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Green Valley Farms a Living Laboratory

Research and Infrastructure Concepts

GVF Living Laboratory
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ADS-B: The proximity of GVF to the Oklahoma City metro area provides excellent opportunities for ADS-B research. As you know, we have been in frequent contact with Harris (formerly Excelis) regarding testing and evaluation of the new "ADS-B Extend" technology. Due to federal funding limitations, Oklahoma only has around 6 or 7 full ADS-B towers. This means that - on average - ADS-B coverage in Oklahoma is limited to altitudes around 600 - 700 ft and higher. The absence of low-altitude ADS-B coverage presents a challenge for future aviation safety in the state. Therefore, it is important that we find ways to install and implement technologies like ADS-B Extend so that full coverage can be provided down to 50 ft altitudes across the state. GVF provides a unique opportunity because it represents a rural location that is adjacent to a populated metro area where types of airspace begin to change. An ADS-B Extend site at GVF would benefit the Purcell airport, the nearby Army National Guard heliport, as well as regional air traffic. ADS-B Extend is well-suited for "mesonet like" co-location on existing weather or mesonet stations.

Test Track Concept: The diverse conditions at GVF in terms of terrain provide an excellent opportunity for an autonomous vehicle test track. An emerging field of autonomous vehicles includes what are called "robotic following vehicles". The military, construction industry, and agriculture will benefit from the use of "convoys" where a human driver is in control of a lead vehicle, but robotic "follower vehicles" track the lead vehicle. The Army is actively developing this technology and it is anticipated to develop in construction and agriculture as well as an intermediate step to eventual fully autonomous vehicle technology. The diversity of track conditions that could be created at GVF make it an ideal location for this type of testing. DII has a pending proposal to the Army to develop this type of technology.

For a test track, it is important to include diversity in terms of number of turns, type of turns, serpentine path, combination of inclines, etc. Also, a big challenge is background imagery to test and "stress" vision-based automation technology. Therefore, it is important to include as much diversity in the property background as possible.

One option for a test track is to remain entirely on one side of the river, but to include a portion that tracks the contour of the river as much as possible (without causing erosion or other ecological issues).

Fiber Optic and Communication: RF congestion is going to be a problem for future industries and technologies located near metro areas. GVF is rural, yet sufficiently close to an urban metro area to simulate some of these issues. To fully enable ADS-B Extend, autonomous ground vehicle testing, and full weather instrumentation, it is very

important that a full fiber optic network be install at GVF so that future communication needs are addressed and supported. At a minimum, a fiber optic network should be co-located alongside the autonomous vehicle test track.

Unique Opportunities for Autonomous Vehicle Testing: One of the unique aspects of GVF is that it is a very long contiguous area that falls under single private ownership. One of the challenges of testing autonomous vehicles at the moment is obtaining legal permission from property owners due to the ambiguity in law addressing lower-altitude "airspace ownership and control". NASA and others are interested in locations such as GVF since tests can be conducted for a large area of property (contiguous). This also makes it ideas for testing of emerging "personal air transportation technology", currently in development by companies like Uber.

Ecological and Environmental Monitoring: The diversity of wildlife and fauna at GVF will benefit from the technology enhancements at the property since improved monitoring of fauna and ecological conditions can be continually monitored and analyzed. The fiber optic network and other improvements will enable a rich suite of monitoring technology to assist in preservation of the conditions and vibrant ecological health of GVF.

Test Site for 3D/4D Mesonet: The emerging new mesonet concepts at the University of Oklahoma require a test location with full ADS-B capabilities and communication infrastructure. GVF is ideal since it is nearby the OU campus and also represents a large contiguous property where multiple vertical profiling stations can be prototyped using unmanned systems ("drones"). This concept is already being funded by NOAA, OU and the NSF. The FAA is also interested in the concepts and technology since it will enhance overall aviation weather safety.

Need to Preserve GVF Conditions: It is critical that GVF be preserved as a large contiguous property to enable the multitude of technology development opportunities. Any types of overreaching easement or utility construction that "divides" or "bisects" the property and restricts access will greatly diminish the value and viability for these types of testing.

GVF Aerial Testing: For aerial testing of autonomous and unmanned systems, the biggest strength of GVF is the long distance from North to South extents of the property. In order to maximize testing capabilities and usefulness, it will be necessary to develop a concept by first "bisecting" the property along a contour curve that represents the longest contiguous path (NW to SE might be optimal). Radar and safety systems would need to be installed at intervals along that contour that bisects the property. Essentially GVF will require a series of overlapping circles (to represent the radar detection zones). For safety systems (such as radar) the entire property must be covered with overlapping “zones”.

To fully exploit autonomous system testing, there is also significant need to video monitoring and related sensor input along the test paths (either ground or aerial). A

fiber network should therefore follow the test paths (i.e. – be installed adjacent to the test paths). This will also facilitate low-power wireless communication in various regions of GVF as needed.

Another important factor is to enable solar or other remote power for the sensor networks. There is considerable opportunity for testing of renewable energy concepts at GVF for remote sensors and sensor networks in support of safety (including general public safety).

Easement Challenges: A big challenge of the pipeline is that it will unfortunately cross these proposed tracks and paths too often and disrupt test capabilities unless confined to as minimal a portion of the property. The most significant value of GVF is the terrain diversity, large contiguous path distances from property boundary extremes, and the many pristine ecological areas. Disrupting any of these conditions and factors greatly diminishes the value of GVF for future technology development and testing applications.

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Establishing a Living Laboratory for UAS Research and Development: A Shared Vision Between Green Valley Farms and the University of Oklahoma

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Oklahoma has a rich history in aviation and aerospace technology. The State is home to many aviation pioneers such as Clyde Cessna and Wiley Post. Over the past century, Oklahoma's role in aviation and aerospace has continued with the leadership of many native sons, such as U.S. Senator Mike Monroney, who established the legislation to create the Federal Aviation Administration (FAA). Moreover, Oklahoma is home to some of the largest defense and commercial maintenance, repair and overhaul (MRO) facilities in the world that service a wide variety of aircraft. Recognizing this, Oklahoma is committed to establishing itself as a leader in the emerging area of unmanned aircraft systems (UAS). Similarly, the University of Oklahoma (OU) has recognized the research and teaching potential of UAS and has been actively exploring opportunities in this arena. To that end, OU has recently established the Center for Autonomous Sensing and Sampling (CASS), which seeks to leverage the university's legacy in weather, engineering, and aviation to broaden and strengthen its core to include unmanned systems (UxS) with a focus on adaptive sensing and sampling capabilities.

This document briefly outlines a plan to partner with Green Valley Farms (GVF) towards establishing a "Living Laboratory" for UAS research and development. The property consists of 3,500 acres with a variety of landscapes, vegetation, and wildlife, which lends itself nicely to several areas of investigation important to Oklahoma. Among some of the key aspects of the GVF property for research and development, we note, for example, that it: 1) offers a rural setting with access to FAA Class G/E airspace (depending on elevation) that facilitates integration of UAS into the national airspace system (NAS); 2) contains a section of the Canadian River with rich geographic features and the presence of roadway bridges over the river; 3) includes railroad tracks that transect the farm, including a trestle over Walnut Creek, and 4) contains an aging gas pipeline, which presents an opportunity for utility surveillance and inspection. Moreover, GVF offers the amenities of in-place infrastructure and being conveniently located near OU. The University has already established a land use agreement

with GVF as a first step towards helping to create the Living Laboratory. This would provide a timely and desperately needed venue for diverse research and teaching opportunities.

Five addressable markets:
Weather Science & Atmospherics
Precision (technology-based) Agriculture
Pipeline Sensing & Surveillance
Overhead & Underground Utilities Surveillance
Disaster Recovery & First Responders

A partial listing of research and teaching themes, which could be conducted at GVF by OU faculty, staff, and students include:

- Data collection to promote weather and climate studies
- Monitoring and mapping of rivers and streams
- Developing and implementing tools for precision agriculture
- First response and recovery related to natural disasters
- Utility and infrastructure inspection and maintenance
- Testing and improving UAS capabilities

Below we expound upon a few of the items from the list as examples of how the GVF Living Laboratory could be utilized. The focus is on research and teaching opportunities from a university perspective, but these would readily translate to commercial and governmental enterprises.

Data collection to promote weather and climate studies: The atmosphere near the surface of the Earth is directly impacted by heating, levels of moisture, features in the landscape and such. The layer of the atmosphere that is impacted by the surface is called the atmospheric boundary layer (ABL) or planetary boundary layer (PBL). The depth of the ABL depends on the time of day and conditions. it is typically shallow during the night and reaches its maximum during the day. A typical ABL height in Oklahoma in the summer can have a depth of about 5,000 - 10,000 ft. The ABL is amazingly and fascinatingly complex and highly variable in time and space. Therefore, it has been difficult to model. However, the ABL is an important driver of how the atmosphere evolves, and as such it is important to understand the state and evolution of the ABL. To achieve this MORE DATA ARE NEEDED. This is widely known and there have been many reports stating this conclusion. But collecting the data in the ABL has been challenging. The ability to collect vertical samples of temperature, humidity, pressure, and wind with UAS offers exciting prospects. We are trying to address such questions as: 1) how can we best collect these data using UAS; 2) what would be the optimal spacing horizontally and frequency in time of the samples; 3) how can we work with the FAA to allow us to collect these data autonomously and unattended; 4) how can we best assimilate the data into models, and so forth. To address these questions, OU has begun regularly collecting atmospheric measurements with UAS near the

Washington Mesonet tower at the OU Kessler Atmospheric and Ecological Field Station. This site was selected because the Mesonet site can provide reference data. However, as we gain confidence in our sensors and sampling strategies, it will be important to begin exploring how diverse landscapes such as those found at GVF impact the atmosphere. To that end, we plan to establish a regular schedule of atmospheric sampling at GVF.

Monitoring and mapping of rivers and streams: Rivers are essential features of the landscape, that provide natural water resources and habitat for aquatic and riverine ecosystems. Sometimes floods and flash-floods impose a condition of deadly natural hazards. Rivers are ubiquitous geomorphic features and exhibit complicated geometry, continuously evolving over time and space. Sustainable management of rivers requires substantial enhancement of instrumentation, monitoring and modeling abilities. In particular, our arena is still not able to predict the large number of morphologic changes that occur to rivers when the balance of sediment and water changes. This research is important because is a novel, accurate and risk-free technique for measuring river bathymetry, velocity profiling and suspended sediment loads. In the future automatic routines might drive UAVs to take measurements during prescribed times to monitor especial fluvial conditions, such as drought and floods. These measurements will also serve as a secondary source of data for high resolution computational models to predict future responses of the morphodynamic changes in the river after different storm events.

Developing and implementing tools for precision agriculture: Dwindling resources coupled with an ever-growing demand for increased food and biofuel production is forcing farmers and land managers to seek innovative and efficient methods of increasing agricultural yields. There has already been much progress in farm management especially in the application of better remote and in-situ monitoring tools. As the research and development continues, UAS will provide a valuable resource. For example, multispectral and hyperspectral images of the surface can be recorded using remote sensing equipment carried by UAS platforms. After processing, these images can provide information, for example, on soil properties, available moisture, crop stress, and yield forecasts. Moreover, UAS allow farmers to survey their properties in high spatial resolution at a much reduced cost compared to manned aircraft. In addition to crop monitoring, UAS can also be used in livestock applications through the use of infrared cameras and RFID tag readers. The development and implementation of UAS tools for precision agriculture at GVF is a logical research topic given the heavy dependence of Oklahoma's economy on agriculture and GVF's and OU's connections with the Noble Foundation.

First response and recovery related to natural disasters: Oklahoma is susceptible to a wide variety of natural disasters. Severe weather events can produce strong winds, damaging hail, flash flooding, power outages, and so forth. In the aftermath of a severe weather event, it is critical to be able to deploy first response assets quickly and efficiently. Often, search and rescue missions are required. Police and fire departments along with first responders need

training to address these issues. Additionally, continuing research is needed to improve the functionality of the UAS platforms and equipment. Training and research could be conducted at GVF. The property is particularly well suited to these activities because of the diverse features discussed above. Grass fires in Oklahoma also pose a natural risk. They can become quite large in land area leading to many hot spots that may flare-up long after fire equipment has moved-on. Smoke is another challenge to locating the real hot-spot to extinguish. The use of unmanned systems can provide a safe and cost effective way for fire personnel to identify and fight the source, not the result of a grass fire. Moreover, infrared imagery from a safe distance above can greatly reduce the danger and increase the efficiency of fire personnel. UAS can provide a downlinked video stream to the command post to direct personnel and to ensure the safety of those personnel during firefighting operations. We see great potential in using GVF for the purpose of training and operational scenarios, which can be developed to aid in the use of these systems for real world events.

Utility and infrastructure inspection and maintenance: Aging structures are an ever-present danger to life and property. Utility companies and telephone companies have many thousands of towers throughout the United States. The potential use of unmanned systems for tower inspections can greatly reduce the human danger of climbing a tower for a routine periodic inspection. The use of multi-spectral imagery on a UAS for routine inspections over time can provide an imagery time-history and trigger human inspections when the need arises. Multi-spectral imagery has been proven to be able to identify corrosion and rust and through image processing techniques, automatically identify potential anomalies needing a closer human inspection. There are many towers and silos at GVF that can be used to develop these techniques and prove their value.

Testing and improving UAS capabilities: Finally, it is critical that we continuously seek to develop more capable UAS platforms and sensor technology. The first steps in this process are typically completed in the laboratory but then testing must be conducted in a controlled but natural environment. The rural setting of GVF, its proximity of OU, and the infrastructure it provides makes this venue highly desirable for this purpose.

Infrastructure Addendum

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From my experiences doing field work and based on my conversations with others, here are some items that I think would be useful for infrastructure

- UAS airfield: A runway that we can use for small UAS seems like a critical component. Here is a link to the OSU UAS site https://unmanned.okstate.edu/node/52. As you can see, in addition to the flight field, it contains small hangers and office space. There is also a small weather tower. The site has power and internet. It could be nice to include a hydraulic or pneumatic launch system. If resources permit, it could be nice to have a tower of sorts to use when monitoring UAS flights.
- High capacity internet backbone: Researchers will need access to internet. Could infrastructure be put in place to allow for that? It would also be nice to have several hot spots in areas where research activities will be concentrated
- Meteorological towers: I know that you are keen on getting a mesonet tower, but I still think that one tower could be overkill. I would advocate for a distributed network of towers that could provide high quality wind data (sonic anemometer) along with pressure, temperature, and humidity. Each tower would cost about $12k.
- It would also be meaningful to have a station, maybe near the UAS airport, that could measure height of cloud base (ceilometer) and visibility (http://www.vaisala.com/en/products/visibilitysensors/Pages/default.aspx)
- I still need to speak with Hernan and Laura again about river monitoring
- There is a growing interest at OU in gas and gas flux monitoring. Xiangming Xiao and Jeff Basara have been working at several sites in OK such as KAEFS and El Reno on this topic. I will reach out to them.

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The Green Valley Farms Living Laboratory Initiative

The mission of the Gallogly College of Engineering (GCoE) is to foster creativity, innovation and professionalism through dynamic research, development and learning experiences. We see great potential to advance our mission through the unique opportunities provided by the Green Valley Farms (GVF) initiative. GCoE will provide leadership and support in performing collaborative research and development across many disciplines aligned with the five addressable markets:

Weather Science & Atmospherics;
Precision (technology-based) Agriculture;
Pipeline Sensing & Surveillance;
Overhead & Underground Utilities Surveillance; and
Disaster Recovery & First Responders.

The GCoE is key to OU's renowned weather enterprise, delivering crucial research and development in weather radar and unmanned aerial systems (UAS) for remote sensing. Current and future projects within the Advanced Radar Research Center (ARRC) and Radar Innovation Lab (RIL) will benefit greatly from the opportunities for experimentation provided by the GVF. In addition to weather applications, we also work in other application areas of remote sensing, including target detection and tracking and surface monitoring. We also have a growing portfolio of expertise and success in small UAS hardware and system development.

The ability to use GVF as a radar/sensing test range in a rural setting (with essentially no urban background noise) is ideal. Establishing a few georeferenced hard targets will enable algorithm development for sensor integration and calibration across multiple platforms. Additionally, if the placement of a "turntable" on GVF is possible, radar bi-static measurements and techniques can be developed and refined for greater accuracy in remote sensing applications. Because the testing of sensors on a military base comes with understandable security challenges, this test range could provide a way for universities and companies to test their sensors and systems in a more cost-effective, less-regulated way before taking them on to official demonstrations on military installations. This approach would be very helpful to the ARRC, as we continue to develop systems oriented toward these types of targets and applications. There is also a potential for commercial and industrial groups to use the test range, especially for access to calibrated hard targets, turntable targets, and reduced regulations. Any research in this area that is subject to possible export controls (e.g., International Traffic in Arms Regulations "ITAR" or Export Administration Regulations "EAR) will be managed in cooperation with OU's Office of Export Controls.

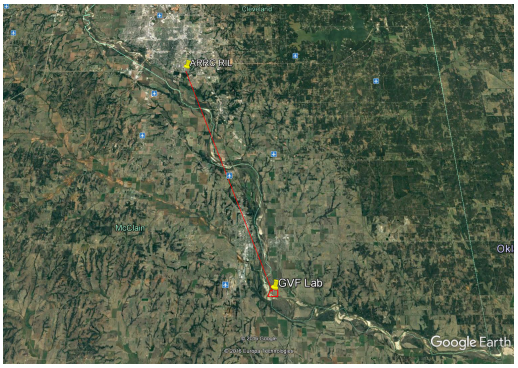
The planned construction of a UAS runway and test track will enable further development of unmanned vehicles and provide a testing space that is currently not available on the main campus. The OU main campus is within Class D Controlled airspace, whereas GVF is not

burdened with this restriction. A specific scenario of interest would be to use GVF as a launching area for radar tests involving detection and tracking of UAS in the airspace. Radar systems could be placed on the roof of the RIL (on the main campus) and we could test the systems as they attempt to detect and track targets flying around the GVF test range. There isn't much altitude needed in order to achieve line of sight from the roof of the RIL to GVF. As mentioned earlier, any research in this area that is subject to possible export controls will be managed in cooperation with OU's Office of Export Controls.

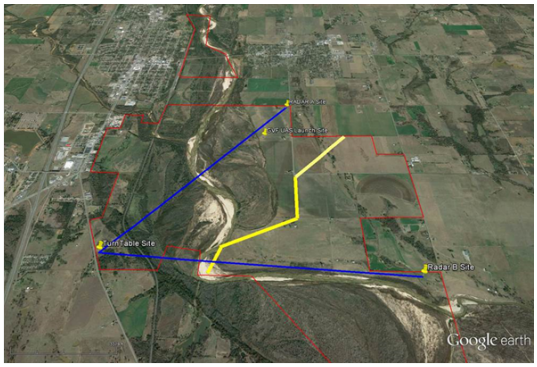
Another opportunity for UAS is the monitoring of soil, crops, and shoreline. Much research is underway to address soil moisture content, nutrient and chemical runoff, and shoreline erosion. We have several researchers working in this area within the School of Civil Engineering and Environmental Sciences, specifically in the OU Water Technologies for Emerging Regions (WaTER) Center. Using multispectral cameras mounted on small UAS we are able to monitor the health of crops, the content of the soil, and map soil erosion. Having a topographically diverse site near OU will enable frequent observations, allowing extensive volumes of data to be collected and analyzed. These data can be integrated into our expanding academic and research programs in data science and analytics.

Also related to agriculture and the environment, GVF offers a river and creek layout ideal for research into ground water runoff capturing and reuse. There is the potential of testing capability to capture the runoff in detention and retention ponds, migrate that water into engineered wetlands and then provide water of acceptable purity back into the aquifer system. There are several faculty and students working in this area and are eager to pursue the "runoff challenges" – and corresponding possibilities –at GVF.

Additional uses for GVF include development of tools and techniques for infrastructure inspection and monitoring (i.e., bridges, towers, and road surfaces), above ground and underground monitoring of pipelines for identifying anomalies that may result in minor or major leaks and spills, and the development of new search and rescue concepts of operations. The proposed infrastructure identified to be built in GVF, including high speed networking, roads – in addition to that which is already in place – will provide a productive and efficient testbed.



GVF to RIL is 13.3 NM



Radar site to turntable is 2.0 NM.

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Implementing the Green Valley Farm Living Laboratory as an Experimental Site to Develop Research in Water Security

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Drought conditions have persisted in Oklahoma for the last decade, which have had wide ranging effects on the economy and the budgets of both state and local governments. Contrastingly, the new climatic trends are showing more intense and more frequent maximum precipitation events with disastrous consequences for ecologic communities and cities. Scientists agree that the combination of human-induced changes to the atmosphere and land cover, population growth and inter-annual macroscale phenomena like ENSO are the main responsible for the observed trends. In order to tackle these new conditions, Oklahoma authorities need to be on the leading edge of climatic and hydrologic forecast, so that water security can be guaranteed during the next decades and life and economic damages due to extreme hydrologic events are minimized.

The University of Oklahoma (OU) recognizes the Green Valley Farm is an excellent experimental site with enormous possibilities for water research due to the presence of the Canadian River and its tributaries, diverse vegetation and ecologic communities and easy accessibility from both the OU campus and the National Weather Center. In this document, we present several research avenues that can be develop at the GVF living laboratory that involve the study of the spatial distribution and temporal variability of the components of the water balance and their patterns. These topics complement

some of the ideas already proposed by Professor Phil Chilson in a complementary document:

- Streamflow and sediment transport monitoring
- Precipitation variability
- Radiation balance and evapotranspiration
- Soil Moisture and drought monitoring

In the following paragraphs we briefly describe these research lines their importance in water decision making and the possibilities at GVF.

Streamflow and sediment transport monitoring

We propose the installation of a network of streamflow and sediment transport sensors in the GVF living laboratory to better understand the river response to flood conditions, flood wave traveling and sediment loads after heavy precipitation events. To complement direct observations, we propose the construction of a monitoring tower in the river banks of the Walnut Creek for purposes of photogrammetry using web and hyperspectral cameras, to monitor the geomorphologic changes and sediment loads. This tower complements our efforts with Unmanned Aerial Systems (UAS) for dynamic monitoring along the channel axis. We are also planning to develop an innovative UAS-based method to measure the river morphology, flow velocity, sediment sampling and water quality, complemented with high resolution modeling, to improve the current river forecasting system in Oklahoma.

Precipitation variability

Improving the accuracy of radar estimates is indispensable to accurately quantify the water inputs in a basin. A dense network of rain gauges can be used to calibrate and evaluate radar reflectivity measurements. The GVF living laboratory constitutes an ideal location to deploy a dense network of rain gauges connected to the high speed optic fiber network for real time corrections of radar estimates addressed to improve early warning systems and climatic monitoring.

Radiation balance and evapotranspiration

Solar radiation is the basis for all life on earth. It also constitutes an invaluable natural resource for sustainable energy supply. The total available energy in the landscape is partitioned into sensible, latent and ground heat flux. Understanding the portioning of net radiation, its inter-annual variability and trends becomes a key to understand the effects of global warming on water resources. Evapotranspiration (i.e, latent heat flux) represents a significant water loss from drainage basins. Different vegetation types have distinct evapotranspiration rates. The GVF living laboratory provides the opportunity to monitor the components of the radiation balance in a large landscaoe footprint as measured by an eddy-covariance tower a radiometric station and a scintillometer transect.

Soil moisture and drought

Hydrologic drought is one most significant stressors of the Oklahoma-Texas economy in terms of agricultural production, water supply and livestock. The new efforts of researching soil moisture variability from space are led by NASA through its Soil Moisture Active Passive (SMAP) mission satellite launched in 2015. However, gains in spatial coverage come at the cost of reduction in spatial resolution. The GVF living laboratory could represent the first soil moisture testing range, in the Great Plains to test and support the creation of an enhanced drought monitoring product, coupling satellite UAS-radar and ground-based soil moisture (e.g. theta probes) observations.

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The Food-Energy-Water Systems (FEWS) study in the Green Valley Farms, Oklahoma

From: Xiangming Xiao, Department of Microbiology and Plant Biology, University of Oklahoma
Date: December 10, 2016

I. Overview

As of June 2016, the world population was estimated at 7.4 billion and is projected to increase to 11.2 billion by 2100 (World Population Clock). The food, energy, and water security and sustainability for the growing population is one of the grand challenges in the 21st century. As many factors affect food, energy, water (FEW) systems, including weather and climate, land cover and use change, soil degradation, markets, as well as human behavior, policies, and governance, it is imperative to have FEWS studies across the scales from field, farm, watershed, region, national, to the world.

In 2015, Oklahoma had 4.6 million cattle and ranked 5th (Texas – 11.8 million, Nebraska – 6.3 million, Kansas-6 million, and California – 5.17 million) among the 50 states (a total of 89.8 million). In 2015, Oklahoma planted 5.3 million acre of winter wheat and harvested 3.8 million acre of winter wheat, ranking 7th in wheat grain production among the 50 states. Winter wheat and beef cattle food supply chains in Oklahoma play important roles in food security from local to national scales, but are very sensitive to climate variability and change.

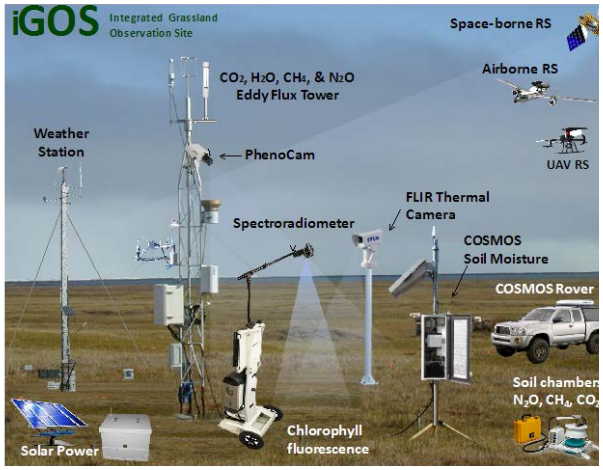

Figure 1. A schematic diagram on multi-scale observations of FEWS in Oklahoma.

The Green Valley Farms in Oklahoma, which has both winter wheat and beef cattle production, is a representative sample of many farms in Oklahoma and Southern Great Plains, and could be used to support an integrated study of FEWS at the farm scale.

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II. Potential joint research activities between GVF and OU

1. FEW security and sustainability at the farm scale

GVF can work with researchers from OU and other institutions to carry out system analysis and integration of FEW security and sustainability at the farm scale, which is an essential component for the society at large to better understand and strengthen FEWS.

GVF as a farm-scale site of the Oklahoma FEWS-Social Observatory
Built upon the Oklahoma Ecological-Social Observatory from the current NSF EPSCoR Track 1 project, the researchers in Oklahoma are interested to develop the Oklahoma FEWS-Social Observatory, with a specific focus on FEWS. The GVF could serve as one of sites of the observatory at the farm scale. Figure 1 shows likely measurements from the FEWS observatory. The social observatory will include collection and analyses of social, economic and management data relevant to winter wheat and beef cattle productions.

GVF as a farm-scale site for the Oklahoma FEWS and Social Synthesis and Decision Support
We are developing context-specific decision support tools to enable producers, consumers, and stakeholders to make science- and evidence-based decisions that would strengthen FEW security and sustainability. GVF could serve as one of sites for (1) FEWS and social synthesis and (2) development, evaluation and use of the decision support tools.

Important Notes

GVF is a private farm, and the privacy would be one of major concerns. Many of our research activities will result in publications that may have some information about the FEWS in the farm. Thus, the privacy issue needs to be carefully addressed to ensure that GVF privacy is well guarded.

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A tower similar to the Boulder Atmospheric Observatory (BAO) (~100 to 300 m) would be highly valuable to both the UAV and the meteorological community in Norman. It would provide a validation system for UAS systems (e.g., by instrumenting the tower from the ground upwards). For the meteorological community, it would provide one-of-a-kind observations of the ABL (atmospheric boundary layer). It would also provide insights into key phenomena that occur across the Plains including cold fronts, low level jets, dry lines, etc.

Such a tower is a costly endeavor. In speaking with the BAO manager, he told me they estimated it would cost around $1 M to disassemble the existing tower, and the age of the materials make them not worth moving to Oklahoma. Thus, it would likely be more cost effective to build with new, local materials here in central Oklahoma. The existing BAO tower has 50-60' deep concrete foundations. I would presume some of the current methods/technologies for installing wind turbines would be similar.

The Boulder tower was 300 m. In talking with Phil Chilson, we felt that even 100 m would be very useful. I would guess that going from 100 m to 200 m to 300 m significantly changes costs.

I could foresee having hundreds of sensors, all linked wirelessly throughout a tall tower at GVF. Sensors would include air temperature, windspeed and direction, relative humidity, sensible and latent heat flux, and perhaps green house gases (e.g., CO2).

The BAO website lists over 100 publications (https://www.esrl.noaa.gov/psd/technology/bao/pubs/). Such an infrastructure for the Norman weather community would likely be leveraged for countless new grants at OU.

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I am specifically interested in using sUAS for ecological and biogeographic studies. This would entail data collection, monitoring, and mapping of land cover data. Such data would be processed and classified for incorporation into geographic information systems (GIS). Additionally, there is a desire to test the applicability of using sUAS to aid in field surveys of specific plant species. These capabilities can also be expanded to monitor animal habitat (e.g. Bald Eagle nesting sites). My interests, nonetheless, overlap with some of the bulleted points. For instance, the ecological data of interest could also be useful for "data collection to promote weather and climate studies," "monitoring and mapping rivers and streams," and "developing and implementing tools for precision agriculture."

As for infrastructure, my current interests involve the use of multi-rotor copters, which only require relatively flat ground for take-off and landing. At some point, though, using fixed-wing aircraft may become advantageous. As such, a runway could be beneficial. Otherwise, there is not any specific infrastructure that I need for my studies.

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Thank you for requesting my input on your Living Laboratory plans. This is a very exciting project for you and the university. Dr. Chilson's plan is extensive and somewhat unrelated to my goals as a conservation biologist. My foremost interest concerning Green Valley Farms is the protection of natural habitat for rare species. While I am collecting data on both the Bald Eagle nest and Interior Least Tern colonies, my work is primarily concerned with protection and conservation of these species and their habitat. Although my work does not necessarily complement Dr. Chilson's proposed research, we would need to coordinate work so that these federally protected species and their habitat are not negatively impacted. My work to monitor the eagles and terns does not require any significant infrastructure. I simply need temporary fencing and signs to protect the tern colonies.

Beginning in January I would like to make regular trips to Green Valley Farms to make Bald Eagle nest observations. I have studied the quarantined map attached to your last email. Unfortunately, the nest tree is within the quarantined area, but I will be sure to observe from outside the area outlined in blue.