UofM Forever Green Initiative

$5.0 M Investment

Infrastructure Investment Needs

(1) [*2022 top priorit*y] Infrastructure for agronomic research ($2.35M)

The University of Minnesota has a network of Research and Outreach Centers strategically located in the major agriculture ecological regions of Minnesota. The ROC's provide students and faculty with unique sites to develop and evaluate crops and cropping systems that produce high yields of proteins with good functionality and high nutritional quality. The ROCs also provide the opportunity to evaluate the cropping systems for erosion management, nutrient use efficiency, soil health, carbon sequestration, water quality, and other ecosystem services. To support these research efforts at the ROC's, it is imperative to strengthen the infrastructure at the sites. This will include an investment in the specific tillage, planting, and crop management infrastructure necessary to support research on small and large-seeded high protein crops currently under development in the genomic and breeding programs.

- Wintersteiger, 8-row plot drill with no-till openers, and indexing system (2 @ $75,000 = $150,000)
- Hydraulically driven soil probe for collecting soil cores to a depth of 1.5 M ($25,000 on a 4-wheel drive 1-ton pickup $55,000. Total $80,000)
- Great Plains no-till drill 10-foot-wide (3 @ $50,000 = $150,000)
- Vertical-till implement 11-foot-wide KUHN Krause Accelerator 8005-11 (2 @ $60,000 = $120,000)
- Strip-till implement 10-foot-wide 4-row KUHN Krause Gladiator 1210M-430 (2 @ $125,000 = $250,000)
- 4-row no-till precision row-crop planters equipped with RTK GPS, row cleaners and cutting coulters (2 @ 125,000 = $250,000)
- Plot combines equipped with GPS and yield monitor capacity with 5-foot harvesting with for row and drilled crops (3 @ $300,000 = $900,000)
- 110 HP tractor equipped with Precision Ag technology planting capacity (1 @ 150,000 = $150,000)
- Duel wheel truck and transport trailer (1 set @ 150,000)

(2) [*2022 top priority*] Sustainable FGI crop breeding and genetics infrastructure needs ($2.6M)

The following infrastructure investments are needed to support the crop breeding teams that are focused on the development of climate-smart FGI crops. There is a need for an investment to upgrade the facilities necessary to support research and teaching in plant breeding and genomics that will enhance the development of high-yielding protein crops that produce high-quality functional and nutritious proteins for the food industry. The facilities will provide the infrastructure to effectively and efficiently select crop germplasm that are frost tolerant, winter hardy, drought, and heat-tolerant which are adapted to the current and future Minnesota climate. These investments will ensure the crop technologies and associated basic science on, for example, environmental benefits of sustainable protein crops. The chambers will also speed up the breeding process by allowing for multiple breeding cycles per year which is not possible in Minnesota field environments. This infrastructure will accelerate the release of new improved crop varieties that can be released to seed suppliers and made available to farmers for production and marketing of the seed for use in the food industry. (40 @ $50,000 = $2,000,000)

Climate controlled FGI crop germplasm preservation facility. There is the need to develop a facility that will protect and preserve the germplasm developed by the breeding programs. If the germplasm developed by the breeding programs is not protected it would result in the loss of very valuable material and would result in delay in the release of new and improved crop varieties. It is important for both short and long-term protection of the germplasm developed by the crop genomic and breeding teams (1 @ $600,000 = $600,000)protein production, are sufficiently developed to serve as engines of regional economic growth and transformation in the food and agricultural sector.

Environmental Plant Growth Chambers for development of climate smart FGI crops. The environmental chambers will allow plant breeders to rapidly select for stress-tolerant germplasm in a range of high

(3) Forever Green crop seed processing and storage facilities ($505,950)

Provide infrastructure support at selected U of M Research and Outreach Centers ROCs to serve as resource clusters for rural growers and communities, and to improve collaboration with seed and supply chain industry partners. Host training events and field days for growers and industry to showcase the equipment and capacity. These investments will provide the necessary infrastructure and capacity to support university agronomists and food scientists to collaborate with industry partners on piloting and scaling novel sustainable protein crops. The Infrastructure and equipment needed includes:

- Mid-scale seed cleaning processing infrastructure with gravity table (3 @ $60,000 = $180,000)
- Grain dryers 600 bu. Capacity (3 @ $60,000 = $180,000)
- 14.7-ton grain bins for storage of FGI crops (10 @ $10,195 = $101,950)
- Grain bin aeration fans (20 @ $2,000 = $40,000)
- Grain bin moisture gauges (20 @ $200.00 = $4,000)
- Equipment delivery and setup $50,000

(4) Infrastructure investment for first phase commercialization of Forever Green crops ($453,950)

Collaborate with internationally leading sustainable protein brands such as PURIS and Field Theory to develop the cross-sector capacity to pilot and scale winter and perennial oilseed production and processing. Mid-scale commercial facilities with appropriate equipment and willingness to work closely with university-based agricultural innovation platforms are few to non-existent. Equipping select commercial partners with the appropriate equipment to grow, dry, store, sort, and process these novel sustainable protein crops will provide the essential bridge from university to industry partners needed to scale new protein systems. The below requests will allow for i) Pilot production of sustainable protein crops of the future onsite at PURIS's rural Western MN pea protein processing plant in Dawson, MN), ii) Storage and handling equipment at Field Theory home farm (Hastings, MN) to facilitate pilot production and aggregation of novel sustainable protein, iii) Drying, oilseed crushing, and separators onsite in Dawson and/orHastings to facilitate oilseed drying and crushing, oil extraction, and novel plant-based protein separation

- Roller crimper connection ($33,500)
- Air-seeder ($60,000)
- 1,750 bu. hopper bin ($17,500)
- 4,000 bu. hopper storage bin ($27,000 ea. x 2 = $54,000)
- Grain auger ($10,000)
- Mobile grain dryer ($15,000)
- 10-20 tph oilseed press ($30,000)
- Filter press ($17,500)
- Separators:

- One disc stack centrifuge separator ($50,000)
- Horizontal decanter ($70,000)

(5) Integrated field-based facility to support breeding FGI crops for climate resilience ($1.5M - $2.0M)

The increased frequency of extreme climate events such as freezing stress in the winter and heat stress, nighttime warming and drought in the spring/summer seasons is threatening the sustainability of crop production systems worldwide.

To address this critical challenge, we propose the development of a new facility at the St. Paul campus of the University of Minnesota that deploys versatile, field-based infrastructure to enable the imposition of various combinations of cold/freezing stress (fall/winter), heat stress, nighttime warming and drought (spring/summer) regimes impossible to simulate under growth chamber condition. The infrastructure would consist of an integrated cyber-physical "climate simulator" system operating across all four seasons.

- **Summer**: the facility would include an automated rainout shelter with temperature and humidity regulation capability, and an advanced irrigation system regulated by a network of weather, soil and plant microclimate sensor nodes.
- **Fall/winter**: the facility would be configured to enable routine screening for enhanced freezing survival while preventing interference from snow cover (which protects the plant from freezing).
- **Spring**: the facility would be configured to subject breeding lines to highly specific water availability and temperature regimes imposed during critical windows (e.g., flowering, seed fill) that drive grain yield and protein content sensitivity to climate change stressors.

he infrastructure would be designed to enable 1) the physiology/agronomy teams to conduct trait discovery research, 2) the phenomics/breeding teams to deploy remote-sensing equipment for rapid, proxy-screening of climate resilience traits, and 3) the soil health teams to investigate effect of climate change regimes on carbon sequestration, biological activity, and their interaction with desirable plant traits. Based on informal discussion with experts and colleagues, the total estimated cost of such infrastructure would be in the $1.5-$2.0 million.

(6) Infrastructure to access greenhouse gas efficiency and carbon management in Forever Green crops and cropping systems ($260,000)

Infrastructure needs for the eddy covariance research include eddy covariance towers for instrumenting additional fields. Instrumentation to continuously monitor CO_2 and water vapor fluxes includes open-path infrared gas analyzers, three-dimensional sonic anemometers, pyranometers, pyrgeometers, quantum sensors, air temperature and humidity sensors, rain gauges, soil moisture and soil heat flux sensors, and associated data loggers, power supply, and mounting hardware. Current costs to instrument a single field are approximately $65,000 each. Adding four additional towers to the Forever Green program would expand existing work (currently two fields) so that additional crops, rotations, or management practices can be evaluated simultaneously under similar weather conditions.

(7) Infrastructure to evaluate hydrology dynamics in Forever Green cropping systems ($1.1M)

We intend to establish an extensive soil moisture monitoring network across representative soils and slope classes at six Research and Outreach Centers (ROCs) to gain a better understanding of soil hydrology and water dynamics in Forever Green Initiative crops. We intend to monitor soil moisture and soil matric potential at two depths for roughly 100 locations in each ROC. The soil moisture monitoring network would facilitate better interpretation of soil water uptake, evapotranspiration, and soil water balance by deep rooted FGI crops. This network would also allow calibration of satellite remote sensing products that estimate surface soil moisture, such as Sentinel 1

SAR. With SAR, soil moisture could be estimated across the entire state of Minnesota. Estimated costs are $480,000 for soil sensors, $370,000 for data-loggers, and $250,000 for the deep lysimeter systems.

(8) Develop in-field infrastructure to measure carbon sequestration/soil health, microbial dynamics, and nutrient cycling in Forever Green crops and cropping systems ($3,470,400)

General Infrastructure updates are required for the research team to perform optimally. The first request would be a new general-purpose building at the Rosemount Outreach and Experiment Station. The facility should include space for tractor, truck, equipment storage, insulated and/or heated rooms with running water and sinks for processing soil, root, and plant samples; insulated and/or heated room with drainage and plumbing for washing root samples, a bathroom, and gathering space for team gatherings or lunch for the field crew. High speed internet connectivity, as described elsewhere in this proposal, would also be immensely helpful. Cost is estimated $2.0M.

Other soil and root analysis equipment would position the soil health and carbon sequestration team to conduct higher throughput and/or more sophisticated research about nutrient cycling dynamics. These include:

- Probe truck sampling vehicle would alleviate scheduling issues and offer higher throughput ability for sampling soil and roots.
  - Ford F-450 with 9 ft. aluminum flat bed ($75,000)
  - Giddings hydraulic probe - Model #35-SCS/XHDGSRPS: 35 hp 3 cylinder diesel engine ($63,400)
- A Biotek Synergy 96 well plate reading spectrophotometer/fluorormeter- flexible machine for measuring soil microbial activity, and water chemical composition ($32,000).
- A Gillison's Root Washing Hydropneumatic Elutriation System ($50,000)
- 24 root towers modeled after the Deep Frontier project at the University of Copenhagen - Root towers are 4 m tall mesocosms that allow for visual monitoring of roots, sensor installation at precise locations within the soil depth horizons, and ports for injecting isotope labelled materials (water, fertilizer, etc.)($500,000)
- Field-scale minirhizotron root monitoring system. Permanent minirhizotron tubes buried beneath crop research fields following methods described by Svane et atl. (2019). $750,000

(9) Infrastructure for internet connectivity in research fields and facilities that support Forever Green crop development ($3.0M)

Connectivity to computational and analytical platforms is key to many components of modern research infrastructure.

- **Field connectivity**: outdoor internet connectivity is essential to fully exploit outdoor research facilities, such as agriculture field space. Tools as simple as a standard digital camera now make use of Wi-Fi for the upload of high-definition images. Wi-Fi 33 6 (also known as AX WiFi or 802.11ax) provides both high throughput data transfer, with speeds approaching 10 Gpbs, but also higher capacity in terms of the number of devices that can be connected. This connectivity is important for a field environment that hosts drones for imaging, hyspectral cameras, and devices for automated phenotyping.

- **Lab connectivity**: In university research spaces, ethernet connections are still important for data transfer and for always-on connections to high-performance computing facilities. Individual laboratories can routinely collect >15 Gigabases of long-read DNA sequences on USB stick-sized devices, but the downstream analysis of this data requires transfer to high-performance computing facilities. Much of the ethernet infrastructure on university campuses, including the University of Minnesota, dates to the earliest iterations of the internet, using a technology known as 10BASE-T compared to current technologies that 1000BASE-T (Gigabit) ethernet or faster.

(10) Upgrade laboratory/instrumentation equipment in support of Forever Green crop natural product research and development ($2,333,032)

The instrumentation will be installed into the Plant Metabolomics Laboratory shared instrumentation facility co-managed by Hegeman and Cohen on the UMN-Twin Cities campus in Alderman Hall. Installation in this facility will provide access to the instrumentation by the Forever Green crop development projects. This placement will also provide a mechanism for distributing maintenance costs, and eventual replacement via depreciation costs, both factored into the fee-for-service structure moving forward.

There are six significant pieces of instrumentation that will improve the infrastructure for doing 21st century metabolomic studies: a third-generation quadrupole Orbitrap LC-MS/MS, an inductively coupled plasma mass spectrometer, an ultra-high sensitivity GC-3Q-MS, a small molecule imaging ion mobility MS/MS, an advanced scanning spectrophotometer and a research grade dual scanning spectrofluorometer.

- High-resolution accurate-mass quadrupole Orbitrap LC-MS & MS/MS ($558,145)
- Inductively coupled plasma mass spectrometer (ICP-MS) ($260,589)
- Gas chromatograph-triple quadrupole mass spectrometer ($332,000)
- Full Spectrum Mass Spectrometry Molecular Imaging ($833,915)
- Multi-modal Scanning UV-Visible to Near IR Spectrophotometer ($124,803)
- Phosphorescence and Fluorescence Spectrometer ($223,580)

(11) Field facility for assessment of deacclimation in Forever Green crops to support the selection of germplasm for climate resilience ($1.75M)

An important aspect of winter hardiness in crops is the ability to withstand fluctuations in temperature during the winter. Therefore, we propose the building of a perennial plant field deacclimation research facility on the St. Paul campus. The facility would use the same technology that is currently used to heat soil profiles in major league sports facilities in the northern U.S., including Target Field in Minneapolis.

The facility would include at least 9 plots, each approximately 0.1 ha in size, with each plot built as an individual zone allowing for uniform soil profile temperature control. This design would allow for replicated field trials on a larger scale than is currently possible and be a valuable resource for plant physiologists and plant breeders, allowing for more rapid selection of climate-resilient genotypes. Cost assumptions based on conversations with SubAir--includes allowance for a small building/structure to house mechanicals.

Forever Green Initiative infrastructure needs grand total: $19,317,382