

TSensors to Feed 9 Billion

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Introduction

- World's population is projected to grow from 7B today to 9 billion by 2050.
- Hunger is one of the global problems to be solved to reach [Abundance](#).
 - 1 billion people on Earth don't have enough to eat.
 - In developing countries, 33% children show problems resulting from malnutrition.
 - Lack of vitamin A kills million infants every year.
- UN believes that food production will have to increase by 70% in the next 35 years to prevent widespread hunger.

Industrial Food Production Applied Brute Force

- Farming:
 - It takes 10 calories of oil to produce 1 calorie of food.
 - Irrigation systems pumped our reservoir dry, global warming reduces arable land, creating dust bowls.
 - Toxic herbicides and pesticides destroyed our water ways.
 - Runoff from nitrogen-laden fertilizer turned our costal waters into dead zones.
 - Food production per acre increased 2.2 times between 1961 and 2011, but...
 - Productivity flattened due to lack of new improvements.
- Fishing:
 - Bottom trawling destroys about 6 million square miles of sea floor every year.
 - At current pace, the world would run out of seafood by 2048.

New Farming Technologies

- Vertical farming:
 - Traditional agriculture: uses 70% of the water on the planet.
 - Hydroponics: growing plants in water.
 - 70% more efficient than traditional agriculture.
 - Aeorponics: growing plants in air delivering food through nutrient rich mist.
 - 70% more efficient than hydroponics,.
 - Reducing 70% water usage for traditional agriculture to just 6%.
 - Ten to fifteen years before massive deployment.
- Will require
 - Temperature, PH and nutrient flow.
 - Biosensors
 - AI
 - Robotics

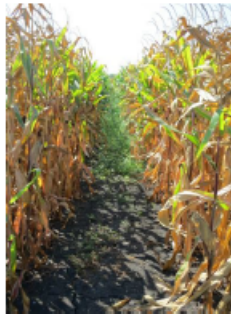
New Farming Technologies

- Conversion of annual crops to perennials (Kansas Land Institute).
 - Impact could be fantastic.
 - Expected commercialization in 20 years.
- Biosynthetic optimization could increase crops by 50% in 10-15 years.
- Optimized LEDs to deliver spectrum plants want and eliminate these unused: further yield increase.
- Sensors: hyperspectral imagers, in addition to chemical sensors.

Sensing Requirement for Farming

Trillions: Plants

Precision Agriculture has the goal to maximize yields and minimize inputs down to a plant by plant growth.



What does a plant need:

- Sunlight
- Water/available moisture
- Air temperature
- CO₂
- N P K
- Soil type
- Root development
- Plant biology

Manage/introduce stress for maximum output.

Weeds take away the needs from the plant.



Precision Farming

- Defined as information and technology based farm management system
 - To identify, analyze, and manage variability within fields for optimum profitability, sustainability, and protection of land resources.
 - Guides farmers about:
 - Right time to plant and harvest
 - Amount of fertilizers and pesticides needed for better yield production.
 - Where to wafer/fertilize.
 - Detect pests and infections early.
 - Close inspection of plants and fruits.
 - Application of pesticides and dertilizers.
 - Physical removal of pests.
 - Robotic pollination.
 - Helps cut down input costs, fuel usage, and labor, and negate the environmental impact.
- Precision farming market is expected to grow 12.2%/y to 2020 and reach \$4.6B.

<http://www.marketsandmarkets.com/Market-Reports/precision-farming-market-1243.html>

Genome Sequencing

- First plant genome sequenced in 2000
 - Took 7 years, \$70M and 500 people.
 - Today: 3 minutes and \$100.
- Next generation of Genetically Engineered (GE) crops:
 - Can grow in drought condition and in saline conditions.
 - Crops can be nutritionally fortified.
 - Crops can act as medicine.
 - Crops that increase yields and lower the use for pesticides, herbicides and fossil fuel.
 - Crops that requires no maintenance nor farming skills.
- Gates Foundation leads effort BioCassava Plus:
 - Cassava: one of the world's largest staple crops feeding 250M people.
 - GE target: fortify it with protein, vitamins A and E, iron, zinc, lower its natural cyanide content, make it virus resistant and increase storage from 1 day to 2 weeks.
- New initiative: call for open source of GE seeds.

Genetically Modified Organism (GMO)

- GMO was a major contributor to increase food crops:
 - 1 .7M hectares in 1996
 - 148M hectares in 2010
 - Genetically Engineered (GE) seeds became the fastest adopted crop technology.
 - There are over 2250 mutants around, most certified as organic.
- Dominated by threes seeds: cotton, corn, soybean.
- Emerging: golden rice fortified with vitamin A.
- Five to 10 years away from significant changes.
- Will require genomic sensors for safety monitoring.

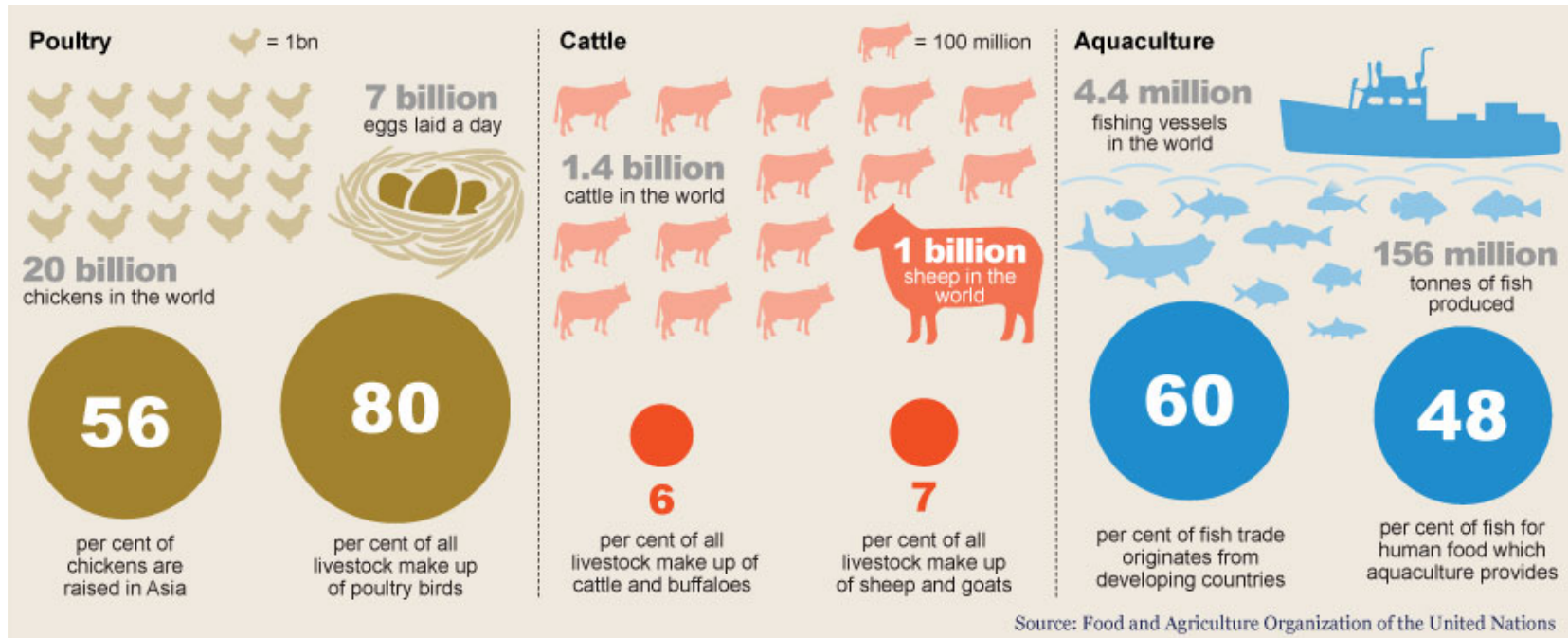
Cloud Farming

- Big Data analysis can increase crop yields by helping farmers make better decisions about when to plant, manage and harvest their crops.
- E.g., Climate Corporation (founded by two ex-Google employees and acquired by Monsanto in 2013 for \$1.1B) operates a cloud-based system including:
 - Weather measurements from 2.5 million locations every day.
 - 150 billion soil observations (hyperspectral sensors on satellites)
 - To generate 10 trillion weather simulation data points, to provide:
 - Temperature, rain and wind forecasts for 200 acres lots, for the forthcoming 24-hour and seven-day periods.
 - The system also uses weather data from the past few months and the last 30 growing seasons to provide yield estimates for crops in individual fields.

Protein Production

- Optimal human health needs 10% to 20% of calories to come from protein.
- Livestock: energy input to energy output is 54:1 (5.4 times worse than plants).
 - 40 billion animals are killed for food every year in the US alone.
 - 70% of all agricultural land is used to feed livestock.
 - Livestock produces more greenhouse gases than all cars in the world.
 - Is leading cause of soil erosion and deforestation.
 - Fatty acids contribute to heart diseases.
- Tightly pack herds are breeding grounds for pandemics.
 - 70% of diseases come from livestock
- Demand for meat is expected to double by 2050.
- Major savior technologies:
 - Aquaculture
 - In-vitro (cultured) meat

Protein Production by Numbers



Wireless sensor arrays monitoring health, feeding and location of poultry, cattle and fish represent large TSensors market.

MooMonitor to Measures Cow's Health & Fertility

- Cows cannot produce milk without getting pregnant.
 - A missed heat costs €250 per cow.
- The MooMonitor captures 210,000 data points/y/cow:
 - Temperature
 - Fertility cycle
 - Breeding cycle.
 - Cow's behavior to determine movement patterns.
 - Location with GPS.
- Mandatory animal electronic life-tagging to provide full traceability from farm to the fork is expected.
- Sensing technology could help speed up the progress toward having soil-free farms (crops grown in greenhouses) that are suitable for desert climates.



<http://www.thenational.ae/business/industry-insights/technology/farm-technology-a-growth-industry-in-the-emirates#full>

Sonar Cows

- 40% of dairy cows get ill each year.
- US Department of Agriculture says total economic loss from animal sickness and death is more than \$5B a year, with global losses amounting to 12 times this.
- Early warning or auto-detection can help minimize losses.
- The sensor, or e-Pill can be swallowed by cows and sit in the cow's rumen.
- Uses sonar technology to collect information about animal's:
 - Heart rate
 - Temperature
 - Rumination time
 - Rumen acidity
 - Oestrogen levels.



Soon cows could be transmitting health data from e-Pills in their stomachs

In-vitro (Cultured) meat

- Grown from stem cells, pioneered by NASA in late 1990s.
- Evolution:
 - 2007: In-Vitro Meat Consortium was formed.
 - Meat grown in bioreactors cost competitive with European beef prices.
 - Prevents heart attacks.
 - 2008: People for the Ethical Treatment of Animals (PETA) created \$1M incentive prize to move things along.
 - 2009: pig's stems cells were turned into pork inside petri dish.
 - Ten to fifteen years to widespread deployment.
- Advantages of cultured meat:
 - Less vulnerable to emerging diseases, 70% of which come from livestock.
 - Eliminates fatty acids, thus no contribution to heart disease.
 - Eliminates problems and inefficiencies related to livestock.
- Sensors: chemical and bio for quality control.

Agricultural Drones

- Drones with advanced sensors and imaging enable new ways to increase yields and reduce crop damage.
 - Compared with satellite imagery, it's much cheaper, offers higher resolution and unobstructed by clouds view available anytime.
- Drone technology in combination with Google's stratospheric balloons Project Loon has the potential to take it to 7 billion by 2020.
- Enabled due largely to remarkable advances in MEMS sensor technology:
 - Accelerometers,
 - Gyros,
 - Magnetometers
 - Pressure sensors
 - GPS modules

<http://www.technologyreview.com/featuredstory/526491/agricultural-drones/>
<http://singularityhub.com/2014/05/08/drones-overhead-seeing-everything-always-inside-google-and-facebooks-latest-acquisitions/>

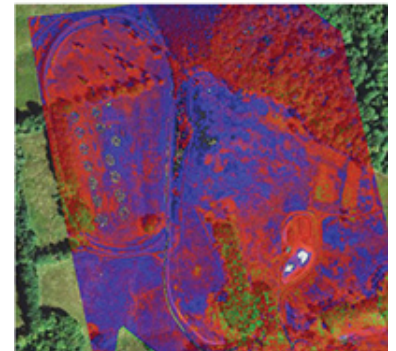


Image depicts vegetation in near--infrared light to show chlorophyll levels

Agroecology

- Blends the best of agronomy, forestry, ecology, hydrology and few other sciences.
- Targets production of more food on less land while enhancing ecosystems and promoting biodiversity.
- In 57 countries, agroecology increased crops on average by 80%, with best at 116%.
 - One of the most successful: push-pull system for Kenyan maize farmers:
 - Intercropping system where farmers plant specific plants between rows of corn.
 - Some plants release odors “pushing” insects away.
 - Others like sticky molasses grass “pull” insects in.
 - With such systems, crop yields increased up to 400%.
- Agroecology has no social backlash associated with GE food.
- Sensors: broad range of chemical, bio and spectral, to measure soil conditions, seeding rates, crop yields and many other variables.

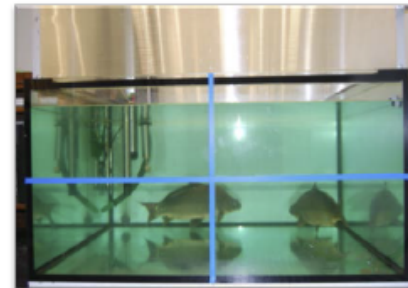
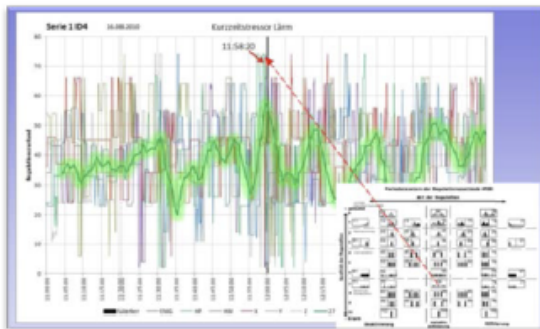
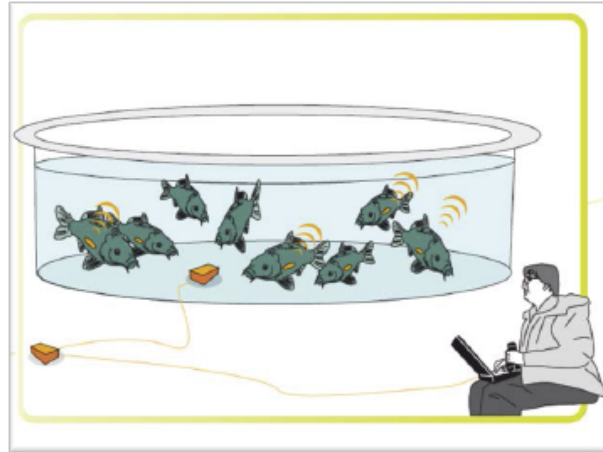
Health Monitoring of Fishes

Application scenario

- Optimization of food and medical feeding for fishes in aquaculture establishments

Measurement quantities

- Movement activity
- Skin resistance and potential
- Temperature
- Pressure (heart and breathing rates)



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Aquaculture

- US imports \$10B of seafood.
- Aquaculture is the fastest growing animal food production.
 - Production increased from 2M ton in 1950 to 50M ton in 2007.
- Aquaculture supplies about 30% of our seafood.
- But... 90% of large fish is already gone...
- Genetically engineered fish proved major yield improvements
 - It is safe to eat???



Around-the-Clock Ocean Measurements

- NASA's Goddard Space Flight Center developed an instrument capable of observing ocean color during normal sunlight conditions and under moonlight.
 - First-ever capability that allows to monitor the health and chemistry of the planet's oceans literally around the clock.
- Prototype Ocean Color Underwater Low Light Advanced Radiometer (OCULLAR) has shown that it can measure ocean color under low-light conditions across multiple wavelength bands, from UV to NIR.
- The successful OCULLAR demonstration leads the way to anticipated commercialization of the biological productivity of oceans, coastal areas, and inland waters.



Reducing Food Waste

- About 10% to 15% of food that is transported chilled spoils during transport, costing around \$25B.

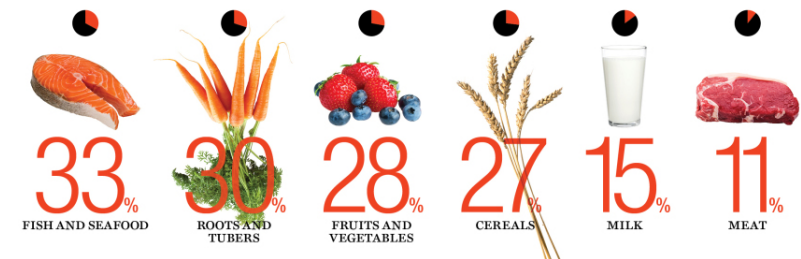
- Sensors in food containers measure:
 - Temperature
 - Humidity
 - Oxygen and other parameters,
 - Location with GPS.

- Household food waste

- About 25% of household food is wasted due to a “use by” label.
 - That’s \$162B.
 - Food freshness sensors would help eliminating this waste.
- Doug Rauch, a former president of Trader Joe’s, thinks he has a partial solution to the problem: sell food past its “best by” date.
 - First store to open in Boston.

HOUSEHOLD FOOD WASTE

Some estimates say Americans throw out 25% of the food they buy. Here's the share of each commodity that ends up in consumers' trash.



AgTech in Silicon Valley

- Several large AgTech startups acquisitions (e.g., Climate Corporation for \$1.1B) caught attention of VC industry.
- In 2003, VCs invested \$103M in AgTech.
- The RoyseLaw AgTech Incubator has announced a call for applications from technology companies focused on agriculture and food production.
 - Up to eight startups will be accepted into the three month mentoring and coaching program in Palo Alto.
 - Apply to the Incubator <http://www.royselawincubator.com> or email rroyse@RoyseLawIncubator.com.
 - The application deadline is December 31, 2014.

Steinbeck Innovation Foundation

- Salinas Valley is the food capital of California joined forces with Silicon Valley to drive Agriculture innovation and technology.
 - This major initiative called [Steinbeck Innovation](#) was conceived by [SVG Partners](#) and developed in conjunction with the City of Salinas.
- SVG Partners is now launching a strategic venture fund and accelerator program called [Thrive](#) in partnership with major agriculture corporations to drive investment in disruptive new technologies in AgTech.
- The Steinbeck Innovation Foundation is composed of four pillars of development support:
 - Education (including training and advanced research)
 - Startup acceleration
 - Investment
 - Corporate strategic engagement.

<http://steinbeckinnovation.org/about/>

Khoshla Ventures AgTech Portfolio

- [ALOHA](#)
 - Health and wellness company focused on producing nutrient-rich, gluten-free, all natural vegan foods and essential minerals.
- [BioConsortia](#)
 - Agricultural biotechnology company selecting beneficial microbial consortia for crop improvement.
- [Blue River Technologies](#)
 - Employs computer vision and robotics to build intelligent techniques for identifying weeds and selectively killing unwanted plants.
- [Climate Corporation](#)
 - Delivers the best measurements, insights and execution tools to farmers through a combination of hardware, software and services.
- [Granular](#)
 - Cloud software and analytics platform helps farmers become more efficient and make better business decisions.
- [Hampton Creek Foods](#)
 - Enables consumers, food manufacturers and retailers to offer better, healthier products at a more affordable cost.
- [Lyrical Foods](#)
 - Makes cheeses from simple, natural plant ingredients, using traditional, artisanal cheese-making methods and cultures.
- [Nu-Tek Salt](#)
 - Aims to help create great-tasting and affordable food that enhances global health and wellness.
- [UNREAL Brands](#)
 - Attempting to rid the world of junk food by providing healthier candy and snack options.

Strategy to Feed 9 Billion People

- Sustainable intensification backed by agroecological principles:
 - GE crops
 - Synthetic biology
 - Perennial polycultures
 - Vertical farms
 - Robotics and AI
 - Integrated agriculture
 - Upgraded aquaculture
 - Cultured meat
- Adoption of a broad range of new technologies.
- Most will need sensors, and many of these applications will need TSensors.
- All these developments will accelerate Abundance and create major business opportunities.

We need Volunteers

to contribute white papers to the Roadmap on:

- Emerging ultrahigh volume applications
- Emerging sensor technologies supporting ultrahigh volume applications
- Emerging infrastructure for sensors
- Solutions for requested sensors

Next TSensors Summit:

November 12-13, San Diego

December 8-9, Tokyo, Japan

Please contact: Janusz Bryzek

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Thank you