Using a Novel One Health Multi-Dimensional Matrix Tool to Examine Complex GeoHealth Challenges Relating to Food Safety and Security, Antimicrobial Resistance, and Climate Change

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Abstract

The One Health concept provides a framework to examine the linkages between human, animal, plant, environmental, and ecosystem health. This framework can be represented as a multi-dimensional matrix tool that can be used to examine and address complex GeoHealth challenges. This matrix tool facilitates comprehensive, systems-based thinking and can include up to four dimensions depending upon users’ needs. This presentation will briefly review the One Health matrix tool and apply it, as an example, to examine the global impact of human and animal fecal wastes. Applying the tool reveals linkages between food-borne illnesses, food insecurity, antimicrobial resistance, and climate change. Understanding these linkages is necessary for developing effective and equitable public policies that are needed to achieve many of the United Nations’ Sustainable Development Goals.
A One Health Analysis of Food Safety & Security, Antimicrobial Resistance, and Climate Change in the 21st Century

Laura H. Kahn, MD, MPH, MPP
Virtual GeoHealth Symposium
American Geophysical Union Annual Fall Meeting
December 2021
Climate Change Threatens Agriculture and Food Security

Agriculture: Foundation of Civilization

Antimicrobial Resistance Threatens Antimicrobial Use and Food Safety

Antimicrobials: Foundation of Modern Medicine
Definitions

**FOOD SYSTEMS**

Food Systems include all activities related to the production, distribution, and consumption of food that affect nutrition and health.

**FOOD SECURITY**

Food Security exists when "all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life."

**FOOD SAFETY**

Food Safety includes activities, processes, and policies encompassing the food chain, aimed at ensuring food is safe for consumption.

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Food Security means No Hunger

Food Safety means No Foodborne Illness

AMR means bacteria resistant to antibiotics
The One Health concept: human, animal, plant, environmental & ecosystem health are linked.

This concept provides a useful framework for examining complex issues such as food safety & security, AMR, and climate change.

We must examine the root causes of spillover events if we are to develop effective policies to address them.

People interact with their environment every day by inhaling air, drinking water, and ingesting plants and animals (i.e. food).

http://www.onehealthinitiative.com
Multi-Dimensional One Health Matrix: A Cube

One Health Factors

Humans & Animals
Plants
Environments & Ecosystems

Complexity Factors

Microbial
Individual
Population

Political, Social, Economic Factors

Local/Regional
National
International/Global

One Health Framework in 2 Dimensions

<table>
<thead>
<tr>
<th>One Health and Complexity Factors</th>
<th>Microbial</th>
<th>Individual</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humans</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environments &amp; Ecosystems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Political, Social, Economic Factors</strong></td>
<td>Local &amp; Regional</td>
<td>National</td>
<td>International &amp; Global</td>
</tr>
</tbody>
</table>

Environments: abiotic (e.g. soil, water, air) aspects of defined geographic areas.
Ecosystems: biotic interactions (e.g. microbial, flora, fauna) within defined geographic areas.

A One Health Analysis

One Health Factors:
- Humans & Animals (Domesticated, Terrestrial Livestock)
- Plants (Cereal Crops)
- Environments & Ecosystems (Water, Soil, Air) (Global Resistome)

Complexity Factors:
- Microbial & Populations (Fecal Microbes)

Political, Social, Economic Factors:
- International/Global Food Security
- Global Demand for Meat

Time Factor: Years
A One Health Satellite Perspective
First One Health Analysis

Humans & Animals (Domesticated Livestock)

Microbial & Populations

International/Global
Global Human & Animal Populations

Almost 8 Billion Humans

Around 30 Billion Terrestrial Food Animals

Source: FAOSTAT (Jul 19, 2021)
Biodiversity, land use and ecosystem services

Humans and domesticated livestock constitute approximately 96 to 98% of global terrestrial mammalian biomass.

Broiler chickens are a signal of a human reconfigured biosphere

Broiler chickens combined mass exceeds all other birds on Earth. Standing population of almost 23 billion.
All animals eat so...
We produce around 4 trillion kilograms of feces each year!
Total fecal matter produced by humans and livestock in 2014 would...

fill over 1.6 million Olympic-sized swimming pools, and by 2030, over 1.8 million Olympic-sized swimming pools with feces.

Or, to put it another way...

bury the entire surface areas of Los Angeles + NYC in 6 feet of feces.

We produce increasing amounts each year.
Human Fecal Matter

673 Million People Still Defecate Outdoors
% of the population practicing open defecation in 2017

Where People Don't Have Access to Basic Sanitation
Share of people without access to at least basic sanitation services in 2017*

Global rate of open defecation
2000 21% (1.3 billion people)
2017 9% (673 million people)

* defined as facilities that are not shared and that are safely managed
Source: WHO
Animal Fecal Matter (Manure)

Global Assessment of Manure Management Policies and Practices

2.1 Manure Policies

Thirty out of the 34 countries in the survey have national policies related to manure management. The map in Figure 1 shows the responding countries with and without manure related policies.

Figure 1. Surveyed countries with (green) and without (red) manure management related policies.

Having legislation on manure management is one thing, enforcing it is a whole other issue. Generally, enforcement of manure policies is regarded as being weak (Figure 3). Particularly in situations where multiple ministries are involved, there is often a lack of coordination between the ministries and their enforcing bodies resulting in unclear procedures and penalties. Enforcement of regulation was found to vary across the surveyed countries; respondents from China, Viet Nam, Malaysia, Panama, Ecuador and Chile indicated well-coordinated law enforcement.

Figure 3. Level of enforcement

- Green = very strict: non-compliance immediately leads to penalties;
- Yellow = moderate; strict but first a warning and a time frame within which improvements have to be made;
- Orange = weak/none: rules are not enforced or just on selected farms (based on size, location etc.).
Concentrated Animal Feeding Operations (CAFO)
Report to Congressional Requesters:

United States Government Accountability Office:
GAO:

September 2008:

Concentrated Animal feeding operations:

EPA Needs More Information and a Clearly Defined Strategy to Protect Air and Water Quality from Pollutants of Concern:

GAO-08-944:

GAO Highlights:

Highlights of GAO-08-944, a report to congressional requesters.

What GAO Found:

Because no federal agency collects consistent, reliable data on CAFOs, GAO could not determine the trends in these operations over the past 30 years. However, using USDA data for large farms that raise animals as a proxy for CAFOs, it appears that the number of these operations increased by about 230 percent, going from about 3,600 in 1982 to almost 12,000 in 2002. Also, during this 20-year period the number of animals per farm had increased, although it varied by animal type. Moreover, GAO found that EPA does not have comprehensive, accurate information on the number of permitted CAFOs nationwide. As a result, EPA does not have the information it needs to effectively regulate these CAFOs. EPA is currently working with the states to establish a new national data system.

The amount of manure generated by large farms that raise animals depends on the type and number of animals raised, but large operations can produce more than 1.6 million tons of manure a year. Some large farms that raise animals can generate more raw waste than the populations of some U.S. cities produce annually. In addition, according to some agricultural experts, the clustering of large operations in certain geographic areas may result in large amounts of manure that cannot be effectively used as fertilizer on adjacent cropland and could increase the potential of pollutants reaching nearby waters and degrading water quality.
Pathogens in Human Feces

In the following tables a comprehensive list of the various microbes generally found in human excreta and the diseases caused due to each have been mentioned.

**VIRAL PATHOGENIC EXCRETED IN FAECES**

<table>
<thead>
<tr>
<th>Viruses</th>
<th>Diseases</th>
<th>Symptom</th>
<th>Human Carrier</th>
<th>States Reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polioviruses</td>
<td>Poliomyelitis</td>
<td>Paralysis and other conditions</td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>Hepatitis A Virus</td>
<td>Infectious hepatitis</td>
<td></td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>Rotaviruses</td>
<td>Diarrhoea</td>
<td></td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>Echoviruses</td>
<td>Numerious conditions</td>
<td></td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>Coxsackie viruses</td>
<td>Numerious conditions</td>
<td></td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>Reoviruses</td>
<td>Numerious conditions</td>
<td></td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>Adenoviruses</td>
<td>Numerious conditions</td>
<td></td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>Astroviruses (many types)</td>
<td>Gastroenteritis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calicovirus (several types)</td>
<td>Gastroenteritis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corona virus</td>
<td>Gastroenteritis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enteroviruses (many types)</td>
<td>Gastroenteritis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatitis E virus</td>
<td>Infectious hepatitis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norwalk virus</td>
<td>Gastroenteritis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norwalk-like viruses</td>
<td>Gastroenteritis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parvovirus (several types)</td>
<td>Fifth disease</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**BACTERIAL PATHOGENS EXCRETED IN FAECES**

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Diseases</th>
<th>Bacteria excreted also in urine</th>
<th>Symptom</th>
<th>Human carrier</th>
<th>States Reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmonella typhi</td>
<td>Typhoid fever</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>Paratyphi</td>
<td>Paratyphoid</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>Other salmonella</td>
<td>Food poisoning etc.</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Human &amp; Animal</td>
</tr>
<tr>
<td>Shigella</td>
<td>Bacillary dysentery</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>V. Cholera</td>
<td>Cholera</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Human</td>
</tr>
<tr>
<td>Pathogenic E. Coli</td>
<td>Diarrhoea or gastroenteritis</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Human &amp; Animal</td>
</tr>
<tr>
<td>Yersin</td>
<td>Yersiniosis</td>
<td>Yes</td>
<td>Yes</td>
<td>Animal &amp; Man (b)</td>
<td></td>
</tr>
<tr>
<td>Campylobacter</td>
<td>Diarrhoea</td>
<td>No</td>
<td>Yes</td>
<td>Animal&amp;Man(?)</td>
<td></td>
</tr>
<tr>
<td>Leptospira (sp.)</td>
<td>Leptospirosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helicobacter pylori</td>
<td>Abdominal pain, peptic ulcers, gastric cancer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlamydia trachomatis</td>
<td>Trachoma</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Each serotype is more or less specific to a particular animal host.
2. Some 30 or more serotypes appear to be associated with particular animal species. Any specific distinct serotypes, specific to prionates, is still under investigation.

Pathogen means microbe that causes disease.

One gram of faeces contains:
- 10,000,000 Viruses
- 1,000,000 Bacteria
- 1,000 Parasite cysts
- 100 parasitic eggs.

These pathogens cause infections which lead to over 1.3 million deaths worldwide annually. Children and the immunodeficient are the most vulnerable to these organisms which contributes to this burden, specifically bacteria, viruses and parasites.
Few studies examine pathogens in animal feces.

<table>
<thead>
<tr>
<th>Region</th>
<th>n (%)</th>
<th>Pathogens</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>19 (58%)</td>
<td><em>Achromobacter hydrophila</em></td>
<td>1 (2%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Campylobacter spp.</em></td>
<td>9 (15%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Chlamydia trachomatis</em></td>
<td>3 (5%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Escherichia coli</em></td>
<td>13 (21%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>E. coli</em></td>
<td>1 (2%)</td>
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<tr>
<td></td>
<td></td>
<td><em>Salmonella spp.</em></td>
<td>5 (9%)</td>
</tr>
<tr>
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<td></td>
<td><em>Shigella spp.</em></td>
<td>5 (9%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Vibrio spp.</em></td>
<td>4 (7%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Yersinia spp.</em></td>
<td>2 (3%)</td>
</tr>
<tr>
<td>Asia</td>
<td>9 (15%)</td>
<td><em>Achromobacter hydrophila</em></td>
<td>1 (2%)</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td><em>Yersinia spp.</em></td>
<td>2 (3%)</td>
</tr>
<tr>
<td>South America</td>
<td>12 (19%)</td>
<td><em>Achromobacter hydrophila</em></td>
<td>1 (2%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Campylobacter spp.</em></td>
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<td><em>Yersinia spp.</em></td>
<td>2 (3%)</td>
</tr>
<tr>
<td>Global</td>
<td>1 (2%)</td>
<td><em>Achromobacter hydrophila</em></td>
<td>1 (2%)</td>
</tr>
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<td></td>
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<tr>
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<td><em>Yersinia spp.</em></td>
<td>2 (3%)</td>
</tr>
</tbody>
</table>
In 2015, WHO released a report estimating global burden of foodborne illnesses.

About 1 in 10 people is sickened by food each year. Of the 600 million people who get sick, around 420,000 die. Children under 5 years make up 40% of the cases.

Diarrheal disease agents cause around 550 million illnesses and 230,000 deaths.

### Diarrheal Disease Agents

- Campylobacter spp., Cryptosporidium spp., Entamoeba histolytica, Enteropathogenic E. coli (EPEC), Enterotoxigenic E. coli (ETEC), Giardia spp., Norovirus, Salmonella enterica (non-invasive infections) non-typhoidal, Shigella spp., Shiga toxin-producing E. coli (STEC), Vibrio cholerae

### Invasive Infectious Disease Agents

- Brucella spp., Hepatitis A virus, Listeria spp., Mycobacterium bovis, Salmonella enterica (invasive infections) non-typhoidal, Salmonella enterica Paratyphi A, Salmonella enterica Typhi

### Helminths


### Chemicals

- Aflatoxin, Cassava cyanide, Dioxin

Second One Health Analysis

Plants
(Cereal Crops)

Microbial & Populations

International/Global
The world has over 50,000 edible plants. Just three of them, rice, maize and wheat, provide 60 percent of the world’s food energy intake.

Source: FAO

Source: SSWM & GENSCH (2010)
The Green Revolution

In 1944, Borlaug worked for the Rockefeller Foundation’s technical assistance program in Mexico.

Production problems limited wheat harvests.

New wheat varieties with disease resistance, adapted to different growing conditions with high yields.

New wheat varieties and crop management practices spread from Mexico to Asia and South America becoming known as “The Green Revolution.”


The Green Revolution

Change in cereal production, yield and land use, World, 1961 to 2018
Population and cereal production, yield and land use figures are indexed to the year 1961 (i.e. 1961 = 0).

Source: OWID based on World Bank; and UN FAO
OurWorldInData.org/crop-yields • CC BY

Global land spared as a result of cereal yield improvements
Land sparing is calculated as the amount of additional land that would have been needed to meet global cereal production if average crop yields had not increased since 1961.

Source: OWID based on UN Food and Agriculture Organization
OurWorldInData.org/land-use • CC BY
Cereal yield, 2018

Cereal yields are measured in tonnes per hectare. Cereals include wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains.

Source: UN Food and Agriculture Organization (FAO)
Problems with Green Revolution

- Intensive farming practices
  - Soil erosion
  - Water shortages
  - Micronutrient deficiencies
  - Dependency on chemicals
  - Vulnerability to pests
  - Loss of control over seeds

- Genetically engineered crops (Genetically Modified Organisms—GMO’s) led to political opposition.
Manure Vs Synthetic Fertilizer Use in Agriculture

Manure (Nitrogen)  
- 1961: 18.4 B kilograms  
- 2019: 27.1 B kilograms  
- 1961: 1.5 times more manure used than fertilizer  
- 2019: 4 times more fertilizer used than manure

Synthetic Fertilizer (Nitrogen)  
- 1961: 11.4 B kilograms  
- 2019: 108.8 B kilograms

Source: FAOSTAT
If manure is not being used as fertilizer, what’s being done with it?
Third One Health Analysis

Environments & Ecosystems

Microbial & Populations

International/Global
Environments:
Climate Change Threatens Agriculture
Agriculture Worsens Climate Change

https://climate.nasa.gov/effects/
Time of Complex Life on Earth

Paleozoic Era

Cambrian Explosion: Thriving life in seas but barren land

Permian-Triassic Extinction

Early hominids

Earth is 4.5 Billion Years Old
The Frozen Thames, Britain, 1677
Frost fairs lasted from 1607 to 1814

Ice skating on main canal of Pompenburg, Rotterdam, 1825.

Little Ice Age noted for crop failures, bread riots, famine, wars.

The hunters in the snow, Pieter Brueghel the Elder, 1565
Estimated agricultural yields in 2050 due to climate change effects, assuming current agricultural practices and crop varieties.


https://openknowledge.worldbank.org/handle/10986/4387
2020 World Hunger Map

https://www.wfp.org/publications/hunger-map-2020
Manure (And Synthetic Fertilizers) Emit Greenhouse Gases

They are Major Sources of Methane and Nitrous Oxide
**2017 U.S. Methane Emissions, By Source**

- **Coal Mining**: 8%
- **Landfills**: 16%
- **Natural Gas and Petroleum Systems**: 31%
- **Enteric Fermentation**: 27%
- **Other**: 8%
- **Manure Management**: 9%

**2017 U.S. Nitrous Oxide Emissions, By Source**

- **Agricultural Soil Management**: 74%
- **Manure Management**: 5%
- **Transportation**: 5%
- **Industry or Chemical Production**: 6%
- **Stationary Combustion**: 8%
- **Other**: 2%

**Enteric Fermentation + Manure Management**
Contribute Approx. **36%** of U.S. Methane Emissions

**Agricultural Soil Management + Manure Management**
Contribute Approx. **79%** of U.S. Nitrous Oxide Emissions

[https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane](https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane)
[https://www.epa.gov/ghgemissions/overview-greenhouse-gases#nitrous-oxide](https://www.epa.gov/ghgemissions/overview-greenhouse-gases#nitrous-oxide)
Global greenhouse gas emissions and warming scenarios

- Each pathway comes with uncertainty, marked by the shading from low to high emissions under each scenario.
- Warming refers to the expected global temperature rise by 2100, relative to pre-industrial temperatures.

Annual global greenhouse gas emissions in gigatonnes of carbon dioxide-equivalents

- **150 Gt**
- **100 Gt**
- **50 Gt**

**Greenhouse gas emissions up to the present**

**No climate policies**

4.1 – 4.8 °C

- expected emissions in a baseline scenario if countries had not implemented climate reduction policies.

**Current policies**

2.7 – 3.1 °C

- emissions with current climate policies in place result in warming of 2.7 to 3.1°C by 2100.

**Pledges & targets (2.4 °C)**

- emissions if all countries delivered on reduction pledges result in warming of 2.4°C by 2100.

**2°C pathways**

**1.5°C pathways**

Data source: Climate Action Tracker (based on national policies and pledges as of May 2021).

OurWorldinData.org – Research and data to make progress against the world’s largest problems.

Last updated: July 2021.

Licensed under CC-BY by the authors Hannah Ritchie & Max Roser.
Ecosystems: The Global Resistome

AMR is ancient & everywhere!

Antibiotic resistance is ancient

Vanessa M D'Costa, Christine E King, Lindsay Kalan, Mariya Morar, Wilson W L Sung, Carsten Schwarz, Duane Froese, Grant Zazula, Fabrice Calmels, Regis Debruyne, G Brian Golding, Hendrik N Polnar, Gerard O Wright

Affiliations + expand
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How are humans adversely impacting the Global Resistome?

- Poor sanitation
- Indiscriminate antibiotic use
- Untreated human and animal waste
- Land and water contamination
- Spread of resistant microbes and resistant genes by wildlife
Environmental fecal waste and antibiotic use: Is there a relationship?
Review

Manure as a Potential Hotspot for Antibiotic Resistance Dissemination by Horizontal Gene Transfer Events

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Abstract: The increasing demand for animal-derived foods has led to intensive and large-scale livestock production with the consequent formation of large amounts of manure. Livestock manure is widely used in agricultural practices as soil fertilizer worldwide. However, several antibiotic residues, antibiotic resistance genes (ARGs) and antibiotic-resistant bacteria are frequently detected in manure and manure-amended soils. This review explores the role of manure in the persistence and dissemination of ARGs in the environment, analyzes the procedures used to decrease antimicrobial resistance in manure and the potential impact of manure application in public health. We highlight that manure shows unique features as a hotspot for antimicrobial gene dissemination by horizontal transfer events: richness in nutrients, a high abundance and diversity of bacteria populations and antibiotic residues that may exert a selective pressure on bacteria and trigger gene mobilization; reduction methodologies are able to reduce the concentrations of some, but not all, antimicrobials and microorganisms. Conjugation events are often seen in the manure environment, even after composting. Antibiotic resistance is considered a growing threat to human, animal and environmental health. Therefore, it is crucial to reduce the amount of antimicrobials and the load of antimicrobial resistant bacteria that end up in soil.
Fourth One Health Analysis

Humans

Populations

Political, Social, Economic Factors: International/Global Food Security
Food Security: The Foundation of Civilization

- Food Security means no hungry people.
- Food Security is built on 3 pillars:
  - Food availability
  - Food access (affordability)
  - Food use
Food Security (Zero Hunger) United Nation’s #2 SDG
High food prices lead to civil unrest. People riot when food becomes unavailable. Civilization breaks down.

Where Meat Consumption Is Highest & Lowest

Total per capita meat consumption worldwide in 2014 (in kg)*

- 0–10
- 10–20
- 20–40
- 40–60
- 60–80
- 80–100
- 100–120
- No data

* 2014 is the latest year data is available. Excludes seafood.
Source: UN Food and Agriculture Organization via Our World in Data
Pros and Cons of Eating Meat

**Pros**
- Meat provides important micronutrients such as Vitamin B12 and iron.
- Evidence we evolved into modern humans because we hunted, cooked, and ate meat.
- Eating meat is an integral part of many religions and cultures.

**Cons**
- Meat is not essential if supplement diet with Vitamin B12 and other vitamins and minerals.
- Increases zoonotic spillover risks.
- Raising domesticated animals and/or hunting wild animals contaminates environments, ecosystems, and reduces biodiversity.
Global meat production

Source: UN Food and Agriculture Organization (FAO)
Eating Meat Is the Norm Almost Everywhere

Share of respondents who said they ate meat (in %)

- Japan: 96
- Russia: 94
- U.S.: 90
- Germany: 86
- Ø 39 Countries: 86
- China: 75
- India: 43

1,000-5,000 respondents 18-64 y/o per country surveyed Feb 2020 - March 2021
Source: Statista Global Consumer Survey
Changing National Dietary Preferences is Possible

More Americans Cutting Back On Meat Consumption

"In the past 12 months, have you been eating more, less or the same amount of meat?"

- More
- Same amount
- Less

U.S. adults:
- More: 72%
- Same amount: 23%
- Less: 5%

Men:
- More: 79%
- Same amount: 6%
- Less: 19%

Women:
- More: 65%
- Same amount: 31%
- Less: 4%

Why Americans Cut Back on Meat Consumption

Percentage of Americans responding on reasons why they ate less meat in 2019

- Major reason
- Minor reason
- Irrelevant

Health:
- Major reason: 70%
- Minor reason: 20%
- Irrelevant: 10%

Environment:
- Major reason: 49%
- Minor reason: 21%
- Irrelevant: 30%

Food Safety:
- Major reason: 43%
- Minor reason: 30%
- Irrelevant: 27%

Animal Welfare:
- Major reason: 34%
- Minor reason: 41%
- Irrelevant: 25%

Convenience:
- Major reason: 59%
- Minor reason: 24%
- Irrelevant: 16%

n=2,341 U.S. adults (Sept 16-30, 2019).
Source: Gallup

But Requires Cultural and Societal Change
Our One Health Analysis Findings

**One Health Factors:**

- Humans & Animals (Fecal Wastes)
- Plants (Fertilizers)
- Environments & Ecosystems (Water, Soil, Air) (Global Resistome)

**Complexity Factors:**

- Microbial & Populations
- Microbial & Populations
- Microbial & Populations

**Political, Social, Economic Factors:**

- International/Global Food Security
- Global Demand for Meat

**Time Factor:** Years
One Health Analysis Findings

• Human and domesticated animal populations are growing and producing increasing amounts of fecal matter each year.
• Animals produce 80 percent of global fecal matter, but it’s generally ignored.
• Human and animal fecal matter contain many pathogens, but sanitation systems are designed to process human waste.
• Little oversight of manure management in many middle- and low- income countries. Little oversight of CAFO manure management in the U.S.
• Plants need nitrogen, phosphorus, and potassium—which are contained in manure, but synthetic fertilizer use predominates.
• Manure management and agricultural soil management emit methane and nitrous oxide, potent greenhouse gases into the atmosphere worsening climate change.
• Manure risks contaminating the ‘Global Resistome’ which worsens AMR.
• These findings impact food safety and the practice of medicine as well as food security and the continuation of agriculture.
What can be done to reduce agriculture’s greenhouse gas contributions?
“One Health”

Recognizing that the main impact of antimicrobial resistance is on human health, but that both the contributing factors and the consequences, including economic and others, go beyond health, and that there is a need for a coherent, comprehensive and integrated approach at global, regional and national levels, in a “One Health” approach and beyond, involving different actors and sectors such as human and veterinary medicine, agriculture, finance, environment and consumers.5

Alignment with AMR global action plan

The goal of the AMR global action plan is: “To ensure, for as long as possible, continuity of successful treatment and prevention of infectious diseases with effective and safe medicines that are quality-assured, used in a responsible way, and accessible to all who need them”.

its five strategic objectives are:

Objective 1: Improve awareness and understanding of antimicrobial resistance through effective communication, education and training.

Objective 2: Strengthen the knowledge and evidence base through surveillance and research.

Objective 3: Reduce the incidence of infection through effective sanitation, hygiene and infection prevention measures.

Objective 4: Optimize the use of antimicrobial medicines in human and animal health.

Objective 5: Develop the economic case for sustainable investment that takes account of the needs of all countries, and increase investment in new medicines, diagnostic tools, vaccines and other interventions.

No Mention of Manure Management and Ecosystem Impact.
No mention of curtailing agriculture’s greenhouse gas emissions
Strategies to Reduce CH4 & N2O Emissions

**Manure Management:** Change the way manure is stored and handled; methane digesters capture and convert emissions into renewable energy.

**Agricultural Soil Management:** Avoid over-fertilization of soils, urea-based (low N) fertilizer use, subsurface drip irrigation, nitrification inhibitors, monitoring soil N, cover crops, no-till farming.

https://ucanr.edu/sites/Nutrient_Management_Solutions/stateofscience/Nitrous_Oxide__In_focus/
https://ucanr.edu/sites/Nutrient_Management_Solutions/stateofscience/Nitrous_Oxide__In_focus/#N2O%20management%20practices
California Senate Bill 605, Chapter 523 Short-lived Climate Pollutant Reduction Strategies, 2014

Senate Bill 605 (Lara, Chapter 523, Statutes of 2014) and Senate Bill 1383 (Lara, Chapter 295, Statutes of 2016) direct California Air Resources Board (CARB) to reduce dairy methane emissions by 40 percent by 2030.

Budget Act of 2014 allocated $12 million to support dairy methane reduction projects such as the Dairy Digester Research and Development Program—captures methane from manure to use as energy source.

Ricardo Lara, Democrat
Calif. Senate 2012-2019
Currently, Calif. Insurance Commissioner

https://ww3.arb.ca.gov/cc/shortlived/meetings/03142017/final_slcp_report.pdf
We must restore our beautiful planet.

One Health recognizes that life is interconnected.

• What can you do?
• Learn about One Health
• Spread the word
• Interdisciplinary colleagues
• Organize and be change agents
About this Course

Welcome to "Bats, Ducks, and Pandemics: An Introduction to One Health Policy".

One Health is the concept that human, animal, and environmental/ecosystem health are linked. The concept provides a useful framework for examining complex health issues such as food safety and security, emerging and vector-borne diseases, and antimicrobial resistance. It can be used to analyze government policies to determine if they are effective in improving health and well-being.

WHAT YOU WILL LEARN

- Define One Health and provide examples where the concept can be used
- Identify the components of an effective organization
- Investigate the politics of disease outbreaks—leadership, communication, health care access, and corruption

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Thank you! Questions?

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