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SKILLS FOR SMART SPECIALISATION IN MONTENEGRO

Aligning skills, technologies and productivity in the 'Sustainable Agriculture and Food Value Chain' priority domain

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Authors: Pirita Vuorinen (ETF), Benjamin Torić (local expert)

Peer reviewer: Cristina Mereuta (ETF)

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EXECUTIVE SUMMARY

Montenegro's *Agriculture and food value chain* domain has strong foundations in traditional production and food processing, but competitiveness and productivity are increasingly constrained by skills shortages, slow diffusion of digital and green technologies, and limited technician-level capacity.

Smart specialisation, as an EU innovation policy approach designed to boost economic competitiveness, requires a clear strategic focus. Achieving its objectives depends on on prioritising a small number of high-impact technology clusters, addressing core skills bottlenecks, and mobilising the skills ecosystem.

Top 3 high-impact technology clusters

Food processing technologies

Modern processing systems, pasteurisation, fermentation, food standards and quality management

Digital, smart agriculture and traceability technologies
Sensors and IoT, drones, disease detection, predictive analytics, computer vision, smart irrigation, digital traceability, early-stage robotics

Sustainability and circular-economy technologies
Organic and traditional production, biofertilisers and biopesticides, biomass and waste-to-value solutions, green packaging

Core skills bottlenecks

Severe shortages of mid-level technicians and operators

Food processing technicians, quality-control staff, maintenance workers, digital agriculture technicians and environmental technicians are in short supply. These profiles are critical for operating processing lines, sensors, IoT devices, traceability systems and basic automation.

Weak practical and job-ready skills

VET and higher education programmes remain overly theoretical. Limited hands-on exposure to modern equipment, digital tools and real production environments.

Insufficient digital and data skills at operational level

Many producers lack basic competences to read dashboards, interpret alerts, manage traceability data and use monitoring tools. This constrains scaling of smart agriculture pilots.

Limited sustainability and circular-economy competences

Skills related to waste management, biomass use, environmental compliance and One-Health practices remain fragmented and underdeveloped.

Underdeveloped adult learning and re-skilling pathways

Heavy reliance on informal, company-based training with little certification or recognition. Lack of short modular courses and micro-qualifications slows upskilling

Three priority action areas

1. **Priority action area 1: Upgrade food processing through strengthened operational and technical skills**

Focus on HACCP, hygiene routines, quality assurance, processing-line operation and equipment maintenance. Build a continuous pipeline of job-ready food processing technicians.

Roles across the skills ecosystem:

- **VET providers:** Make processing and food safety competences core curriculum content; expand work-based learning.
- **Higher education:** Strengthen applied food technology and engineering, pilot plants and industry projects.
- **Adult learning & BSOs:** Deliver certified short courses, fast-track requalification and on-site advisory support for SMEs.

2. **Priority action area 2: Accelerate digital and data-driven operations through targeted smart-agriculture skills**

Start with scalable, low-complexity technologies (sensors, IoT, traceability). Build technician-level competences in data recording, basic analytics, device operation and monitoring. Use digitalisation to increase the attractiveness of agriculture careers.

Roles across the skills ecosystem:

- **VET providers:** Embed compulsory digital modules; establish school-based demo sites and field trials.
- **Higher education:** Introduce interdisciplinary agritech modules linking agriculture, ICT and engineering; expand applied research and labs.
- **Adult learning & BSOs:** Scale hands-on short courses, demonstration farms, peer learning and continuous advisory services linked to investment support.

3. **Priority action area 3: Strengthen sustainability and circular-economy skills to scale high-value organic, traditional and tourism-linked production**

Develop practical skills in organic production, waste-to-value, biomass use, environmental compliance and One-Health. Link agriculture and tourism for high-value niches suited to small producers.

Roles across the skills ecosystem:

- VET providers: Integrate sustainability, circular practices and agritourism into core training with hands-on learning.
- Higher education: Develop interdisciplinary modules linking agriculture, environment, energy and tourism; support applied research.
- Adult learning & BSOs: Provide modular training, demonstration projects, cooperative models and local cluster facilitation.

Key message for decision-makers

Montenegro's competitiveness depends on a focused skills agenda prioritising technician-level capacity, practical training and targeted technology adoption. The quickest gains come from upgrading food processing skills. Digitalisation should scale gradually through simple tools (sensors, IoT, traceability) supported by basic skills and advisory services. Sustainability competences are key for value creation, especially in organic and tourism-linked niches. Skills systems need to become more flexible, practice-oriented and collaborative.

1. INTRODUCTION

1.1 The agri-food sector in Europe's competitiveness and green transition

Food is a cornerstone of Europe's competitiveness. The EU is the world's largest agri-food exporter, with a steadily growing trade surplus. The agri-food sector generated an estimated €900 billion in gross value added (Eurostat, 2024) and is dominated by small and medium-sized enterprises, which account for over 99% of businesses. The broader agri-food system still employs over 30 million people, mostly beyond primary production (Eurostat, 2024). Beyond its economic weight, agriculture and food remain central to employment, trade, food security and rural vitality across Europe, even as economies develop.

The sector is strategically critical but increasingly exposed to systemic risks. Recent geopolitical shocks, including Russia's invasion of Ukraine and conflicts in the Middle East, have revealed vulnerabilities in food supply chains through higher energy and fertiliser prices. While the EU food system has shown resilience, persistent geopolitical tensions, climate change and structural pressures threaten long-term viability and strategic autonomy. Food and agriculture are recognised as critical for Europe's defence readiness, with EU-level action - particularly through the Common Agricultural Policy - remaining essential to safeguard food sovereignty and ensure access to safe, high-quality food.

Technology is central to food security, productivity and competitiveness, but adoption remains uneven. Smart farming technologies, combining AI, automation and the Internet of Things through sensors, robotics, data analytics and predictive modelling, are transforming crop and livestock management by improving decision-making, productivity and sustainability. Digitalisation is accelerating across the agri-food sector in response to rising input costs, labour shortages and growing consumer demand for transparency and sustainability. However, adoption remains uneven, particularly among small producers, due to high investment costs, limited access to high-quality data, interoperability challenges and regulatory uncertainty (Rauch, B et al 2025). In organic farming, digital tools such as blockchain are increasingly used to strengthen traceability and consumer trust (ETF, 2025).

Structural change and demographic pressures are reshaping the sector. The number of farms continues to decline. In 2020, the EU counted 9.1 million farms managing 1.55 million km² of land, around 38% of the EU's territory (Eurostat, 2025). Between 2005 and 2020, the number of farms fell by 5.3 million (37%), with small farms under 5 ha accounting for 87% of this decline. Farmers under 40 manage only 12% of EU farms (EC, 2025) and tend to operate larger holdings (31%) and have higher levels of agricultural training (21.4 % vs 3.6 % for over 65-year-olds), including exposure to innovative and climate-neutral practices such as organic and agroecological farming (Eurostat, 2022). Although the share of women farm managers rose from 26.4% in 2005 to 31.6% in 2020 (Eurostat, 2022), young female farmers represent only 3% of farm managers under 40 (EC, 2025). Competitive pressures to scale up or exit the sector contribute to broader rural-to-urban migration trends and weaken the long-term competitiveness of small and medium-sized producers. However, generational renewal remains weak, with young farmers under-represented and gender imbalances persisting (EC, 2025). These trends limit investment capacity, slow innovation and weaken the long-term sustainability of rural communities.

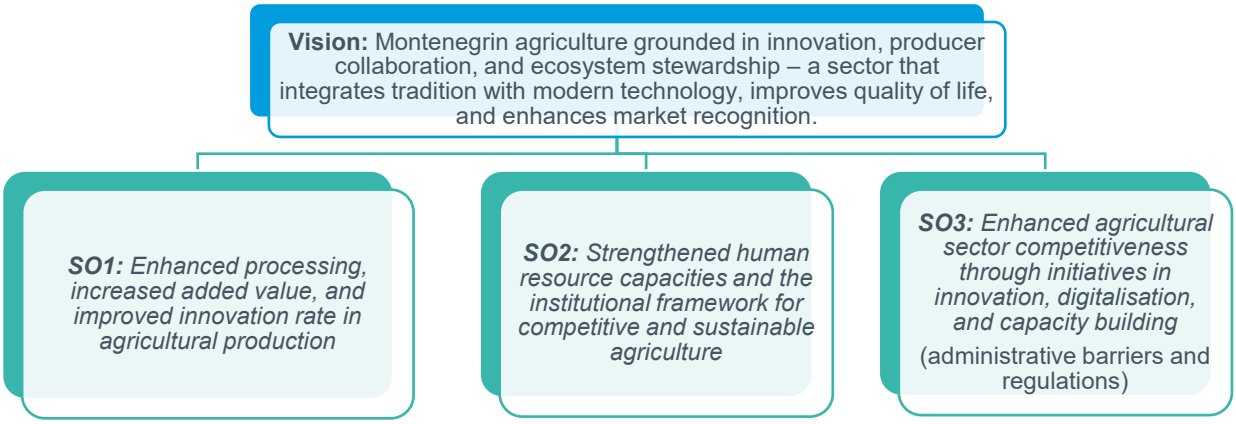
1.2 Montenegro's smart specialisation context and policy objectives

Montenegro is preparing its second Smart Specialisation Strategy for the period 2026–2031. Within this process, the European Training Foundation (ETF) has been requested to provide analytical support focused on identifying skills needs for the implementation of the strategy. This includes identifying skills needs for strengthening productivity, competitiveness, and technology adoption, while ensuring alignment with European policy priorities, including the Competitiveness Compass and the Union of Skills.

The scope of the analysis was defined around the objectives for smart specialisation defined through the Entrepreneurial Discovery Process (EDP) which was conducted in compliance with the smart specialisation methodological framework and the European Commission's EDP guidelines. In addition to the European Commission's EDP guidelines, the process was carried out in line with the *Methodology for Policy Development, Drafting and Monitoring of Strategic Planning Documents* prescribed by the Secretariat-General of the Government of Montenegro.

The Entrepreneurial Discovery Process (EDP) resulted in the definition of the following vision, strategic objectives and operational objectives in the priority domain *Sustainable Agriculture and Food Value Chain*.

Figure 1. Vision and the strategic objectives of the priority domain Sustainable Agriculture and Food Value Chain



Source: Bole D, al (2026), Final report on the Entrepreneurial Discovery Process (EDP) implemented in the preparation of the smart specialisation strategy 2026-2031.

During the Inception phase, the specific focus areas for the priority domain were clarified as outlined in Table 1.

Table 1. Sustainable Agriculture and Food Value Chain: Priority domains and sub-sectors for the analysis

Sub-sectors	NACE Codes (In-Scope)	Out-of-Scope
I level of priority Viticulture and wine production Cultivation of olives and oil production Cultivation of permanent crops (fruit and others) Dairy products Animal farming and meat products II level of priority Food safety and standards	A01.1 - Growing of non-perennial crops A01.2 - Growing of perennial crops A01.4 - Animal production C10.1 - Processing and preserving of meat and production of meat products C10.3 - Processing and preserving of fruit and vegetables C10.4 - Manufacture of vegetable and animal oils and fats C10.5 - Manufacture of dairy products and edible ice C11.02 - Manufacture of wine from grape	Fisheries Arable crops

Source: Erre Quadro

1.3 Analytical logic and methodology: from technologies to skills and occupations

The ETF's analytical contribution focuses on three interrelated dimensions that together provide a comprehensive understanding of the technological and skills transformation required in the *Sustainable Agriculture and Food Value Chain* priority domain. The analytical framework is designed to link global technological developments with Montenegro's national context and to translate these insights into evidence on emerging skills and occupational needs. All stages of the analysis were informed by extensive stakeholder consultations, ensuring close alignment with sector realities and national priorities.

The first analytical dimension concerns **innovation dynamics**. This dimension examines global technological developments shaping the agriculture and food value chain through the analysis of more than 30 years of worldwide patent data. The use of global patent evidence is particularly important given Montenegro's position as a small, predominantly technology-adopting economy, where most innovations influencing domestic production and processing originate outside the country. The patent analysis enables the identification of major technological trends, growth trajectories and potential disruptors across the domain, and provides a forward-looking perspective on technologies likely to influence productivity and competitiveness in the short to medium term.

The second dimension focuses on **technology adoption readiness**. Global innovation trends do not automatically translate into national uptake. To address this gap, the analysis assesses Montenegro's readiness to adopt and deploy identified technologies by comparing global developments with national capabilities, institutional maturity, regulatory conditions and existing industry practices. This assessment applies a four-level readiness scale (low, increasing, high and stabilising) and draws on expert analysis, desk research and three rounds of stakeholder consultations. Readiness scores therefore reflect Montenegro's capacity to absorb, operate and scale external technologies, rather than domestic innovation output.

The third dimension examines **skills implications** arising from technological change. Building on the identification of priority technologies and readiness levels, the analysis applies ESCO-based semantic matching, supported by proprietary tools, to link technologies with relevant skills, competences, knowledge areas and occupational profiles. This approach makes it possible to identify skills likely to experience demand growth, highlight emerging or hybrid occupational profiles, and detect potential mismatches between technology adoption and workforce capacity. As with the readiness assessment, results were validated through expert input and stakeholder consultations to ensure their relevance for the Montenegrin labour market.

While these three dimensions structure the analytical work, the report presents its findings in two main analytical steps, reflecting how evidence is organised and used throughout the report. First, an analysis of global patent trends combined with technology-readiness scoring identifies priority technologies and assesses Montenegro's capacity to adopt and deploy them in the *Sustainable Agriculture and Food Value Chain* domain (Chapter 2). Second, the skills and occupations associated with these technologies are identified (Chapter 3). Finally, the findings are translated into priority action areas and measures to operationalise smart specialisation through skills development and ecosystem mobilisation (Chapter 4). The recommendations were developed through a structured and iterative process that combines all analytical dimensions with extensive stakeholder consultations, ensuring close alignment with sector realities and a focus on producing actionable measures for integration into the national Smart Specialisation Strategy and its Action Plan.

This approach ensures a coherent progression from global technological developments to national adoption capacity and, ultimately, to the skills, occupations, and implementation measures required to deliver Montenegro's smart specialisation objectives.

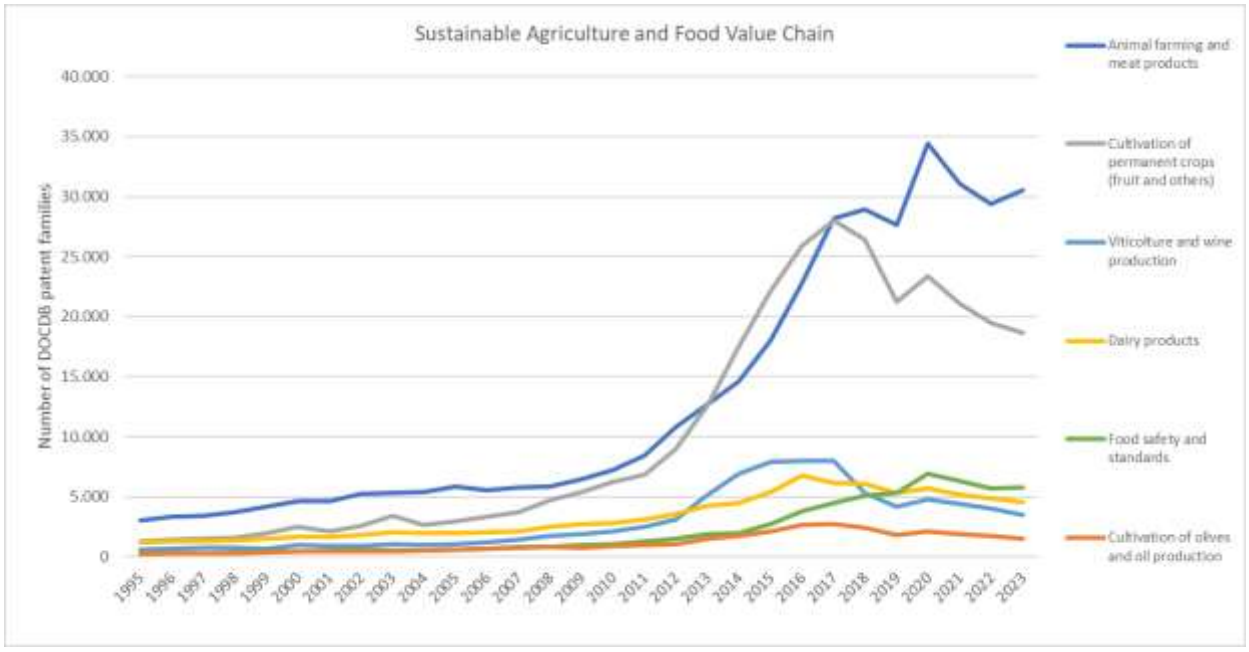
2. TECHNOLOGICAL DEVELOPMENT IN THE 'SUSTAINABLE AGRICULTURE AND FOOD VALUE CHAIN' PRIORITY DOMAIN

To achieve the long-term vision and strategic objectives for smart specialisation outlined in Figure 1, Montenegro will need to adopt and scale technologies that strengthen productivity, support the green and digital transition, and increase value added across the *Agriculture and food value chain* domain. This requires improving processing efficiency, enhancing traceability and sustainability practices, and building the human, digital and institutional capacities needed to absorb and operate new technologies. Chapter 2 therefore reviews the global technological landscape and assesses Montenegro's readiness to adopt relevant technologies, highlighting those most important for advancing smart specialisation objectives and the key barriers that continue to limit wider uptake.

2.1 Global patent trend analysis

For this analysis, more than **1.2 million patent documents worldwide** were examined for the period **1995–2025**, focusing on the identified sub-sectors in the *Sustainable Agriculture and Food Value Chain* domain (see Introduction in Chapter 1). In contrast, only **56 Montenegrin patents** were identified during the same period, mostly related to viticulture and fungicidal solutions and primarily generated by individual inventors. This confirms that Montenegro is predominantly **a technology-adopting, rather than technology-developing, economy** in the agrifood domain.

Figure 2. Time series of patent families' filings in the Sustainable Agriculture and Food Value Chain domain



Source: Erre Quadro's own elaboration

A first methodological consideration concerns the fact that certain subsectors are not fully mutually exclusive. For instance, the subsector *Cultivation of permanent crops (fruit and others)* partially overlaps with *Viticulture and wine production* and *Cultivation of olives and oil production*, as olives and grapevine are indeed permanent crops, and as reflected in the size and composition of the corresponding patent sets.

A second important consideration is that many patents may have been drafted to protect a technical solution that, while applicable to a specific crop (e.g., olive cultivation), is in practice relevant to Agriculture more broadly. This may influence the apparent distribution of patents across subsectors and should be considered when interpreting recent trends.

Against this backdrop, the analysis shows that *Animal farming and meat products* is characterized by both rising patent volumes and a strong upward trend. Conversely, *Cultivation of permanent crops (fruit and others)*, despite its overall high patent volume, reached a peak in 2017 and has subsequently followed a downward trend.

Finally, the subsector *Food safety and standards*, although smaller in scale, displays a steadily increasing growth trajectory, underscoring its emerging relevance in the broader agricultural innovation landscape.

2.2 Technology readiness scoring and local relevance

The identified technologies in each subsector were ranked using a **Global Score** that combines patent volume, growth rate and the strategic relevance of the corresponding subsectors. High-scoring technologies represent widely researched innovations with rapid growth driven by significant R&D investment and are therefore most likely to achieve widespread adoption and shape future skills demand. Lower-scoring technologies (below 0.5) remain relevant either because they are established but require updated skills, or because they are early-stage innovations with longer-term potential.

To complement the patent analysis, Montenegro's **readiness** to adopt each technology was assessed using expert insights and stakeholder consultations, supported by desk research, EU policy reviews, and available proxy indicators. This resulted in a four-level *Readiness Score*: low (), increasing (°), high (°°), and stabilizing (°°°).

Together, these two assessments provide a structured lens for identifying the technologies most relevant for Montenegro and understanding their potential contribution to the country's vision and strategic objectives.

Table 2 presents the full list of identified technological concepts. A small number of non-technological entries, *Food standards (HACCP) & Quality management* and *SEO & Marketing*, are included for completeness and marked with the tag "N.T." at the bottom of the ranking.

Table 2. Emerging technology and innovation clusters for Sustainable Agriculture and food value chain sector.

Technological and Innovation Concepts	Global Score	Readiness Score
Predictive Analytics	1.000	°°
Digital Traceability Solutions	0.909	°
Sensors & IoT	0.902	°°
Food processing	0.882	°°°
Waste Management & Material Reuse	0.855	°
Fermentation	0.848	°°°
Smart Irrigation	0.838	°°
Computer Vision & Image processing	0.837	°°
Agbot /Agrobot	0.833	

Technological and Innovation Concepts	Global Score	Readiness Score
Remote sensing technologies	0.786	°°
Bio-digesters & Biomass	0.762	°°
Drones	0.728	°°
Smart Weather Protection Systems	0.683	°
Functional Food	0.645	
Biofertilizer	0.643	°
Livestock Precision Monitoring	0.626	°
Disease Detection	0.590	°°
Plant-Based Dairy & Meat Alternatives	0.587	
Pasteurization	0.577	°°°
Synthetic Meat	0.524	
Genetic Engineering	0.511	
Biopesticide	0.472	°
Organic farming	0.458	°°
Vertical Farming	0.445	
Cold Chain Monitoring	0.428	°
Green Packaging	0.373	°
Agro bacterium	0.351	°
Chemical Traceability Solutions	0.147	
Food standards (HACCP) & Quality management	N.T.1	°°°
SEO & Marketing	N.T.	°°

Source: Erre Quadro's own elaboration

Digital technologies lead globally and show high readiness in Montenegro's strongest niches. Digitalisation is transforming agriculture worldwide through predictive analytics, digital traceability, sensors, computer vision and smart irrigation. Montenegro shows high readiness in these technologies where digital viticulture and pilot projects already operate, proving that local capacity exists for advanced data-driven approaches. This strong niche capability reflects active cooperation between innovators and research institutions, even if uptake remains concentrated in a few subsectors. To support subsequent skills analysis, the identified technologies were clustered and prioritised through stakeholder consultations, reflecting their local relevance for Montenegro's agriculture and food sectors and implementation capacity.

Broader digital readiness is increasing but held back by structural constraints. Global markets are rapidly adopting connected tools across entire value chains, while Montenegro's adoption remains uneven outside leading subsectors. Readiness is increasing, yet diffusion is slowed by small farm

[1] non-technological concepts

structures, limited digital skills and weak advisory services. Pilot success demonstrates potential, but wider deployment will require tailored support for small producers.

Food processing technologies show very high readiness in Montenegro. Processing, pasteurisation and fermentation are central to meeting food safety standards. Montenegro shows very high readiness because processing sectors already use modern equipment and longstanding traditions support fermentation-based products. This alignment gives Montenegro an immediate competitiveness advantage, as processing upgrades deliver fast quality improvements.

Predictive analytics, AI-enabled monitoring and decision-support tools show high readiness in specific domestic applications. Globally, advanced analytics are reshaping crop and livestock management. Montenegro demonstrates high readiness where AI and IoT models are applied in digital viticulture, helping producers optimise production decisions and differentiate products. Readiness remains lower in other subsectors due to cost barriers and limited digital literacy among small producers.

Sustainability-oriented technologies show mixed readiness in Montenegro. Technologies such as waste management, biopesticides, biofertilizers, biomass solutions and green packaging are accelerating globally due to environmental pressures. Montenegro shows uneven readiness: organic production is advanced due to strong regulation and certification system, while other sustainability technologies lag because recycling systems are weak and supportive infrastructure is missing.

Organic production is globally established and shows high readiness in Montenegro. Organic agriculture is expanding worldwide as consumers demand healthier and environmentally responsible products. Montenegro shows high readiness, supported by legal frameworks, certification systems and relevant research capacity. Scaling is limited mainly by the small share of certified land and the need for additional institutional support.

Waste-to-value technologies lag despite global growth. Valorisation of agricultural residues is becoming a global priority, creating new revenue streams while reducing environmental impacts. Montenegro has significant biomass potential, yet readiness is low because recycling infrastructure is outdated and collection systems are not systematic. Interest exists, but practical barriers slow adoption and prevent consolidation into viable circular economy models.

Climate-related monitoring technologies expand globally and show increasing readiness in Montenegro. Remote sensing, smart weather protection and cold chain monitoring support climate resilience across food systems. Montenegro shows increasing readiness through research projects and pilot use, although farmer-level adoption remains limited by cost, digital skills and traditional practices. Broader uptake will require accessible tools and targeted training.

Frontier technologies show global acceleration but very low readiness in Montenegro. Vertical farming, plant-based alternatives, synthetic meat and genetic engineering are advancing quickly in innovation-driven markets. Montenegro shows very low readiness because domestic R&D capacity is limited, regulatory restrictions apply and market demand is small. Agricultural robotics is an exception, offering future potential to address labour shortages, but readiness remains at an early stage.

Crosscutting constraints explain gaps between global trends and domestic readiness. High upfront cost limited advisory systems, low profit margins, labour shortages and administrative burdens hinder the scaling of newer technologies. These systemic issues reduce producers' ability to adopt global innovations and slow the transfer of pilot results into everyday practice. Overcoming these barriers is essential to close readiness gaps.

3. THE IMPACT OF TECHNOLOGICAL DEVELOPMENT ON SKILLS DEMAND IN THE 'SUSTAINABLE AGRICULTURE AND FOOD VALUE CHAIN' DOMAIN

To achieve the long-term vision and strategic objectives for smart specialisation to boost economic competitiveness, Montenegro will need a workforce capable of integrating the technologies that enhance processing efficiency, increase product value and support innovation across the agriculture and food value chain. This requires skills that strengthen product quality, enable the adoption of digital and sustainability-oriented solutions, and help producers overcome regulatory and operational barriers to technology uptake. Chapter 3 examines these requirements in detail and links the strategic objectives for smart specialisation with the human capital needed to deliver them.

The technologies–skills–occupations mapping used in this chapter makes it possible to identify emerging skills needs and the potential rise of new professional profiles. This type of skills intelligence is essential for curriculum development, targeted training design and stronger cooperation between education providers and employers. It also highlights where skill gaps are likely to appear and where labour demand may grow in the near future.

The analysis draws on semantic algorithms that match technologies with ESCO skills and occupations. This approach reflects international developments in how digital, green and advanced technologies reshape workforce needs and generate demand for new hybrid roles. In Montenegro, these findings were examined in three dedicated stakeholder meetings, where participants assessed their relevance for the national context. Their insights confirmed that the top skill and occupation profiles identified through the analysis correspond closely to Montenegro's emerging needs and offer a solid basis for planning future workforce development.

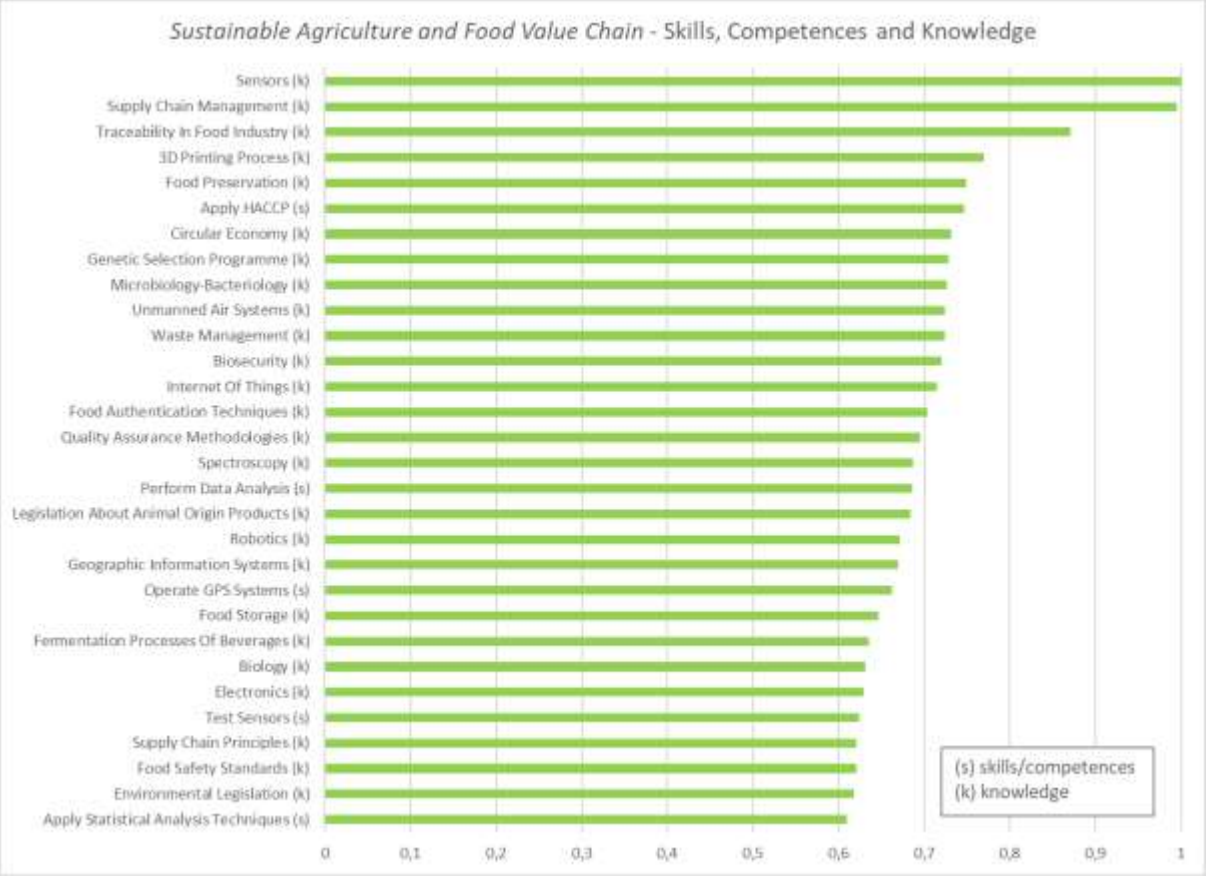
3.1 Skills demand emerging from technological change

Technological change is reshaping agriculture and food systems worldwide and generating new patterns of skills demand across processing, primary production, logistics and quality management. For Montenegro, understanding these shifts is essential to ensure that its workforce can adopt the technologies that enhance product quality, strengthen competitiveness and support sustainable growth across the agri-food value chain.

This chapter examines how global technological trends translate into specific skill needs and identifies where new capabilities must be developed to operationalise the country's smart specialisation priorities. It also highlights how emerging technologies influence both traditional roles and the creation of new hybrid profiles, underscoring the importance of continuous upskilling, reskilling and closer cooperation between education providers and employers.

Error! Reference source not found. ranks the top 30 skills associated with technologies likely to impact the *Sustainable Agriculture and Food Value Chain* in the future. These skills reflect the growing relevance of advanced processing techniques, digital tools such as sensors and traceability systems, and sustainability-related competencies linked to circular economy approaches and environmental stewardship. Together, they provide a foundation for identifying priority areas for workforce development and ensuring that Montenegro can align its human capital with future technological trajectories.

Figure 3. Top 30 ESCO skills, competences and knowledge in Sustainable Agriculture and Food Value Chain.



Source: Erre Quadro's own elaboration

Processing capabilities, underpinned by robust food safety standards, drive near-term competitiveness. Processing capabilities remain the strongest and most immediate lever for raising competitiveness in Montenegro's agriculture and food sector. Core skills such as HACCP implementation, quality assurance, preservation techniques and storage management underpin the ability of producers to meet domestic and EU market requirements. Stakeholders emphasised that, despite pockets of excellence, consistent application of these fundamentals remains uneven across producers and processors. They agreed that strengthening these skills is essential for ensuring food safety, reducing losses and improving product consistency. This foundation also determines whether companies can scale, differentiate their products and eventually integrate more advanced technologies. Without reliable day-to-day operational discipline, neither digitalisation nor sustainability measures can deliver meaningful gains.

Processing technologies should be upgraded to keep pace with evolving industry trends. Food processing technologies, such as pasteurisation, fermentation and modern processing line management, are widely used in Montenegro and show high readiness for further scaling. Stakeholders confirmed that these technologies are embedded in dairy, meat, wine and beverage production and form a strong base for raising quality and reducing waste. They highlighted that investing in improved processing practices brings immediate returns, strengthens compliance with EU standards and enhances product value. Processing technologies are also easier to integrate into existing workflows compared to more complex digital or sustainability tools. Stakeholders emphasised that building on these established processes should remain a priority before shifting attention to advanced innovations.

Traceability links processing and digital upgrades. Traceability serves as a critical bridge between traditional production practices and the digital systems shaping modern food value chains. Stakeholders highlighted that traceability is no longer simply a compliance tool; it has become a core

requirement for market access, consumer confidence and strong links with retailers. The shift from paper-based records to digital systems is viewed as inevitable and increasingly urgent. Digital traceability reduces errors, supports recall procedures, improves transparency and strengthens Montenegro's positioning in the domestic market, where imported products dominate. They fully agreed that strengthening traceability skills, both analogue and digital, is essential to improve accountability, streamline audits and support future integration with advanced monitoring technologies.

Digital pilots exist, but diffusion is narrow. Although several digital pilots have demonstrated strong potential, particularly in viticulture, stakeholders observed that adoption across the wider sector remains limited. High costs, fragmented farm structures, and weak advisory services were cited as major barriers preventing diffusion. Even where technologies have been successfully piloted, producers often lack the skills or confidence to integrate them into routine operations. Stakeholders stressed the need for more demonstration sites, practical training and advisory support to help producers understand benefits and overcome uncertainties. They also noted that pilot initiatives often depend on external funding and are not always designed with scalability in mind, reinforcing the need for more systematic digital rollout strategies.

Sensors, IoT and basic digital skills first, then scale up. Digital technologies such as sensors, IoT devices and geospatial tools offer practical opportunities for improving efficiency and decision-making. Stakeholders recognised their value but stressed that introduction must be gradual and aligned with the realities of small producers. Many farms and processing facilities lack the technical capacity to adopt complex tools, so the emphasis should be on simple, affordable solutions supported by hands-on training. Basic digital skills, including the ability to read dashboards, interpret alerts and understand simple analytics, were seen as the minimum requirement for digital adoption. Stakeholders asked for step-by-step integration of these technologies into existing practices, education and training, starting with monitoring tools, building digital confidence and gradually enabling producers to progress toward more advanced systems.

Sustainability skills under a "One Health" lens. Sustainability-related competencies are becoming essential across the agriculture and food value chain. Stakeholders highlighted the growing importance of skills related to circular economy models, environmental legislation, waste reduction and biosecurity. They proposed using a One Health framing, which connects animal, plant, human and environmental health, to help structure training pathways and make sustainability more accessible to producers. This integrated perspective also mirrors EU policy directions and supports Montenegro's ambitions to align agricultural practices with environmental standards. Stakeholders stressed that many companies still lack awareness of sustainability requirements or see them as burdensome, so capacity building should focus on practical, achievable actions that reduce environmental impact while supporting long-term competitiveness.

Organic and traditional production offer a strong foundation for high-value niche development linked with tourism. Stakeholders emphasised that, given the predominance of small farm structures, organic and traditional products are well-positioned to compete on quality, authenticity, and origin rather than volume. Stakeholders noted that when effectively integrated with tourism - through short supply chains, on-farm experiences, and local branding - these products can generate significant additional value.

Waste and biobased valorisation unlock new niches. Technologies related to waste management, biomass utilisation, bioproducts and green packaging offer promising opportunities for value addition and diversification. Stakeholders agreed that waste-to-value approaches can reduce environmental impact while generating new revenue streams. However, they noted that progress is uneven, with recycling systems underdeveloped and many producers lacking the scale required to adopt biobased solutions. Stakeholders recommended combining skills training with targeted support for small-scale waste processing models and cooperative approaches that help producers pool resources. They also pointed out that circular economy solutions align with EU policy trends and could help Montenegro differentiate its products through sustainability branding.

Frontier tech is low priority for now. While robotics, advanced biotechnology, vertical farming and synthetic or plant-based alternatives are part of the broader technological landscape, stakeholders

were clear that these areas are not realistic priorities for Montenegro at present. They cited high investment costs, regulatory restrictions, limited research capacity and low consumer demand as the main reasons for deprioritising frontier technologies. Stakeholders emphasised that focusing on these areas now would divert resources from more practical and achievable improvements. Nevertheless, they agreed that keeping an eye on emerging technologies remains important to anticipate future trends and avoid falling behind in areas where global innovation is accelerating.

Shortage of workers with job-ready skills. Stakeholders reported persistent shortages of vocationally trained workers and university graduates equipped with practical, job-ready skills in an environment of declining interest in agriculture careers. Many companies rely on on-the-job training to fill gaps, but this approach is insufficient given the scale of current and future needs. Stakeholders also highlighted challenges such as fraudulent diplomas, limited motivation, limited practical exposure in training programmes and the tendency of graduates to favour public sector jobs. Improving vocational training, strengthening practical components and building closer links between education providers and employers were identified as essential steps for addressing this skills bottleneck.

Market context sets the priorities: win home market first. Key priorities include: strengthening and building on foundational skills; modernising and innovating food processing by upgrading technologies and strengthening quality and food safety management systems across the value chain; integrating targeted digital technologies on-farm to enhance efficiency and traceability, and, within education systems, to increase the attractiveness of agriculture careers; expanding organic and traditional production as high-value niche segments linked with tourism; and building sustainability skills.

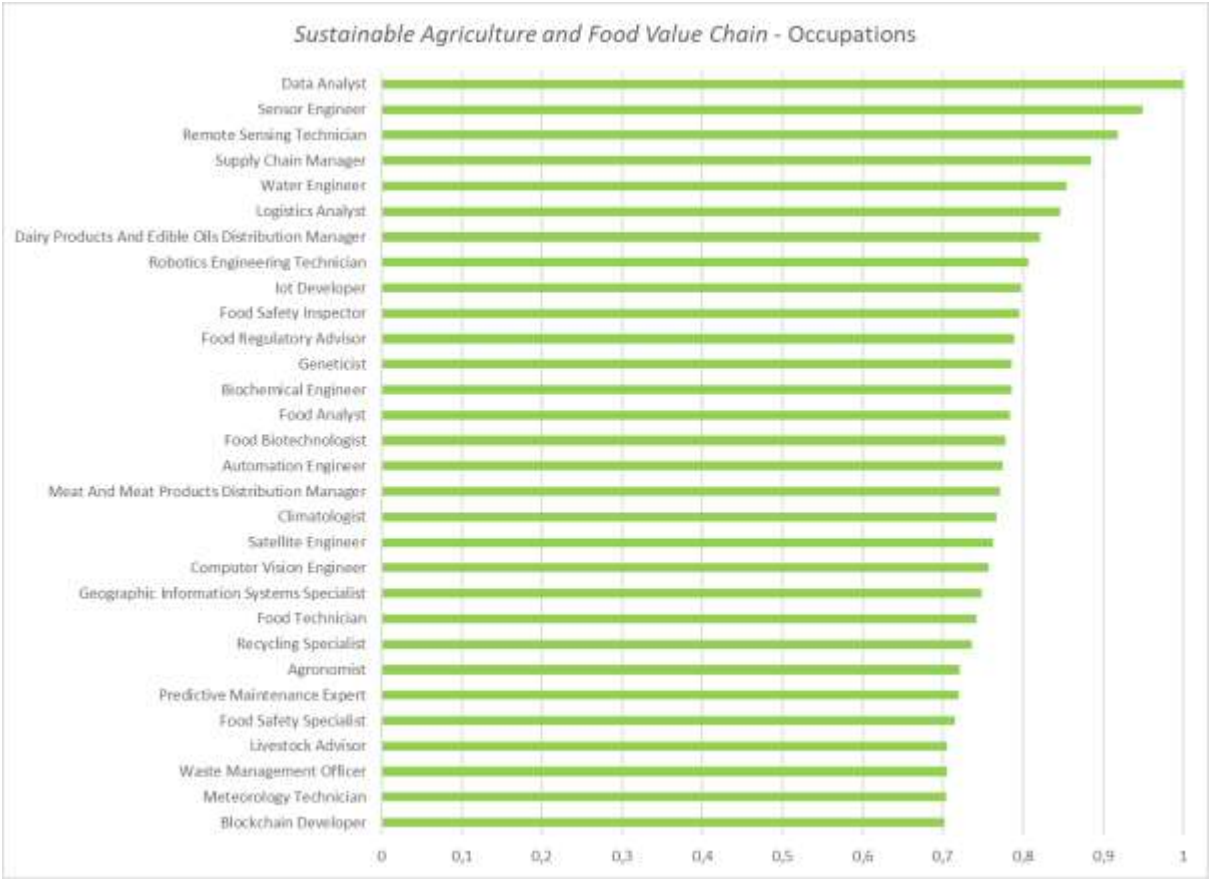
3.2 Occupations shaped by emerging technologies

Technological change is reshaping not only skills but also the occupational profiles required to strengthen Montenegro's agriculture and food value chain. As digital tools, sensing technologies, advanced monitoring systems and stricter food-quality requirements gain importance, workforce needs are shifting toward data-driven roles, supply-chain optimisation functions and specialised food-safety and compliance occupations.

This chapter examines how global occupational trends intersect with Montenegro's production structure, regulatory environment and technological readiness. It highlights which occupations are emerging, which remain essential for meeting domestic market standards, and which are constrained by limited adoption capacity. Together, these insights provide a basis for developing a future-ready workforce capable of supporting higher product quality, stronger traceability, and gradual digital transformation across the sector.

Figure 4 ranks the top 30 occupations associated to skills and technologies expected to influence the *Sustainable Agriculture and Food Value Chain* domain in the future.

Figure 4. Top 30 ESCO occupations in Sustainable Agriculture and Food Value Chain.



Source: Erre Quadro's own elaboration

Data-driven monitoring roles emerge as core occupational needs. Demand is rising for occupations such as Data Analysts, Sensor Engineers and Remote Sensing Technicians, which support precision agriculture, data-driven monitoring and real-time decision-making. These roles reflect the shift toward technology-enabled production systems. Stakeholders recognised their relevance but noted that uptake will be gradual because many producers still lack basic digital experience. They emphasised that these roles would become more important as simple monitoring tools spread across farms and processing units.

Supply chain and logistics profiles gain strategic relevance. The modernisation of food systems increases the importance of Supply Chain Managers, Logistics Analysts and Distribution Managers. These profiles help ensure traceability, maintain cold chain integrity and reduce losses along the value chain. Stakeholders agreed on the importance of supply chain-related occupations but stressed the need for practical and low-cost tools that match the realities of small-scale producers. They also noted that strengthening domestic supply chains matters more than export-oriented functions at this stage.

Quality, safety and regulatory professionals remain essential. Food Safety Inspectors, Food Analysts and regulatory compliance professionals remain central to meeting domestic and EU market requirements. These occupations ensure that HACCP, food safety rules and quality standards are consistently applied across production and processing. Stakeholders strongly agreed and highlighted inconsistencies in compliance, particularly among smaller producers. They noted that existing education system produces graduates with knowledge and skills in these areas; however, continuous upskilling - particularly in practical implementation and digital traceability - and ongoing training aligned with EU standards are needed to keep pace with evolving trends.

Biotechnology and advanced processing roles show growing long-term importance. Biotechnology-related occupations such as Geneticists, Food Biotechnologists and Biochemical Engineers are linked to innovation in plant resilience, microbial processing and value-added food

products. Their relevance is increasing as global trends shift toward functional foods and biobased production. Stakeholders acknowledged their potential but explained that current demand is limited due to small R&D capacity and low investment in advanced food technology. The gap arises mainly from Montenegro's small research ecosystem and the absence of industry-driven innovation in these areas.

Automation, IoT and robotics technicians slowly enter the landscape. Automation-related occupations such as IoT Developers, Sensor Operators, Drone Operators, Robotics Technicians and Computer Vision Engineers point to a gradual shift toward smart farming systems. Stakeholders agreed with the long-term direction but said that most producers are not yet ready to adopt complex automated solutions. High costs, limited advisory support and fragmented production structures slow demand for these occupations. These barriers explain the gap between global technological trends and Montenegro's current absorption capacity. Stakeholders recommended up-skilling of existing agriculture technicians, agronomists, farmers, extension officers, in these fields.

Environmental monitoring and climate-related professions rise in prominence. Climate-related occupations, including Climatologists, Satellite Engineers and Meteorology Technicians, are becoming more relevant as Montenegro faces increasing climate pressures. These roles support climate risk assessments, water management and adaptation planning. Stakeholders agreed and highlighted the scarcity of nationally trained specialists in these areas. They noted that limited educational pathways and stronger job prospects abroad contribute to shortages in these occupations.

Sustainability-linked advisory roles gain importance across subsectors. Recycling Specialists, Livestock Advisors, Circular Economy Advisors and Environmental Technicians are increasingly needed as sustainability becomes a core competitiveness factor. Stakeholders stressed that such advisory roles are crucial for helping small producers meet environmental requirements in practical ways. They agreed that these roles are essential but observed that uptake is slowed by weak extension services and limited awareness among producers. This reflects a system level challenge rather than a lack of occupational relevance.

Hybrid roles emerge at the intersection of traditional and digital skills. The occupational landscape shows rising demand for hybrid roles that combine agricultural knowledge with digital, engineering or environmental skills. Stakeholders confirmed this, noting that hybrid functions often fall within a single job because companies lack resources to hire multiple specialists. This aligns with Montenegro's small-scale production structure, where employers prefer multiskilled workers who can manage both operational tasks and emerging digital tools. integrating targeted digital technologies on-farm to enhance efficiency and traceability, and, within education systems, to increase the attractiveness of agriculture careers.

Persistent shortage of midlevel technical professionals limits uptake. Technicians, machine operators, maintenance staff and quality-control workers are in short supply, even though they form the backbone of processing and digital operations. Stakeholders highlighted serious gaps in vocational training, including limited practical exposure and concerns about the quality of some formal qualifications. They also noted that many graduates prefer public-sector roles, reducing the pool of job-ready technical workers. These shortages slow technology adoption and reduce companies' ability to upgrade production processes.

Market context reinforces demand for practical, job-ready occupations. Modernisation of the sector increases demand for practical and applied occupations that support day-to-day operations. Stakeholders stressed that producers must first strengthen domestic market presence before moving toward specialised or export-oriented roles. This is not a disagreement with the occupational ranking but a sequencing issue: the sector needs occupational profiles that raise quality, improve efficiency and stabilise supply chains before it can absorb more advanced roles.

3.3 Structural constraints shaping skills demand and technology adoption

The technician skills are the most important levers for raising productivity and accelerating the green and digital transition. However, a set of interconnected structural gaps, across qualification approval, programme design, VET provision, workforce supply and institutional capacity, continue to slow the sector's modernisation and limits the pace at which new technologies can be adopted. These constraints manifest across multiple parts of the skills and innovation ecosystem, including:

Severe shortages of mid-level technicians, operators and specialised profiles. There are notable shortages of mid-level technicians, operators and specialised profiles. The sector has limited availability of digital technicians, sustainability and environmental-standards specialists, agriculture technicians, and skilled food processing technicians. This reduces companies' capacity to introduce and operate modern processing, digital monitoring and circular-economy technologies.

Delayed Adoption of Productivity-Enhancing Technologies. Montenegro would benefit from accelerating technology adoption, as modern solutions can help ease pressures arising from workforce shortages. The country remains in a catching-up phase regarding the integration of digital, processing and sustainability-oriented technologies.

Advisory and extension services remain too weak to support digital and green technologies. Small producers often have limited exposure to modern technologies, as well as limited practical guidance and support to adopt sensors, IoT tools, traceability systems or waste-to-value solutions. This continues to slow diffusion beyond pilot projects. Technology diffusion could be fostered through practical, ROI-oriented advisory services, demonstration farms, and peer-learning mechanisms to bridge the gap between research, pilots, and commercial adoption.

Institutional and regulatory gaps hinder technology uptake. Administrative burdens, and slow procedural reforms can weaken demand for digital traceability, environmental compliance, and circular-economy solutions, reducing incentives for companies to invest.

Organic and traditional production potential is underexploited. Although Montenegro has around 350 certified organic producers, systemic support structures are inadequate, domestic demand is limited, and links to tourism as a high-value niche are not fully leveraged.

Curriculum adaptation cycles remain too slow and rigid. VET schools and universities face long accreditation cycles (5 years at university level), delaying updates needed to new technology trends and skill requirements. Inter-disciplinary and technology-rich programmes remain rare. Universities currently do not offer short, flexible training courses.

Adult learning remains underdeveloped. Most companies rely on internal, informal training. Micro-qualifications can serve as a mechanism to recognise these informal learning experiences as verifiable skills and are urgently needed to support upskilling in HACCP, processing, digital tools and sustainability competences. Ongoing qualifications legislation reform provides an opportunity to introduce micro-qualifications tailored to specific skills needs (e.g., 30-hour modules equivalent to 5 ECTS credits).

New occupational profiles are emerging in digital agriculture, food safety, environmental monitoring and circular economy. However, education systems continue to prioritise traditional pathways, which can slow the introduction of hybrid, technologically-oriented profiles aligned with future market needs. Universities would benefit from embedding more technological and digital content, particularly in biotechnical and mechanical engineering, as well as ICT, to support the development of modern inter disciplinary qualifications.

Cooperation between companies and education providers remains weak. Although good examples exist, collaboration is often not systemic or aligned with real industry needs. The legal requirement for companies to provide financial support to third-year students in work-based learning education is difficult to enforce.

Work-based learning remains insufficiently developed. Dual diploma or specialisation models could help the sector keep pace with technological change, as current university and VET programmes place excessive emphasis on theoretical knowledge and insufficient attention on practical, job-ready skills. Specialisation courses could therefore be designed to prioritise hands-on learning and skills development.

Persistent low interest in agrifood careers and poor enrolment in initial VET. Relatively low remuneration, limited sector attractiveness and prevailing social norms continue to reduce enrolment in agriculture and food programmes, undermining generational renewal and constraining the talent pipeline. Career orientation remains weak, and many students choose pathways based on peer influence or social media rather than professional guidance on labour-market prospects. As a result, many VET and university graduates end up in occupations unrelated to their fields of study. Stronger career guidance and better data on graduate transitions would be beneficial, as companies continue to face challenges in building a job-ready workforce.

Lack of a strategic approach to attract people to agriculture. Montenegro does not yet have a comprehensive strategy to make agrifood careers more appealing. Rural residents and farmers often face economic vulnerability, while in neighbouring countries those working in organic farming and traditional tourism benefit from more stable employment and higher income opportunities. Prioritising agriculture and tourism together would create stronger economic prospects. Experiences from Austria, Slovenia and Serbia provide relevant inspiration. Incentivising enrolment through financial support for agriculture students (such as the program in Šavnik) or dual programs with the private sector could increase the attractiveness of the agriculture sector.

Towards higher enrolment and improved attractiveness. Introducing cross-sectoral profiles that integrate digital technologies, tourism, organic farming and sustainable development would better reflect Montenegro's competitive advantages and offer more attractive, future-oriented career options. Growing interest among young people in new technologies presents an opportunity to attract them to agriculture by integrating digital technologies into agriculture programs.

Insufficient offer across diverse learning modes. There is a growing need to clarify, expand, and ensure certification for multiple learning pathways, initial and continuing VET, micro-credentials, short-term technology-specific trainings, and modular upskilling. The current landscape lacks coherence and sufficient training volume across these modes.

Teacher and trainer professional development remains limited. Teachers and trainers need continuous professional development to keep pace with new technologies. Investment in school equipment and partnerships with private companies are necessary to ensure learners have access to modern tools, devices, and practical training environments. Curricula and textbooks also require systematic adaptation to reflect emerging technologies and smart specialisation priorities.

Need for alignment with European skills initiatives. Keeping pace with European platforms such as the Pact for Skills, net-zero academies, sectoral cooperation frameworks, Centres of Vocational Excellence (CoVEs), and joint VET and university diplomas will be essential to ensure Montenegro's competitiveness and integration into the evolving EU skills ecosystem.

Taken together, these reforms form the foundation for a more competitive, innovative and resilient agriculture and food value chain. By closing technician-level shortages, accelerating curriculum and qualification updates, modernising VET and higher education, strengthening advisory services and reducing administrative barriers, Montenegro can adopt productivity-enhancing technologies more rapidly and at scale. Advancing these changes will enable the country to operationalise its smart specialisation objectives, strengthen its position in the domestic market, and support a sustained green and digital transition across the sector.

4. Operationalising smart specialisation

Chapter 6 translates the analytical findings on technologies, skills and occupations into concrete priorities for action. While previous chapters examined global innovation trends, Montenegro's readiness to adopt key technologies, and the resulting implications for skills demand, this chapter focuses on how the smart specialisation agenda can be operationalised through targeted investment in human capital and skills ecosystems. It identifies the technology–skill combinations that offer the highest potential productivity gains and outlines how education, training and workforce development systems can be mobilised to support their deployment.

Building on stakeholder consultations and evidence from the technology readiness and skills analysis, the chapter highlights a limited number of high-impact technology clusters that are critical for Montenegro's future competitiveness. For each cluster, it clarifies the skills priorities required across qualification levels and proposes structured actions for vocational education and training, higher education, adult learning and business support organisations. Together, these actions provide a coherent framework for aligning skills development with smart specialisation objectives, strengthening implementation capacity, and ensuring that the workforce can effectively support the adoption, operation and scaling of priority technologies.

4.1 High-impact technology clusters and related skills priorities

Montenegro's agriculture and food value chain is undergoing rapid transformation shaped by technological progress, EU accession requirements, and persistent workforce shortages. While the sector benefits from strong foundations in traditional production, established processing capabilities, and alignment with EU regulatory frameworks, systemic human-capital constraints, limited curriculum adaptability, insufficient cooperation between businesses and training providers, and slow diffusion of modern digital and green technologies continue to hinder competitiveness and productivity.

Montenegro's future competitiveness will increasingly depend on adopting technologies that deliver the highest productivity gains and support the smart specialisation vision. Three technology clusters stand out as the most critical.

Table 3. Top 3 high impact technology clusters and associated skills for Montenegro's agriculture and food value chain and future competitiveness

Technology	Associated skills
Food processing technologies (modern processing systems, pasteurisation and fermentation, food standards and quality management)	Skills in innovative food processing, quality assurance, and food safety management systems across the value chain Modernising food processing in Montenegro requires strengthening core operational competencies alongside gradual technological upgrades. Priority skills include innovative food processing knowledge and skills, stronger capabilities in HACCP implementation, food safety routines, quality assurance, and consistent process control, while technicians require practical skills in operating processing lines, applying hygiene standards, troubleshooting equipment, and maintaining production stability. These skills are essential for scaling processing upgrades, meeting EU market requirements, and enhancing readiness. It is recommended to continue to prioritise investment in core competencies in food processing while integrating new technologies.
Digital, smart agriculture, and traceability technologies (sensors and IoT devices, drones, disease detection, predictive analytics, computer vision, smart irrigation, digital traceability, and robotics)	Skills in sensors, IoT, drones, data recording and analysis Advancing digital and smart agriculture requires strong capabilities in both agriculture and ICT. The adoption of these technologies is constrained by limited digital literacy among majority of producers, weak advisory support related to digital technologies, insufficient integration of digital technologies into education and training systems, and low ROI among smallholders, leaving many producers unable to operationalise existing smart agriculture pilots. Technicians will increasingly need hands-on competences in operating sensors and IoT devices,

Technology	Associated skills
	recording and interpreting data, managing digital traceability procedures, supporting real-time monitoring tasks, and skills related to agricultural robotics. These skills form the basis for gradual digital transformation and automatization across farms and processing units. It is recommended to continue to prioritise investment in core competencies in agricultural production while integrating new technologies.
Sustainability and circular economy technologies (organic and traditional production, biofertilizers and biopesticides, biomass and waste-to-value solutions, and green packaging)	Environmental compliance, One-Health practices, and eco-efficiency skills Developing sustainable, circular, organic, and traditional farming systems requires a mix of environmental, regulatory, and applied production skills anchored in a One Health perspective that links plant, animal, human, and ecosystem health. Priority competencies include understanding environmental legislation, implementing circular economy practices, improving resource efficiency, and applying biosecurity and waste reduction measures in day-to-day operations. Producers need practical skills to implement organic and traditional production methods, including quality differentiation, certification processes, and integration with short supply chains and agritourism models. Capabilities in waste valorisation - such as biomass utilisation, bioproduct development, and sustainable packaging – require interdisciplinary skills related to energy, and environmental technologies. These capabilities are central to advancing sustainability and competitiveness.

Source: Authors

4.2 Mobilising the skills ecosystem to support technology adoption

The following three recommendations translate the high-impact technology–skill pairings into concrete action areas. They outline where Montenegro should prioritise investment and reform to raise productivity, strengthen competitiveness and support the green and digital transitions across the *Agriculture and food value chain*.

Priority action area 1 - Upgrading food processing technologies through strengthened operational and technical skills to meet EU food safety standards and scale competitiveness

Of the three high-impact technology–skill pairings identified, this area shows the highest level of readiness in Montenegro, both institutionally and in the private sector. At secondary level, vocational schools delivering Food Technician programmes (Level IV, ISCED 3) are in Bijelo Polje, Nikšić and Podgorica. Higher-education provision is well established. The University of Montenegro, through its Biotechnical Faculty, offers undergraduate programmes that include fruit and vegetable processing, as well as Master's programmes in food safety. The University of Donja Gorica offers applied Bachelor programmes in food technology, food safety and Hotel, Restaurant, and Café (HoReCa) systems, with a strong emphasis on industry-relevant skills. It also hosts the FoodHub, a Centre of Excellence for Digitalisation of Microbial Food Safety Risk Assessment and Quality Parameters for Accurate Food Authenticity Certification, which strengthens applied research and innovation capacity. In addition, sectoral organisations, notably the Chamber of Commerce, provide short courses and workshops targeting SMEs, further reinforcing skills development in food processing and safety.

Measures to upgrade food processing technologies through strengthened operational and technical skills

VET (secondary and non-tertiary level)	Higher education	Adult learning	
		CVET	Business support organisations (BSOs)
Introduce new modules on innovative food-processing practices, hygiene routines and HACCP implementation, making food-processing competences core content rather than elective subjects. Integrate equipment-level diagnostics, processing-line operation and basic quality-assurance tasks into practical training. Connect structured learning with real work environments through work-based learning and expand hands-on training using real processing lines, sanitation systems and troubleshooting practice.	Expand applied food-technology and engineering programmes with content on modern processing-systems, pasteurisation, fermentation and digital quality-management tools. Strengthen applied learning through internships, industry-led projects, and pilot plants. Increase laboratory work using processing equipment, monitoring devices and digital traceability tools. Promote joint applied projects with processors on technology upgrading, HACCP implementation and EU-compliant quality systems.	Co-design short, certified, modular courses in HACCP routines, sanitation procedures, equipment operation and process-control basics (e.g. micro-credentials) with industry for key roles such as line operators and QA technicians. Create fast-track requalification pathways for operators and technicians entering food-processing roles. Validate prior learning to accelerate entry into processing-related occupations.	Support companies in identifying skill gaps related to food-safety routines and processing-line operation. Provide advisory services on HACCP, hygiene standards and EU alignment through on-site coaching, mentorship and demonstration-based training in real production environments. Facilitate cooperation between companies to promote peer learning. Facilitate cooperation between companies and training providers to co-design practical training modules. Promote participation in European food-safety and processing-technology partnerships to strengthen training provision and attract investment.

Source: Authors

Implementing the above measures would:

- Build a continuous pipeline of food-processing technicians with job-ready competences.
- Strengthen HACCP implementation, hygiene routines and quality-assurance practices across the sector.
- Support companies in upgrading processing lines and meeting EU food-safety requirements.
- Improve productivity, consistency and competitiveness of Montenegro's food-processing industry in line with smart specialisation objectives.
- Support continuous innovation in line with industry trends and market demand.
- Ensure Montenegro's strong base is supported by ongoing technology and processing upgrades.

Priority action area 2 - Accelerating digital and data-driven operations through targeted on-farm smart-agriculture technologies to improve efficiency and traceability.

Digital and smart-agriculture skills in Montenegro remain underdeveloped and unevenly integrated across the agri-food system. The University of Montenegro provides extensive studies through its Biotechnical Faculty, covering plant and animal production, viticulture, food safety, agribusiness, and advanced specialisations up to PhD level. Exposure to digital technologies in these programs is limited or optional and often depends on individual professors or project-based initiatives rather than being systematically embedded in curricula. The Centre of Excellence for Digitalisation of Microbial Food Safety Risk Assessment and Quality Parameters for Accurate Food Authenticity Certification at the University of Donja Gorica, provides a structured approach to integrating modern technologies into

agri-food systems. The secondary vocational schools offering Agricultural Technician (Level IV Montenegro scale / ISCED 3) and Agricultural Producer (Level III Montenegro scale / ISCED 2) programs are distributed across multiple municipalities in Montenegro, including Andrijevica, Bar, Petnjica. Podgorica, Rožaje, Šavnik, and Zeta. These programs, already facing low enrolment, continue to focus primarily on agronomic practices, with minimal exposure to digital tools, further constrained by limited access to modern equipment and demonstration environments. Adult learning and non-formal programs, including pilot and demonstration activities, currently serve as the main channels for building digital skills; however, they remain too limited in scale, with insufficient demonstration sites and peer-learning opportunities to support wider adoption. As a result, while digital pilots have demonstrated clear potential, their scalability remains constrained. At the same time, growing interest among young people in new technologies presents an opportunity to attract them to agriculture by more strongly integrating digital and technological innovation into the sector. It is therefore recommended to promote technology-driven agriculture careers (smart farming) to increase enrolment in VET and higher education programs related to agriculture and food.

Measures to accelerate the adoption of digital monitoring and smart agriculture technologies through targeted skills development

VET (secondary and non-tertiary level)	Higher education	Adult learning	
		CVET	Business support organisations (BSOs)
Introduce new modules on basic digital literacy, including apps, dashboards and sensors, across all agri-food programmes ((e.g. Agriculture technician, Agricultural producer) by embedding compulsory practical modules and making digital competences core content rather than elective subjects. Update curricula to include traceability systems, IoT, and basic analytics; invest in training labs and pilot processing lines Integrate equipment-level diagnostics, sensor calibration and basic IoT operation into practical training. Introduce inter-disciplinary modules combining agri-food, basic IT, and entrepreneurship in VET programmes Establish school-based demo sites showcasing scalable sensor and IoT technologies and connect local producers to these innovations through on-farm trials, peer-to-peer learning and field days.	Introduce interdisciplinary modules/subjects integrating agriculture, ICT, and engineering and offering the subject to students across respective faculties. Support applied research and field labs focused on understanding of costs, benefits, and ROI and scaling proven solutions; strengthen industry collaboration Embed advanced modules on digital traceability, data systems, and smart agriculture; co-develop curricula with industry. Develop joint modules in agritech (linking agriculture, ICT, and engineering).[2] Encourage cross-faculty collaboration in module design, implementation, and student participation. Increase laboratory work using sensors, IoT devices, drones, simulation environments and real-time monitoring software. Promote joint applied projects with farms, food processors and digital-solution providers on AI-enabled crop and livestock monitoring.	Offer short, modular courses on digital basics including sensors, drone operations, dashboards, alerts, simple analytics (e.g. micro-credentials).[3] Provide hands-on training using real tools and platforms; align with EU compliance and market requirements. Offer integrated training combining technical, digital, and business skills (e.g. traceability + marketing + compliance) Create fast-track requalification pathways for technicians needing hands-on experience with IoT devices and real-time monitoring tasks. Validate prior learning to accelerate entry into digital and data-driven agricultural occupations.	Expand extension services to provide continuous technical support before, during, and after adoption, link training to investment support schemes. Support companies in identifying digital skill gaps linked to sensors, IoT devices, data workflows and traceability systems. Use demonstration farms, peer learning, and advisory visits to raise awareness of digital technologies through hands-on exposure Provide advisory services on integrating IoT devices, digital traceability and real-time data tools into everyday operations. Facilitate cooperation between companies and training providers to co-design applied digital-skills training modules. Promote farmer networks and “lead adopters” to showcase successful use cases and facilitate peer-to-peer diffusion. Promote participation in European digital-skills and green-transition partnerships to enhance training provision and attract investment.

Source: Authors

[2] See for example the Smart farming and IoT in Agriculture course (5 ECTs) at the Technical University of Munich.
[3] See for example. Available here: https://macskillsdevelopment.com/me/course/internet-of-things-iot-in-agriculture-training-course

Implementing the above measures would:

- Build a continuous pipeline of digitally capable agricultural technicians with job-ready competences.
- Strengthen the use of sensors, IoT tools and digital traceability across farms and processing units.
- Support producers in adopting practical monitoring tools and meeting EU requirements for data-driven traceability.
- Improve productivity, consistency and decision-making across Montenegro's agri-food sector in line with smart specialisation objectives.
- Support continuous innovation in line with global trends in digital agriculture and market demand.
- Ensure Montenegro's strong subsector niches are supported by gradual, scalable digital upgrades.

Priority action area 3 – Strengthening sustainability and circular-economy skills to scale high-value organic, traditional and tourism-linked production

In Montenegro, education and training related to sustainability, circular economy, and organic farming are evolving but remain fragmented and not yet fully aligned with sector needs. In higher education, these topics are partially integrated into existing agriculture programs; for example, organic production is offered as a dedicated subject (6 ECTS) within programs such as plant production at Bachelor level at the Biotechnical Faculty, University of Montenegro, while steps have been taken to introduce a subject on circular technologies with a focus on biowaste utilisation. At the VET level, elements of sustainable and organic practices are present, but programs such as Agricultural Technician (Level IV Montenegro scale / ISCED 3) and Agricultural Producer (Level III Montenegro scale / ISCED 2) continue to prioritise conventional production, with limited hands-on exposure to circular approaches and resource-efficient technologies. Adult learning, including extension services, plays a key role in introducing sustainability concept but provision is largely project-based, short-term, and uneven in reach.

Measures to strengthen sustainability and circular economy skills to scale high value organic, traditional and tourism linked production

VET (secondary and non-tertiary level)	Higher education	Adult learning	
		CVET	Business support organisations (BSOs)
Introduce new modules on basic sustainability, circular economy, and environmental practices into all agri-food curricula as core content, not elective subjects. Integrate composting, biomass use, basic waste-processing technologies and safe waste-handling into practical training and expand hands-on exercises. Update curricula to include organic production methods, integrated pest management, soil health, and basic agri-business/branding modules; ensure hands-on training through school	Embed interdisciplinary modules linking agriculture, environmental science, and health (One Health); use case-based learning. Introduce a university module/subject (e.g. biowaste, bioenergy, circular systems) with interdisciplinary links with energy. Support joint applied research on bioproducts, green packaging, and circular business models Strengthen existing agriculture and food technology programs with advanced topics in organic farming, pest and soil management in organic production; promote	Offer short, modular courses in environmental compliance, resource efficiency, waste reduction (e.g. micro-credentials). Provide targeted training on developing agritourism services, short supply chains, and customer experience, link with local tourism initiatives and funding schemes. Create fast-track requalification pathways for technicians supporting organic production, green-packaging lines and waste-to-value processes. Validate prior learning to accelerate entry into sustainability-oriented technical occupations.	Support companies in identifying sustainability skill gaps linked to environmental compliance, waste-to-value systems and One-Health practices. Deliver short, practice-oriented courses, demonstration farms and peer-learning activities to showcase viable small-scale waste-management solutions, cooperative resource-pooling models, successful organic practices and branding strategies. Facilitate local networks and clusters connecting farmers, processors, and tourism operators; promote pilot projects and success

VET (secondary and non-tertiary level)	Higher education	Adult learning	
		CVET	Business support organisations (BSOs)
farms and the private sector. Embed agritourism concepts (farm stays, on-farm experiences, local product promotion) into VET programs (Agriculture and Food Technician); include practical exposure through partnerships with tourism operators.	applied research on organic systems Develop joint programs/modules linking agriculture, tourism, and business (e.g. agritourism, rural development); support student projects with local agritourism enterprises.		stories to demonstrate viable models. Facilitate cooperation between companies and training providers to co-design hands-on sustainability and waste-management training modules. Promote participation in European green-skills partnerships to enhance training provision and attract investment in circular-economy technologies.

Source: Authors

Implementing the above measures would:

- Establish a coherent and continuous skills pipeline in sustainability, circular economy, and organic and traditional farming across VET, higher education, and adult learning.
- Strengthen practical, hands-on competences in resource-efficient and circular production methods, composting, biomass use, waste-to-value processes, and resource-efficient production.
- Improve alignment with labour market and EU requirements by equipping learners and producers with skills in environmental compliance, organic standards, traceability, and sustainable business practices.
- Expand the reach, consistency, and continuity of adult learning and extension services beyond short-term, project-based provision.
- Foster interdisciplinary and applied learning by linking agriculture with environmental science, energy, health (One Health), and tourism, including the development of agritourism and circular business models.
- Enhance productivity, resilience, and environmental performance across Montenegro's agrifood sector.
- Support innovation and competitiveness by embedding sustainability and circular practices in line with EU Green Deal priorities and evolving market demand.

ACRONYMS

AI	Artificial Intelligence
BSO	Business Support Organisation
CoVE	Centres of Vocational Excellence
ECTS	European Credit Transfer and Accumulation System
EDP	Entrepreneurial Discovery Phase
ESCO	European Skills, Competences, Qualifications and Occupations
ETF	European Training Foundation.
EU	European Union
HACCP	Hazard Analysis and Critical Control Points
HoReCa	Hotel, Restaurant, and Café
IoT	Internet of Things
ISCED	International Standard Classification of Education
NLP	Natural Language Processing
ROI	Return on Investment
R&D	Research and development
SEO	Search Engine Optimization
SME	Small and Medium Enterprise
VET	Vocational Education and Training

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