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ASU Complex Adaptive Systems Initiative
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Characteristics, Accomplishments and Challenges of Existing Systems

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National Academy of Engineering Forum on Complex Unifiable Systems
Complex Food and Agricultural Systems:
Engineering For Sustainability and Resilience
September 9, 2021

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

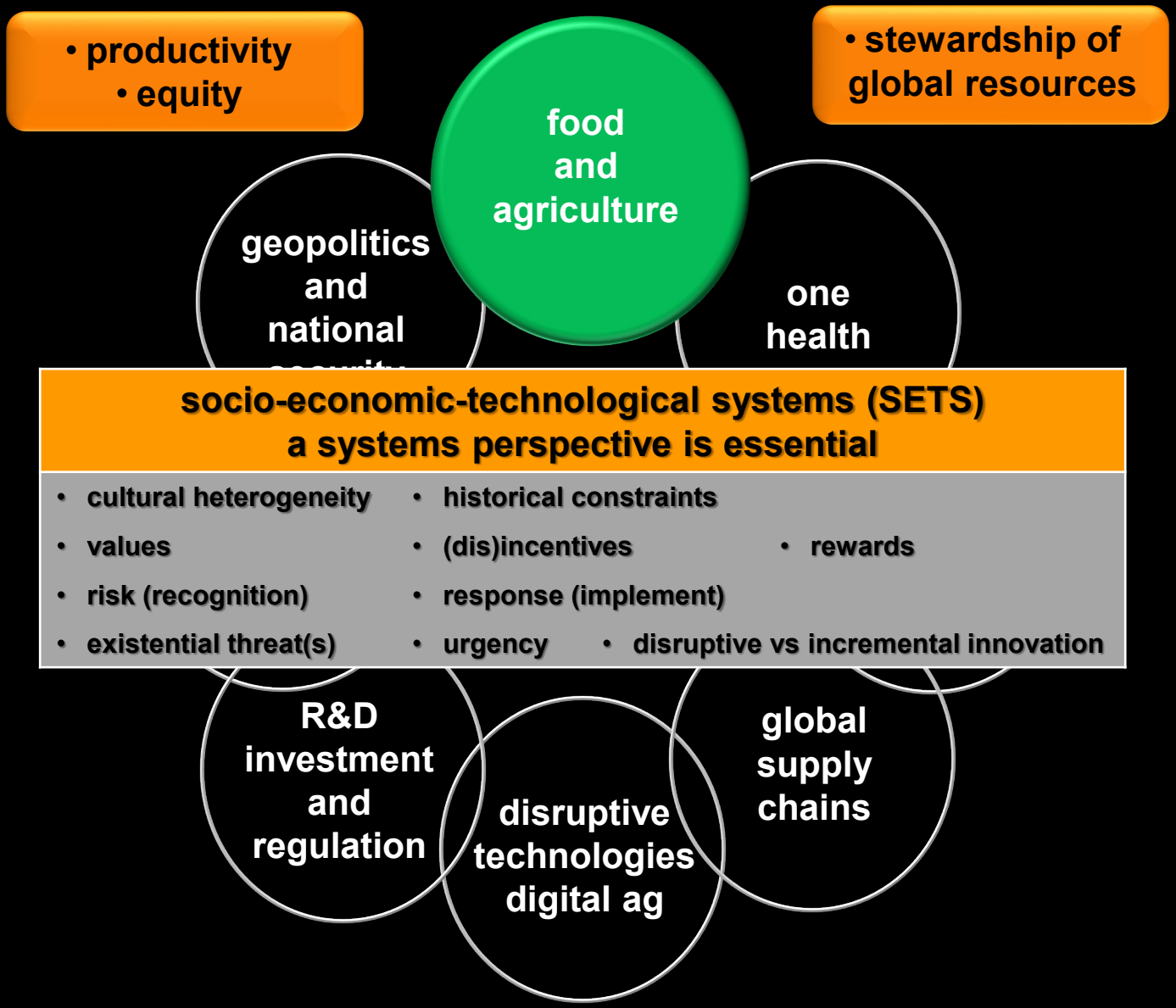
Complex Food and Agricultural Systems: Challenges

- 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



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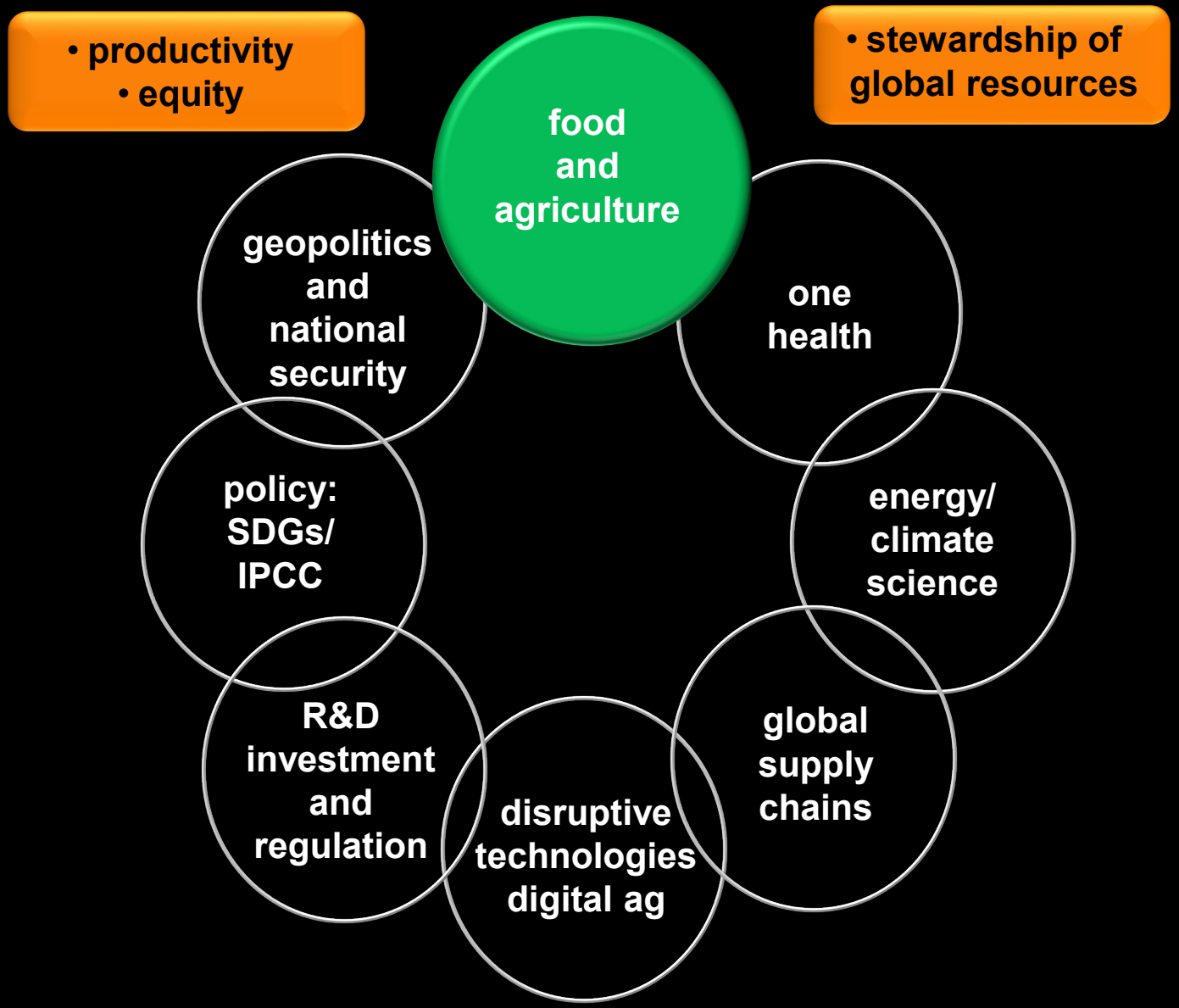
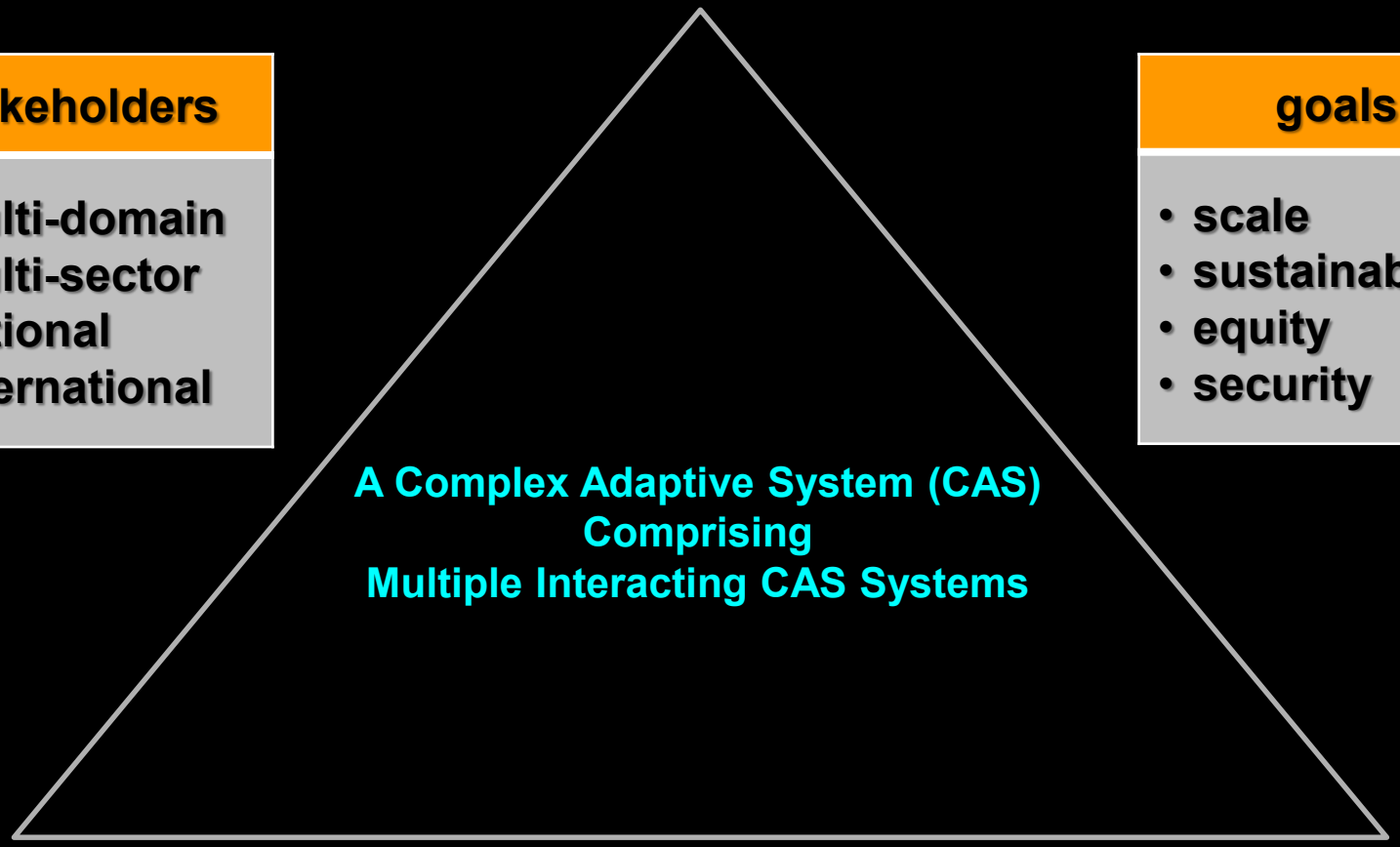


The Global Food and Agricultural System



stakeholders

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

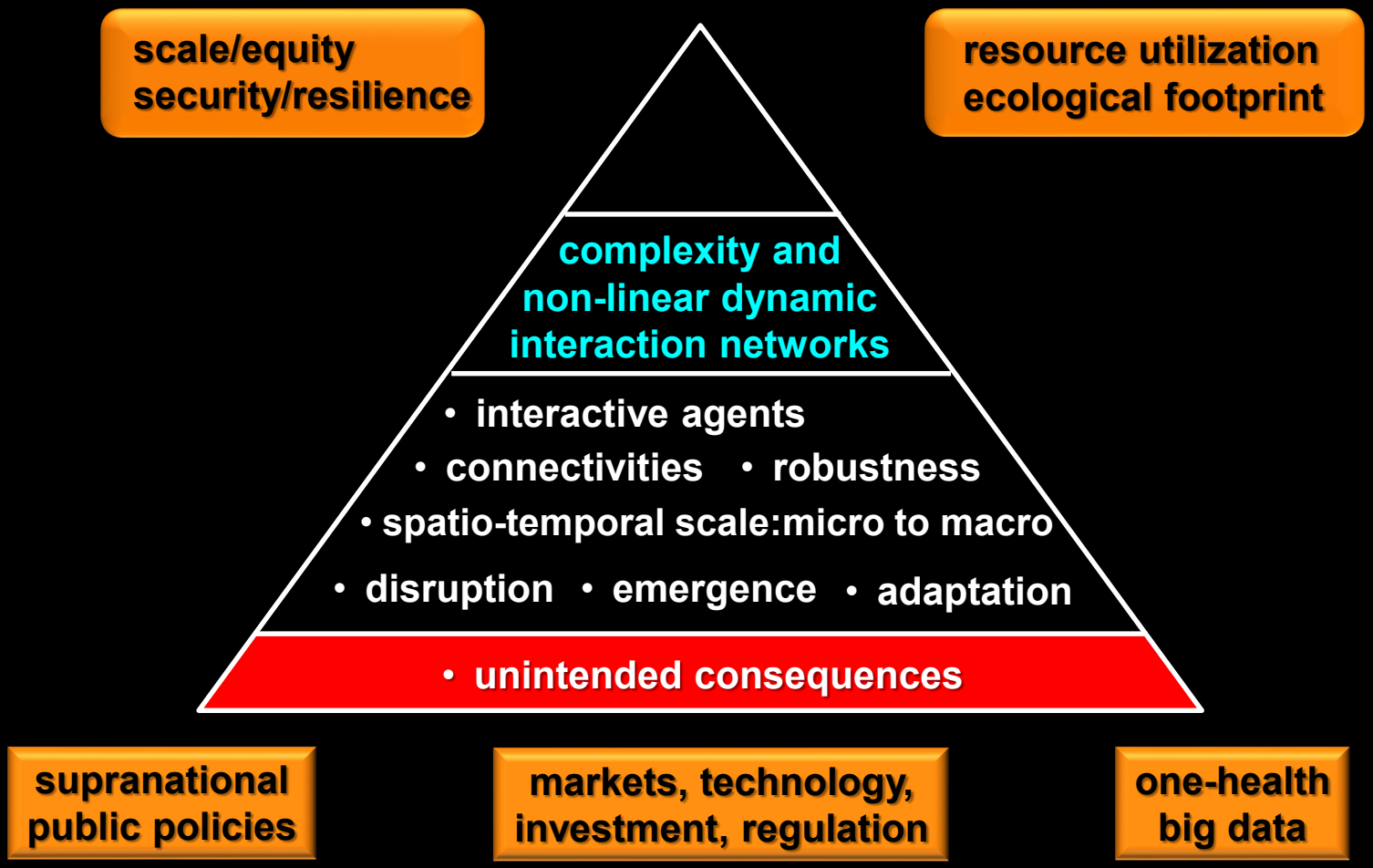
goals

- scale
- sustainable
- equity
- security

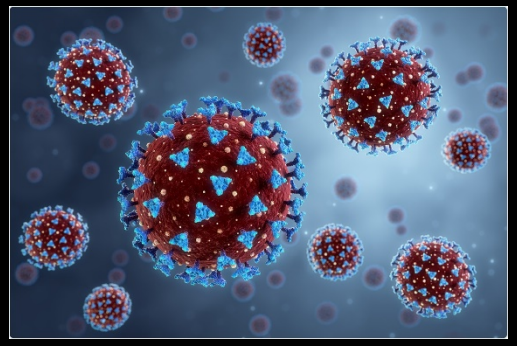
strategic drivers

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

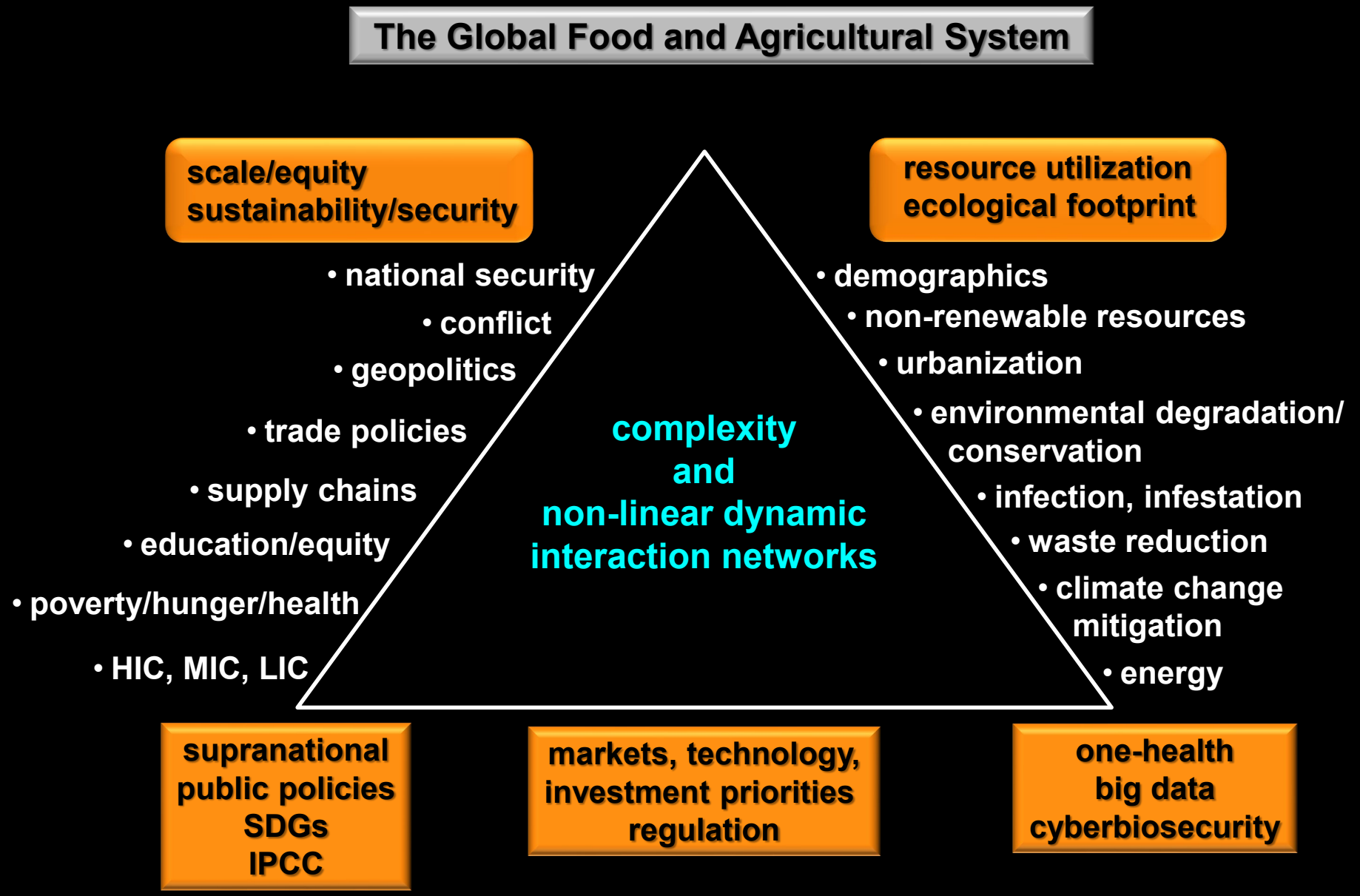
The Global Food and Agricultural System



The US Food and Agricultural Ecosystem Is Not Optimized for Resilience

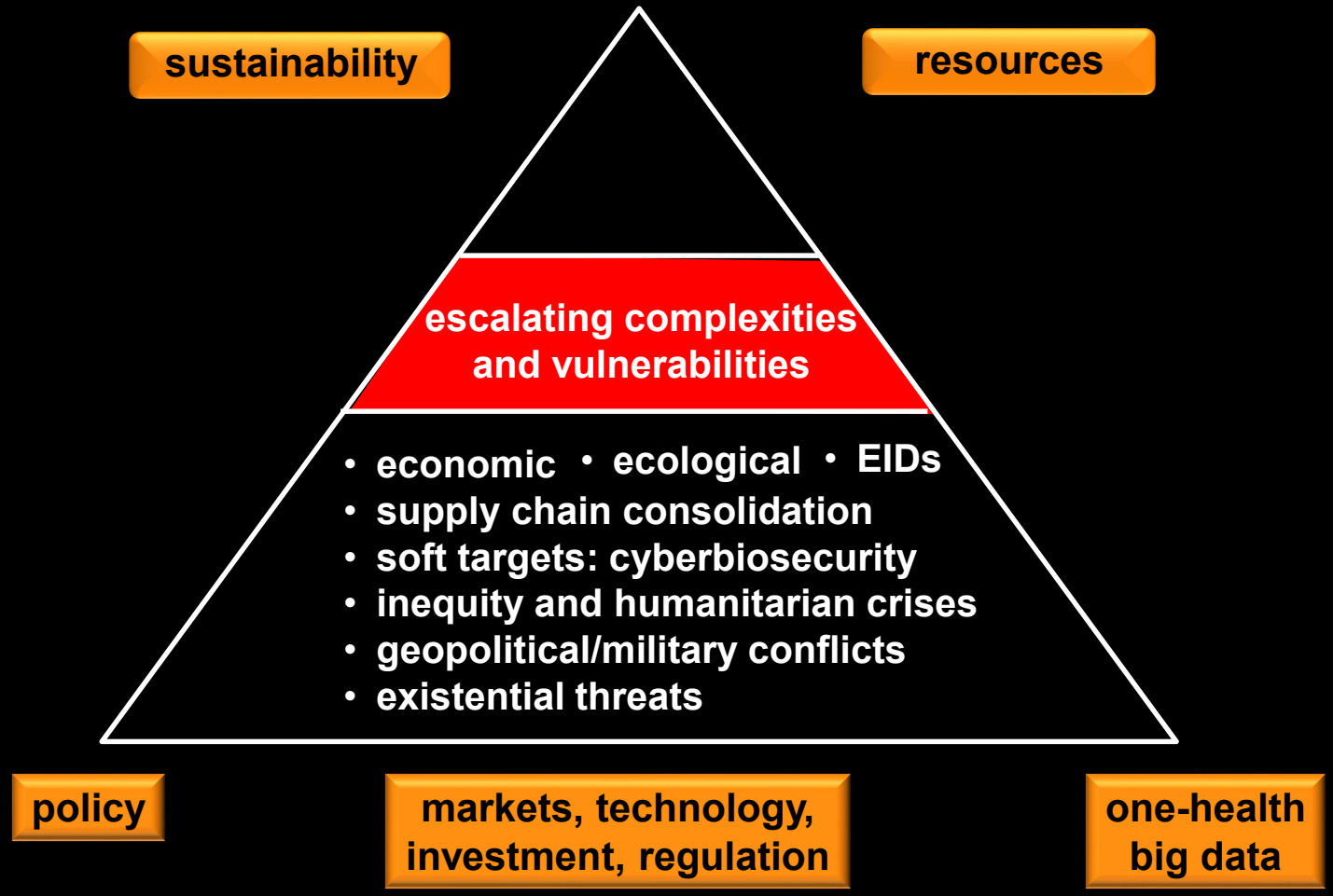


- dramatic escalation of food insecurity in the COVID-19 pandemic
- 54 million Americans (18 million children) experienced uncertainty in reliable food supply
- choke points in supply chain driven by processing plant consolidations
  - 12 plants produce > 50% beef; 12 produce > 50% pork products
- processing 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
scale/equity
sustainability/security
resource utilization
ecological footprint
• national security
• conflict
• geopolitics
• trade policies
• supply chains
• education/equity
• poverty/hunger/health
• HIC, MIC, LIC
• demographics
• non-renewable resources
• urbanization
• environmental degradation/ conservation
• infection, infestation
• waste reduction
• climate change mitigation
• energy
complexity
and
non-linear dynamic
interaction networks
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



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 polices and priorities will amplify risk, vulnerabilities and disparities and trigger escalating socio-economic stresses, humanitarian crises, geopolitical instabilities and conflicts