Role of federal funding in development of GIS:
An enabling technology for Precision Agriculture

Geographic Information Systems (GIS[1]) are incredibly powerful tools linking a great diversity of data to positions on the Earth surface. The ability they provide to capture, store, check and display spatial datasets -- providing farmers a much more intimate view of their own fields -- has unleashed game-changing capabilities in precision agriculture, including enabling farmers to optimize farm returns, reduce unnecessary applications of fertilizers and pesticides, preserve natural resources, and contend with impending weather events.

GIS in precision agriculture[2] uses a blend of components that together become a transformative spatial computing[3] technology:

- Computerized map visualization to understand inter- and intra-field variability[4];
- spatial databases[5] to collect and query location-aware data about soil properties, plant properties, farm management practices, and yield;
- path planning and navigation systems to efficiently traverse farms and without unnecessary soil compaction
- spatial statistical[6] analysis to delineate management zones, and
- spatial decision support system to optimize yield while preserving natural and farm resources.

Without exception, these technologies, and others like them, have their roots in early stage scientific research and all bear the stamp of federal support. In 1930s, Spatial Statistics started with US Department of Agriculture sponsored[8] Statistical Survey Laboratory at the Iowa State University. More recently in 1990s, SaTScan[9], a Spatial Statistics software for hotspot identification was developed at the National Cancer Institute with funding from National Institute of Health, Center for Disease Control and Sloan foundation. Computerized map visualization systems were born[11][12] out of work at the US Bureau of Census, US Geological Survey, US Postal Service and other federal agencies in early 1960s along with academic developments at Harvard, University of Washington, etc. In 1980s, Spatial Database management systems started with a NASA sponsored research project at the University of California, Berkeley, where I attended graduate school. In 1990s, federal agencies kicked started world-wide-web-based virtual globe with NASA's sponsored University of Minnesota MapServer and NSF sponsored Alexandria digital library projects. It was followed by Microsoft Terraserver and a USDOD-funded startup Keyhole, which underlies the popular Google Earth today. In 1990s, US Department of Transportation's Intelligent Vehicle Highway System initiative along earlier federal contributions such as Census Bureau's TIGER files facilitated the development of path planning and navigation systems underlying Google Maps and in-vehicle navigation systems sometimes called consumer GPS devices.

But while the history of the development of these technologies is important, research going on now – largely supported by the Federal government , let us consider a few future opportunities that are potentially even more compelling for food security in face of population growth and rapid urbanization around the world. For example, high-throughput phenotyping technology may help us move from precision agriculture at plot level to high-precision agriculture to nurture individual plants. Spatial data mining[13] and machine learning techniques may analyze UAVs based hi-frequency farm

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[1] Encyclopedia of GIS, (Ed. S. Shekhar and H. Xiong), Springer, 2008.

[2] Precision Agriculture in the 21st Century: Geospatial and Information Technologies in Crop Management, National Academy Press, Washington, D.C., 1997 (www.nap.edu/openbook.php?record_id=5491).

[3] From GPS and Virtual Globes to Spatial Computing 2020, Computing Community Consortium, 2013 (www.cra.org/ccc/files/docs/Spatial_Computing_Report-2013.pdf).

[4] Soil Spatial Variability, (Eds. D.R. Nielsen & J. Bouma), Proc. 1984 Workshop of the ISSS and the SSSA, Pudoc, Wageningen, 1985.

[5] Spatial Databases: A Tour, S. Shekhar and S. Chawla, Prentice Hall, 2003.

[6] Handbook of Spatial Statistics (Ed. A. Gelfand et al.), CRC Press, 2010.

[8] The Story of U.S. Agricultural Estimates, USDA Statistical Reporting Service, US Govt. Print. Press, 1969.

[9] SaTScan, (http://gis.cancer.gov/tools/satscan.html), retrieved on March 1st, 2015.

[11] The History of GIS, J Coppock and D. Rhind, in Geographical Information Systems: principles and applications (Ed. D. Maguire, M. F. Goodchild and D. W. Rhind), Essex: Longman Scientific & Technical, 1991.

[12] The History of GIS (Geographic Information Systems): Perspectives from the Pioneers, T. Foresman, Series in Geographic Information Science, Prentice Hall, 1997 (isbn-13: 007-6092033172).

monitoring datasets to detect and manage anomalous areas where plants are growing too fast or too slow. Location aware small vehicles (e.g., Huskies, Grizzlies) may safely move between growing plants to deliver individualized care to nurture plants with anomalous growth and robotic bees may help with pollination to address recent decline in bee populations. Connected and automated vehicles research may lead to self-driving tractors to relieve farmers to attend to more important tasks such as assessing impacts of anomalous plant growth areas on projected yield and to refine management practice toward meeting yield goals.

It's also important to point out that early-stage research (also known as "basic" or "fundamental" research) taking place in universities and federal labs does not supplant work done in industry. Early-stage scientific research has a number of characteristics that make it an appropriate responsibility of the Federal government and inappropriate for industry. It often takes a long time before it pays off -- sometimes decades; industry is generally focused on the next product cycle or two. It often pays off in unanticipated ways -- developments in one sector frequently enable advancements in others, often serendipitously. It's difficult for industry to capture the benefit of early stage research because the results of that research, by nature, are available to everyone, including the competition.

But, as GIS demonstrates, Federal support for early stage research is truly an investment with a history of extraordinary payoff -- in the explosion of new technologies that have touched nearly every aspect of our lives, and in economic terms, in the improving farm and agro-industry profitability and new precision agriculture jobs.

Geographic Information Systems underlying precision agriculture isn't a culmination of spatial computing technologies, it's a mile-marker on a continuum of innovation that is improving farm productivity and our quality of life by preserving natural resources, a continuum of innovation made possible by federal research. The federally supported research of today will drive the innovations that will change our lives in the years and decade(s) ahead.

Role of federal funding in development of GIS:
An enabling technology for Precision Agriculture

1. Geographic Information Systems (GIS[14])
   a. Are incredibly powerful tools linking a great diversity of data to positions on the Earth surface.
   b. With ability they provide to capture, store, check and display spatial datasets -- providing farmers a much more intimate view of their own fields –
   c. has unleashed game-changing capabilities in precision agriculture, including enabling farmers to optimize farm returns, reduce unnecessary applications of fertilizers and pesticides, preserve natural resources, and contend with impending weather events.
2. GIS in precision agriculture uses a blend of components that together become a transformative spatial computing technology:
   - Computerized map visualization to understand inter- and intra-field variability;
   - spatial databases[15] to collect and query location-aware data about soil properties, plant properties, farm management practices, and yield;
   - path planning and navigation systems to efficiently traverse farms and without unnecessary soil compaction
   - spatial statistical[16] analysis to delineate management zones, and
   - spatial decision support system to optimize yield while preserving natural and farm resources.
3. Without exception, these technologies, and others like them, have their roots in early stage scientific research and all bear the stamp of federal support.
   a. Spatial Statistics started with US Department of Agriculture, Census Bureau and National Weather Service supported work at Iowa State University, North Carolina, U. C. Davis, …
   b. Computerized map visualization started at US Bureau of Census, US Geological Survey, US Postal Service, Harvard, University of Washington, etc.
   c. Spatial Database management systems started with a NASA sponsored research project at the University of California, Berkeley, where I attended graduate school.
   d. World-wide-web-based virtual globe started with with NASA's sponsored University of Minnesota MapServer and NSF sponsored Alexandria digital library projects, followed by Microsoft Terraserver and a USDOD-funded startup Keyhole, which underlies the popular Google Earth today.
   e. Civilian path planning navigation systems such as Google Maps started with US Department of Transportation's Intelligent Vehicle Highway System initiative along earlier work at Census Bureau's TIGER files and other USDOD projects.
4. while the history of the development of these technologies is important, research going on now – largely supported by the Federal government, let us consider a few future opportunities that are potentially even more compelling for food security in face of population growth and rapid urbanization around the world.
   a. For example, high-throughput phenotyping technology may help us move from precision agriculture at plot level to high-precision agriculture to nurture individual plants.
   b. Spatial data mining and machine learning techniques may analyze UAVs based hi-frequency farm monitoring datasets to detect anomalous areas where plants are growing too fast or too slow.
   c. Location aware small vehicles (e.g., grizzlies) may safely move between growing plants to deliver

[14] Encyclopedia of GIS, (Ed. S. Shekhar and H. Xiong), Springer, 2008.
[15] Spatial Databases: A Tour, S. Shekhar and S. Chawla, Prentice Hall, 2003.
[16] Handbook of Spatial Statistics (Ed. A. Gelfand et al.), CRC Press, 2010.

individualized care to nurture plants with anomalous growth and robotic bees may help with pollination to address recent decline in bee populations.

d. Connected and automated vehicles research may lead to self-driving tractors to relieve farmers to attend to more important tasks such as assessing impacts of anomalous plant growth areas on projected yield and to refine management practice toward meeting yield goals.

5. It's also important to point out that early-stage research (also known as "basic" or "fundamental" research) taking place in universities and federal labs does not supplant work done in industry.
   a. Early-stage scientific research has a number of characteristics that make it an appropriate responsibility of the Federal government and inappropriate for industry.
   b. It often takes a long time before it pays off -- sometimes decades; industry is generally focused on the next product cycle or two.
   c. It often pays off in unanticipated ways -- developments in one sector frequently enable advancements in others, often serendipitously.
   d. It's difficult for industry to capture the benefit of early stage research because the results of that research, by nature, are available to everyone, including the competition.
6. But, as GIS demonstrates, Federal support for early stage research is truly an investment
   a. with a history of extraordinary payoff –
   b. in the explosion of new technologies that have touched nearly every aspect of our lives,
   c. and in economic terms, in the improving farm and agro-industry profitability and new precision agriculture jobs.
7. Geographic Information Systems underlying precision agriculture isn't a culmination of spatial computing technologies,
   a. it's a mile-marker on a continuum of innovation that is improving farm productivity and our quality of life by preserving natural resources, a continuum of innovation made possible by federal research.
   b. The federally supported research of today will drive the innovations that will change our lives in the years and decade(s) ahead.

Guidance from Bethany Johns: Each speaker is allowed 5 minutes (about 500 words) for remarks to tell stories illustrating influence of federal funding for science and technology (e.g., GIS) on precision agriculture. Remarks may address the following: (a) speaker's background, (b) influence of past federal funding on GIS, (c) case for continued federal funding for science and technology research

TODO:

(a) Add reference from Mulla

(b) Practice timing to be under 5 minutes

(c) Memorize it if possible

My 2011 Statement on Broader Interaction with Federal Agencies

Federal investments in information technology (IT) have served our society well by bringing prosperity (e.g., Internet, e-commerce and social media), by facilitating security (e.g. global positioning systems, precision targeting) and by supporting our cherished values (e.g., freedom of speech). It has transformed how we manufacture, how we conduct commerce, how we preserve our national security, how government functions, how we communicate, and how we are entertain. Remarkable economic growth in late 1990s was spurred by productivity growth enabled almost completely by information technology[17]. Science and engineering have benefited from new drivers of scientific discovery including computer modeling, visualization and data analysis to complement observation, theory and experiments.

The IT discipline continues to see quantum leaps in its capabilities and opportunities. Recent breakthroughs include smart-phones, social media, big-data, and cloud computing, which will bring large economic benefits. It is hard to imagine a field with greater opportunity to transform the world. In the 1950s, the launch of Sputnik galvanized our country to invest in mathematics and science to secure our future. In the coming decades, opportunities in cyber-space not outer space, will determine our future[18].

However, such a future is not guaranteed. High schools offering rigorous IT (e.g., computer science) courses have fallen from 40 percent to 27 percent in recent years according a survey of Computer Science Teachers Association. Even though federal research is at the heart of IT research and development eco-system, continued federal investment is at risk due to budget deficit concerns. Thus, it is critical for IT researchers to understand science policy and engage it constructively, e.g. by responding to requests for assistance to science policy-makers to work towards meeting societal needs. As a computer scientist, it is my duty to serve as needed. For example, a 2011 industry report[19] estimates that IT advances in big-data may save a trillion dollars annually while creating hundreds of thousands of new jobs across health-care, manufacturing, transportation and location-based services. These also represent new opportunities for IT research community to engage health and transportation related federal agencies, such as NIH, USDOT, FHWA, etc. I have worked with transportation community for two decades and can help build relationships with transportation agencies.

My service experiences include community building and advising federal agencies. Community building activities include roles of program co-chair for the 3rd ACM International Workshop on Advances in GIS (1996), co-Editor-in-chief for the "Geo-Informatica: An International Journal on Computer Science Advances for GIS" (Springer), member of formation committee for ACM Special Interest Group (SIG) on Spatial Computing (2008), and general co-chair for the 12th International Symposium on Spatial and Temporal Databases with an inaugural track on challenge and vision papers with CCC sponsorship. In addition, I have had the honor of making presentation at a Congressional breakfast on homeland security in context of my research on evacuation route planning problem, which was identified as a crucial need in a workshop on Geographic Information Systems (GIS) and Homeland Security in the aftermath of the events of September 11, 2011. Books[20]-[21], I co-authored or co-edited, found audience with program managers at federal agencies. Consequently, I served on the Mapping Sciences Committee at the National Research Council (NRC) and listened to policy makers from many federal agencies. Service on the NRC committee on GEOINT research[22] provided an opportunity to provide advice and recommendations. Currently I am serving on the NRC committee on "Future U.S. Workforce for Geospatial Intelligence."

[17] D. Jorgenseon et al, Information Technology and American Growth Resurgence, MIT Press, 2005.
[18] M. Klawe et al., Computing Our Children's Future, Huffington Post, Dec. 11th, 2009.
[19] New Ways to Exploit Raw Data May Bring Surge of Innovation, a Study Says, NewYork Times, May 13th, 2011.
[20] Encyclopedia of GIS, (Eds. S. Shekhar, and H. Xiong) Springer, 2008.
[21] Spatial Databases: A Tour, (S. Shekhar, and S. Chawla), Prentice Hall, 2003.
[22] Priorities for GEOINT Research at the National Geospatial-Intelligence Agency, National Academies Press, 2006.

Key Points from “Deconstructing iPad” event

- The iPhone and iPad, and similar modern smart devices, are transformative devices that encapsulate a remarkable confluence of technologies: supercomputer-like processing capability; a sensor suite (cameras, GPS, microphone, compass, accelerometer) robust enough to know where the device is and what it’s looking at; and an interface that isrevolutionary in its ease of use.
- These technologies have enabled game-changing capabilities -- the ability to translate signs simply by pointing a camera at them, convert foreign speech into one’s native tongue, tap into real-time networks that provide traffic information, or have at your fingertips access to all the world’s information.
- Without exception, these technologies, and others like them, have their roots in early stage scientific research and all bear the stamp of federal support.
- The iPad processor, as well as all the support and interface chips, was born out of work on the first integrated circuit at Texas Instruments and Fairchild in 1958; the GPS system that allows the iPad to know its location to a few feet was born out of early-stage physics research in U.S. universities in the ‘40s and 50’s; and the touchscreen and multi-touch interface was born out of Defense-research in the late 60s and 70s and NSF-funded research in the 80s and 90s. All are examples of enabling technologies that are products of an enormously productive research ecosystem, an interplay of privately funded industrial labs, federally-funded university researchers, and federal labs, that produce a constant stream of people and ideas to drive American innovation.
- This early-stage research (also known as “basic” or “fundamental” research) in universities and federal labs does not supplant work done in industry. Early-stage scientific research has a number of characteristics that make it an appropriate responsibility of the Federal government and inappropriate for industry:
- It often takes a long time before it pays off -- sometimes decades; industry is generally focused on the next product cycle or two;
- It often pays off in unanticipated ways -- developments in one sector frequently enable advancements in others, often serendipitously;
- It’s difficult for industry to capture the benefit of early stage research because the results of that research, by nature, are available to everyone, including the competition.
- Federal support for early stage research is truly an investment with a history of extraordinary payoff -- in the explosion of new technologies that have touched nearly every aspect of our lives, and in economic terms, in the creation of new industries and literally millions of new jobs.
- The iPad isn’t a culmination of technology, it’s a mile-marker on a continuum of innovation that is improving our quality of life, a continuum of innovation made possible by federal research. The federally supported research of today will drive the innovations that will change our livesin the years and decade(s) ahead

Event Sponsors: American Chemical Society (acs.org); APS Physics (aps.org); Computing Research Association (cra.org); IEEE-USA (ieeeusa.org); Materials Research Society (mrs.org); Texas Instruments (ti.com)

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