CALL FOR SUBMISSIONS:

From Foresight to Field: Exploring regional and multistakeholder perspectives to implement a foresight on emerging technologies and innovations in agrifood systems

In 2023, FAO published the report “Harvesting change: Harnessing emerging technologies and innovations for agrifood system transformation”. The report explores the critical role of technology and innovation in transforming agrifood systems to address future challenges in the attempt to shorten the time lag between research and investment innovation phases and the uptake of technology and innovation, thus creating preparedness an ensuring inclusive, resilient, and sustainable agrifood systems transformation.

Since the global foresight synthesis report is published only in English, the OIN team has prepared the background document that is available in the six UN languages (Arabic, Chinese, English, French, Russian and Spanish). This document can serve as a reference for completing the template for submissions.

Please use this submission template to share your experience and views on the potential pathways of the agrifood system transformation at regional level.

The call for submissions is open until 03 June 2024.

For the necessary background and guidance, please refer to the topic note and the background document available at this call webpage. You can upload the completed form upon login to your account with the FSN Forum or, alternatively, send it to fsn-moderator@fao.org.
From Foresight to Field: Exploring regional and multistakeholder perspectives to implement a foresight on emerging technologies and innovations in agrifood systems

Template for submissions

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|-----------------------------------|
| What region are you from?         | ☒ Europe and Central Asia  
☐ Latin America  
☒ North Africa and Near East  
☒ Sub-Saharan Africa  
☐ Asia and Pacific  
☐ North America |
| Affiliation                       | ☐ Farmers and producer organizations  
☒ Research and academia  
☐ Government  
☐ Private Sector  
☐ Civil Society Organization  
☐ International Organization  
☐ Other (please specify) |

1. In the foresight synthesis report "Harvesting change: Harnessing emerging technologies and innovations for agrifood system transformation" (FAO and CIRAD, 2023), 20 emerging or pre-emerging technologies and innovations have been identified with highest potential to impact the agrifood systems from now to 2100. From those 20 innovations, select the three key technologies and innovations that have the potential to accelerate each of the following: a) inclusion; b) sustainability; and c) resilience.

The decrease in honeybee numbers caused by illnesses such as Varroa mites, Nosema, and Colony Collapse Disorder (CCD) presents a substantial risk to both world food security and biodiversity. Emerging technologies and developments have the potential to effectively regulate gene expression in honeybees, providing promising solutions to solve the difficulties at hand[1].

1. The study and use of biotechnology and CRISPR technologies.

The use of biotechnology, namely the CRISPR-Cas9 gene-editing technique, has the capacity to fundamentally transform the way honeybee illnesses are controlled. Scientists can boost the resilience of honeybee strains to infections by selectively targeting genes associated with illness susceptibility. This precise breeding technique has the potential to greatly decrease the need for
chemical treatments, which in turn can help foster a healthier and more sustainable beekeeping industry[2]–[4].
Utilizing this precise breeding technique can greatly diminish the need for chemical interventions, hence fostering a more robust and environmentally-friendly beekeeping sector[2]–[4].

### 2. Synthetic biology

Synthetic biology facilitates the creation and assembly of novel biological components and systems. Synthetic biology can be employed in honeybee health to develop probiotics or genetically modified microbes that can be put into honeybee colonies to bolster their immunity and ability to withstand infections. These helpful microorganisms can be engineered to create antimicrobial substances that specifically combat the pathogens that harm honeybees [5]–[7].

These advantageous microorganisms may be engineered to synthesize antimicrobial substances that particularly combat infections that impact honeybees[5]–[7].

### 3. Implementation of digital monitoring and early warning systems powered by artificial intelligence.

Utilizing digital monitoring tools and AI-driven early warning systems can be essential in effectively controlling the health of honeybees. Beekeepers may obtain real-time data on the health of their colonies by using sensors and cameras to continually monitor hive conditions and bee behavior. Artificial intelligence systems have the capability to examine this data in order to identify initial indications of illness, enabling prompt intervention. Implementing this preventive method can effectively avert disease outbreaks and significantly reduce colony losses [8]–[10].

Utilizing these developing technologies and innovations can greatly aid in the transition of agrifood systems by improving the incorporation, sustainability, and resilience of honeybee populations. Through the use of biotechnology, synthetic biology, and digital monitoring, we may control gene expression in honeybees. This can lead to the development of innovative methods to reduce the negative effects of illnesses on honeybees. By doing so, we can ensure the long-term viability of pollination services, which are crucial for world food supply.

| 2. In applying those emergent technologies and innovations, what would be the trade-offs and for whom if we advance: a) inclusion; b) sustainability; and c) resilience? How to minimize them while maximizing the benefits? |

The decrease in honeybee populations caused by diseases like Varroa mites, Nosema, and Colony Collapse Disorder (CCD) presents a major challenge to both global food security and biodiversity. New technologies and innovations show great potential in tackling these challenges by controlling gene expression in honeybees. Through the exploration of biotechnology, synthetic biology, and digital monitoring, we have the potential to create innovative methods that can improve the well-being and adaptability of honeybees.

**Exploring the Field of Biotechnology and CRISPR Technology:**

Biotechnology, specifically the CRISPR-Cas9 gene-editing technology, holds immense promise in transforming the way we address honeybee diseases. Through the focused identification of key genes associated with disease susceptibility, researchers have the potential to cultivate honeybee strains...
that possess heightened resilience against pathogens. This precise breeding method has the potential to greatly decrease the need for chemical treatments, which in turn can support a more sustainable and healthier beekeeping industry[3].

Trade-offs:

- Environmental and Ethical Considerations: Genetic modifications can give rise to ethical concerns and potential risks of unintended ecological consequences.
- Cost and Accessibility: Accessibility for small-scale beekeepers can be limited due to high initial costs and the requirement for specialized knowledge[11].

Minimizing Trade-offs:

- Implementing rigorous regulatory oversight and conducting thorough environmental impact assessments.
- Offering financial assistance and educational initiatives to promote equal access to biotechnological advancements.

The field of Synthetic Biology:

Through the field of synthetic biology, scientists are able to create and assemble novel biological components and systems. Within the realm of honeybee health, synthetic biology offers the potential to develop probiotics or engineered microorganisms that can be introduced into honeybee colonies. This can bolster their immunity and fortify their ability to combat diseases. Beneficial microbes have the potential to be engineered in a way that allows them to produce antimicrobial compounds that specifically combat the pathogens that harm honeybees[5].

Trade-offs:

- Potential Ecological Imbalances: The introduction of engineered microorganisms could potentially disrupt the delicate ecological balances that exist.
- Public Acceptance: Synthetic biology applications may encounter opposition from the public due to concerns regarding safety and ethics.

Minimizing Trade-offs:

- Performing comprehensive ecological studies and risk assessments prior to implementation.
- Interacting with the public and stakeholders to foster trust and comprehension of synthetic biology applications.

Digital monitoring and early warning systems driven by artificial intelligence:

The incorporation of digital monitoring tools and AI-driven early warning systems can have a significant impact on the management of honeybee health. Through the use of sensors and cameras, beekeepers can gather real-time data on colony health by closely monitoring hive conditions and bee behavior. AI algorithms have the ability to analyze this data and identify early signs of disease,
enabling prompt intervention. This proactive approach has the potential to effectively prevent disease outbreaks and significantly reduce colony losses [8]–[10].

**Trade-offs:**
- Technological Dependence: Relying too heavily on technology can result in vulnerabilities in the event of system failures or compromises.
- Data Privacy and Security: It is of utmost importance to prioritize the privacy and security of data collected through digital monitoring systems.

**Addressing Trade-offs:**
- Implementing strong cybersecurity measures and backup systems to ensure protection against failures:
- Establishing transparent data privacy policies and protocols to safeguard beekeeper data.

**In conclusion**
Utilizing these emerging technologies and innovations can greatly contribute to the transformation of agrifood systems by improving the inclusion, sustainability, and resilience of honeybee populations. Through meticulous consideration of trade-offs and a focus on inclusive, sustainable, and resilient approaches, we can devise innovative strategies to minimize the effects of diseases on honeybees. This will safeguard the long-term viability of pollination services, which are crucial for global food production.

3. What are the capacities needed, including at enabling environment level, and related gaps in generating, adopting and transferring new technologies and knowledge in the low and low-middle income countries (LMICs)? What should be the role of organizations like FAO?

In order to effectively generate, adopt, and transfer new technologies and knowledge in low and low-middle-income countries (LMICs), there are several key capacities that are crucial:

1. **Enhancing Research and Development (R&D) Capacity:** Low- and middle-income countries (LMICs) should focus on bolstering their R&D capabilities in order to create and customize technologies that are well-suited for their specific circumstances. This involves making investments in research institutions, equipping researchers with the necessary training, and ensuring they have access to funding and resources [12]–[14].

2. **Infrastructure and Resources:** Developing countries need up-to-date infrastructure, including laboratories, equipment, and digital connectivity, to effectively support research and development activities. In addition, having access to important resources such as funding, personnel, and expertise is vital [12].

3. **Policy and Regulatory Frameworks:** It is crucial to have well-designed policies and regulations in place to foster an environment that promotes innovation. This involves setting up precise guidelines for the adoption of technology, safeguarding intellectual property, and creating regulatory frameworks for emerging technologies.
4. **Knowledge Sharing and Extension Services**: It is crucial for LMICs to establish effective methods of sharing knowledge and providing extension services. This will ensure that farmers, beekeepers, and other stakeholders have access to the latest technologies and best practices.

Deficiencies in these abilities can impede the acceptance and dissemination of new technologies, especially in low- and middle-income countries. As an example:

1. **Limited R&D Capacity**: Developing countries often face challenges in terms of research and development infrastructure, funding, and expertise, which can hinder their ability to develop and adapt technologies that are suitable for their specific needs.

2. **Insufficient Infrastructure and Resources**: Low- and middle-income countries (LMICs) frequently face challenges in accessing modern infrastructure, resources, and funding. These limitations can impede research and development efforts as well as the adoption of new technologies.

3. **Ineffective Policy and Regulatory Frameworks**: Insufficient policies and regulations can hinder innovation, making it challenging for new technologies to be embraced and shared.

4. **Limited Knowledge Sharing and Extension Services**: In many low- and middle-income countries (LMICs), there is a lack of efficient methods for sharing knowledge and providing extension services. This creates difficulties in spreading new technologies and best practices to farmers and other individuals involved in the agricultural sector [12]–[14].

To address these gaps, organizations such as FAO can play a vital role in:

1. **Offering Technical Assistance**: FAO has the capability to provide technical assistance to LMICs in order to enhance their research and development capacities, infrastructure, and policy frameworks.

2. **Funding and Resource Mobilization**: FAO has the ability to secure funding and resources to assist with research and development efforts, as well as the development of infrastructure and the adoption of technology in low- and middle-income countries.

3. **Knowledge Sharing and Capacity Building**: FAO can support knowledge sharing and capacity building by offering training programs, workshops, and online platforms. These initiatives aim to empower farmers, beekeepers, and other stakeholders.

4. **FAO can offer policy and regulatory support to LMICs in order to establish a conducive environment for the adoption of innovation and technology [12]–[14].**

FAO can play a crucial role in assisting low- and middle-income countries (LMICs) in the development and implementation of new technologies to combat honeybee diseases. This involves bolstering R&D capabilities, infrastructure, and policy frameworks in LMICs through the provision of financial support, technical assistance, and knowledge exchange.

In the coming decade or two, Turkey is poised to witness significant advancements in the fields of new materials, proteins, and circular economy. This progress will be propelled by the growing
emphasis on sustainable practices and creative solutions to tackle issues in different sectors, such as the beekeeping industry.

The application of cutting-edge technologies and advancements to create innovative methods for controlling gene expression in honeybee diseases is in line with the emphasis on new materials, proteins, and circular economy. Through the utilization of genomics, disease resistance, and sustainable practices, Turkey has the potential to improve the well-being and efficiency of honeybee populations. This would greatly contribute to the preservation and long-term viability of the beekeeping industry [15].

In addition, focusing on circular economy principles, such as reducing waste, optimizing resources, and promoting environmental sustainability, can foster innovative approaches to managing honeybee health and developing new products. This comprehensive approach has the potential to enhance the efficient use of resources, minimize negative effects on the environment, and guarantee the sustainability of the beekeeping industry.

The incorporation of cutting-edge technologies and the adoption of circular economy principles in the beekeeping sector have the potential to bring about a significant transformation in various aspects of honeybee well-being, disease control, and the overall quality of honeybee products. Through the implementation of sustainable methods and the introduction of creative solutions, Turkey has the potential to become a frontrunner in advocating for eco-friendly and economically sound practices in beekeeping. This would greatly benefit the well-being of honeybee populations and ensure the long-term viability of the industry [15].

5. What are the 3 most important triggers of change (hypothetical future events, positive or negative), which could potentially enable rapid development of emerging technologies and innovations in your region? Please consider the following:

- Advancement of other technologies. Which ones?
- Societal consensus and higher ethical standards
- Removed barriers for adoption
- Governance and business environment
- Rapid acquiring of skills/human capital
- Open and trustworthy communication
- Other

In the field of utilizing emerging technologies and innovations to create new methods for controlling gene expression in honeybee diseases, there are three key factors that are essential for facilitating rapid progress in Africa, Asia, and Turkey:

1. **Progression of Other Technologies Cause:**

AI-driven Monitoring Systems have proven to be highly effective in real-time hive monitoring and predictive disease modeling. These systems have the ability to detect diseases in honeybee populations at an early stage, allowing for timely intervention and minimizing the impact on the bees [8]–[10].
2. Societal Consensus and Elevated Ethical Standards

Gene editing technologies have the potential to enhance honeybee resilience against diseases, contributing to ecological balance and sustainability. By adhering to higher ethical standards and gaining public support, we can ensure the responsible application of these technologies [5].

3. Efficient Acquisition of Skills/Human Capital

Experienced Beekeepers and Researchers: By equipping our workforce with advanced biotechnological and digital monitoring techniques, we can effectively implement innovative methods to regulate gene expression in honeybee diseases. This will ultimately lead to improved hive health and productivity, as highlighted by the FAO and CIRAD in 2023.

The rapid development of emerging technologies and innovations in Africa, Asia, and Turkey can be greatly impacted by the progress made in AI and machine learning, the societal agreement and ethical principles surrounding biotechnologies, and the swift acquisition of necessary skills and human resources. These triggers can facilitate advancements in the application of technologies such as CRISPR and synthetic biology to create innovative methods for controlling gene expression in honeybee diseases. This, in turn, promotes the adoption of sustainable and resilient beekeeping practices.

6. From the five global scenarios, identified in the report, which future scenario is the most plausible in your region/country and why? Please, mention the name of the country in your response.

Turkey appears to be heading towards a future of "Regulated Efficiency," in line with its policies, technological capabilities, and priorities. With the help of advanced technologies such as biotechnology and digital monitoring, Turkey has the potential to tackle honeybee diseases and strengthen agricultural sustainability.

In the scenario of the "Biotech Revolution," gene expression in honeybee diseases is regulated through biotechnology. This utilizes cutting-edge technology to enhance food production and promote sustainability.

1. Controlled Biotechnology:

Turkey has the potential to utilize CRISPR gene editing to develop disease-resistant honeybees, while adhering to stringent regulations[3]. Through advanced sequencing techniques, scientists can now identify specific genetic markers that are crucial for disease resistance, productivity, and other desirable traits. This breakthrough in technology has greatly assisted in the field of breeding and has opened up new possibilities for improving crop yields and overall agricultural productivity. Studying hygienic behavior is crucial for maintaining the health of a colony, and genome-wide DNA analysis plays a key role in this research.
This scenario is in line with Turkey’s honeybee conservation efforts, where they have been actively registering various subspecies. By embracing biotech, Turkey enhances its capabilities in this field.

2. Utilizing digital monitoring: Turkey has the opportunity to employ digital systems to monitor the health of honeybees and swiftly detect disease outbreaks, thereby reducing potential losses [8]–[10]. Adhering to regulatory standards guarantees the precision of data, safeguards privacy, and enhances disease management.

3. Support for Synthetic Biology: Probiotics can be developed through synthetic biology to enhance honeybee immunity. Regulation is crucial for ensuring the safety of bees and the environment, as highlighted by Keasling (2010)[5].

It appears that Turkey is poised for a potential revolution in the field of biotechnology, with a particular emphasis on utilizing cutting-edge technology to combat honeybee diseases by regulating gene expression. With the expertise of a microbiologist, Turkey is making significant strides in honeybee conservation and breeding, while also exploring the potential of biotechnology. These efforts bring a glimmer of hope for the future of honeybee populations.

7. What does this foresight synthesis report and its recommendations mean for your country and your region? How to implement them? What actions diverse stakeholder groups have to take (policy makers, farmers, researchers, private sector, civil society etc.)?

The foresight synthesis report "Harvesting Change" suggests that stakeholders in Turkey should collaborate to harness emerging technologies in order to regulate gene expression in honeybee diseases.

**Policymakers:** It is important for policymakers to consider the adoption of emerging technologies, such as biotechnology, in honeybee research. By developing policies that support the integration of these technologies, we can enhance our understanding of honeybee populations and their impact on the environment. In order to achieve their goals, it is crucial for them to ensure sufficient financial resources and promote partnerships with organizations from around the world [16].

It is important for farmers and beekeepers to actively participate in data collection, utilize creative approaches to regulate gene expression, and work closely with researchers and policymakers in order to effectively tackle the challenges faced by the industry [17].

Scientists should utilize advanced techniques such as next-generation sequencing to identify genetic markers associated with disease resistance. It would be beneficial for them to consider techniques such as genome editing and foster international collaboration.

The private sector has a crucial role to play in investing in research, developing products that support beekeeping, and fostering collaboration to tackle the challenges faced by the industry.

It is important for civil society to actively promote awareness, support research initiatives, and advocate for policies that encourage the adoption of technology.

By implementing these recommendations, Turkey can develop effective strategies for regulating gene expression in honeybee diseases. This will not only support the preservation of bee populations, but also enhance industry productivity in the face of various challenges[17].
8. What will be the technologies and innovations the most likely to bring about gender equality in the agrifood systems? Can social norms be tackled to merge the gender divide and how?

Technologies and ideas that address women’s core challenges can enhance gender equality in agrifood systems. They should also confront and change gender-distributive social norms. Important technologies and innovations include[18].

1. **Digital technologies and platforms**: Mobile phones, the internet, and e-commerce platforms empower women economically and socially by providing access to information, markets, and financial services [19]. However, acknowledging the digital gender difference and ensuring women have equal access to digital technology and abilities is crucial.

2. **Gender-responsive agricultural innovations**: Climate-smart technology, automation, and post-harvest management should take women’s needs into account. This includes considering women’s workloads, resources, and family and community decision-making authority[20].

3. **Gender-transformative extension and advisory services**: Extension services must be inclusive and sensitive to women farmers. This might involve hiring more female extension agents, providing gender-sensitive training, and incorporating men and women in family concerns.

4. **Gender-responsive financing and value chain integration**: Women need better access to credit, savings, and insurance. For gender equality and economic empowerment, women must be included in value chains at all levels. Their engagement as producers, processors, and entrepreneurs allows them to access markets and get fair rates[21].

A comprehensive plan is needed to address societal norms and close the gender gap:

1. **Involving men and boys**: Men and boys should be allies in gender equality. This may entail working with community leaders, religious organizations, and schools to combat harmful gender stereotypes and promote healthy masculinity [21].

2. **Empowering women’s voice and agency**: Education, leadership training, and decision-making chances are essential. This involves home, community, and beyond engagement.

3. **Promoting gender equality in agrifood systems**: Policies and institutions must be gender-responsive. This might include gender-responsive budgeting, land and resource rights protection, and policy-making engagement by women [21].

4. **Fostering partnerships and collaboration**: Governments, civil society organisations, business sector players, and research institutions must engage together to promote gender equality in agrifood systems[22].

Women must be prioritized in the development and implementation of honeybee disease gene expression regulation technologies and advances. It ensures a more complete and diversified research strategy. This might involve integrating women beekeepers and researchers, eliminating gender-specific impediments, and distributing innovative gains equally.
9. How do you envision the role of women in innovation in the next 10, 20 and 50 years?

Women are projected to lead innovation in the future decades, notably in leveraging new technology and concepts to regulate gene expression to reduce honeybee illnesses. Here’s my view on their role: Women in STEM areas will expand significantly in the coming decade. Specialized education and mentorship, especially in biotechnology and genetics, will enable this [11], [23].

Female researchers can develop honeybee gene expression regulation technologies. Genome-wide DNA analysis can discover disease-resistant and desirable characteristics [16]. Innovative honeybee health and productivity enterprises will be founded by women entrepreneurs. Their unique ideas and remarkable problem-solving skills will drive cutting-edge technology and solution [24].

We may anticipate the gender gap in invention and creativity to shrink in 20 years. By 2041, current trends predict that 50% of innovators will be women [11].

- Women are expected to influence the marketing and uptake of honeybee gene expression technology. Their participation will make these advancements available to beekeepers of all sizes and backgrounds, benefiting the industry [23], [24].
- Collaborative networks and collaborations involving women innovators, academics, and beekeeping stakeholders will generate holistic honeybee health and sustainability solutions [16], [24].

In 50 years, gender parity in invention and creativity is expected by 2061. Women will contribute equally to the creation of innovative technology and solutions in all fields, including honeybee health [11].

- Innovation and transformation in the beekeeping business and beyond will be attributed to women’s web thinking, social skills, and long-term planning [24].
- The accomplishments of women inventors will be recognized, inspiring future generations of girls and women to pursue STEM jobs and entrepreneurship [11].

Women will help create novel honeybee illness gene expression regulation tactics using cutting-edge technology and breakthroughs. Their efforts might transform the beekeeping sector and protect honeybee numbers. This has major ramifications for ecological equilibrium and global food production.

**Link(s) to specific references**

Please include attachment(s) or add here link(s) to documents with specific references.


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