GIS HERALDS HARVEST HIGH

GIS holds the key to viable solutions for agriculture at a time when a host of factors, including climate change and urbanisation, emerge as real and present threats to feeding the world.

Today, users demand an extremely simple and streamlined data-collection user experience, while on the go. ArcGIS QuickCapture is specifically designed to effectively support this through at-speed and rapid data collection workflows. Need a plan to save time? ArcGIS QuickCapture helps you send data back to the office for analysis in real-time, eliminating time spent on manually processing handwritten notes. At-speed asset inventories, aerial surveys, pipeline patrols, quick on-the-go inspections, or crop scouting are some of the workflows where ArcGIS QuickCapture excels.

The search for agrarian justice led to the Green Revolution in the seventies, with significant investment in research, infrastructure and extension services across South Asia. Flash forward fifty years, and we are looking at a paradigm shift in agricultural operations. A shift that will be powered by real-time spatial analysis, Internet of Things, and Big Data, all tied together through customized, interactive maps and apps. A shift that holds out the promise

of sustainability to future generations.

Increased urbanization is the way of the future; between now and 2050, estimates peg a net addition of 2.4 billion people to towns and cities. In 2018, the Gaon Bandh and Kisan Mukti Morcha heralded a sea change in Indian agriculture - a new national consciousness among farmers. The plethora of hash-tags that accompanied these marches exhibited the centrality of agrarian justice, even within the urban Indian's imagination. As global scenarios transform and mutate at a rapid pace, this quest for agrarian justice – from plough to plate – is set to become a central theme in technology as well.

The World Government Summit 2018 has listed four main challenges that face the 'legacy agriculture model' in meeting demands of a largely urban future: demographics, scarcity of natural resources, climate change, and food waste. Smallholders (cultivating in plots below 2 hectares) are at the vanguard of the associated socio-economic, structural and institutional challenges that face agriculture in the coming years. Concentrated in China, India, Indonesia, Bangladesh and Vietnam, smallholders produce nearly 80% of the food consumed in the developing world, and feed one-third of the global population. The specialized and contextual solutions that are being demanded do not merely depend on information; they require a powerful database that can integrate a systems-thinking approach into agriculture; leverage the power of cloud computing; understand relations between different trends and sectors; and, arrive at reasonable predictions that can mitigate risk and vulnerability.

USING BIG DATA TO THINK BIG

In 2017, India's NITI Aayog put the onus on digital and precision agriculture, through Pradhan Mantri Krishi Sinchai Yojana (PMKSY), Soil Health Cards, Electronic National Agricultural Market (eNAM), etc. Precision agriculture is the ability to manage land by the square meter instead of the square mile. As developing countries push for precision, it is estimated that the average farm will generate 4.1 million data points daily in 2050, up from 190,000 in 2014. This is but a harbinger of the immense data revolution that is set to storm agriculture. The level of data that will be collated globally requires a solution beyond mere observation. In this background, it is important that we move past simply measuring and analysing data to understand and solve some of the biggest problems facing the world.

Cross-country and cross-disciplinary empirical investigations become critical in precision agriculture. Esri recognises that precision can only be an outcome of an Edge-IoT platform-Enterprise system that aggregates granular, real-time data from a variety of sources - environmental sensors in the field; NDVI images from UAVs; sensors on field equipment; weather forecast data; and soil databases. To achieve economies of scale – an advantage lacking in Indian agriculture so far – it becomes necessary to aggregate data, streamline workflows, eliminate redundancy, and manage inputs (land/labour/capital).

At Esri, we have steadily stepped up our game to meet these demands of the future. While our Living Atlas of the World works at the top of the pyramid to ensure a central repository of global spatial data, our ArcGIS QuickCapture works from the grassroots up. From sorghum to satellites, maps are steadily becoming a common language across organizations. Esri is here to help.

THE SCIENCE OF WHERE FOR PEOPLE

Even with the rapid pace of economic development, agriculture has remained the

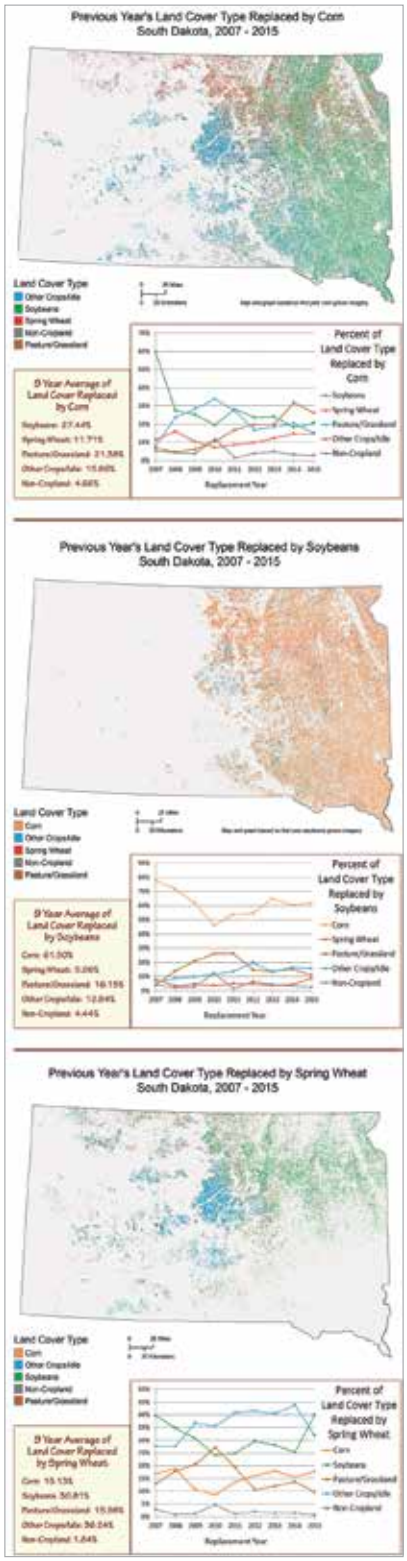
> "The new world needs a new nervous system — an intelligent and responsive platform to create more understanding, collaboration and action. Geography is the only way forward."

Jack Dangermond, **Founder and President, Esri Inc.**

mainstay of the nearly 60% of the Indian population. While projecting a large working-age cohort in future, researchers warn that the flexibility of future agricultural models may be marred by a man-power retreat from the non-remunerative conditions of legacy agriculture. As diets diversify, the skill sets of agricultural labourers that cultivate them will also require specialization. GIS can be used to coordinate and direct labour availability for agriculture, eliminating challenges of disguised unemployment and distress migration.

In the post-GR period, prosperity turned large segments of farmers in Punjab and Haryana into farm 'managers'; without outside labour, the agricultural sector here faces danger of collapse. Farmers that can visualize labourers as data points can plan crop rotations based on labour availability and location. We have already laid the foundations for such operations through the 'Agricultural Workers' layer in Esri's Living Atlas of the World.

MHRD advocates the "Science of Delivery" to increase, and address disparity, of rural incomes; it involves developing a technology spine that leverages Aadhaar IndiaStack, GIS, and SDI supported by hybrid cloud systems. Esri's i-DGIS solution for National Dairy Development Board (NDDB) thinks along these lines. i-DGIS facilitates convergence planning among multiple stakeholders including Milk Unions/Federations, the Department of Animal Husbandry, and Livestock Development Boards of state governments. It uses a simple GUI that enables monitoring and planning of activities like milk procurement, ration balancing, fodder development, artificial insemination etc. i-DGIS helped replace a layman's solution conducted on paper maps with an integrated database that included information on citizens, livestock and land use/land cover. i-DGIS integrated data and graphical information in multiple ways that churn gigabytes of actionable intelligence.



India's population growth is forecasted to surpass China's over the next two decades, making it the fastest-growing nation in the world. To leverage the potential value of such large populations, and to respond to diverse problems with flexible solutions, requires decentralised data logging. Scientific crowdsourcing has been around since 2014, when the Consultative Group on International Agriculture Research (CGIAR), an organization that coordinates agricultural research internationally, set up the Roots, Tubers and Bananas (RTB) for Food Security and Income program. The RTB program is supported by an application called RTB Maps which aggregates spatial imagery to show crop distribution, desolate areas, pest and disease locations, and socio-economic data. RTB Maps was built with ArcGIS server technology from Esri.

The 2030 Agenda for Sustainable Development embodies a vision that goes beyond the divide of 'developed' and 'developing' countries. We at Esri salute this sentiment; as a common spatial language that utilises earth observation emerges, no person's data can be dismissed as another person's noise.

THE SCIENCE OF WHERE FOR ECOLOGY

"In the next 20 years we have to do the Green Revolution again in terms of the increase in production. We've got to do it in half the time and with less energy and inputs – and all the easy stuff has already been achieved."

According to the UN, 91% of all disasters between 1998 and 2017 were caused by floods, storms, droughts, heat-waves and other extreme weather events. We are also staring down the barrel of global warming; South Korean studies have documented how rising temperatures have promoted harmful pests that cause massive damage to horticulture.

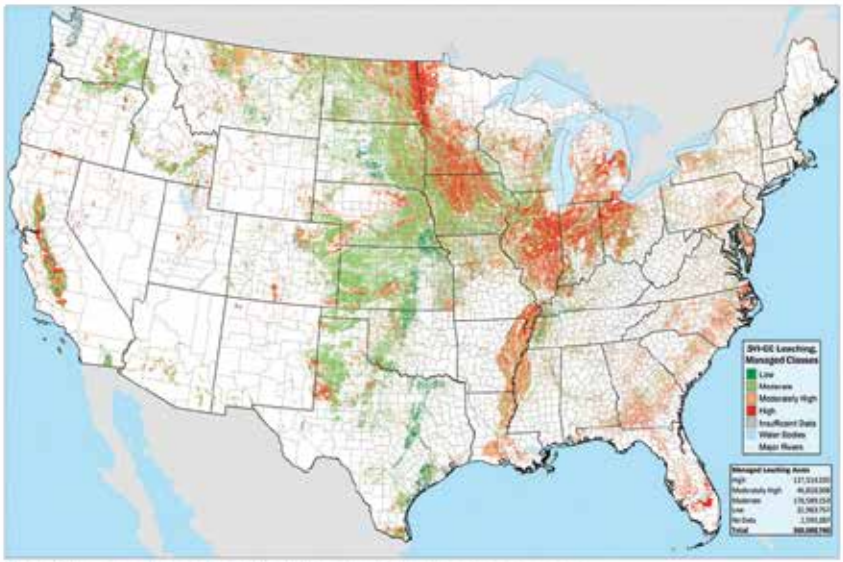
> In the next 20 years we have to do the Green Revolution again in terms of the increase in production. We've got to do it in half the time and with less energy and inputs – and all the easy stuff has already been achieved.

Professor John Crawford,
Integrated Solutions Lab Flagship Leader at Rothamsted Research

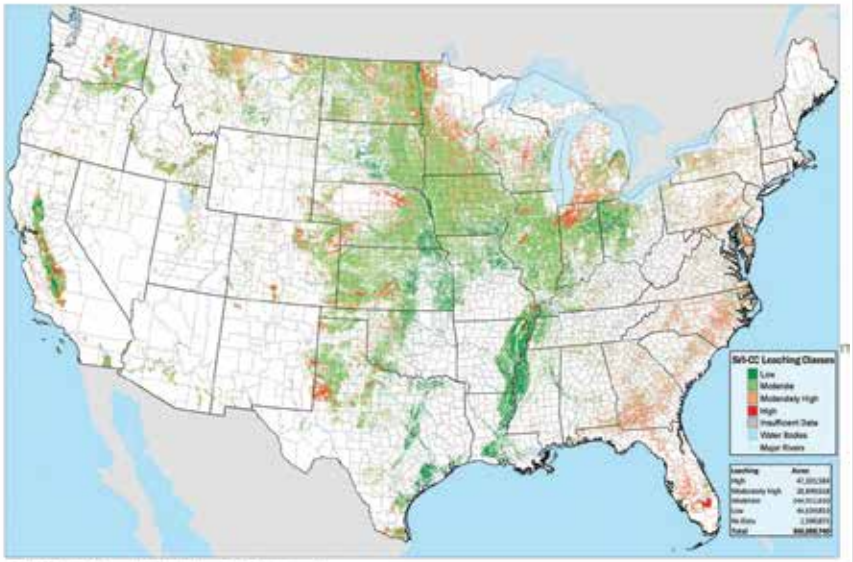
Globally, by 2030, UNFAO estimates that 653 million people could face malnourishment under a business-as-usual scenario. In the post-GR world, cultivation has skewed in favour of rice and wheat due to various input subsidies. Steady mono-cropping has resulted in pest build-up, overuse of fertilisers, and cropping incompatible with agro-climatic zones. This, in turn, reduces resilience to weather hazards, increases water stress and degrades ecosystems. Significantly, crop diversification is mandatory not just to counter malnutrition, but also for climate resilience, ecological stability and efficient natural resource use. GIS hold the solution in building a systems approach into government schemes - like PM-AASHA - that are pushing for crop diversification in favour of pulses. It can ensure that the imperative of nourishment is

not at the cost of ecosystem damage. If programmes such as GoI's Integrated Watershed Management Programme (IWMP) are to truly succeed, they require spatial analysis that goes above and beyond political boundaries.

Given these contexts, Esri foresees the need to think of future spatial patterns in terms of historical imagery. Global earth observation projects are helping monitor the way the Earth's landscape is changing; they provide a valuable archive for the future. Agriculture and Agri-Food Canada (AAFC) is a government organization that tapped into the capabilities of ArcGIS Online to help producers make decisions. The organization launched UMAP, a self-service, cloud-based portal, where users could combine data such as annual crop inventories, historic crop yield, and production statistics, with interoperable data from other organizations and third parties such as Esri; the Land Use app is a part of this suite, and allows users to analyse changes in land use across Canada. For producers looking to rent, the Land Use app showed which crops have been planted in previous years; it has since allowed producers to make the most effective and environmentally conscientious decision about which land to farm and what to cultivate on it.

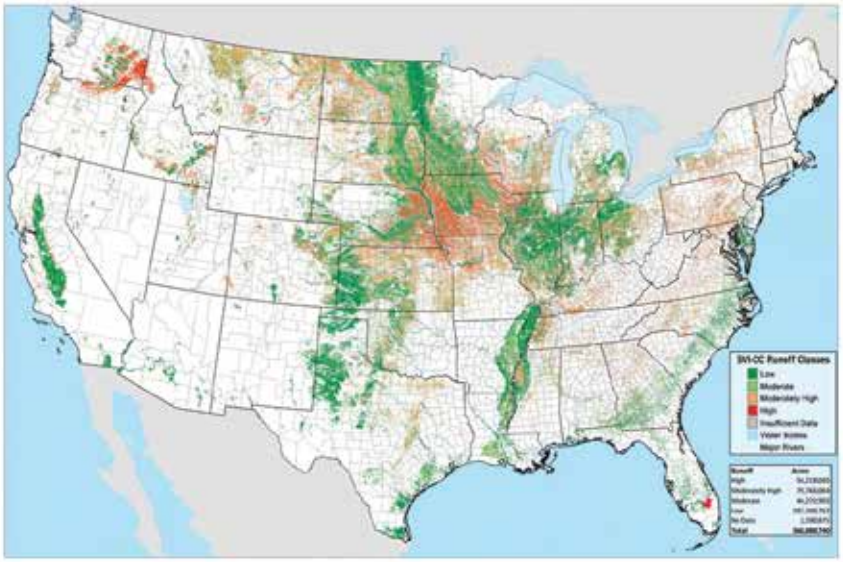


CEAP Soil Vulnerability Index for Cultivated Cropland (SVI-cc) Leaching, Managed



CEAP Soil Vulnerability Index for Cultivated Cropland (SVI-cc) Leaching

Courtesy of USDA-NRCS.



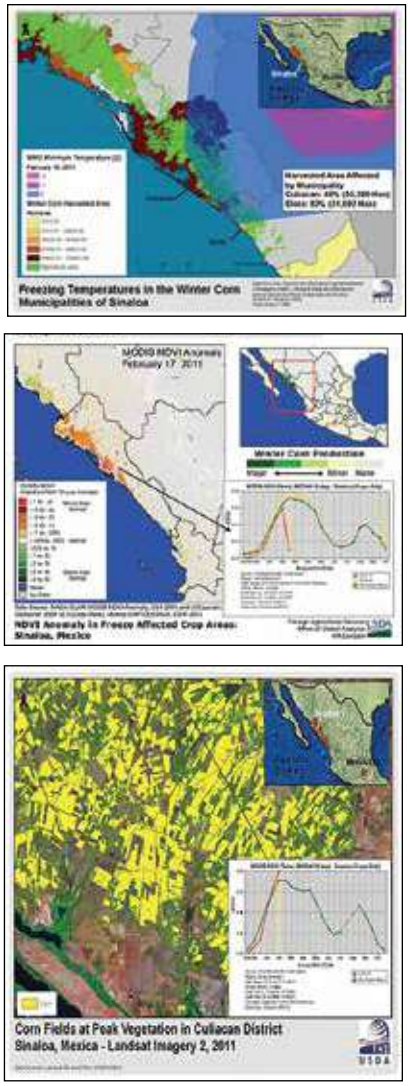
CEAP Soil Vulnerability Index for Cultivated Cropland (SVI-cc) Runoff

The Conservation Effects Assesment Project (CEAP) indexes soil vulnerability to help integrate soil conservation, agricultural and marine pollution-based responses for a more coherent policy response.

THE SCIENCE OF WHERE FOR CLIMATE

20 years after the Rio Declaration, Rio+20 pushed for new geospatial technologies, satellite remote sensing, geographic information systems, and global positioning systems for a comprehensive worldwide assessment of environmental conditions. Indian agricultural land alone has 15 agro-ecologies and 46 of 60 different global soil types; this uniquely positions Esri's already robust database to design, develop and deliver solutions for producers that will have global applications. The USDA CropScape application that uses the Esri database does just this - it enables farmers to see what crops are growing where and how much, thereby helping farmers plan what to produce.

Indian agriculture and livestock accounts for 18% of gross national emissions; it is the third-highest contributor after energy and industry. As Indian incomes grow, a dietary transition toward higher consumption of meat, fruits and vegetables is likely. Increasingly, these demands will be met through imports; lengthening distances between plough and plate further raise 'the resource-, energy-, and emission-intensity of the global food system'. The role of GIS in marketing chains has gained significance with these increasing lengths. A niche opportunity has been created for data-sensing companies; precision agriculture start-ups such as AgNext have captured several of the key, controllable input factors of



The USDA's Risk Management Agency has been using the Landsat 8 satellite since 2013 to determine whether damage to crops after a flood or other weather event has occurred.

production (harvest, planting, application, and irrigation data) to provide management decision support to producers. At the top of the pyramid, EU's Copernicus programme has cleared the table for many space-based start-ups to take big steps forward, thanks to its free and open data programme. We stand at a crossroads of human development; here, Esri aims to tie together different sets of background data, to allow teams to gain unprecedented powers of classification, interpretation, prediction, and forensics.

THE SCIENCE OF WHERE FOR HUNGER

Through input-intensive legacy agriculture, India's trend growth rates achieved significant levels in food production; however, the growth in per-capita food production has been negative, indicating worsening food availability. Indian studies show that for every 1°C rise in temperature, wheat production will go down by four to five million tonnes. Surprisingly, on the other hand, it takes a land mass larger than China to grow food that ultimately goes uneaten – food that accounts for 25 per cent of all fresh water consumption globally. These massive market inefficiencies defy FAO's warnings of global hunger. GIS can play a major role in enhancing accountability, transparency, and the reach of e-governance to ensure three-way robust communication between the public, government and corporation. Crop insurance in the aftermath of a disaster is one such example; GIS capabilities have been used to streamline pay-outs to beneficiaries, while minimising fraudulent claims of crop losses. The USDA's Risk Management Agency has been using the Landsat 8 satellite since 2013 to determine whether damage to crops after a flood or other weather event has actually occurred.

Consumer demand for organic, GMO-and antibiotic-free food is often dampened by news of fraudulent labelling; it throws a wrench in global supply systems,

and the farmers that depend on them. GIS can allow the smallest transactions – at farm, warehouse, or factory – to be monitored and communicated across the entire supply chain, when paired with IoT technologies, such as sensors and RFID tags. For example, Olio has an app that connects people with their neighbours and local shops, allowing surplus food to be shared, rather than be discarded. VegScape - another USDA Web GIS application - provides weekly maps, and displays crop health based on infrared data from NASA's MODIS satellite.

The significant spatial and technical challenges present in Sub-Saharan Africa and Southern Asia have prevented the use of remote sensing technology in many areas. These data lacunae need to be tapped at the grassroots through scientific crowdsourcing, which can be supported by applications like ArcGIS QuickCature, GeoAnalytics and Tracker for ArcGIS. Most importantly, the challenge of the future is not limited to changing scenarios but also changing data. As more data is reported in a decentralized manner, and findings logged and analysed, dynamic policy-making will be required to keep abreast of the idea of 'sustainability'. Esri aims to be in the driving seat and ahead of the curve when sustainability converts from being merely a watchword to a relevant – and moving – bulls-eye.

> "Let the dataset change your mindset."
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> **Lt. Hans Rosling,**
> Chairman, Gapminder Foundation

THE SCIENCE OF WHERE FOR THE FUTURE

In 2017, the UNFAO explicitly stated the relevance of reliable and timely geospatial information on natural resources, environmental conditions and their changes as one of the prerequisites of sustainable agricultural development. While global policy is pushing towards technological solutions, a large part of agriculture in the developing world is being conducted in rural areas that have reported high work participation rates among those above 60 years of age. Challenges are also expected from a steadily globalizing world. Isolated solutions in subsistence-oriented agriculture are insufficient to tackle new challenges of intellectual property rights; animal welfare; sanitary and phyto-sanitary measures, etc.

Esri aims to ensure that the benefits of spatial thinking become accessible, even to technologically-handicapped populations, by extending the power of mapping to anyone who wants it. Raising competencies in GIS can help capture the economy of scale that eludes agriculture. As more people begin thinking spatially and visually through the use of coherently tied datasets, Esri's databases hope to become a container for really creative ways of re-conceiving and redefining problems in ways that are relevant for those in a particular area, while ensuring that the solutions do not outsource problems elsewhere. The Science of Where is geared up to enable people worldwide to 'work collaboratively towards creating a better world'.

Staggering inconsistencies between ground realities and data availability, technological diffusion, national priorities, environmental concerns and livelihood demands defy a conventional agricultural solution. At the Esri User Conference in San Diego this year, President Jack Dangermond enjoined communities and called for "vision and willingness on part of individuals to envision what's possible by learning, sharing and collaborating, with a passion to create understanding and create a better world." This is what Esri India is looking forward to – harnessing the potential of spatial analysis to power sustainable agriculture. ■