COVER SHEET FOR GRANT PROPOSALS

State Board of Education

SBOE PROPOSAL NUMBER: (to be assigned by SBOE)	AMOUNT REQUESTED: $74,500

TITLE OF PROPOSED PROJECT:

Drought Mapping Using a Small Unmanned Aerial System (sUAS) for Precision Agriculture in Idaho

SPECIFIC PROJECT FOCUS:

The proposed research will advance drought monitoring using a small unmanned aerial system (sUAS). With Idaho incubation fund (IIF), the University of Idaho will enhance Idaho's economic competitiveness by working agricultural producers and industry partners. Through this project, the research team will transform research concepts, discoveries and application prototypes into products and services across the state of Idaho and beyond. Ultimately, the proposed research will contribute to Idaho's economy by establishing and commercializing a mobile-based decision support tool (Mobile App) using sUAS inputs. A localized drought detection for precision agriculture using sUAS-based data products will enable agriculture professionals to make more timely and effective management decisions thus increasing yields and decreasing operational costs. During the course of the project, the team will develop a proof of concept and test such a concept to verify how near real-time drought information in a mobile environment can mitigate drought impacts at local levels during growing seasons, thereby increasing economic revenue.

The sUAS-mounted sensors and cameras will be used to monitor and identify crop stresses driven by water shortage. Collaborations with local growers in Caldwell, Nampa, and Parma areas have already been established and necessary field setup arrangement details await IIF support. **The main goal of the proposed research is to develop a mobile-based decision tool for drought mitigation in irrigated agriculture through four primary objectives**, including to 1) strengthen drought monitoring to better characterize local conditions for irrigated agriculture, 2) enhance an early warning of crop stresses driven by drought using a sUAS equipped with a suite of sensors, 3) develop a mobile –based decision support tool (Mobile App) to advance early drought monitoring in irrigated agriculture, and 4) promote collaborative ag research and enhance Idaho's economic competiveness by working with ag producers and industrial partners.

PROJECT START DATE: July 1, 2016	PROJECT END DATE: June 30, 2017
NAME OF INSTITUTION: University of Idaho	DEPARTMENT: Biological and Agricultural Engineering
ADDRESS: 322 E Front St., Boise Idaho 83702	
E-MAIL ADDRESS: jryu@uidaho.edu	PHONE NUMBER: (208) 332-4402

	NAME:	TITLE:	SIGNATURE:
PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR	Jae Ryu	Assistant Professor	

NAME OF PARTNERING COMPANY: KARIOSYS COMPANY REPRESENTATIVE NAME: ANTHONY BROWER

	NAME:	SIGNATURE:
Authorized Organizational Representative	Anthony Brower	
VP. Research & Econ. Dev	J. K. McIver	

Project title: Drought Mapping Using a Small Unmanned Aerial System (sUAS) for Precision Agriculture in Idaho

1. Name of Idaho public institution: University of Idaho
2. Name of principal investigator: Jae Ryu, Assistant Professor, CALS/UI
3. Previous incubation Fund: Not Applicable
4. Executive Summary:

The proposed research will advance drought monitoring using a small unmanned aerial system (sUAS). With Idaho incubation fund (IIF), the University of Idaho will enhance Idaho's economic competitiveness by working agricultural producers and industry partners. Through this project, the research team will transform research concepts, discoveries and application prototypes into products and services across the state of Idaho and beyond. Ultimately, the proposed research will contribute to Idaho's economy by establishing and commercializing a mobile-based decision support tool (Mobile App) using sUAS inputs. A localized drought detection for precision agriculture using sUAS-based data products will enable agriculture professionals to make more timely and effective management decisions thus increasing yields and decreasing operational costs. During the course of the project, the team will develop a proof of concept and test such a concept to verify how near real-time drought information in a mobile environment can mitigate drought impacts at local levels during growing seasons, thereby increasing economic revenue.

The sUAS-mounted sensors and cameras will be used to monitor and identify crop stresses driven by water shortage. Collaborations with local growers in Caldwell, Nampa, and Parma areas have already been established and necessary field setup arrangement details await IIF support. **The main goal of the proposed research is to develop a mobile-based decision tool for drought mitigation in irrigated agriculture**

through four primary objectives, including to 1) strengthen drought monitoring to better characterize local conditions for irrigated agriculture, 2) enhance an early warning of crop stresses driven by drought using a sUAS equipped with a suite of sensors, 3) develop a mobile –based decision support tool (Mobile App) to advance early drought monitoring in irrigated agriculture, and 4) promote collaborative ag research and enhance Idaho's economic competiveness by working with ag producers and industrial partners.

5. "Gap" Project Objective (Obj.) and **Total Amount Requested ($74,497)**:

Obj. 1: Strengthen drought monitoring to better characterize local conditions for irrigated agriculture: Drought increasingly threatens the sustainability of western agriculture. The Department of Commerce's National Climatic Data Center has recorded 17 drought years in the U.S. from 1980 to 2012 that have exceeded $144 billion in damages and costs (Lott et al., 2013), equivalent to average annual loss of about $8.5 billion. Given current trends in climate variability and change, economic losses from drought are likely to continue to increase. One very effective way to mitigate some of these costs and potentially catastrophic losses may be to use a small Unmanned Aerial System (sUAS) technology to improve understanding of the factors that drive the onset and development of water stress driven by drought at local scales. This knowledge would enable planners and end users to more effectively manage and meter out limited water resources.

One major limitation for farmers, agribusiness personnel, and policy makers in estimating water availability in planning for mitigation of impacts of drought is a lack of clear understanding of the currently evolving drought condition as well as capability

to more accurately estimate more water availability for the growing season. The proposed research seeks to fill this gap by enhancing drought monitoring and early detection of crop stresses associated with drought using a small Unmanned Aerial Systems (sUAS) data products to better monitor and to manage drought for irrigated agriculture.

Obj. 2: Enhance an early warning of crop stresses driven by drought using a sUAS equipped with suite of sensors: To improve drought early warning, a sUAS, such as the DJI Phantom quadcopter with the GoPro Hero 3 camera and the sensor package composed of Micro ADC, GPS receiver, and Battery pack will be used. GPS coordinates and other data will be saved in the sensor's image memory as metadata in ASCII format. Teflon calibration pad will be also used to minimize image distortion affected by sunlight before the sUAS takes off. Since safety is the first priority during sUAS test flights, authorized and qualified personnel will be on the site so that regulations and guidelines set forth in FAA rule making will be strictly enforced. The test flight will take place at University of Idaho Parma Research and Experiment Center (PREC). At the center, a sUAS equipped with camera (e.g., GoPro, Cannon Powershot with customized infrared (IR) light) will fly over the farm field to record video by following safety rules. Once video records are available, image processing will be executed to identify zones potentially vulnerable to drought and potential improvements in water management. Still images will be created for further drought analysis. During the flight, various images, including 3D egocentric image and 2D navigational information will be collected and recorded to monitor vegetation greenness for model validation. An autopilot system will be utilized to avoid possible human errors. Robust

sensors, such as infrared sensors that are widely accepted will be later incorporated into many sensor suites to enable computation of water fluxes; thus greatly extending the utility of this UAS application for hydrology and wildfire science applications. Note that no drought monitoring study has been published with this kind of sensor configuration and local arrangement to advance drought monitoring in irrigated agriculture. Therefore, the proposed research will fill the technology gap between fast-moving IT/robotic/sensor technologies and their real-world applications and adaptation through this incubation fund.

Obj. 3: Develop a mobile-based decision support tool (Mobile App) to advance early drought monitoring in irrigated agriculture: With better monitoring capability, near real-time drought information available at mobile environment is critical for the end user to mitigate drought impacts sooner rather than later. Such information will be related to their particular drought management targets. For example, surface water and groundwater irrigators will need to update their irrigation scheduling. Throughout this incubation fund, therefore, the team will develop a mobile app named "Drought Bee, shortly D-Bee" integrated with Google Map API. For drought mapping, Google Map API will be used to develop D-Bee and disseminate drought information in a mobile platform. Additional web mapping technology known as Asynchronous JavaScript and XML (AJAX) will be also employed to pursue more stable functionality, fast interactivity between servers and clients, and cost-effective data exchanges between the servers behind the scenes. AJAX is based on open standards, which means this technology is less dependent on a specific operating system and/or commercial software.

Obj. 4: Promote collaborative ag research and enhance Idaho's economic competiveness by working with ag producers and industrial partners: The team will develop recommendations for best practices of sUAS in agricultural crops studied in this project. One producer workshop will be conducted in Canyon County, Idaho to disseminate basic information about the project and teach best practices for the value of sUAS in alfalfa seed and vineyard crops. Additionally, we are proposing a field demonstration at the University of Idaho Parma Research and Education Center (PREC), to increase knowledge of the research project and recommended best practices. Project outcomes, such as using sUAS and D-Bee for integrated crop management and irrigation scheduling programs, will be also presented at appropriate grower and industry seminars and conferences such as Idaho Ag Tech events, appropriate commodity conferences, and the Treasure Valley Irrigation Conference. Note that PI, Ryu attended such meetings and met many ag producers and industry partners, including Kairosys in this research team. The project team will use the existing soil moisture devices and monitoring equipment already installed by Kairosys to cross-validate monitoring accuracy between airborne sensors and ground truth dataset (See the supporting letter). Additionally, grower surveys will be conducted at the workshop, field demonstration event, and industry seminars in order to measure the increase in knowledge, and anticipated change in grower agricultural practices after learning about the results of this proposed project. These data will be summarized and published in a UI Extension Impact Statement and/or popular press. After the conclusion of the project timeline, all data and information collected will be analyzed by the project team to develop a manuscript for a journal article submission as well.

6. Description of how resource commitments reflect the priorities of the home institution:

The vested interest and commitment for this project is leveraged by the University of Idaho (UI). From the university perspectives, PI, Ryu from College of Agricultural and Life Sciences (CALS) at UI has expertise in agricultural engineering and has applied various models for drought management and forecasting. As a faculty hire on the Idaho EPSCoR Research Infrastructure Improvement grand funded by National Science Foundation (NSF), he conducted many research activities to allow Idaho to achieve an overall growth in competitive research that exceeds growth nationally in the last few years. His strong commitment to water and drought research is embedded in the research, teaching and extension plan of the College of Agricultural and Life Sciences (CALS). The research objectives in the proposal have great merit for the Departmental Creative Activity Goal (DCAG), which Dr. Ryu helped develop. The DCAG specifically aims to provide high quality research to students, to improve the multidisciplinary research environment, to provide a complete educational experience through scientific research and extracurricular activities, and to encourage scholarly service in water resources research. As a result, the proposed research using a small Unmanned Aerial System (sUAS) will greatly increase the visibility and research productivity of CALS and beyond (See the supporting letter from Associate Dean of CALS at UI).

7. Evidence that the project will have a potential impact to the economy of Idaho:

Across the rapidly growing western US, water acts as a constraint on patterns of development and economic activity. Over the last 30 years, drought-prone regions of

the western US, including Idaho have shown both rapid increases in population density and an increase in hydroclimate variability. Recent shifts toward a more arid environment across the western states could become the norm in the coming decades due to anthropogenic forcing (Gleick, 2010). Decreases in water availability are anticipated to be exacerbated by decreases in mountain snowpack in a warmer climate (Miller, 2003). Due to the scarcity of current and anticipated water supplies across the western US, the ability to empower and prepare stakeholders with information to improve their productivity and resiliency in the face of climate change is required.

According to a United States Drought Monitor report (NDMC, 2016), the Gem State tends to be in drought regardless of year. Based on the Drought Monitor's data over the last decade –to 2005, about 99 percent of the state was considered to be in a drought, thus the whole state had dried up this much by mid-spring. In the low 90s, 2007 came close; conversely, for 2006 and 2011 no drought existed at all in Idaho at the end of May (Idaho Statesman, 2014). Under the circumstance, drought will continue to be progressively worse as climate change acts as an external driver. As such, the proposed research will mitigate drought impacts, thereby maximizing economic revenue by advancing drought monitoring efforts for irrigated agriculture in the Gem State.

8. <u>The Market Opportunity</u>:

According to a market research report, "World Mobile applications Market (2010-2015)", the total global mobile app market is expected to be worth $25 billion in 2015 (Markets and Markets, 2015). Note that about 1 billion smartphone were sold in 2015 and the number of ownership of smartphone is now higher than that of Desktop computers (Bosomworth, 2016). These days, the average mobile app user spends more

than 30 hours a month on more than two dozen apps, which mean average US family spend a lot of time with their portable devices. Given that 46 percent of app users report having paid for their apps and it is expected that over 268 billion downloads will generate $77 billion worth of revenue by 2017 (Clifford, 2014). As such, the mobile app developed through this incubation fund will draw attention from many users locally and nationally once the proof of concept is tested through this pilot research. A trial version will be freely available via Apple App store while users have to pay for a stable version (e.g. $5.00 plus update packages, $1 per week) with add-ons. The D-Bee app will be also demonstrated during Ag Tech workshop for broad applications. The research project is entering a market space that is currently underserved or inadequate due to shortcomings and prohibitive costs of existing technology. Examples of potential consumers of this product (D-Bee, a mobile app with sUAS inputs) in the marketplace include individual farmers and growers, agronomists, agriculture consultants, soil scientists, researchers, irrigation districts, water managers, state government including the Idaho Department of Water Resources and the Department of Agriculture, federal government agencies including the Natural Resource Conservation Service (NRCS), the Farm Service Agency (FSA), the US Geological Survey (USGS), the US Forest Service (USFS), the Bureau of Land Management (BLM), and a host of other consumers interested in drought or moisture monitoring, soils, plant health, etc.

9. The Technology and Path to Commercialization:

One of the outcomes from this project will be a prototype of drought web mapping in Google Map platform so that local decision makers responsible for drought response plans and management can easily identify the spatial extent of areas

vulnerable to upcoming severe droughts. Since the project follows conceptual design principles by integrating multiple data sources to improve our understanding drought, the research outcomes will provide researchers, educators, and decision makers with drought information in enhanced quality and depth broadly. Although a trial version of D-Bee will be simply available at Apple App store for end users (e.g., farmers, ranchers, and the general public) in public domain (http://www.apple.com), a strategic pathway toward commercialization will be discussed via collaborative commercialization efforts driven by industry partners, market analysis, and user's feedback and comments. A stable version of D-Bee will cost about $5.00 plus update packages $1.00 per week.

10. Commercialization Partners: Collaborations with Kairosys (www.kairosys.net) in Caldwell, Idaho have already initiated, although the necessary field setup and arrangements will be discussed in details once this proposal is granted by Idaho State Board of Education (ISBE). Kairosys has experiences to develop a mobile app for agricultural decision making. Monitoring sensors on the field monitoring environmental conditions will help cross-validate sUAS-based drought maps to better portray drought monitoring at field scales. Kairosys's role will be primarily in providing the equipment and technology necessary to conduct field data collection, including a GPS system for establishing ground control, software, integrating acquired sensors, and expertise in mobile app development. Specific collaboration as a commercialization partner is described in the attached supporting letter.

11. Specific Project Plan and Detailed Use of Funds: PI, Ryu at University of Idaho will take principle lead in project oversight. He will work for 100 hours ($49.5) during

summer sessions. Ryu will have overall responsibility for the project management. The Graduate Research Assistant (GRA) will be supported during the project period. GRA will collect multiple data sources to compute drought indices to be available for D-Bee (Mobile app). He/she will earn $3,573 ($440/week * 8 weeks) during summer session. It is anticipated that involvement of the graduate student is integral for timely completion of the proposed studies. One IT technician's time is also budgeted to develop D-Bee (Mobile App) with Google Map API ($30/hr * 160 hrs = $4,800). To operate sUAS, there will be irregular helpers (Pilot-in-Command/Observer) supported for approximately 160 hours with the rate of $50 each. A reasonable travel cost to attend professional meetings/field trips/ag events (Ag Tech) is also budgeted and $70 per diem is applied. A total of $3,000 is included to cover per-page charges for publications, and $300 is allocated to print posters and brochures related with the educational material of this project. Also, for this project, $850 is requested for computer software. A total amount of $4,350 are also allocated for environmental monitoring sensors, such as hyperspectral sensors to monitor drought. Additionally, research supply, including sUAS/battery/cameras will be purchased to conduct the proposed research through the budget line.

12. Institutional and Other Sector Support: If this grant is awarded, CALS at UI, through State Hatch funds, reasonable research supplies and material will made for enhancement of Dr. Ryu's research to achieve objectives stated in this proposal (See the attached letter from Dr. Larry Markus, Associate Dean of College of Agricultural and Life Sciences at University of Idaho (CALS/UI).

Project title: Drought Mapping Using a Small Unmanned Aerial System (sUAS) for Precision Agriculture in Idaho

References

Brown, B., J. Hart, D. Horneck, and A. Moore.2010. Nutrient Management for Field Corn Silage and Grain. http://www.cals.uidaho.edu/edcomm/pdf/PNW/PNW0615.pdf

Lott, N., Smith, A., Houston, T., Shein, K., and Crouch, J. (2013). "Billion-Dollar U.S. Weather/Climate Disasters 1980-2012." *National Climatic Data Center*, Asheville, NC, Accessed April 2, 2013.

Bosomworth, D. (2016). "Mobile Marketing Statistics compliation.", Smart Insights, available at http://www.smartinsights.com/mobile-marketing/mobile-marketing-analytics/mobile-marketing-statistics/, accessed March 28, 2016.

Clifford, C. (2014). "By 2017, the App Market Will Be a $77 Billion Industry (Infographic).", Entrepreneur, available at http://www.entrepreneur.com/article/236832, accessed, March 28, 2016.

Gleick, P.H. (2010). "Roadmap for sustainable water resources in southwestern North America." Proceeding of the National Academy of Sciences USA, 107(50), 21300-21305.

Idaho Statesman, (2014), "Update: All of Idaho is now in a drought or heading into drought, scientists say", Environment Section, available at http://www.idahostatesman.com/news/local/environment/article40860939.html, accessed, March 28, 2016.

Markets and Markets, (2015). "World Mobile Applications Market Worth US$25 Billion by 2015.", Markets and Markets, available at http://www.marketsandmarkets.com/PressReleases/mobile-applications-market.asp, accessed, March 28, 2016.

Miller, M.L. and Palmer, R.N. (2003). "Developing an Extended Streamflow Forecast for the Pacific Northwest.", World Water & Environmental Resources Congress, ASCE Publication

NDMC, (2016). "National Drought Monitor", National Drought Mitigation Center (NDMC), University of Nebraska-Lincoln, available at http://droughtmonitor.unl.edu/, accessed, March 28, 2016

SUMMARY PROPOSAL BUDGET

Name of Institution: University of Idaho

Name of Project Director: Jae Ryu

A. PERSONNEL COST (Faculty, Staff, Visiting Professors, Post-Doctoral Associates, Graduate/Undergraduate Students, Other)

Name/ Title	Salary/Rate of Pay	Fringe	Dollar Amount Requested
Jae Ryu/Assistant Professor	$49.50/hr * 100 hrs = $10,300	$3,200 (31.1%)	$13,500
Graduate Research Assistant	$22/hr * 160 hrs=$7,100	$200 (2%)	$7,300
IT Technician/Mobile App Development	$30/hr * 80 hrs = $4,800	$400 (7.4%)	$5,200
Irregular Helper/Pilot-in-Command/Visual Observer/Training	$50/hr * 160 hrs= $16,000	$1,200 (7.4%)	$17,200

% OF TOTAL BUDGET:	57.6%	SUBTOTAL:	$43,200

B. EQUIPMENT: (List each item with a cost in excess of $1000.00.)

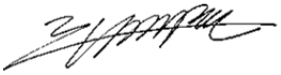
Item/Description	Dollar Amount Requested
Environmental Sensors (e.g., hyperspectral image sensor)	$6,200
Rotary-wing small Unmanned Aerial System (sUAS)	$5,100
SUBTOTAL:	$11,300

G. TRAVEL:

Dates of Travel (from/to)	No. of Persons	Total Days	Transportation	Lodging	Per Diem	Dollar Amount Requested
Professional meeting/Ag Tech Workshop	1	4 * 2 times	$300	$180	$71/day	$3,700
Field trips	2	2* 10 times	$140	$80	$45/day	$12,200
					SUBTOTAL:	$15,900

H. Participant Support Costs:

	Dollar Amount Requested
1. Stipends	
4. Other	
SUBTOTAL:	$0

I. Other Direct Costs:	Dollar Amount Requested
1. Materials and Supplies	$300
2. Publication Costs/Page Charges	$3,000
3. Consultant Services (Include Travel Expenses)	
4. Computer Services	$1,000
5. Subcontracts	
6. Other (specify nature & breakdown if over $1000)	
SUBTOTAL:	$4,300
J. Total Costs: (Add subtotals, sections A through I) TOTAL:	$74,500
K. Amount Requested: TOTAL:	$74,500
Project Director's Signature: 	Date: March 30, 2016

INSTITUTIONAL AND OTHER SECTOR SUPPORT

(add additional pages as necessary)

A. INSTITUTIONAL / OTHER SECTOR DOLLARS

Source / Description	Amount
In-kind contributions from Kairosys as an industry partner	$20,000

B. FACULTY / STAFF POSITIONS

Description

C. CAPITAL EQUIPMENT

Description

D. FACILITIES & INSTRUMENTATION (Description)

Project title: Drought Mapping Using a Small Unmanned Aerial System (sUAS) for Precision Agriculture in Idaho

Appendices

Facilities and Equipment

Water Resources Research Lab at University of Idaho

Dr. Ryu Laboratory: Dr. Ryu's water research laboratory is located in Idaho Water Center (IWC) in Boise. The IWC is the primary base of the University of Idaho Boise and the university's unique collaborative site for research and programs focusing on water and environmental issues. The IWC houses diverse water entities and fosters cohesive collaborative water research among government, business, and higher education. Dr. Ryu's lab accommodate graduate students and personal computers. His lab also contains 2 computer workstations and 1 Linux server with 3Tb of disk storage to support the data analysis, archiving and modeling tasks.

Project title: Drought Mapping Using a Small Unmanned Aerial System (sUAS) for Precision Agriculture in Idaho

Biographical Sketching and Individual Support

Jae Ryu, Ph.D.
Assistant Professor, Department of Biological and Agricultural Engineering
University of Idaho

Professional Preparation

Konkuk University	Seoul, Korea	Ag Engineering	B.A., 1996
University of Washington	Seattle, WA	Civil & Env Eng	M.S., 2001
University of Washington	Seattle, WA	Civil & Env. Eng	Ph.D, 2006
University of Nebraska	Lincoln, NE	School of Nat Res	Jun/06-Dec/09

Appointments

2010-present Assistant Professor of Biological & Agricultural Engineering, University of Idaho

2015 Visiting Professor, US Air Force Academy (USAFA), Air Force Summer Faculty Program

2010-2014 Adjunct Faculty, School of Natural Resources, University of Nebraska-Lincoln

2006-2010 Research Associate, School of Natural Resources, University of Nebraska-Lincoln

2001-2006 Graduate Research Assistant, Department of Civil and Environmental Engineering, University of Washington, Seattle, WA

A list of current support

- "Enhancing water supply monitoring and forecasting using NASA satellite data products" by NASA Idaho NASA EPSCoR, 6/25/2013-10/17/2016, Role: PI, UI Budget#:FPK177, $50,000, 80% research, 10% extension, 10% advising
- "Advancing drought monitoring to promote climate-resilient water management in the west" by USDA Hatch, 7/1/2014-6/30/2015, Role: PI, UI Budget# BFH507, $68,000, 80% research, 10% extension, 10% advising
- "IGERT: Adaptation to change in water resources: Science to inform decision-making across disciplines, cultures, and scales, Collaborators: Jan Boll and many UI faculty, My Role: Faculty Participant, $3M total, FY2013-FY2017, 80% research, 10% extension, 10% advising

Publications: *,# indicate graduate student and postdoc, respectively

*Sohrabi, M., Ryu, J. H., Abatzoglou, J., Tracy, J., 2015. "Development of Soil Moisture Drought Index (SODI) to Characterize Hydrological Drought", Journal of Hydrological Engineering, (in press)

Ryu, J. H., *Sohrabi, M., #Acharya, A. 2014. "Toward mapping gridded drought indices to evaluate local drought in a rapidly changing global environment", Water Resources Management, 28(11), 3859-3869

*Sohrabi, M., Ryu, J. H., Abatzoglou, J. Tracy, J. 2013. "Climate extreme and its linkage to regional drought over Idaho, USA", Natural Hazard, 65, 653-681

Hoekema, Ryu, J.H. 2013. "Evaluating economic impacts of water conservation and hydrological forecasts in the Salmon Tract, Southern Idaho", Transactions of the American Society of Agricultural and Biological Engineers (ASABE), 56(4), 1399-1410.

Ryu, J. Svoboda, M.D., Lenters, J.D., Tadesse, T., Knutson, C.L., 2010. "Potential extents for ENSO-driven hydrologic drought forecasts in the United States", Climatic Change, 101, 575-597

Ryu, J.H., Jeong, S., Park, S.K., Lee, J., Han, K., 2011. "The impacts of climate change on the local hydrology and drought (low flow) frequency", Hydrological Processes, 25(22), 3437-3447

Ryu, J.H., Palmer, R.N., Jeong, S., Lee, J., Kim, Y.-O., 2009. "Sustainable Water Resources Management in the Conflict Resolution Framework", Journal of the American Water Resources Association, 45(2), 485-499

Ryu, J.H., Palmer, R.N., Wiley, M.W., Jeong, S., 2009. "Mid-range streamflow forecasts based on climate modeling-statistical correction and evaluation", Journal of the American Water Resources Association, 45(2), 355-368.

Ryu, J.H., 2009. "Application of HSPF to the Distributed Model Intercomparison Project: Case Study", Journal of Hydrological Engineering, American Society of Civil Engineers (ASCE), 14(8), 847-857

Ryu, J.H., Lee, J.H., Jeong, S., Park, S.K., Han, K. 2011. "The impacts of climate change on local hydrology and low flow frequency in the Geum River Basin, Korea", Hydrological Processes, 25, 3437-3447.

KAIROSYS
AGRICULTURE DESICION SUPPORT SOLUTIONS

March 28, 2016

Idaho Incubation Fund Program
Idaho State Board of Education
650 W State St #307
Boise, Idaho 83720
(208) 334-2270

Dear Fund Selection Committee,

I am writing this letter to confirm my collaboration to conduct research /outreach activities described in the proposal titled *"Drought Mapping Using a Small Unmanned Aerial System (sUAS) for Precision Agriculture in Idaho"*, proposed by Dr. Jae Ryu's research team. As an industry partner, Kairosys will provide expertise where data is gathered in the field electronically and then transmitted to office computer systems for further processing. We have particular expertise in decision support ssolutions that rely on location aware sensor gathered data. Our products and services are available for a wide variety of applications, including crop monitoring, crop yield enhancement, and managed pollinator control solutions.

Kairosys supports the research project proposed by Dr. Jae Ryu involving the use of sUAS for drought monitoring and agricultural research and Kairosys can add value to the project through the skills of our staff, and our ability to provide expertise on mobile app development. Kairosys has a vested interest in the project because we desire to grow our business by expanding the agricultural decision support tools in Idaho and we have identified agriculture as a primary target market for our business. Expertise in applying unique drought monitoring protocols utilizing sUAS technology will give us an opportunity to expand our research portfolio to become a knowledgeable authority on the topic.

Kairosys is pleased to offer in-kind contributions of resources to the University of Idaho for this project upon being awarded the Idaho Incubation Fund Program. It is anticipated that the value of these in-kind contributions will be valued at or near $20,000.

Kairosys's in-kind contributions will consists of a combination of the following donated services or goods: (a) staff time in the form of consulting, project planning and design (b) travel costs to conduct field work, attend collaboration meetings, and other project activities, (c) use of GPS, computer and other sensor equipment in field, and/or (d) use of materials in the form of software, computers, or other company assets needed to complete the project and approved by Kairosys management.

Depending on the personnel needed, Kairosys would assist by contacting and convening a group of growers to represent the end user group or workshop featured in Dr. Ryu's proposal.

Sincerely,

Anthony Brower
Kairosys Inc.

University of Idaho
College of Agricultural and Life Sciences

Academic Programs

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Moscow, Idaho
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March 29, 2016

Idaho Incubation Fund Program
Idaho State Board of Education
650 W State St #307
Boise, Idaho 83720
(208) 334-2270

Dear Fund Selection Committee:

RE: College Endorsement of Idaho Incubation Fund Proposal for Dr. Jae Ryu

Integration with University of Idaho and College Level Goals

The University of Idaho has expressed in its Strategic Planning document the need to make this university the campus of choice for higher education in the Pacific Northwest. Dr. Ryu's initiative to promote the Sustainable Water Resources Management Discipline which cuts across departments and colleges clearly contributes to that mission. This proposal also helps meet the mission statement to serve the needs of the State of Idaho in terms of environmental quality and education of its citizens. Overall, the proposed project helps the University of Idaho and its colleges become a more globally competitive center for high quality graduate, professional, and research programs.

College Support: If this grant is awarded, the following support will be provided:

Office space: The College of Agricultural and Life Sciences (CALS) will provide space in the Boise Water Center engineering building to accommodate Dr. Ryu's research assistants for analyses of water data, developing drought monitoring system, and visualization.

Mentoring: This proposal's education and research activities are of great interest to CALS, and I look forward to mentoring Dr. Ryu with other members of the advisory panel when needed. I will provide assistance by assessing and approving annual reports.

Equipment for research: Reasonable research supplies and materials will be provided by CALS for the enhancement of Dr. Ryu's research to achieve objectives stated in this proposal.

I have read and endorse the proposed proposal. I support this research initiative enthusiastically.

Larry D. Makus, Ph.D.
Associate Dean and Interim Head of Biological and Agricultural Engineering
College of Agricultural and Life Sciences, University of Idaho