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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
UNIVERSITÀ DI PISA

One Health Technologies in Agriculture

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One Health Technologies in Agriculture

- **Lecture Outline**

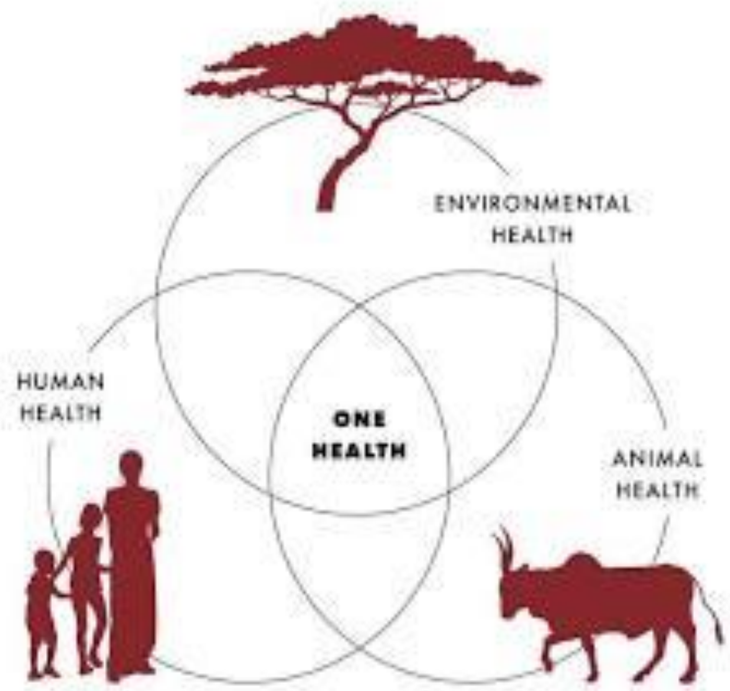
One Health Technologies in Agriculture

Definition & Core Principles

One Health in agriculture is an integrated and collaborative approach that recognizes the interconnected health of people, animals (domestic and wild), plants, and the environment (including ecosystems)

. This approach aims to sustainably manage these elements to address complex health challenges.

- **Integrated Approach:** It promotes collaboration among human health, animal health, agriculture, and environmental sectors, moving away from isolated efforts.
- **Broad Focus:** Modern One Health includes plant and soil health alongside human, animal, and environmental health.
- **Goal:** To prevent and respond to health threats while ensuring essential resources like clean water, energy, air, and safe food.


ENVIRONMENTAL HEALTH
HUMAN HEALTH
ONE HEALTH
ANIMAL HEALTH

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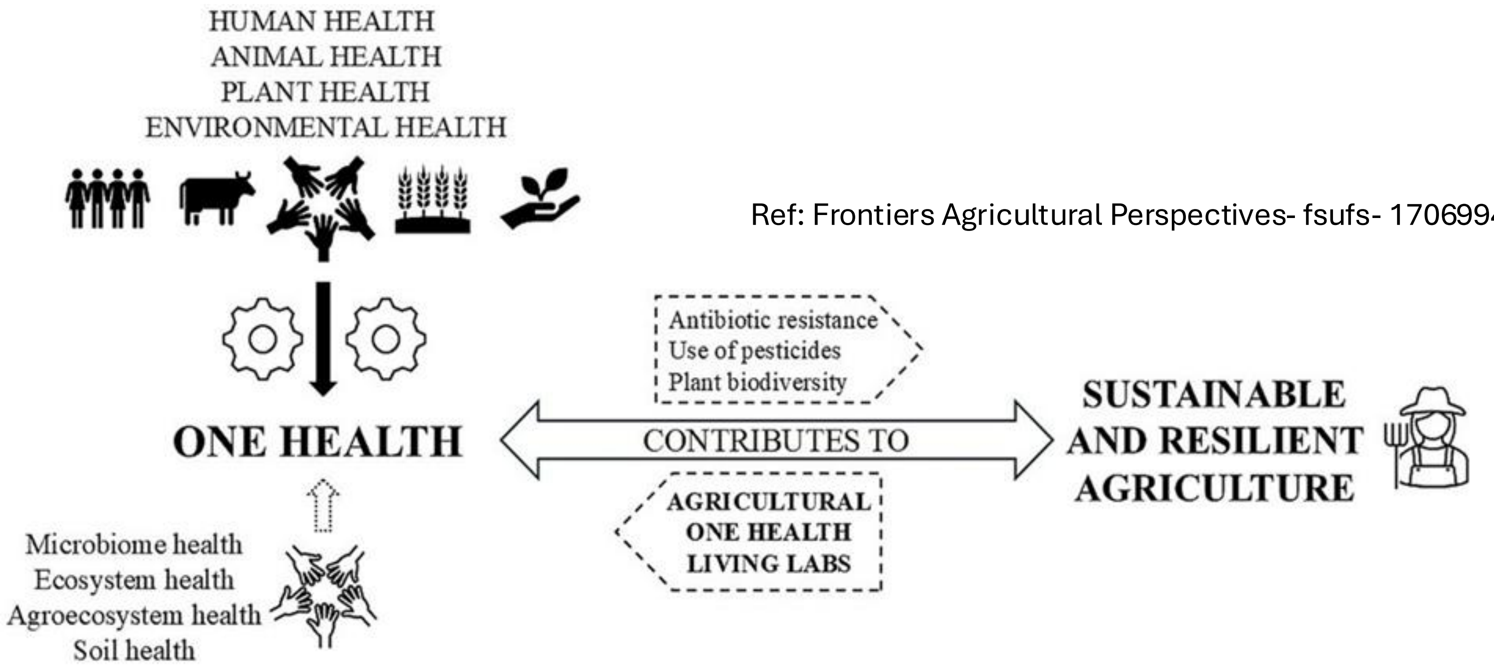
Introduction to One Health in Agriculture

Scope of One Health in Agriculture

- **Antimicrobial Resistance (AMR):** This is a key area, focusing on managing antibiotic use in livestock, aquaculture, and crops to prevent the spread of drug-resistant bacteria.
- **Zoonotic Diseases:** Works to prevent and control diseases transmitted between animals and humans, especially those linked to farming practices and habitat changes.
- **Food Safety and Security:** Aims for safe, sustainable, and resilient food production systems to reduce foodborne illnesses and improve nutrition.
- **Soil and Plant Health:** Addresses soil contamination and promotes practices like regenerative agriculture and integrated pest management to minimize chemical use.
- **Environmental Degradation & Climate Change:** Mitigates the health risks associated with land-use changes and climate change impacts on food production.
- **Vector-Borne Diseases:** Manages diseases spread by vectors like ticks and mosquitoes, which are increasing with changing temperatures in agricultural areas.

Interconnectedness



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- **Key Objectives in Agriculture and Drivers of Change**

1. **Sustainable Production:** Balancing farm productivity with environmental protection.

2. **Early Warning Systems:** Using shared data for predicting and responding to health outbreaks.

3. **Behavior Change:** Encouraging safer practices in farming and food handling

4. **The global human population** is increasing rapidly and the interactions of people, animals and the environment

Key One Health Challenges in Agriculture

- **Zoonotic Diseases and Spillover:** Over 75% of emerging infectious diseases originate from animals, with increased risks in intensive livestock systems and close human-animal interactions.
- **Antimicrobial Resistance (AMR):** The misuse of antibiotics in livestock production accelerates the spread of resistant bacteria, threatening both animal health and food safety.
- **Environmental Degradation and Climate Change:** Unsustainable practices lead to soil degradation, water scarcity, and biodiversity loss, which reduce ecosystem resilience and promote disease transmission.
- **Food Safety and Security:** Contamination of food products (e.g., from pathogens or chemicals) poses significant public health risks, exacerbated by poor sanitation in food supply chains.
- **Occupational Health Hazards:** Pesticide exposure and zoonotic pathogen contact endanger farmers and farmworkers.
- **Implementation and Governance Gaps:** Challenges include inadequate cross-sectoral collaboration, limited funding, and insufficient surveillance systems to detect and manage health risks early.

Zoonosis

- **Antimicrobial Resistance (AMR)**

. AMR refers to the fact that many pathogenic bacteria, fungi, parasites, and viruses do not longer respond to antimicrobial compounds.

. The transmission of antibiotic-resistant zoonotic pathogens between animals and humans

. Two main antibiotic-resistance routes of connection among the four health spheres: (i) antibiotics and their residues, as well as ARB and ARGs,

(ii) the microbiomes of livestock, manure, soil, crops, and humans are connected

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• Food Safety and Security

Food Safety (Protection from Illness)

- **Definition:** Measures taken across the food chain to ensure food is free from contaminants, toxins, or health risks.
- **Impact:** Unsafe food causes over 200 diseases, causing ~420,000 deaths yearly, with children under 5 bearing 40% of this burden.
- **The 4 Cs of Safety:** Cleaning (washing hands/surfaces), Cooking (proper temperatures), Chilling (safe storage), and preventing Cross-contamination.
- **Key Practices:** Using safe water, separating raw and cooked items, and proper food hygiene.

Food Security (Access to Nutrition)

- **Definition:** When all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs.
- **Four Pillars:** Availability, Access, Utilization, and Stability.
- **Challenges:** Poverty, conflict, climate change, and food deserts restrict access, making nutritious food unavailable or unaffordable.

- **Occupational Health Hazards**

- Pesticides in agriculture for Plant health but potential hazard to humans, animals and environment
- Workers involved in their application- use of PPEs

- **Environmental Degradation**

The deterioration of the environment through the depletion of natural resources

Key Causes

- **Pollution:-** Release of harmful chemicals, greenhouse gases
- **Deforestation:** Loss of forests reduces carbon sequestration.
- **Water Pollution:** Industrial waste, oil spills, and plastic contamination.
- **Atmospheric Degradation:** Depletion of the ozone layer and smog formation.
- **Land Degradation:** Soil pollution from fertilizers, pesticides, and mining

Major Impacts

- **Loss of Biodiversity**: Destruction of habitats leading to species extinction.
- **Climate Change**: Increased greenhouse gas emissions leading to global warming, sea-level rise, and glacier retreat.
- **Health Hazards**: Air and water pollution cause diseases and premature death.
- **Land and Water Degradation**: Soil erosion, desertification, and contamination of water bodies, compromising agricultural productivity.

Solutions and Mitigation

- **Sustainable Practices:** Reducing, reusing, and recycling; using sustainable agriculture; and limiting industrial emissions.
- **Conservation:** Protecting ecosystems, reforestation, and enforcing environmental laws.
- **Renewable Energy:** Shifting from fossil fuels to solar, wind, and geothermal energy to combat climate chang

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Technological Innovations for One Health Agriculture

• Digital Platforms and Integration

Unite disparate data sources into a single, cohesive system,

- enabling real-time analytics
- improved decision-making
- streamlined operations. They act as a central hub
- connecting applications, databases, and IoT devices, essential for digital transformation and overcoming data silos.

Common Data Integration Platforms
Leading solutions for integrating and managing data include:

- **Cloud & Enterprise Tools:** Microsoft Azure, Informatica, MuleSoft, and Oracle Data Integrator.
- **Specialized Platforms:** Boomi, SnapLogic, Talend, and Jitterbit.

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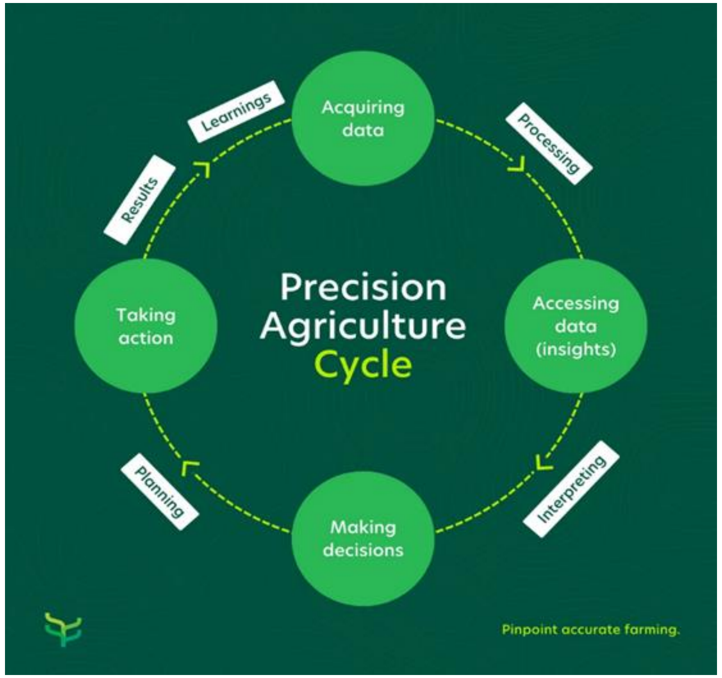
Precision Agriculture

Is a data-driven farm management approach using technology which enables farmers to apply inputs (water, fertilizer, pesticides) precisely where needed, optimizing yield, profitability, and sustainability.

Key Technologies Used:

- **GPS & GIS**: For mapping fields and guiding automated machinery like tractors.
- **Drones & Satellites**: Provide aerial imagery for monitoring crop health, stress, and growth patterns.
- **Sensors (IoT)**: Measure soil moisture, nutrient levels (pH, nitrogen), and crop characteristics (height, biomass) in real-time.
- **AI & Machine Learning**: Analyze data from sensors and imagery to create actionable insights and automate decisions.
- **Variable Rate Technology (VRT)**: Automatically adjusts application rates of inputs (seeds, fertilizer) within the field.

- **Precision Agriculture Cycle**



Molecular Technologies and Diagnostics

• Types

- **PCR (Polymerase Chain Reaction)**: Amplifies specific DNA sequences for precise identification of pathogens.
- **LAMP (Loop-Mediated Isothermal Amplification)**: A rapid, portable method allowing for field-based testing (Point-of-Care) without complex equipment.
- **Next-Generation Sequencing (NGS)**: Used for identifying novel pathogens and characterising plant microbiome.
- **ELISA (Enzyme-Linked Immunosorbent Assay)**: Detects proteins/antigens for fast, cost-effective screening.
- **Nano-biosensors and Microarrays**: Advanced tools for real-time monitoring of crop health and environmental monitoring.

Key Applications

- **Pathogen and Disease Detection:** Early identification of viruses, bacteria, and fungi before symptoms appear.
- **Pest and Resistance Management:** Identifying pesticide resistance to optimize chemical use and reduce environmental impact.
- **Molecular Breeding & Genetic Identification:** Screening for beneficial traits, GMO detection, and ensuring seed purity.
- **In-field Diagnosis:** Use of mobile-connected sensors and portable kits (e.g., smartphone-based diagnostics) for quick, on-site results.

• Uses in Animal Production

- **Health and Disease Detection:** Sensors monitor activity, feeding, and rumination (e.g., *CowManager*, *Smartbow*), allowing for early detection of health issues, often flagging illnesses before visible symptoms.
- **Reproductive Management:** Accelerometers on collars and tags are widely used to detect heat (estrus) to optimize breeding schedules, as shown in studies by *DairyNZ*.
- **Behavioral Monitoring:** Devices track, lying, walking, and grazing, providing insights into animal comfort and welfare.
- **Performance Tracking:** In addition to health, sensors can monitor milk production, feed intake, and weight.

Sensor types: Collars, Ear tags, Boluses and leg sensors

- **Benefits:** Increased, better animal welfare, and proactive health management.

- **AI and Big Data Analytics**

AI and Big Data Analytics combine machine learning with massive datasets to automate complex data processing, identify hidden patterns, and enable predictive decision-making. AI accelerates the entire data lifecycle, from ingestion and cleaning to analysis and visualization, transforming raw information into actionable insights. This synergy drives innovation across sectors like healthcare (disease diagnosis) and business (fraud detection, forecasting

Bioengineering and Biologicals

• Scope and Key areas of Application

Bioengineering applies engineering principles, design concepts, and technologies to biological systems, organisms, or materials to create functional, sustainable, and economically viable products

. This interdisciplinary field bridges engineering, life sciences, and medicine to improve healthcare, agriculture, and industrial processes, ranging from developing artificial organs to creating sustainable biofuels.

Key Areas and Applications

- **Tissue Engineering**: Developing synthetic or biological materials to repair, replace, or regenerate human tissues and organs.
- **Genetic Engineering**: Modifying organisms for agricultural, medical, or industrial purposes, including, for example, creating transgenic plants.
- **Bioprocess Engineering**: Utilizing cells and microorganisms for manufacturing, such as producing pharmaceuticals, food, and biofuels.
- **Biomedical Devices & Imaging**: Designing advanced diagnostic tools, prosthetics, and imaging technology to improve patient care.
- **Environmental & Agricultural Bioengineering**: Enhancing food production, waste management, and developing eco-friendly materials to reduce environmental impact.

Innovative Approaches & Methodologies

- **One Health Workers**

- interdisciplinary professionals—including doctors, veterinarians, epidemiologists, and environmental scientists—who collaborate to monitor, prevent, and control health threats at the human-animal-environment interface. They use a, shared, multisectoral approach to manage zoonotic diseases, antimicrobial resistance, and food safety, reducing risks before they impact human populations.

Block Chains for Traceability

- **Improved Transparency:** Provides a shared view for all stakeholders, allowing them to verify a product's journey instantly.
- **Immutability:** Data recorded on a blockchain cannot be altered, which builds trust and ensures security.
- **Efficiency:** Streamlines supply chain management, facilitating faster, more accurate audits and reducing fraud.
- **Applications:**
  - **Food Safety:** Tracking agricultural produce from farm to table to manage recalls and verify quality.
  - **Logistics:** Real-time, end-to-end monitoring of cargo, improving visibility.
  - **Compliance:** Assisting with regulatory compliance, such as EUDR in product exports.
  - **Technology Integration:** Frequently combined with IoT sensors for real-time environmental monitoring

- **Agroecology and Regenerative Agriculture**
- Are sustainable, nature-based farming approaches that aim to restore ecosystems, improve soil health, and enhance biodiversity while reducing reliance on external chemical inputs. While regenerative agriculture often focuses on technical practices like no-till and carbon sequestration, agroecology encompasses a broader, more holistic, and political,, movement, integrating social, economic, and ecological dimensions to create resilient food systems

Policy, Implementation, and Future Directions

- Policy Implications

- **Integrated Surveillance & Data Sharing:** Facilitate the sharing of data
- **AMR Regulation:** to curb the rise of AMR.
- **Resilience & Sustainability:** Incentivize "climate-smart" agricultural practices,
- **Investments in Technology & Capacity:** There is a need to invest in infrastructure
- **Food Safety Standards:** Enhanced regulations

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- **Implementation**

•**Operationalizing One Health** - Adopting the Quadripartite (FAO, UNEP, WHO, WOAH) One Health Joint Plan of
•which covers surveillance, food safety, and environmental integration.
•**Digital & Genomic Surveillance:** Directions are pointing toward using AI, digital platforms,
•and genomic sequencing for the rapid detection of pathogens at the livestock-wildlife-human interface.
•**"One Health" Agricultural Incentives:** Policies are increasingly favoring the adoption of
•regenerative agriculture and biodiversity-friendly farming practices to enhance ecosystem resilience.
•**Community-Based Approaches:** A major, emerging direction is the strengthening of "bottom-up"
•surveillance, such as training community-based animal health workers to act as "One Health" monitors.

- **Implementation**

- Operationalize One Health Joint Plan- FAO, WHO, WAOH and UNEP
- Digital & Genomic Surveillance
- One Health" Agricultural Incentives
- Community-Based Approaches
- Focus on Environmental Health
- Capacity building to train the next generation of professionals

Conclusion and Recommendations

- Take aways

- One Health is a practical framework for sustainable and resilient agriculture.

- Innovative technology must be paired with policy, education, and community involvement to achieve optimal global health.

- ***By adopting a One Health approach, agricultural systems can prioritize human well-being, animal welfare, and environmental conservation, ensuring sustainability for future generations***

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