indicate fixed wireless network deployment costs with multiple sectors per tower typically range from roughly $125,000 per tower to $145,000 per tower, depending on factors such as the number of sectors and type of vertical structure (commercial tower, water tower, grain silo, etc.). Using the higher deployment cost figure of $145,000 per tower and the calculated figure of 206 towers needed to provide coverage across the net service area of 5,780 square miles for the ten counties, the CAPEX would be 206 X $145,000 = $29,870,000. Note that our analysis and estimates assume the use of contemporary fixed wireless broadband network service, not fiber. The CAPEX for a fiber deployment would likely be 20 times more expensive, take 10 or more years to build out, and provide no faster, nor more affordable, nor more reliable service to farms, homes, and businesses across the region.

Our White Paper includes a marketing strategy plan that specifies the product, price, place, and promotion strategies and tactics for the new fixed wireless broadband service company. Using WISPA industry data and data from deployment and operations of other fixed wireless broadband service companies in similar rural locations across America results in an average estimated annual gross revenue of $26,224,697 for the new company.

The White Paper in Appendix D also includes a pro forma operating expense budget (OPEX) based on WISPA industry data and assuming deployment on 206 vertical structures; 12 employees with average salary of $70,000 per year; 5 company vehicles; 5 local customer service and operations office locations; and no CAPEX or loan repayment expenses. With these assumptions, the annual OPEX after federal taxes for the rural portion of this ten county service area would be about $12,838,955 which is significantly lower than the average estimated gross revenue of $26,224,697.

So in summary, we find the answer to the key question, “Is it possible for a business to sustainably provide affordable and reliable fixed wireless broadband service to unserved and underserved rural locations in Washington, Tyrrell, Hyde, Beaufort, Pitt, Greene, Lenoir, Jones, Craven, and Pamlico counties in Eastern North Carolina?” is, “Yes”.

Hopefully this White Paper will contribute to efforts to close the Digital Divide across North Carolina and encourage new companies to provide affordable and reliable Internet service to households, farms, and businesses in rural parts of the state where such service has been unavailable for far too long a time.

Major Basis for Project Success – Deploy Where Needed

The overall major basis for determining project success was stated in the EPA in NC project narrative as -- ***The major basis for determining the project is a success after 12 months is that this project results in the establishment of a new broadband network and service across the ten county region which provides affordable, reliable, and robust high-speed broadband connectivity in the field and farm office for PA applications and PA benefits, and in the home and business settings for others across the region.***

It is generally believed that there is more recognition of the need for broadband deployment in unserved and underserved rural areas today than perhaps ever before. This is probably attributable to many factors, including the shift of public schools across America to virtual because of the COVID-10 pandemic. This shift highlighted the disparity between families who live on the "good" side of the Digital Divide, versus those who live on the "bad" side of the Digital Divide. In response, massive federal funding from the American Rescue Plan Act and other federal recovery initiatives have earmarked substantial funds to support needed broadband deployment and to help families afford Internet service.

Within this context, it was unsurprising that interest and attendance at our August 19 field day demonstration event exceeded our wildest expectations. Nor was it surprising that Governor Cooper considered using our event as an opportunity to advocate for more broadband deployment across rural North Carolina. Nor was it surprising that the governor sent his newly appointed state Director of the Office of Digital Equity and Literacy to speak on his behalf. Nor was it surprising that many of the August 19 event attendees came because of interest in our TelRad non-line-of-site (NLOS) CBRS network to provide PA connectivity.

So, as of today, here is our report card on this major metric:

- Our August 19 event was attended by the founder and CEO of Eastern Carolina Broadband, a fixed wireless broadband service company headquartered in Pink Hill, North Carolina. Eastern Carolina Broadband currently offers service in several Eastern North Carolina locations using 32 towers and plans to add additional service territory in southeastern North Carolina in the future.
- North Carolina Global TransPark Authority, located in Kinston, North Carolina, has submitted a major NTIA grant proposal to deploy fiber optic broadband service across unserved and underserved areas in Lenoir and Greene counties. Representatives involved in this initiative also attended our August 19 event.
- The founder and CEO of InfinityLink Communications, headquartered in Snow Hill, North Carolina, attended our August 19 event. InfinityLink has previously provided broadband service to Greene, Lenoir, and Pitt counties and has now just announced they will be expanding to also offer service in the town of Tarboro, North Carolina.
- Several NC Cooperative Extension county agents and broadband advocacy leaders, in addition to state DHHS telemedicine project leaders, were helpful colleagues throughout the project and also spoke during the "Tent Talks" at the August 19 event. As we noted earlier, the August 19 event was a field day wherein demonstrations of connectivity and PA applications were provided, and the event also enabled and encouraged networking and discussion among many like-minded individuals. This gathering contributed to the creation of the newly formed North Carolina Agriculture Digital Alliance led by Natalie Rivera and Kenneth Sherin. The first quarterly meeting of the Alliance was held October 13, 2021.

- Specifically on target with this major metric for project success, several members of the EPA in NC project team have now established a new fixed wireless broadband service company named HarvestBeam. HarvestBeam is currently weeks away from its initial deployment in Grifton, North Carolina, and will eventually provide affordable, robust, and reliable service across all ten counties involved in this project, and beyond. HarvestBeam is also planning to deploy next in Vanceboro, North Carolina, and has also submitted a federal Community Connect Grant Proposal to provide service to the most rural and unserved areas of five counties. The mission of HarvestBeam is to provide service where it is most needed – to unserved and underserved areas of rural North Carolina.

So in summary, has the major basis for determining project success been met? The new expansion plans by two existing rural broadband companies in the region, the new deployment initiative led by a major economic asset in the region, the newly launched advocacy Alliance, and – most of all – the newly formed broadband service company dedicated to providing service across the rural parts of all ten counties involved in this project demonstrate the answer to this question is a resounding, “Yes!”.

APPENDIX A. Quarterly Performance Reports

Enabling Precision Agriculture in North Carolina
USDA RBDG

Professor Nicholas Didow, PI
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Quarterly Performance Report
October - December 2020

Project Abstract: Farmers across Eastern North Carolina are becoming increasingly dependent on precision agriculture technologies to control costs, sustain profit, and compete nationally and globally. The agriculture sector has embraced telematics and other automated data centric analytical tools within the general descriptive name "precision agriculture" to increase farming efficiencies and reduce operating costs. Yet, none of these benefits can be realized without access to reliable and robust broadband in the field or farm office. Today, the majority of growers in Eastern North Carolina have either intermittent or no access to high-speed wireless broadband connectivity due to a lack of coverage and speed on the farm. This project seeks to:

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I was thrilled, excited, and appreciative to receive this amazing USDA RBDG grant for such a worthwhile project. To design and conduct an ambitious largely field project like this is certainly challenging even in the best of circumstances, but to do it during the COVID-19 pandemic was unbelievably challenging. When the award was announced and as the project started on October 1, 2020, I began daily to watch the status of the COVID-19 pandemic, ever hopeful that we would quickly return to normal. That has not yet happened, but we have successfully planned and conducted this project and accomplished all deliverables at high quality and major impact. This entire project was conducted in accordance with federal and state COVID-19 protocol guidelines with respect to vaccinations, masks, indoor gatherings, and outdoor gatherings including limitations on crowd size and physical spacing for both indoor and outdoor gatherings.

Much of October to December 2020 was spent formally processing the three key personnel for this project – Jessica Zufolo, Jack McNairy, and Jason Ward – and key contract service providers – Steven Warwick of Connected Devices for equipment connectivity and field network equipment deployment, CelPlan for dataset analysis and RF network engineering, and Ian Moore of Alaska Map Science for mapping services. Jessica's involvement also brought the insights and perspectives from the FCC Precision Agriculture Task Force of which she is a member. Jack's involvement gave us personal and professional insights and perspectives from his leadership of a major farm operation in Eastern North

Carolina. Jason's involvement brought us access to the latest thinking about precision agriculture technology and innovation, as well as access to the NC Ag Extension community.

Getting them properly approved and appointed through the Office of Sponsored Research (OSR) and Human Resources at UNC as Independent Contractors or authorized service providers was challenging to say the least and involved massive amounts of forms and paperwork, but we got it done. I am particularly grateful to my budget and grants staff Karen McFarland and Tammy Moravansky at KFBS.

It was surprisingly complicated and challenging to bring Professor Jason Ward from North Carolina State University into this project as a key partner, as I was the PI and the grant was awarded to me at the University of North Carolina in Chapel Hill. Several discussions and exchanges were required between OSR at UNC and their administrative counterparts at NCSU in order to determine how to best engage Professor Ward. The final determination was to engage him in this project through a sub award to NCSU.

Planning for the project with weekly Zoom calls began immediately among all of us in good faith that the paperwork would eventually be completed.

Jack and Jessica were formally approved as Independent Contractors in late October, both Ian and CelPlan were approved in early November, the sub award with Jason at NCSU was approved in December, and the service contract with Steven Warwick of Connected Devices was finally approved in January, 2021.

During this quarter I made several visits to the farm site outside Kinston, NC, where we planned to deploy a wireless broadband network on an underutilized tower structure to provide connectivity for various precision agriculture technologies and applications.

And all of us kept hoping the COVID pandemic would quickly subside and we could all be together like normal out in the fields of Eastern North Carolina…

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January – March 2021

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2. Perform a ten county market analysis of the broadband coverage needs and economic benefits to farm businesses and the other businesses that benefit directly and indirectly from PA adoption enabled by broadband access; and,
3. Develop a sustainable business and marketing plan for an innovative ten-county 5G mobile broadband network service for farms, businesses, families, community anchor institutions, and individuals in the ten county area.

As 2021 began, our entire team continued to watch the status of the COVID-19 pandemic, ever hopeful that we would quickly return to normal. That did not happen during the first quarter of 2021, nor has it yet happened later in 2021, but we have successfully planned and conducted this project and accomplished all deliverables at high quality and major impact even in spite of restrictions and limitations put in place in response to the COVID-19 pandemic. Again, this entire project was conducted in accordance with federal and state COVID-19 protocol guidelines with respect to vaccinations, masks, indoor gatherings, and outdoor gatherings including limitations on crowd size and physical spacing for both indoor and outdoor gatherings.

January to March 2021 was spent largely planning, coordinating, and making appropriate decisions about network technology, deployment sites, and precision agriculture technologies to enable. Underlying every decision was the hope that things would soon return to normal and the recognition that producing the deliverables for this project would likely be clustered in the final quarter rather than spread evenly throughout the period of performance.

We held weekly EPA in NC project planning and coordination meetings for the entire team using Zoom.

Jessica and Jason made contact with state and local 4H and FFA leaders, in addition to agriculture extension agents in the Eastern North Carolina region.

Decisions about network technology, deployment sites, and precision agriculture technologies were aided by the addition of Alex Freylekhman from TelRad to the planning and coordination team. We had originally chosen TelRad as the likely network equipment because of their technology leadership in wireless broadband networks that use CBRS spectrum. TelRad network systems and CBRS spectrum appear to have advantages over other technologies and other spectrum in their ability to provide connectivity in non-line-of-sight circumstances, as well as in line-of-sight conditions. Non-line-of-sight in Eastern North Carolina farm locations are more frequent than line-of-sight due to mostly to tree lines and other dense foliage. In February Alex came to our farm demonstration sites outside Kinston from his TelRad office in Cleveland to meet with Jack and me to tour the potential deployment sites and offer his opinions as to the pros and cons of our different options. This was an extremely helpful visit and Alex continued to be a very valuable resource and team member throughout the remainder of the project.

We also reviewed existing and emerging precision agriculture technologies and applications during this quarter in order to decide which PA applications, in addition to the ag equipment already on the farm site provided by Jack McNairy, we wanted to enable and feature in our field tests and demonstrations.

The result of all this was the series of significant steps we made during this period to decide the deployment site on the RTK tower and farm fields at Harvey Farms off Bill Smith Road outside Kinston; order the necessary TelRad network equipment and deployment materials; and also order a Sentek Arable Mark II field monitor and a HOBO greenhouse monitor to add to the PA applications available for our demonstrations and field tests enabled by deploying using underutilized tower infrastructure.

Using Jessica's knowledge from her membership on the FCC Precision Agriculture Task Force, we also made initial contact with Chinmay Soman, the founder and CEO of EarthSense, one of the most innovation PA robotics businesses in the world. Our hope was that we might be able to include one of his agriculture field robots in our field trials and connectivity demonstrations.

And all of us kept hoping the COVID pandemic would quickly subside so we could all be together like normal out in the fields of Eastern North Carolina…

Enabling Precision Agriculture in North Carolina
USDA RBDG

Professor Nicholas Didow, PI
Kenan-Flagler Business School
University of North Carolina
Chapel Hill, NC 27599-3490

Quarterly Performance Report
April - June 2021

Project Abstract: Farmers across Eastern North Carolina are becoming increasingly dependent on precision agriculture technologies to control costs, sustain profit, and compete nationally and globally. The agriculture sector has embraced telematics and other automated data centric analytical tools within the general descriptive name "precision agriculture" to increase farming efficiencies and reduce operating costs. Yet, none of these benefits can be realized without access to reliable and robust broadband in the field or farm office. Today, the majority of growers in Eastern North Carolina have either intermittent or no access to high-speed wireless broadband connectivity due to a lack of coverage and speed on the farm. This project seeks to:

1. Conduct on a farm in Lenoir County a field-test of an innovative way to provide an affordable, reliable, and robust high-speed 5G mobile broadband network in rural North Carolina by leveraging existing underutilized tower infrastructure;
2. Perform a ten county market analysis of the broadband coverage needs and economic benefits to farm businesses and the other businesses that benefit directly and indirectly from PA adoption enabled by broadband access; and,
3. Develop a sustainable business and marketing plan for an innovative ten-county 5G mobile broadband network service for farms, businesses, families, community anchor institutions, and individuals in the ten county area.

As we transitioned into Spring and early Summer of 2021, we continued to watch the status of the COVID-19 pandemic and to be ever hopeful that we would quickly return to normal. That did not happen during the second quarter of 2021, but we have successfully planned and conducted this project and accomplished all deliverables at high quality and major impact even in spite of ongoing restrictions and continuing limitations put in place in response to the COVID-19 pandemic. Again, this entire project was conducted in accordance with federal and state COVID-19 protocol guidelines with respect to vaccinations, masks, indoor gatherings, and outdoor gatherings including limitations on crowd size and physical spacing for both indoor and outdoor gatherings.

The second quarter of 2021 – April-June – brought significant tangible results to the project as a result of the previous months of careful planning and coordination. January-March 2021 was spent largely planning, coordinating, and making appropriate decisions about network technology, deployment sites, and precision agriculture technologies to enable. April-June featured network deployment and PA connectivity, plus initial background research in the broadband coverage needs data from Ian and economic benefits to farms from PA adoption enabled by connectivity, and preliminary data needed to develop a sustainable business and marketing plan for a new 5G mobile broadband network service in the ten county region.

On the morning of April 6, 2021, the TelRad network was effectively deployed by Steven Warwick and his Connected Devices team at an elevation of 50 feet on the existing RTK tower located on Harvey Farm off Bill Smith Road outside Kinston in Lenoir County. The network provided wireless connectivity to traditional agriculture PA applications across the farm. We also deployed a TelRad CPE (Consumer Premises Equipment) at the employee lodging facility located about a half mile from the RTK tower and provided connectivity to the migrant workers residing in that facility. A significant portion of the first project deliverable was accomplished.

We continued to periodically field-test different PA applications on site at the farm using the connectivity we had effectively established. We were looking forward to similarly deploying and field-testing the HOBO and Arable Mark II in July when they would be available.

Underlying every decision was the hope that things would soon return to normal and the recognition that producing the deliverables for this project would likely be clustered in the final quarter rather than spread evenly throughout the period of performance. We identified a major annual agriculture gathering called the Blacklands Farm Managers Tour scheduled to be held in person in Washington County on August 4 and followed it closely as a marker for our ability to schedule a similar PA field-day demonstration in person at our deployment site later in August.

We held weekly EPA in NC project planning and coordination meetings for the entire team using Zoom.

Jessica and Jason continued to make contact with state and local 4H and FFA leaders, in addition to agriculture extension agents in the Eastern North Carolina region, to get a good understanding of the level of interest and experience they had with PA applications.

In the midst of this welcomed substantive progress on the project came a dose of reality that this project was awarded to me as a faculty member at UNC and UNC has its own way of doing things. The period of performance for this USDA RBDG project was October 1 2020 to September 30 2021, yet UNC's budget year runs annually from July 1 to June 30. Imagine my surprise when I was informed in June by UNC's OSR that I had to reappoint Jack, Jessica, and Ian to enable them to continue to be part of my project team from July 1 to September 30. So Jack, Jessica, Ian, and I again went through the same paperwork and review to qualify them and re-appoint them as Independent Contractors for the project during the remaining three months in the period of performance. Again, I am so thankful for my KFBS budget and grants staff of Karen McFarland and Tammy Moravansky.

And from April through June, 2021, each of us kept hoping the COVID pandemic would subside so we could all be together again like normal out in the fields of Eastern North Carolina…

Enabling Precision Agriculture in North Carolina
USDA RBDG

Professor Nicholas Didow, PI
Kenan-Flagler Business School
University of North Carolina
Chapel Hill, NC 27599-3490

Quarterly Performance Report
July - September 2021

Project Abstract: Farmers across Eastern North Carolina are becoming increasingly dependent on precision agriculture technologies to control costs, sustain profit, and compete nationally and globally. The agriculture sector has embraced telematics and other automated data centric analytical tools within the general descriptive name "precision agriculture" to increase farming efficiencies and reduce operating costs. Yet, none of these benefits can be realized without access to reliable and robust broadband in the field or farm office. Today, the majority of growers in Eastern North Carolina have either intermittent or no access to high-speed wireless broadband connectivity due to a lack of coverage and speed on the farm. This project seeks to:

1. Conduct on a farm in Lenoir County a field-test of an innovative way to provide an affordable, reliable, and robust high-speed 5G mobile broadband network in rural North Carolina by leveraging existing underutilized tower infrastructure;
2. Perform a ten county market analysis of the broadband coverage needs and economic benefits to farm businesses and the other businesses that benefit directly and indirectly from PA adoption enabled by broadband access; and,
3. Develop a sustainable business and marketing plan for an innovative ten-county 5G mobile broadband network service for farms, businesses, families, community anchor institutions, and individuals in the ten county area.

As the calendar changed from June to July and we entered the final three months for the period of performance for this project, we continued to watch the status of the COVID-19 pandemic and to be ever hopeful that we would quickly return to normal. While that did not happen during July - September 2021, we were nonetheless able to accomplish all deliverables for this project at high quality and with a major positive impact in spite of ongoing restrictions and continuing limitations put in place in response to the COVID-19 pandemic. This entire project was conducted in accordance with federal and state COVID-19 protocol guidelines with respect to vaccinations, masks, indoor gatherings, and outdoor gatherings including limitations on crowd size and physical spacing for both indoor and outdoor gatherings.

Our team continued to hold weekly EPA in NC project planning and coordination meetings using Zoom. We knew that, because of COVID-19 complications and restrictions, the deliverables for this project would be largely "end loaded" to be completed during the final three months of the project. That turned out to be the case, and we were able to complete all deliverables for this project before the end of September 2021.

In early July we decided on the date of August 19, 2021, as the most likely date for our planned precision agriculture field day demonstrations to be held at the donated Harvey Farms site off Bill Smith Road where we had deployed a wireless network using an existing RTK tower. We established an agenda for

the day and finalized commitments from several precision agriculture and broadband connectivity leaders to provide field PA demonstrations and to speak in "Tent Talks" about innovations and benefits from connectivity enabled PA technologies. These participants included:

- Alex Freylekman, TelRad Networks, CBRS spectrum innovations in agriculture using RTK towers
- Steven Swain, Quality Equipment and John Deere
- Jason Ward, NCSU, HOBO greenhouse monitoring and UAVs
- Travis Daniels, Harvey Farms, drones and data analysis
- Jason Ward, NCSU, Arable Mark II soil sensor
- Chinmay Soman, EarthSense, real time field data collection and analytics with robotics
- Jeremy Collins, NCDIT and Hometown Strong Office of Digital Equity and Literacy
- Natalie Rivera, NC DHHS Farmworker Health Program
- Kenneth Sherin, NC State Ag Extension, Broadband Access and Education Coordinator

We distributed printed and electronic invitations to attend the precision agriculture field day event through all our networks, communication channels, and with flyers I distributed when I attended the Blackland Farm Manager's Tour on August 4. We also made arrangements to host everyone outside on August 19 under a large tent for shade, with clean porta-johns, BBQ and ice cream during lunch.

Our planning target for the number of attendees was 40 +/-. We quickly saw the number of registrants pass that figure, and ended up with 70 to 75 attendees outside on the farm in 98 degree sunshine and under the tent for conversation, networking, lunch, and talks. About 40 of the attendees were farmers or from farm businesses in the region, 20 were NC Ag Extension agents and staff, and 15 or so were media, interested citizens, and public policy advocates.

One of the many interesting moments during the week prior to the August 19 event was the 24 hour period in which we were told that North Carolina Governor Roy Cooper would be attending our event and wanted a few minutes to speak about the importance of rural broadband deployment to enable PA and provide connectivity to farms, farm offices, homes, and businesses in rural North Carolina. We had no idea that our date of August 19 was the Thursday in the Governor's Rural Broadband Week throughout the state. As it turned out, Governor Cooper decided he needed to be in rural Western North Carolina on August 19, rather than with us in rural Eastern North Carolina, so he sent Jeremy Collins to represent him and speak on his behalf at our event. Jeremy did an excellent job and we were delighted to have him attend and speak.

Our original plan was to offer the PA field day demonstrations several times on different days. However, due to the ongoing COVID-19 situation and state and federal guidelines, we decided to video and audio all the demonstrations and talks and post these resources on a website available to everyone. Ag Extension attendees also made video and audio recordings for them to use at a later date with other interested audiences.

In this way we finally fully accomplished our first project deliverable -- Conduct on a farm in Lenoir County a field-test of an innovative way to provide an affordable, reliable, and robust high-speed 5G mobile broadband network in rural North Carolina by leveraging existing underutilized tower infrastructure.

During this last three month period we also completed data gathering and drafted two White Papers to accomplish our other two project deliverables.

One White Paper develops a sustainable business and marketing plan for an innovative 5G mobile broadband network service for farms, businesses, families, community anchor institutions, and individuals in the unserved and underserved ten county region of Eastern North Carolina.

A second White Paper performs a ten county market analysis of broadband coverage needs and economic benefits to farm businesses and other businesses that benefit directly and indirectly from precision agriculture adoption enabled by broadband access.

These two White Papers will be included in our Final Report and have been distributed widely through the project team member networks and channels including those at UNC and NCSU, NC Ag Extension agents and staff, and by and through others who attended the August 19 field day demonstration event.

APPENDIX B. Precision Agriculture Field Day Demonstration Event program August 19, 2021

PRECISION AGRICULTURE FIELD

August 19, 2021 - Harvey Farms Kinston, NC

Harvey Farms, Bill Smith Road, Kinston, N.C.
Thursday, August 19th: 9:30 am– 3 pm EST

9:30 am — **Arrival and check in at tent.**

9:45 -10:00 am — **Welcome remarks by USDA Enabling Precision Agriculture in North Carolina project lead Professor Nicholas Didow**

- Jack McNairy, Executive Vice President of Harvey Farms: welcome remarks and overview of connectivity challenges facing the agriculture sector in North Carolina and Harvey Farms experience adopting precision agriculture applications.
- Jessica Zufolo, Project Coordinator and Co-Team lead: background and objectives of the USDA Enabling Precision Agriculture in North Carolina project
- Professor Didow will provide an overview of the agriculture technology field demon strations throughout the morning and logistics

10 - 11:30 am — **Field demonstrations and rotations to all 5 stations**

Each group will spend 15 minutes at each station then rotate to the next one

Precision agriculture field demonstration site stations led by the following experts

1. CBRS spectrum led innovations in agriculture using RTK towers – Alex Freylekman, Telrad Networks
2. Precision Agriculture mobile classroom – Steven Swain, Quality Equipment/John Deere
3. HOBO greenhouse and UAV – Jason Ward, North Carolina State University
   Harvey Farms drone – Travis Daniels, Harvey Farms
4. Arable Mark 2 plus soil sensor
5. Real time field data collection and analysis with robotics – Chinmay Soman, EarthSense

11:30 am — **Return to the main tent for lunch and Tent Talks (speaker bios on back)**

11:45 - 1:15 pm — **Lunch will be served (Kings BBQ and ice cream)**

12:15 pm — **Tent Talks (5 minutes per speaker)**

- Jeremy Collins, NCDIT and Hometown Strong Office of Digital Equity and Literacy
- Alex Freylekhman – Telrad Networks
- Chinmay Soman – EarthSense
- Natalie Rivera – Internet Connectivity Project Coordinator, NC Farmworker Health Program, NC DHHS, "Digital Inclusion and Farmworker Health"
- Steven Swain – Quality Equipment/ John Deere
- Kenneth Sherin – Broadband Access and Education Coordinator, NC State
- Conclusion remarks: Jason Ward- Project Team Member and NCSU & Ag Extension

1:15 pm — **You are invited to revisit any of the demonstration sites and/or talk with any of the exhibitors and speakers**

SPEAKER BIO'S

Nicholas Didow, PhD, Kenan-Flagler Business School, University of North Carolina, Chapel Hill, nick_didow@unc.edu
Professor Didow teaches marketing strategy and market research at UNC Chapel Hill. He also has led many economic development projects in rural North Carolina including: the Golden LEAF Rural Broadband Initiative – the $144M middle mile fiber optic broadband deployment from 2009-2013 serving 67 NC counties and now managed by MCNC; last mile Internet service provider projects in Elizabeth City, Franklinton County, Person County, and Union County, projects for the NC Department of Commerce, NC Christmas Tree Association, and the NC Sweet Potato Commission; and several tourism-based economic development projects for the five historic waterfront towns located in the Albemarle Sound Inner Banks (IBX) region. He also played a role in launching cellular service and wireless text messaging in US market locations.

Jack McNairy, Executive Vice President, Harvey & Gas jhmcnairy@harveys.com
Founded in 1871, Harvey Fertilizer & Gas Company provides agricultural products and services to growers across eastern North Carolina through its ag retail locations, cotton gins, a seed conditioner, and Tidewater Energy retail propane outlets. Harvey Fertilizer & Gas prides itself on hard work, knowledge, progressiveness, and strategic planning to put our customers first. Jack received his both his undergraduate degree and MBA from the University of North Carolina at Chapel Hill

Jessica Zufolo, jazfdc@gmail.com
Jessica has served numerous senior leadership roles throughout federal government and non-profit sectors for over 25 years. Jessica previously served as the Deputy Administrator for the Rural Utilities Service (RUS) at the U.S. Department of Agriculture where she helped oversee a $65 billion federal loan/ grant portfolio that finances rural broadband networks, precision agriculture, electric utility, smart grid projects. Jessica also serves as a founding member of the FCC's Precision Agriculture Task force. Jessica earned her MBA with Honors from the University of North Carolina at Chapel Hill.

Jason K. Ward, PhD, PE, Assistant Professor, Biological and Agricultural Engineering - N.C. State University Jason.ward@ncsu.edu
Jason Ward is an assistant professor and Extension specialist in the Department of Biological and Agricultural Engineering at NC State University where he leads the Advanced Ag Lab. His research and Extension program focus on advancing agricultural technology, sensors, equipment, robotics, and data management, and making precision agriculture technologies more accessible and valuable.

Chinmay Soman, Co Founder, CEO and Co-Inventor of Cure Technologies - EarthSense Inc. chinmay@earthsense.com
EarthSense is leading the creation of a robotics and machine learning platform for healing our planet. Chinmay co-founded EarthSense while he was a National Science Foundation Postdoctoral Fellow researching ways of improving agricultural sustainability. He was previously also the Lead Engineer and co-inventor of key technologies at Soil Diagnostics, Inc. and founder and CEO of Movable Objects, Inc. - a mobile sensing and computation startup.

Steven Swain – Integrated Solutions Manager, Quality Equipment/ John Deere sswain@qualityequip.com
Stephen Swain grew up and still lives on Century Farms in Tyrrell County (Columbia NC). Attended The College of Albemarle for computer engineering until beginning his career with a John Deere dealer in Fairfield as field service technician, achieving master level status. In 2010, Stephen moved to full time Precision Ag consultant with the same dealership, where he grew the department to now 7 employees that support the entire Precision Ag portfolio while also looking for new trends to bring more productivity to Central and Eastern N.C. farms.

Alex Freylekhman, Vice President of Sales, Telrad Networks, alex.freylekhman@telrad.com
Alex is a 20 year wireless industry veteran whose life mission is to make the world faster and more connected one network at a time. Alex oversees sales for Telrad throughout North America and works closely with the entire wireless ISP sector in North Carolina and nationally. He holds a bachelor's degree in computer science and spends most of his time helping rural communities solve their broadband challenges

Kenneth Sherin, Ph.D, Broadband Access and Education Coordinator, County Extension Director, Kenneth_Sherin@ncsu.edu
Kenny Sherin is a North Carolina native. He was born and raised on a family farm in Union County. He attended NC State University in the early nineties where he earned two degrees in natural resources and forestry. After working as a consultant, he attended Campbell University where he earned a Master of Divinity Degree. In pursuing their love of rural communities, Kenny and Karen moved to Columbia, MO where Kenny earned a doctoral degree in Rural Sociology and Community Development from the University of Missouri. That degree took him to South Dakota State University Extension where he was the SDSU Extension state program leader for The Community Vitality Program. Prior to 2019, Kenny lived outside of NC for 12 years and he is glad to back home serving as the County Extension Director for Randolph County and the Broadband Access and Education Coordinator for N.C. Cooperative Extension. Kenny has served on the National Digital Education Extension Team (NDEET) of the Southern Rural Development Center for 5 years.

Natalie D. Rivera, Internet Connectivity Project Coordinator, N.C. Farmworker Health Program with DHHS/Office of Rural Health, Natalie.Rivera@dhhs.nc.gov
Natalie coordinates a sustainable initiative to bring Internet to migrant farmworker housing across North Carolina. The goal is to support the well-being of farmworkers by bridging access to telemedicine, social outlets, emergency communication and educational resources through Internet connectivity. Prior to working with NCFHP, she launched one of their grant funded farmworker health outreach sites in Eastern North Carolina, where she served as the program director/outreach coordinator for over 7 years. She has experience working at Latina lead non profits through both AmeriCorps ACCESS and Student Action with Farmworkers. Natalie completed her undergraduate degree at the University of North Carolina Wilmington and her Master's in Public Health from the University of North Carolina Chapel Hill.

APPENDIX C. Broadband Coverage Needs and Economic Benefits to Farm Businesses from Precision Agriculture Adoption in Eastern North Carolina, White Paper, September 30, 2021

BROADBAND COVERAGE NEEDS AND ECONOMIC BENEFITS TO FARM BUSINESSES FROM PRECISION AGRICULTURE ADOPTION IN EASTERN NORTH CAROLINA

September 30, 2021

Jason Ward, Nicholas Didow, Jessica Zufolo, Jack McNairy
USDA Rural Development's Enabling Precision Agriculture in North Carolina Project

Objective: *Perform a ten-county market analysis of the broadband coverage needs and economic benefits to farm businesses and other businesses that benefit directly and indirectly from precision agriculture adoption enabled by broadband access.*

This White Paper summarizes the findings in the pioneering research and analysis literature pertaining to the economic benefits of precision agriculture technology ("PA") adoption among farming businesses and other equipment, logistics, and input suppliers that support American agricultural operations in North Carolina and nationally. This paper explores the intersection of precision agriculture expansion and the availability of affordable and reliable broadband access on farm fields. Given the lack of fiber facilities that deliver services directly to farms and farming communities, other broadband distribution mechanisms such as fixed wireless broadband are less costly to deploy and more suitable to agricultural environments where there is a lack of density.

This paper also identifies the broadband coverage needs for farm businesses located in ten Eastern North Carolina counties -- Washington, Tyrrell, Hyde, Beaufort, Pitt, Greene, Lenoir, Jones, Craven, and Pamlico – and estimates the potential incremental economic benefits for farm businesses throughout this region from PA adoption. The forecasting and estimation procedure used is to extrapolate from the empirical findings in various PA research studies.

Overview

The USDA Rural Development's Enabling Precision Agriculture in North Carolina Project led by Professor Didow is honored to have been selected by USDA Rural Development in North Carolina for a Rural Business Develop Grant (RBDG) focused on expanding the precision agriculture sector and create broadband enabled "ag tech" jobs in rural Eastern North Carolina with 5G fixed wireless broadband technology.

Broadband deployment and adoption in rural communities throughout the Eastern portion of the state is either spotty or entirely unavailable due to a lack of modern broadband network infrastructure needed to provide robust last mile and middle mile broadband service. Currently, the level of high speed connectivity in these communities today are inadequate to meet the connectivity needs of rural households as well as agricultural businesses such as fertilizer, seed and tractor dealerships and other input vendors that support the farm economy year- round.
The August, 2019, USDA *Farm Computer Usage and Ownership* survey reports that only 43% of North Carolina farmers use desktop or laptop computers for farm business, 50% use smart phones or tablets for farm business, 29% purchase agricultural inputs over the Internet, and 19% conduct agricultural marketing activities over the Internet. The lack of broadband access in this region of the state has added to the chronic level of income disparity in rural communities relative to suburban or urban areas in North Carolina.

The Impact of affordable high speed broadband access on rural economic development

Small to medium sized farms across Eastern North Carolina are struggling economically due to climate change and extreme weather events, an increase in input costs such as fertilizer and labor as well as the level of outmigration. Despite the increase in population throughout other portions of the state, Eastern North Carolina continued to experience a decline in population.

For example, Lenoir County experienced a precipitous decline in population since 2010 of roughly 6%[1] and a 9.4%[2] decline in Washington County. The remaining 8 counties in the Coastal Plains region experienced similar declines or remained stagnant. This is an alarming trend that impacts the health and long-term viability of the entire agriculture sector throughout the Eastern portion of the state.

Additionally, broadband adoption among farmers is slow, largely due to cost and a lack of digital literacy given the average age of the American farmer which is roughly 57 years older[3] than most other sectors.

These sobering economic trends have also been magnified by the Covid-19 Pandemic where farmers and their laborers contracted the virus were unable to work in the fields, thus reducing productivity levels to meet their annual sales forecasts.

The impact of these trends has made farming less attractive to more young people due to arduous and unprofitable nature of the work. Without access to reliable and affordable high speed broadband access, the chances for economic revitalization to occur in these communities are slim to none.
The goal of this project was to examine various methods of incentivizing broadband investment in these communities by exposing farmers to the various technologies that can increase efficiencies, reduce costs and modernize existing farm labor practices.

Through the coordination with local agricultural leaders and business owners, the project team was able to bring agricultural producers together with broadband leaders, precision equipment technology inventors, economic development organizations, local colleges and universities and students and children interested in technology.

Our efforts over the past year have culminated in a region-wide effort to bring fixed wireless broadband access to farming communities as quickly as possible to stabilize the local economies in Eastern North Carolina.

Estimated Economic Benefits from PA Adoption

The research literature on the economic benefits to farm businesses from adopting PA, also sometimes referred to as "Precision Farming," has grown considerably over the past ten years or so. This section of the White Paper summarizes findings from several recent sources.

<u>David Schimmelpfennig</u>

One of the most prominent streams of research on the economic benefits of PA adoption to farm businesses is the work conducted by David Schimmelpfennig (see, for example: Schimmelpfennig, David,

[1] NC Complete Count Committee — NC OSBM (opendatasoft.com)
[2] NC Complete Count Committee — NC OSBM (opendatasoft.com)
[3] 2017Census_Farm_Producers.pdf (usda.gov)

Farm Profits and Adoption of Precision Agriculture, ERR-217, U.S. Department of Agriculture, Economic Research Service, October 2016; and Schimmelpfennig, David, Crop Production Costs, Profits, and Ecosystem Stewardship with Precision Agriculture, Journal of Agricultural and Applied Economics, 50(1):81-103).

Using U.S. Agricultural Resource Management Survey data on corn farm production data from 1996 to 2013, Schimmelpfennig (2016) reports that adoption of three PA applications -- GPS mapping, guidance systems, and variable-rate technology -- increase operating profit for average corn farms by 6.6% and net returns by 5.6%.

USDA: *A CASE FOR RURAL BROADBAND*

In partnership with the American Broadband Initiative, USDA issued *A CASE FOR RURAL BROADBAND: Insights on Rural Broadband Infrastructure and Next Generation Precision Agriculture Technologies* in April 2019. This report was intended to "…convey high-level and broad concepts about the potential benefits of connected agriculture technologies to policymakers, industry leaders, and all who are affected by the lack of high-speed internet service in rural areas that is inhibiting greater productivity and profitability for small producers, stifling American innovation, and undermining potential advancements in food security, food safety, and environmental sustainability…" (p 2).

This document estimated the 2017 U.S. market production annual value for row crops, specialty crops, and livestock and dairy, and the extent to which PA was already included in planning, production, and market coordination by farm businesses across America. It also estimated the range of potential additional gross economic benefits from PA adoption enabled by ubiquitous broadband infrastructure for these three sectors as follows:

	LOW	**HIGH**	**AVERAGE**
Row crops	3.2%	4.2%	3.7%
Specialty crops	12.7%	19.0%	15.9%
Livestock and dairy	5.1%	6.9%	6.0%

John Deere

The April 2021 issue of *Industry Perspectives – A Monthly Research Analyst Series* by Diamond Hill Capital Management, included an article titled, "Harvesting Value: John Deere & Precision Agriculture" by research analyst Brian Bath. In this article, Bath cites sources at Deere who estimate "…its precision ag offerings add roughly $40 of economic value per acre to its customers, while also greatly reducing greenhouse gas emissions through increased efficiency."

Farms.com

In 2021 Farms.com published an online study titled, "Precision Agriculture Economics" in which they opine that precision agriculture technologies of variable population density, row clutches on planters, and variable rate nitrogen are offering the greatest profitability for cash crop farmers. They argue the two major benefits from precision agriculture are increased profitability and increased soil fertility. By adopting current PA technology, they estimate a cash crop farm can expect an annual increase in

revenue of $20,000 to $70,000 per 1,000 acres even by just using some of the less expensive initial PA applications cites above.

Pope and Sonka

Micah Pope and Steve Sonka report the results from interviews with ten Midwestern crop and soybean producers conducted in 2020 (Pope, M. and S. Sonka. "Quantifying the Economic Benefits of On-Farm Digital Technologies." Farmdoc daily (10): 40, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, March 4, 2020). Although this was a pilot investigation with interview data from a small number of farms, the authors found farmers reported a much higher economic benefit from PA applications like GPS guidance for tillage, variable rate technology, automatic section control, and sensors to optimize seed placement and rate. The average net benefit was reported to be about $90 per acre. They also found the economic benefits increased with the farm size, suggesting economies of size to PA technology application.

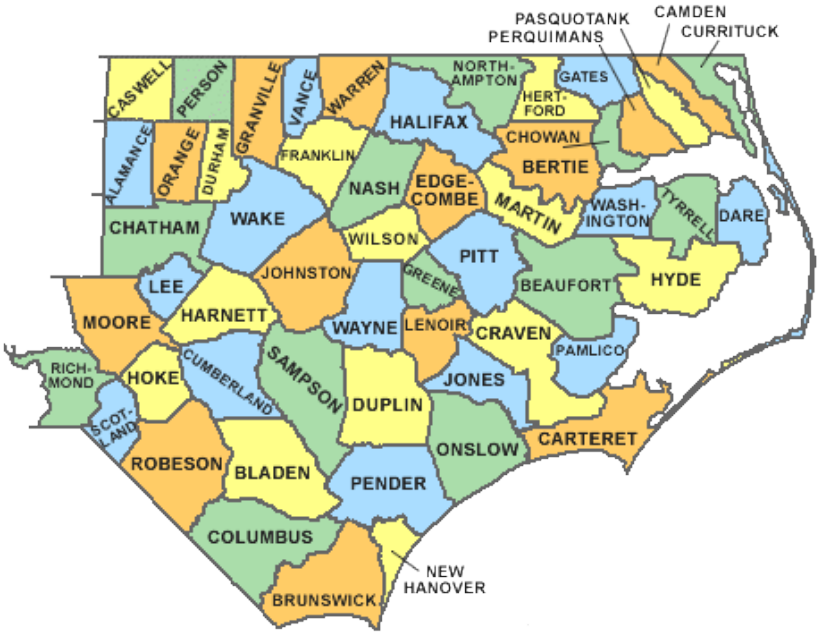
Association of Equipment Manufacturers (AEM)

In early 2021 the Association of Equipment Manufacturers in partnership with the American Soybean Association, CropLife America, and the National Corn Growers Association issued a study titled, "The Environmental Benefits of Precision Agriculture in the United States." While the primary objective of the study was to examine the environmental benefits from PA applications including auto guidance, machine section control, variable rate, machine and fleet analytics, and precision irrigation, the study also estimated the potential for productivity increases from PA adoption. Their nationwide study of auto guidance, variable rate, and section control applications found a total potential productivity increase of 10% resulting from these three PA applications.

In summary, these six studies provide the estimates of economic benefits from PA adoption enabled by broadband access that will be extrapolated and applied to current farm productivity and profitability metrics across the ten county region in Eastern North Carolina.

Farm Businesses in Ten Eastern North Carolina Counties

Farm businesses in ten Eastern North Carolina counties are analyzed in this White Paper. The ten counties are Washington, Tyrrell, Hyde, Beaufort, Pitt, Greene, Lenoir, Jones, Craven, and Pamlico. They are shown among other counties in the following map of Eastern North Carolina.



The table below shows the number of farms in each of the ten counties; the acres of land in farms; the market value of sales; the percent of sales from crops; the percent of sales from livestock, poultry, and products; and, the percent of farms that sell directly to consumers as reported in the USDA's 2017 *Census of Agriculture*.

Counties	Farms	Acres land in farms	Mkt value sales	% sales crops	% sales livestock, poultry, products	% farms sell directly to consumers
Washington	141	79,680	$49,046,000	88%	12%	6%
Tyrrell	68	52,946	$43,561,000	NR	NR	6%
Hyde	138	124,874	$117,383,000	NR	NR	2%
Beaufort	310	139,457	$112,038,000	65%	35%	6%
Pitt	478	186,412	$242,458,000	42%	58%	7%
Greene	207	83,322	$242,483,000	29%	71%	2%
Lenoir	386	113,708	$311,373,000	24%	76%	7%
Jones	177	65,649	$213,623,000	14%	86%	12%
Craven	245	81,360	$71,606,000	51%	49%	11%
Pamlico	100	43,262	$23,373,000	98%	2%	8%
TOTAL	**2,250**	**970,670**	**$1,426,944,000**			

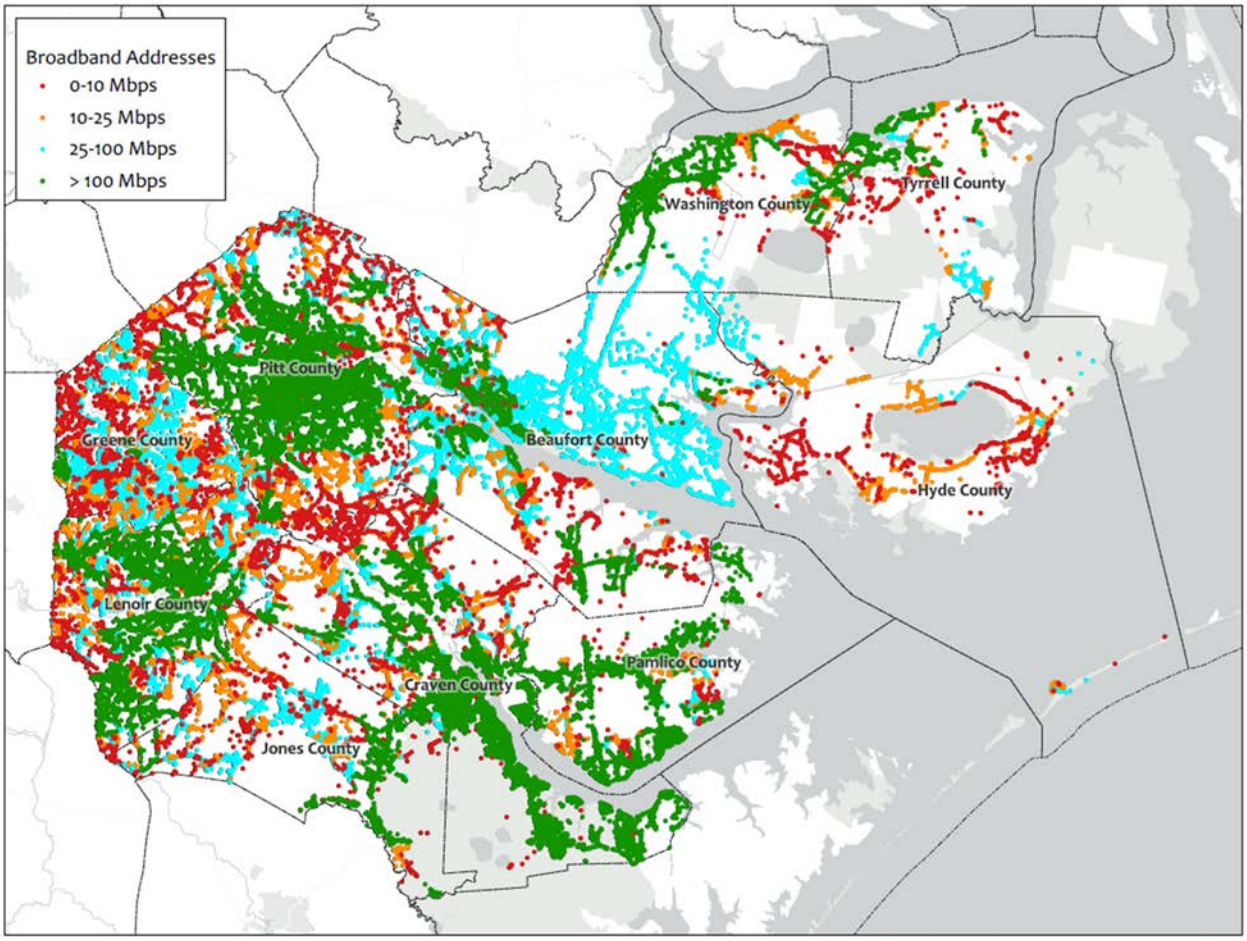
According to the USDA 2017 *Census of Agriculture*, these ten counties in Eastern North Carolina include a total of 2,250 farms on 970,670 acres of farm land, with an average farm size of 431 acres. The total regional annual market value of farm sales is $1,426,944,000 for an average annual market value of farm sales of $634,420. Although they vary from one county to another, overall across the region these market sales are split rather evenly between crop sales and sales of livestock, poultry, and products. Only a small percentage of farms sell directly to consumers.

The total regional annual market value of farm sales is about 10% of the entire State of North Carolina annual market value of sales and the average farms sales of $634,420 in this region is over twice the state average of $277,924.

In January of 2020 the North Carolina Department of Information Technology's Broadband Infrastructure Office (BIO) conducted a major statewide study of Internet connectivity for farms. The major findings indicate that few farms across North Carolina, including those within this ten county region, have access to affordable and reliable high-speed wireless Internet sufficient for reasonable PA applications. Those farms with Internet access most frequently had only DSL wireline service available, with median speeds of only 5.4/.5 Mbps. 63% of farmers reported they had some form of cellular data service, with many indicating cellular service was too slow, unreliable, and/or too expensive.

The findings from this BIO survey are consistent with those from the August 2019 USDA *Farm Computer Usage and Ownership* analysis and from Internet access data analysis and mapping using NTIA data bases, FCC Form 477 (June 30, 2020), and from local community anecdotal knowledge. The governing take away is that few, if any, farms in this ten county region have access to affordable and reliable wireless Internet broadband needed to adopt and fully benefit from basic PA technology applications.

Here is a broadband access map developed from federal data that shows the coverage gaps across this ten county region. Once you are outside the city limits of the four major towns in the region – Greenville, Kinston, New Bern, and Washington – and into the rural farm land, reliable and affordable broadband access necessary for PA adoption in real time quickly diminishes…



Lack of accurate broadband mapping on farm lands further limits precision agriculture adoption

The project team also examined the level of broadband coverage in these counties by evaluating the broadband mapping data produced by the North Carolina Department of Information Technology (DIT), Broadband Infrastructure Office (BIO). The project team then compared the state's broadband data set with other data sets to examine the true level of coverage and where no coverage exists.

Based on all the data sets reviewed, the project team concluded that federal and state broadband maps do not provide a complete and accurate depiction of the lack of broadband coverage on farm lands. This is a significant deficiency that limits investment in precision agriculture technology projects and leaves farmers and local governments with no verifiable data to quantify the problem. More detailed broadband maps that illustrate the lack of connectivity on farm fields is needed to facilitate more precision agriculture adoption and help rural communities attract greater investment in ag tech business ventures that create jobs and accelerate local economic growth.

Farmers throughout Eastern North Carolina need better broadband mapping data of the level of availability on their farms. Without this data, it is impossible for farmers to deal effectively with the constraints they face with precision agriculture adoption.

Participation on the FCC/USDA Precision Agriculture Task Force

To gather a deeper level of analysis, one of our team members was appointed to the FCC's Precision Agriculture Task Force, Mapping Working group which is comprised of agriculture technology experts, agricultural engineers, academic and rural broadband leaders. She joined this working group to learn from other national leaders about how to improve federal and state broadband coverage reporting on agricultural and pastoral lands.

The mapping working group received numerous briefings from broadband mapping experts nationally as well as farmers and ranchers and determined that the FCC should create an interactive map illustrating where farms lack access to adequate connectivity to support the bandwidth demands of precision agriculture. This map should also focus on land currently in production agriculture.

Rural North Carolina farms need more accurate broadband mapping data to improve coverage

An authoritative, federal, interactive map specifically showing unserved and underserved lands can go far in assisting state and local governments efficiently distribute federal funds to support broadband investments in rural and agricultural areas which continue to suffer from a lack of meaningful investments in broadband access.

The project team also learned that agricultural extension agents must be fully utilized to validate broadband mapping data by conducting field surveys needed to ground truth the maps. Precision agriculture relies on fixed and mobile broadband ecosystems, underscoring the need to verify both, especially in the field. The key is having standard testing methods and repeatable results.
The project team discussed these issues with extension agents in Eastern North Carolina at length and determined that without the necessary field level validation, federal and state broadband coverage maps are either accurate nor helpful in guiding farmers on the lack of coverage on their lands.

Based on the emerging interest in broadband mapping on farm lands, agriculture producers across Eastern North Carolina are becoming more engaged in the broadband funding discussions at the state and federal level to support the expansion of high-speed broadband access on their farms. There is no longer any debate that affordable, reliable, and robust broadband connectivity is necessary for effective economic development.

Extrapolating the Estimated Economic Benefits from PA Adoption to Farm Businesses in Eastern North Carolina

In this section we extrapolate the estimated economic benefits from PA adoption found in the research literature to the 2,250 farm businesses in the ten county region of Eastern North Carolina. Some of the published estimates use metrics that do not strongly align with the Eastern North Carolina farm data available to us. Schimmelpfennig, for example, estimates the benefit from PA adoption on "operating profit for corn farms." AEM estimates benefits to "total potential productivity." For this reason, we will select the findings from the other four sources previously cited for our estimated economic benefits from PA adoption.

The four sources and each one's estimated economic benefit from PA adoption are shown in the table below, along with the resulting incremental annual economic benefit to farms across the entire Eastern North Carolina region.

Source	Estimated Economic Benefit from PA Adoption	Incremental Annual Economic Benefit to 2,250 Farms in Ten County Eastern NC Region
USDA -- *A Case for Rural Broadband*	4.85% average increase in annual value row crops and livestock and dairy	$69,206,784
John Deere	additional $40/acre economic value	$38,826,800
Farms.com	additional $45/acre in revenue	$43,468,150
Pope and Sonka	$90/acre average net benefit	$87,360,300
AVERAGE		**$59,715,509**

The average economic benefit for farms across the entire region from PA adoption is estimated to be $59,715,509 per year. The annual benefit for each of the 2,250 farms would average $26,540 or roughly $62 per acre.

Conclusion

This White Paper attempts to estimate the economic benefits to farm businesses and other businesses from precision agriculture adoption across a ten county region in Eastern North Carolina. Extrapolating from PA adoption benefits reported in four previously published studies conducted on farms across different locations with different analytical methods, we find the annual economic benefits from PA adoption to be significant, averaging $26,540 per farm and $62 per acre. The total regional incremental economic benefit is estimated to be $59,715,509 for all 2,250 farms across the ten county region.

This White Paper admittedly focuses only on the potential direct economic benefits to farms and does not include multiplier effects to estimate indirect benefits, nor does it include other considerations such as environmental benefits; telehealth, medical emergency, and other health care benefits; nor migrant labor and other employee benefits. Recognizing these, this White Paper significantly understates the direct and indirect benefits to farms from precision agriculture adoption enabled by access to affordable and reliable wireless broadband.

Even with this shortcoming, these results provide strong support for the economic argument from agriculture and broadband advocates who champion affordable and reliable broadband deployment throughout rural America to finally close the Digital Divide as doing so makes possible the adoption of transformational initiatives such as precision agriculture possible, affordable, and beneficial to all stakeholders.

APPENDIX D. Bringing Connectivity to Rural Eastern North Carolina, White Paper, September 25, 2021

BRINGING CONNECTIVITY TO RURAL EASTERN NORTH CAROLINA

September 25, 2021

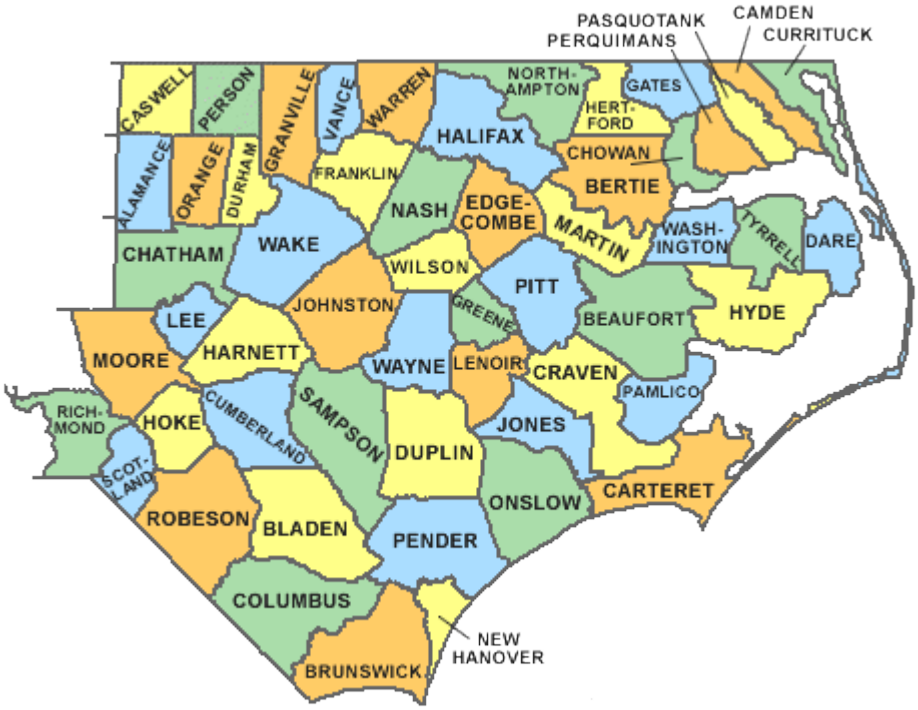
Nicholas Didow, Jessica Zufolo, Jack McNairy, Jason Ward
USDA Enabling Precision Agriculture in North Carolina Project

Objective: *Develop a sustainable business and marketing plan for an innovative 5G mobile broadband network service for farms, businesses, families, community anchor institutions, and individuals in the unserved and underserved ten county rural area of Eastern North Carolina.*

This White Paper addresses the key question: "Is it possible for a business to sustainably provide affordable and reliable fixed wireless broadband service to unserved and underserved rural locations in Washington, Tyrrell, Hyde, Beaufort, Pitt, Greene, Lenoir, Jones, Craven, and Pamlico counties in Eastern North Carolina?" Using prevailing industry and market data, we find the answer is, "Yes," particularly when a significant portion of the CAPEX deployment cost is covered by a grant.

Service Area Demographics

The map below shows the location of the ten Eastern North Carolina counties that are the planned service area of interest -- Washington, Tyrrell, Hyde, Beaufort, Pitt, Greene, Lenoir, Jones, Craven, and Pamlico.



State of North Carolina data sources indicate these ten counties cover a total geographic footprint of 6,538 square miles, ranging from only 266 square miles in Greene County to 1,424 square miles in Hyde County.

The US Census Bureau's 2019 *American Communities Survey* estimates the total population of the ten counties at 449,569 individuals residing in 179,017 households, for an average household size of 2.5 persons. These county population estimates vary from 4,937 individuals in Hyde County to 180,741 in Pitt County.

The following table summarizes the size in square miles, 2019 population estimate, 2017 estimated number of farms, and 2019 estimated number of businesses for each of the ten counties in the service area:

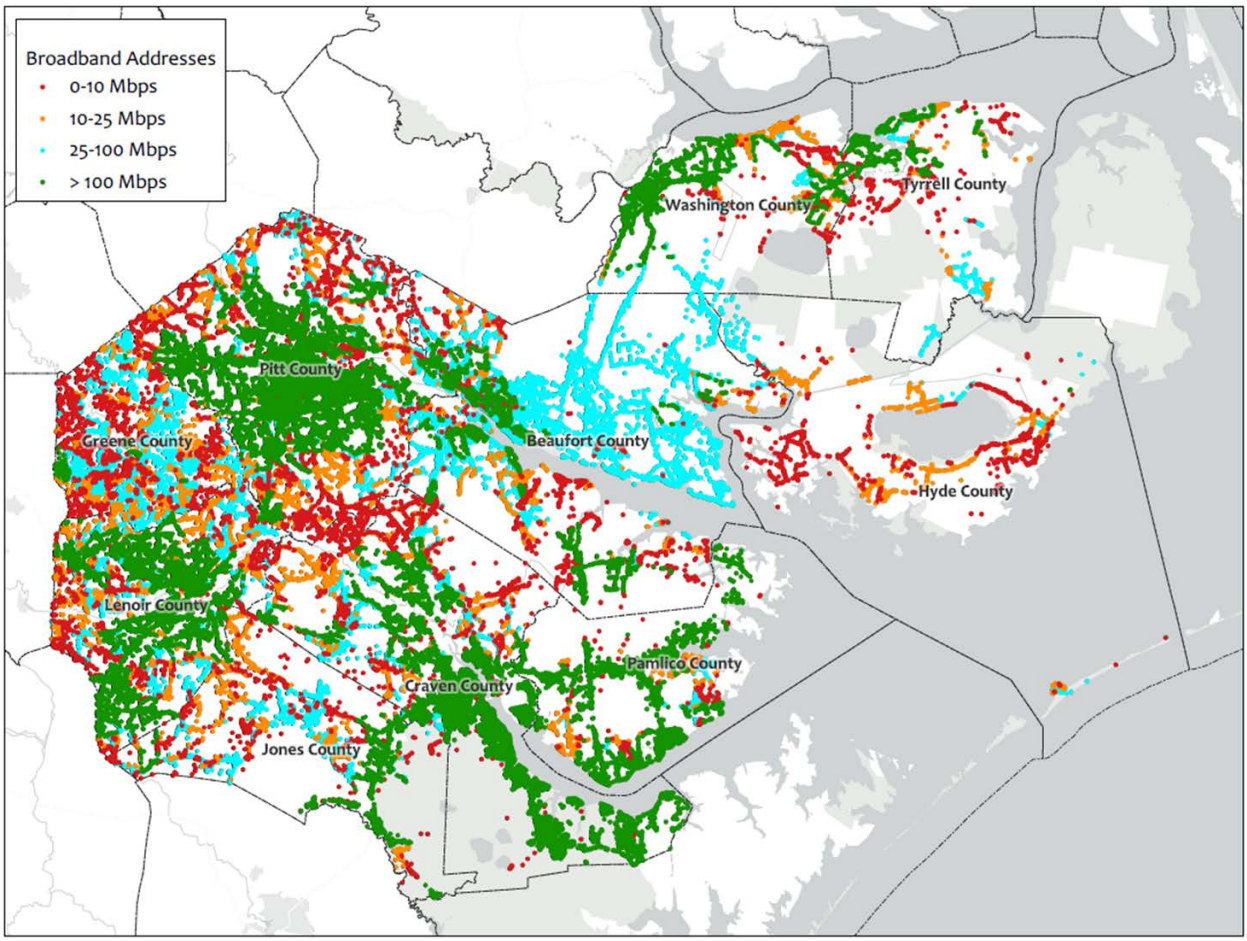
Counties	**Square Miles**	**Population**	**Farms**	**Businesses**
Washington	424	11,580	141	222
Tyrrell	594	4,016	68	72
Hyde	1,424	4,937	138	164
Beaufort	958	46,994	310	1,084
Pitt	655	180,741	478	3,659
Greene	266	21,068	207	261
Lenoir	403	55,949	386	1,173
Jones	473	9,419	177	132
Craven	774	102,139	245	2,158
Pamlico	567	12,726	100	237
TOTALS	**6,538**	**449,569**	**2,250**	**9,162**

According to the 2017 USDA *Census of Agriculture*, there are 2,250 farms operating in this ten county region. The number of farms ranges from a low of 68 in Hyde County to a high of 478 in Pitt County.

NTIA estimates 26.5% of these 449,569 individuals residing in 179,017 households currently have no Internet access and 18.9% have no Computer, no Smartphone, nor Tablet. However, based on a review of broadband service providers throughout the ten county region and local information, broadband service availability varies dramatically from the "good side" of the Digital Divide wherein several Internet providers operate and offer service in the four major towns of Greenville, Kinston, New Bern, and Washington to the "bad side" of the Digital Divide in the rural areas surrounding these four major towns.

Based on Internet access data reported in FCC Form 477 (June 30, 2020) and on local community knowledge, 53% of these 119,427 households, 2,250 farms, and 1,374 businesses are estimated to currently have access to no service or less than 10/1 Mbps service, 35% have access to 10/1 Mbps to less than 25/3 Mbps, 9% have access to 25/3 to less than 100/20 Mbps, and 3% have access to greater than 100/20 Mbps.

Using these federal data sources, the map below shows broadband access by speed tiers across the ten county region. Note that the faster available speed tier locations are all located proximate to the four largest towns in the region – Kinston, Greenville, New Bern, and Washington. The more rural the location, the slower the broadband that is available, assuming any is available at all.



There are also a total of 9,162 "employer establishments," or businesses, in the ten counties as reported by the 2019 US Census Bureau's *QuickFacts*. These range in number from only 72 in Tyrrell County to 3,659 in Pitt County.

About 85% of these "employer establishments" are located within the four major towns of Greenville, Kinston, New Bern, and Washington and therefore are not included in the planned service area. The remaining 15%, or 1,374 businesses are within the planned service area.

The region also includes four major National Parks and Wilderness Areas that total 674 square miles. These parks and areas are the Alligator River National Wildlife Refuge and Reserve, Lake Mattamuskeet, Croatan National Forest, and Hofmann Forest.

Adjusting the service area to remove the 84 square miles, 153,283 population, the 7,788 businesses located within the four major towns of Greenville, Kinston, New Bern, and Washington, and the 674 square miles of parks and wilderness areas results in a net planned service area of 5,780 square miles with a population of 298,567 individuals in 119,427 households, 2,250 farms, and 1,374 businesses. It is logical that the percentage of households without Internet access in the planned service area is much greater than the NTIA ten county estimate of 26.5% as the four major towns are currently served by several existing broadband companies.

Nine of these ten counties are considered Persistent Poverty Counties as reported by U. S. DOT on October 2, 2020; all but one are experiencing out-migration according to the US Census Bureau *American Factfinder 2018*; each county is considered either Extremely Rural or Very Rural by federal standards; and, each county is rated as among either the Most Distressed or Distressed county tiers by the NC Department of Commerce *2021 County Tier Designations*.

In summary, by the metrics of geographic size and population, this rural ten county area is probably the largest single unserved or underserved contiguous region remaining in the Eastern United States.

Deployment CAPEX

Using available industry data and cost estimates, it is possible to estimate the CAPEX costs to deploy a fixed wireless broadband service network across the entire 5,780 square mile ten county net planned service area, excluding the four major towns and the park and wilderness areas.

Two additional key data points are the square miles of effective coverage per tower and the CAPEX cost per tower.

Industry data and RF network modelling suggest that multiple sectors deployed at a reasonable height on vertical structures in these Eastern North Carolina counties should provide effective connectivity to at least 80% of the desired locations within a 3 mile radius of the vertical structure on which they are deployed. A 3 mile effective radius per tower equals coverage of roughly 28 square miles per tower, calculated using the formula for the area of a circle *Area = pi X radius squared*, or in this instance, Area of 28 square miles = 3.14 X (3 miles X 3 miles).

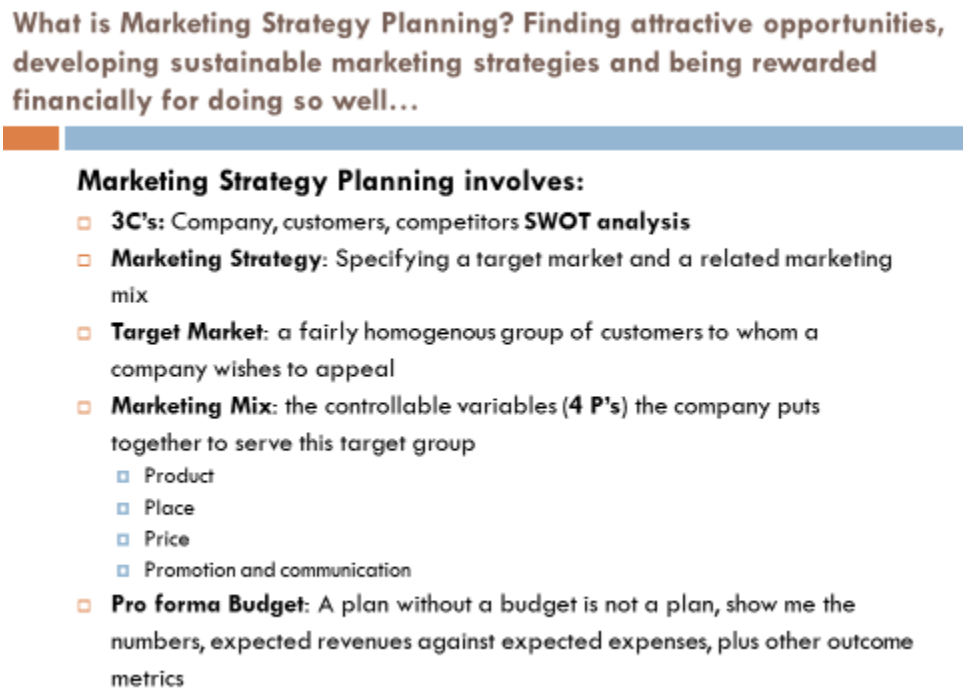
So if the average effective coverage per tower is 28 square miles and the net planned service area is 5,780 square miles, then the number of tower or vertical structure deployments needed is 5,780/28 = 206 towers.

Current available industry cost estimates indicate fixed wireless network deployment costs with multiple sectors per tower typically range from roughly $125,000 per tower to $145,000 per tower, depending on factors such as the number of sectors and type of vertical structure (commercial tower, water tower, grain silo, etc.).

Using the higher deployment cost figure of $145,000 per tower and the calculated figure of 206 towers needed to provide coverage across the net service area of 5,780 square miles for the ten counties, the CAPEX would be 206 X $145,000 = $29,870,000.

Marketing Strategy Plan

As outlined below, the major elements of a comprehensive marketing strategy plan include establishing a good understanding of your potential customers; assessing the strengths, weaknesses, opportunities, and threats associated with your organization and your competitors; selecting a target market and determining the appropriate marketing mix (product, price, place, promotion and communication) which will provide value to that target market; and creating a pro forma budget.



Target Market

In this instance, the mission is to provide affordable and reliable fixed wireless broadband to those within the ten county net service area who are currently unserved or underserved by legacy providers.

The size of the target market is estimated at 119,427 households, many of which are likely associated with the 2,250 farms in the region, and 1,374 businesses.

Marketing Mix

Product: The broadband Internet service product offerings should be tiered offerings based on different download and upload speeds matched with user needs.

The Internet service must be reliable and affordable.

An inexpensive basic tier can provide less than 25/3 Mbps, but other tiers should provide 25/3 Mbps and faster speeds. One or more tiers should provide at least 100/20 Mbps.

Service product offerings should be positioned and provided for households, business and commercial customers, and farm application customers.

Price: Based on competitor analysis and pricing by WISPs in other similar rural service areas, the basic tier service package should cost between $39 to $49 per month, plus fees and taxes.

Monthly subscription prices for faster speed service packages should be priced at between $129 and $149 per month.

Monthly discounts should be offered for enrollment in paperless or auto pay, however many households in this rural service area will pay monthly in cash.

Place: It is important that the broadband service provider in this ten county region have a local presence, with customer service and installation office facilities or physical points of contact readily available across the region. Local presence is important for many reasons including business and account development, installation and repair service, and to enable monthly cash payments from many household subscribers.

Promotion and Communication: The new fixed wireless Internet service provider in this region must deliver on their promises and provide value to the subscribers throughout the ten county area. Word-of-mouth about the new company will dominate any and all paid advertising. This is a region in which people still know each other and talk to each other. This is a region where people still meet and connect around the local schools, churches, downtowns, and stores. The most successful promotion and communication strategy would be a publicity effort that comes from formally partnering with the local schools, the local town leaders, and other local community assets like libraries and asking them to help make people aware that a new fixed wireless broadband service company is coming to their community. The new company would find a website and a Facebook page helpful for promotion and communication, customer acquisition, receiving online payments, operations, and customer relations management.

Estimated Annual Gross Revenue

Annual Gross Revenue can be estimated using WISPA industry data and data from deployment and operations of other fixed wireless broadband providers in somewhat similar rural locations across America.

Key assumptions are that subscriber market penetration of households will likely range from 20% to 33%, and that household ARPU will be $67 per month. Business subscriber market penetration will likely range from 20% to 50% with monthly ARPU of $100 for faster Internet speeds. The key assumption with respect to farm subscriptions is that market penetration will be roughly 10% with a monthly ARPU of $75.

These key assumptions and other previously noted data can be used to estimate both a low and high annual gross revenue as follows.

<u>Low Estimated Annual Gross Revenue</u>

Households:

20% market penetration X 119,427 households X $67 ARPU X 12 months = $19,203,862

Businesses:

20% market penetration X 1,374 businesses X $100 ARPU X 12 months = $329,760

Farms:

10% market penetration X 2,250 farms X $75 ARPU X 12 months = $202,500

Total Low Estimated Annual Gross Revenue = $19,736,122

High Estimated Annual Gross Revenue

Households:

33% market penetration X 119,427 households X $67 ARPU X 12 months = $31,686,372

Businesses:

50% market penetration X 1,374 businesses X $100 ARPU X 12 months = $824,400

Farms:

10% market penetration X 2,250 farms X $75 ARPU X 12 months = $202,500

Total High Estimated Annual Gross Revenue = $32,713,272

Average Estimated Annual Gross Revenue

Averaging these two calculations results in an average estimated annual gross revenue of $26,224,697.

OPEX

Presented below is one version of a pro forma operating expense planning budget, once established, for a new Internet service company modified to reflect this planned deployment. The key assumptions include deployment on 206 towers or other vertical structures, 12 employees with average salary compensation of $70,000 per year, 5 vehicles, 5 physical local customer service and operations office locations, and no CAPEX loan repayment expenses.

Tower	Site Lease	$2,472,000
	Maint.	$24,000
	Permits	$50,000
Fiber	Backhaul	$240,000
Cust. Ops	Billing	$335,000
	Software, etc.	$9,000
5 Vehicles	Ops/gas	$84,000
	Maint.	$60,000
	Depreciation	$500,000
Total Network Expenses		**$3,774,000**

12 employees	Salary	$840,000
	Payroll Tax	$63,840
	Benefits	$277,200
	Training	$40,000
	Expenses	$50,000
Total Employment Expenses		**$1,271,040**
5 locations	Ofc rent	$50,000
	Utilities	$10,000
	Telecom	$48,000
	Mobile	$20,000
	Supplies	$20,000
Total Office Expenses		**$148,000**
	Insurance	$15,000
	Legal	$60,000
	Accounting	$60,000
	Loan Pmt	$0
Total Other Expenses		**$135,000**
Taxes		
28% Fed	Income	$7,342,915
Total Taxes		**$7,342,915**
Total Operating Expenses		**$12,838,955**

Under these assumptions, the annual OPEX after federal taxes to serve the planned ten county net service area would be roughly $12,838,955.

This pro forma OPEX estimate is significantly lower than the average estimated annual gross revenue of $26,224,697.

Conclusion

This White Paper has identified a major ten county regional proposed service area in rural Eastern North Carolina where a new fixed wireless Internet company is needed to provide affordable and reliable broadband service to households, businesses, and farms on the wrong side of the Digital Divide.

Service area demographics were provided and deployment CAPEX, annual gross revenue, and annual operational OPEX were estimated.

The major finding of this analysis is that annual gross revenue far exceeds the anticipated annual operating costs for such a service provider, particularly if the deployment CAPEX expense is offset by federal, state, or other grant sources. While a grant is always preferable to a loan that must be repaid, a new Internet service company could actually cover a substantial portion of its CAPEX deployment costs as a loan, if a willing lender were available.

The CAPEX and sustainability for a service provider may be overly conservative in this analysis due to at least two major factors. First, the elective coverage range of each deployed antennae may be up to 6 miles from the tower or other vertical structure, which would reduce the CAPEX required for deployment by approximately half. Second, there would likely be significant CAPEX depreciation that will shield income from federal taxes for the first 10 years or so; therefore, the estimated $7M in annual taxes is overstated.

So in summary, we find the answer to the key question, “Is it possible for a business to sustainably provide affordable and reliable fixed wireless broadband service to unserved and underserved rural locations in Washington, Tyrrell, Hyde, Beaufort, Pitt, Greene, Lenoir, Jones, Craven, and Pamlico counties in Eastern North Carolina?” is, “Yes”.

Hopefully this White Paper will contribute to efforts to close the Digital Divide across North Carolina and encourage new companies to provide affordable and reliable Internet service to households, farms, and businesses in rural parts of the state where such service has been unavailable for far too long a time.