Characteristics, Accomplishments and Challenges of Existing Systems

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Complex Food and Agricultural Systems:
Engineering For Sustainability and Resilience
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Complex Food and Agricultural Systems: Accomplishments (US-G7 Centric Perspective)

• major gains in productivity, food abundance and affordability
  - mechanization (1900 onwards)
  - plant and animal breeding technologies (1970s onwards)
  - biotechnology (1990s onwards)
  - digital ag (2010 onwards)
• strengthened regulatory frameworks for food quality/standards/safety/labeling and environmental protection
• sophisticated integrated supply chain systems from farm to fork
  - refrigeration, storage and transportation networks
  - provenance and ‘touch points’ across the supply chain
Complex Food and Agricultural Systems: Accomplishments

- next-generation disruptive technologies to enhance productivity and optimize land use/resources management
  - technology convergence (life sciences, engineering, computing)
  - sensor networks, geospatial mapping
  - automation, robotics, drones, autonomous vehicles
  - vertical farms in urban settings
  - synthetic biology, gene editing
  - ‘alt meat’ and other biomimetic nutrition products

- data and digital (precision) ag - the new cash crop
  - unprecedented scale, content, connectivity
  - big data, ML/AI analytics, cyberbiosecurity

- block chain: new business models/contracts/ supply chain provenance
Complex Food and Agricultural Systems: Challenges

- 25% of world population (1.8 billion) live on less than $3/day
- UN WFP estimates 688 million people under-nourished and 2 billion suffer micronutrient deficiencies
- 2.3 billion people suffer from diseases related to unsafe water supplies
- est. 13% global annual crop yields lost to pathogens/pests
- est. 30-50% of global food supply wasted
- est. 25-30% of global anthropogenic greenhouse gases (GHG) attributable to food chain
- direct and indirect consequences of food and ag sector activities intrinsic to all 17 of the Sustainable Development Goals defined in the 2030 Agenda for Sustainable Development
- meeting IPCC goals will require substantial changes in agricultural practices and global resources management
Complex Food and Agricultural Systems: Challenges

- Projected 70% increase in food production needed by 2050 to feed 9 billion people.
- Sustained disparities in access of LICs to benefits of productivity enhancement, sustainability, and safe nutrition.
- LIC locked into a cycle of subsistence farming.
- Disproportionate impact of climate change on LIC/indigenous food systems.
- Distortion of global markets:
  - National subsidies, import tariffs, quotas.
- Lack of LIC commercial wireless network connectivities as obstacles to new technology adoption.
- Balance of food production shifting from HICs to high population MICs:
  - China, Brazil, India, but limited R&D contributors to domestic R&D and CGAIR.
The Global Food and Agricultural System: A Complex Adaptive System (CAS) Comprising Multiple Interacting CAS Systems

- productivity
- equity

- stewardship of global resources

Food and agriculture

Geopolitics and national security

Health

One health

Socio-economic-technological systems (SETS)

A systems perspective is essential

- cultural heterogeneity
- historical constraints
- values
- (dis)incentives
- risk (recognition)
- response (implement)
- existential threat(s)
- urgency
- disruptive vs incremental innovation
- rewards

R&D investment and regulation

Global supply chains

Disruptive technologies digital ag

- productivity
- equity

- stewardship of global resources

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The Global Food and Agricultural System: A Complex Adaptive System (CAS) Comprising Multiple Interacting CAS Systems

- Productivity
- Equity
- Stewardship of global resources

Food and agriculture

- Geopolitics and national security
- Policy: SDGs/ IPCC
- R&D investment and regulation
- Disruptive technologies digital ag
- Energy/climate science
- Global supply chains
- One health
A Complex Adaptive System (CAS) Comprising Multiple Interacting CAS Systems

stakeholders
- multi-domain
- multi-sector
- national
- international

goals
- scale
- sustainable
- equity
- security

strategic drivers
- supranational policies
  - SDGs
  - IPCC
- markets
- technology
- investment
- regulation
- one health
- urbanization
- digital ag and big data
- cyberbiosecurity

The Global Food and Agricultural System
The Global Food and Agricultural System

- Complexity and non-linear dynamic interaction networks
  - Interactive agents
  - Connectivities • Robustness
  - Spatio-temporal scale: Micro to macro
  - Disruption • Emergence • Adaptation

- Unintended consequences

- One-health big data
- Supranational public policies
- Resources utilization ecological footprint
- Markets, technology, investment, regulation

- Scale/equity security/resilience
The US Food and Agricultural Ecosystem Is Not Optimized for Resilience

- dramatic escalation of food insecurity in the COVID-19 pandemic
- 54 million Americans (18 million children) experienced uncertainty in reliable food supply
- choke points in supply chain driven by processing plant consolidations
  - 12 plants produce > 50% beef; 12 produce > 50% pork products
- processing plants as ‘super spreader’ locations
  - est. 300K excess cases and 5K deaths
- plant work force comprises disproportionate marginalized low income/education employees
  - immigrants, refugees, people of color
The Global Food and Agricultural System

- Complexity and non-linear dynamic interaction networks

- Resource utilization and ecological footprint
  - Demographics
  - Non-renewable resources
  - Urbanization
  - Environmental degradation/conervation
  - Infection, infestation
  - Waste reduction
  - Climate change mitigation
  - Energy

- Scale/equity, sustainability/security
  - National security
  - Conflict
  - Geopolitics
  - Trade policies
  - Supply chains
  - Education/equity
  - Poverty/hunger/health
  - HIC, MIC, LIC

- Supranational public policies
  - SDGs
  - IPCC

- Markets, technology, investment priorities, regulation

- One-health big data cyberbiosecurity
Complexity Ignored: Silos Subvert Solutions

fragmented, linear, reductionist concepts, public policies and investments versus holistic, systems-based strategies for risk assessment and mitigation

- economic
- ecological
- EIDs
- supply chain consolidation
- soft targets: cyberbiosecurity
- inequity and humanitarian crises
- geopolitical/military conflicts
- existential threats

- sustainability
- resources
- policy
- markets, technology, investment, regulation
- one-health big data
Complex Food and Agricultural Systems

- The food and agriculture sectors (in common with public health and healthcare) are classic complex adaptive systems (CAS) that comprise multiple interactive CAS subsystems (a system of systems).

- Without more sophisticated system-based approaches to (supranational) public policy and R&D investment by the public and private sectors, the current fragmented patchwork of ‘siloed’ components will persist and fail to achieve the required global resiliency and equity.

- Continued propagation of current reductionist, linear, and siloed policies and priorities will amplify risk, vulnerabilities and disparities and trigger escalating socio-economic stresses, humanitarian crises, geopolitical instabilities and conflicts.