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Keynote article

Agriculture and rural areas facing the "twin transition": principles for a sustainable rural digitalisation[1]

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Abstract. In this paper some of the key issues related to digitalisation in agriculture and rural areas are addressed. In line with the Green Deal, the paper proposes a framework on how to address the "twin transition" (ecological+digital) through transformative policies based on directionality, market integration and reflexivity. The framework is based on a view of digitalisation as a socio-technical process, which implies taking into account the social implications of any technology development, and centring innovation policies on a clear definition of the problems to be addressed. The paper proposes the concept of socio-cyber-physical system as a paradigm for policy strategies and for innovation and discusses its implications for sustainable digitalisation strategies in the field of agriculture and rural areas.

Keywords: digitalisation, transition, transformative policies, innovation.
JEL codes: Q16, O33.

HIGHLIGHTS[1]

- Digitalisation is a socio-technical process.
- To keep together digital transition and ecological transition, transformative policies are needed
- Rural digitalisation strategies should address the specificities of rural areas

1. INTRODUCTION

With the Green Deal, the European Union has committed to transform itself «into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use»

[1] This work was supported by the European Commission's Horizon 2020 project DESIRA (Grant Agreement No. 818194). The content of this article does not reflect the official opinion of the European Commission. The views expressed in this paper are solely those of the authors.

(European Commission, 2020). To achieve this objective, «Europe must leverage the potential of the digital transformation». In other words, the digital and ecological transformations should go in parallel, and should reinforce each other. As the document points out, «Europe needs a digital sector that puts sustainability at its heart».

The choice to stress the link between the two transitions or, as proposed in the Green Deal document, to pursue a "twin transition", addresses a critical point of the strategy. Indeed, the two transitions are very different in in their dynamics and nature. On the one hand, the ecological transition, aiming at reverting the trend towards degradation caused by the fossil-based economy, requires a strong political and societal push, driven by public interest (Mazzucato, 2013). On the other, the digital transformation – at least the one we have experienced so far – is a mainly market-driven process: the advancement of digital technologies has opened huge opportunities for innovative business, which in most cases has taken advantage of regulatory gaps and generated inequalities and harm.

Agriculture plays a key role in the twin transition. Together with energy and mobility, food is considered one of areas where, to meet the sustainability goals, transformation should be deeper (European Environment Agency, 2021). The Farm to Fork strategy[2] emphasizes this aspect. The contribution of agricultural systems to greenhouse gases, reduction of biodiversity, pollution, water scarcity is well-known, as is the importance of the food system for human wellbeing. Ensuring food security and nutrition for all while reverting the trend to ecosystem degradation and ensuring a decent income for farmers and workers is one of the hardest challenges, a "wicked problem" for policymakers. The agro-ecological transition, which translates the ecological transition into agriculture, implies a radical rethinking of landscape infrastructures, farm design, production processes, business models, supply chains, consumption behaviour (Ollivier *et al*., 2021; Duru, Therond, 2015). Digitalisation can provide tools for managing the complexity of more diversified agricultural systems, to optimize the use of inputs, reduce the burden of an unpleasant and heavy workload, simplify administrative tasks, improve communication with peers and consumers, anticipate risk and accelerate adaptation (Rolandi *et al*., 2019). It can also improve the quality of life of farming households by making rural areas more liveable (Cowie *et al*., 2019). However, also different digitalization pathways are possible, much less coherent with the agro-ecological transition and sustainability goals (Klerkx *et al*., 2019). As is evident in countries where it has occurred earlier, digitalization has mainly benefited the dominant agricultural model, based on specialization and large-scale farms, which was the most profitable market for technology providers (Lajoie-O'Malley *et al*., 2020). The mechanical sector has been the fastest to propose digital solutions to farmers, by embodying them into agricultural machinery (Wolf, Buttel, 1996). Decision support tools in precision farming have been focused on a limited number of crops such as wheat, maize, canola, and soybeans. As pointed out by many observers (Bronson, 2019), this might have increased the disparity between large and small farms, providing much lower than needed improvements to the sustainability performance of farms.

Evidence shows that digitalization, driven only by market forces and in the absence of an effective policy environment, might take our food systems far from sustainability. Policy approaches to technological development in many cases have considered the link between market and technology as unproblematic, considering technological innovation fully coherent with the public interest provided it generates efficiency and economic growth (Schot, Steinmueller, 2018). Keeping separate policy agendas for technology development and environmental, health and social issues has generated divergent pathways. Unintended consequences of technology development, framed in policymaking as "market failures", have limited the capacity of public policies to steer the evolution of technology towards societal goals (Weber, Rorhacker, 2012). Coherence between the digital and ecological agendas will require a new generation of policies – transformative policies – that get rid of "market failure" approaches in favour of "directionality" (Duncan *et al*., 2022).

This paper proposes a policy framework for a "sustainable digitalisation", a digitalization pathway that supports the agro-ecological transition of the farming sector by sustaining the competitiveness of low-input, circular, diversified, quality-oriented farms, and prevents the digital divide between rural and urban areas and between large and small farms. Transformative policies in this field require creating the basic (infrastructural and human capital) conditions for digitalization, adapting digitalization to different contexts, favouring digital inclusion, developing digital ecosystems, designing specific policy tools and adaptive governance models.

The paper is arranged as follows: section 2 provides a conceptualisation of digitalisation as a socio-technical process. Section 3 provides an overview of the state of digitalisation, and section 4 describes the main technological opportunities. Section 5 discusses the theoretical implications of transformative digitalisation strategies

[2] https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf

of agriculture and rural areas, and section 6 proposes a framework for sustainable digitalisation strategies.

2. UNDERSTANDING DIGITALISATION

To build strategies for sustainable digitalisation implies a good understanding of what digitalisation is. We start from the analytical distinction between digitisation, digitalisation, and digital transformation, and their relationship with innovation.

Digitisation is an innovation that turns an analogical process/product into a digital one (Rijswijk *et al*., 2020). This innovation has game-changing impacts, because most of the physical processes / products that populate our life have an informational function (for example, paper and ink are physical objects that are combined to produce information, such as text or images). When information is translated into numbers, its storage, reproduction, processing, display, communication can sensibly reduce the weight of the physical components (the handset, printer, electric power) of a digitized process/product per unit of information. The capacity to turn analogical information into digital information enormously amplifies the availability of information.

While digitisation is a purely technical process, digital*is*ation is a term that qualifies the change that digitisation generates in a broader social (or, better, socio-technical) system (Rijswijk *et al*., 2020). When paper and ink are not necessary to produce text, there is a wide set of actors and activities that need reorganization: paper and ink production and distribution, pens and typewriters, writers, publishing companies, booksellers, users. Digitisation has the power to change, in some cases very deeply, the existing networks of actors, artefacts, rules and their relationship with nature. When digitalisation goes beyond the boundaries of local production processes and affects the way the economy and society are organized – the rules, distribution of power, knowledge and resource base – it is possible to talk about digital transformation (Vial, 2021).

To understand – and anticipate – the socio-economic impact of digitisation, it is necessary to analyse the systemic relations between the physical, social, and digital (cyber) worlds and how they change with digitisation. Digitalisation phases have been classified in the literature according to the characteristics of the Internet-related technologies. The current phase of digitalisation, 4.0, is just at its beginnings, and it is based on technologies such as wireless connectivity, cloud storage and computing, artificial intelligence (Schwab, 2017). This phase is characterized by application systems that communicate with each other and act without human mediation. They apply to the concept of “cyber-physical system”: these systems perform *sensing* (gathering and digitising physical information), *communication* (regulating the flow of information between devices), computation (data storage, data analysis and computation architecture), *application* (calculus, classification, prediction), *actuation* (conversion from the digital to the analogical to operate on the physical system) (Bacco *et al*., 2019).

Cyber-physical systems are assemblages of devices designed to perform one or more function in a specific context. For example, a robot that cuts the grass in a vineyard is composed of sensors that allow the robot to recognize its position. The Artificial Intelligence software detects the grass and recognizes the obstacles in its way. Communication devices allow transmission of data to the cloud, computation software signals that the robot is within the assigned perimeter or if the task is done, cutting devices receive information on when to cut and when to stop[3].

As these systems affect the relations between humans and their activities, scholars have introduced the concept of “socio-cyber-physical systems” to consider the systemic effects of digitization on social relations (Rijswijk *et al*., 2021; Frazzon *et al*., 2013). The analysis of socio-cyber-physical systems starts from the classification of its components into the three domains (social, digital, and physical) and from the analysis of their relations, to allow a better understanding of the changes that digital technologies generate. For example, digital technologies can enable new functions and tasks (monitoring quality and classifying production accordingly) or disenable other functions (for example, milking manually) (Metta *et al*., 2022).

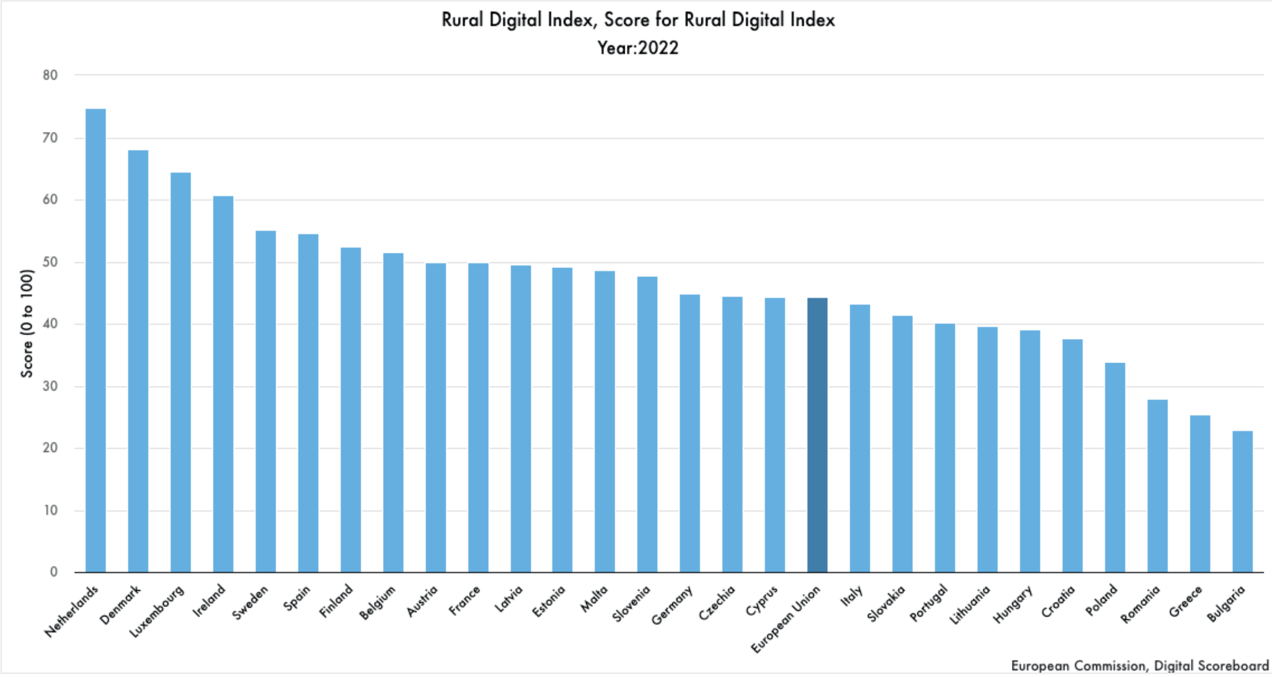
Understanding digitalisation as a transformation of socio-cyber physical systems allows technology developers, policy makers, civil society organisations and users to assess or anticipate the impact of new technologies, making it possible to improve the contribution to sustainable development goals (Rose, Chilvers, 2018).

3. CURRENT STATE OF AGRICULTURAL AND RURAL DIGITALISATION

The landscape of digitalisation in Europe is changing fast. The European Commission measures digitali-

[3] Digitalisation 4.0 is also changing the meaning of “precision farming”, which has existed since the last century (Lowemberg-de Boer, 1996). The power of the new application systems resides not only in the tasks they perform, but also in being part of a network of objects that share huge quantities of data (Wolfert *et al*., 2017). Storage, integration, combination, processing these data gives access to information useful for automatic classification and prediction.

Fig. 1. Rural Digital Index - 2022.



sation through four indicators: infrastructures, human capital, integration of digital technology in the private sector, and digital public services (Russo, 2020). A distinction between rural areas and urban areas is available at aggregated level for the main indicators. In 2022, the average score[4] for the rural digital index was below 50. The countries with the most digitalised areas in Europe are The Netherlands, Denmark, Luxemburg and Ireland, the score of which is above 60. Italy is below average.

Little is known about digitalisation of agriculture. The last census in Italy has allowed to elaborate a "degree of agricultural digitalisation" for Italy. Data show the extent of the digital divide between Northern and Southern Italy, with most Southern regions using very little or no information technologies (Gnesi *et al.*, 2022). These data provide a lens to evaluate the recent technological trends illustrated below, and to warn about policies that don't actively address the digital divide.

4. PERSPECTIVES FOR DIGITAL TECHNOLOGIES IN AGRI-FOOD SYSTEMS

Digital systems of the 4.0 generation are assemblages of multiple technologies (Carolan, 2017) that integrate the variety of functions related to the use of data to provide decision-support or autonomous systems. Some of these assemblages are sold as ready-to-use packages, as in the case of autonomous tractors, which are endowed with GPS systems that track their position and allow automated operations, with sensors to collect data from the field, and devices that connect to the cloud and receive elaborated data and are supported by software that gives real-time instructions to the actuators (for example, spraying)[5]. For most of the other application systems, the design, setup and calibration must be tailored to the characteristics of the farm on which they are applied and requires a mix of digital and agronomic competences (Lin *et al.*, 2019).

Application systems operate in application scenarios (Bacco *et al.*, 2019), defined by the agricultural processes, their purposes and their socio-ecological environments. The study of application scenarios and their specificities is a key to predict the potential uptake of digital technologies. Hereafter we show the most relevant ones, with a review of the related technologies.

[4] The Rural Digital Index score is calculated as the weighted average of the three sub-dimensions: 1 Use of internet (33.3%), 2 Human Capital (33.3%), 3 Connectivity (33.3%). See https://digital-strategy.ec.europa.eu/en/policies/desi

[5] See for example https://www.deere.com/en/technology-products/precision-ag-technology/

4.1. Soil and water management

Restoring the quality of soils is one of the most urgent priorities in the transition. The basic strategy for regeneration is the adoption of agro-ecology principles, but technology can accelerate the process by improving the monitoring of soil quality. Studies show that remote and on-ground sensing, coupled with modelling, are improving the capacity to measure roughness, soil moisture, salinity and organic matter content (Arrouays *et al*., 2021). Also improving the allocation of water for irrigation requires improved monitoring capacity as well as reliable prediction tools (Abioye *et al*., 2020). Remote and on-the-ground sensors can collect a large amount of data on weather, soil and plants. Prediction tools allow closed-loop irrigation strategies, based on controllers that decide automatically when and how much to irrigate based on either predictive models and / or on AI-based intelligent control (Adeyemi *et al*., 2017).

4.2. Crop and livestock management

Sustainable crop management can strongly benefit from the improvement of sensing. Remote sensing based on satellites or drones provide data that can be used to build maps which detect differentials in the status of the crop and allow variable rate operations. Remote sensing is also used to map and estimate weeds in the field (Nawar *et al*., 2017). Machines available on the market are endowed with a myriad of sensors which collect data that are used to adapt their use to the conditions of the environment. The availability of these data allows the development of variable rate systems, which adapt operations to the conditions of the microenvironment where they operate (Antle *et al*., 2017). Digital technologies allow automated coordination between components of the mechanical systems, auto-guidance systems improve adaptation of the operations to the ground conditions. Digital twins – real time simulation models based on a continuous flow of data from the monitored system – can monitor the status of systems in real time, of their energy consumption, or can predict damages, allowing a better planning of maintenance (Pylianidis *et al*., 2021). Unmanned aerial vehicles can collect data and, if endowed with actuators, allow semi-automated operations (Vasconez *et al*., 2019). Unmanned vehicles are already used in harvesting and weeding. 3D printing can be used for producing spare parts locally, limiting delays in repairing the equipment (Javaid *et al*., 2019). Assistive exoskeletons can contribute to relieve agricultural labour and increase labour security (Upasani *et al*., 2019). Digital technologies also offer the possibility to develop alert systems for pest management based on vegetation maps, camera-equipped traps (Jia, Hang, 2019), AI-based recognition of insects and diseases (Abade *et al*., 2021). Variable rate operations can increase the efficiency of applied pesticides.

In the livestock sector, digital technologies allow the monitoring of animal health, to detect diseases early, control movement of animals, monitor emissions, assess the quality of production (Ingrand, 2018). Automation is already widely diffused on livestock farms, especially as far as dairy farming is concerned (John *et al*., 2016), but the possibilities opening with the management of data in the cloud considerably expand the already existing possibilities. Digital twins – simulation models fed by real time data – of animals are being developed to improve the prediction capacity of farmers (Norton *et al*., 2019).

4.3. Farm and supply chain management

Digitalization will also strongly affect other farm management activities. A data-driven approach will benefit from farm management information systems, which will integrate specific decision support systems into platforms that will constitute a dashboard to monitor all operations (Wolfert *et al*., 2017). E-commerce provides alternative outlets to conventional ones and favours the diversification of business models. B2B platforms facilitate the cooperation of farms in the fields of logistics[6], machinery sharing[7], innovation (Rijswijk *et al*., 2019). Access to the internet allows an unprecedented access to information and education – facilitated by the diffusion of smartphones (Schulz *et al*., 2021) – and will encourage advisory services to rethink their organization. Social media allow distance to be overcome and improve organization of work (Morris, James, 160).

There is a growing agreement that the biggest, or the fastest, disruption in the food system will not occur at the level of single activities, but at that of the interaction between activities. We can already recognize the advent of the platform economy in marketing activities, as e-commerce is changing the relational patterns between producers and consumers or between producers. With e-commerce virtually all producers can go on the global markets. Consumers have an unprecedented freedom of choice and the possibility of comparing products (Zhang, Berghäll, 2021). The possibility of getting feedback on customers' behaviour dramatically changes marketing techniques. E-commerce also entails a revolu-

[6] https://lacharrette.org/

[7] https://iottechnews.com/news/2019/may/10/hello-tractor-uber-farming-agriculture/

tion of logistics, which has started to make massive use of digital technologies in administration, planning, control, and goes together with revolution of payments and consumers' purchasing patterns. Platforms have developed sophisticated algorithms to assess the sellers and to match sellers with buyers (Kanoria, Saban, 2021). Consumers can find information on the label, in the shop, or in a cloud-based database which can be accessed through a QRcode (Brewer *et al*., 2021). Increasing availability of bio-physical data will allow the sustainability footprint of each product to be calculated. The increasing amount of information collected at all levels of the supply chains will accompany the products throughout their lifecycle, allowing a full product traceability along the chain. Improved information will increase the responsibility of producers and consumers, as they will be able to link their choice to potential consequences and therefore to account for them. Technologies related to traceability, at present based on documents, will integrate sensing, communication, data management with Internet of Things systems (Lin *et al*., 2020).

5. A POLICY FRAMEWORK FOR SUSTAINABLE DIGITALISATION

The technologies mentioned in the preceding section offer a range of opportunities for the ecological transition of agriculture. However, technology alone will not be sufficient. So far, the most important drivers of technological change have been market forces: farmers adopt digital technologies based on the perspective of reduced costs and increased productivity, and technology developers push innovation where profitability is higher. This means that in the absence of public policies as a balancing driver, digitalisation would tend to fix urgent problems at the expense of long-term objectives, delaying their transformation. Basso & Antle (2021) point out that the efficiency of precision farming could lead to a greater use of fertilizers and pesticides, as precision technologies can put into evidence the areas of the field where the need is higher. To make digital solutions for multifunctionality, agro-ecology and ecosystem services available (Bellon-Maurel *et al*., 2022), they should be actively promoted through adequate innovation policies, which are able to balance market forces by referring to societal challenges (Rose *et al*., 2021). For this reason, digital strategies are needed, and rural and farm communities need to acquire the capacity to obtain control of the incorporation process.

In the new CAP, digitalisation strategies are a component of the National Strategic Plans, where Member States must provide «a description of the strategy for the development of digital technologies in agriculture and rural areas and for the use of those technologies to improve the effectiveness and efficiency of the CAP Strategic Plan interventions»[8]. Digitalisation strategies should explain, in other words, how digitalisation can contribute to the CAP objectives.

However, these strategies risk failure if Member States don't adopt a coherent approach. Transformation cannot be achieved with "normal" policies: transformative policies are needed. As a growing literature shows (Giurca *et al*., 2022), transformative policies tend to address the root causes of emerging problems, and for this purpose they don't refrain from challenging the mental models, assumptions, and coalitions of interests that shape "normal" policies (Köhler *et al*., 2019). To be transformative, policies need to give directionality to the change, to actively shape market forces to make innovative solutions emerge, and be capable of encouraging experiments and learning from them (Duncan *et al*., 2022). However, transformative policies cannot be based on the assumption that the solutions are already there: rather, they mobilize societal forces into innovation processes and leave the pathways of transformation open (Geels, Kemp, 2017). These processes should preferably be "bottom up", by experimenting new patterns of production and consumption, new infrastructures, new rules at local level, and encouraging their scaling up (Geels, 2019; Sengers *et al*., 2019). Transformative policies can offer these experiments a direction (visions and goals backed by evidence and deliberation), enabling environments (financial support, training, regulatory derogations), and can take the outcomes of experiments as inputs for policy learning (Weber, Rorhacker, 2012). They can also actively promote leadership and entrepreneurship of actors, networks and institutions in making change (Hoogstraaten, 2020; Grillitsch *et al*., 2019).

What are the levers that digitalisation strategies can mobilize? The most radical option is regulation: setting mandatory standards or forbidding certain practices or technologies, so creating space for alternative ones. However, excessive use of regulation might limit the creative capacity of actors and innovation. More "soft" measures would tend to leave actors free while influencing their behaviour, for example by altering the cost-benefit balance among options, as in the case of

[8] reg. (EU) 2021/2115 of the European Parliament and of the Council of 2 December 2021 establishing rules on support for strategic plans to be drawn up by Member States under the Common Agricultural Policy (CAP Strategic Plans) and financed by the European Agricultural Guarantee Fund (EAGF) and by the European Agricultural Fund for Rural Development (EAFRD) and repealing reg. (EU) 1305/2013 and (EU) 1307/2013.

compensation for extra costs of recommended options. They can also act on motivations of choice with information, education and training. Innovation policies can be important levers for transformation strategies.

As research and education are largely funded by public money, public policies can do a lot to balance market forces in technology development. This can start from embodying the principles of responsible research and innovation into policies (Klerkx, Rose, 2020; Rose, Chilvers, 2018; Rose *et al.*, 2021), according to which researchers should involve users and stakeholders in the research design, reflect on the motivations, purposes and possible consequences associated with their research, and are directly involved in processes of change.

Following these insights, the DESIRA project[9] has proposed a framework that adopts the socio-cyber-physical system paradigm and identifies three critical properties of Socio-Cyber-Physical Systems (SCPS): design, access and complexity (Rijswijk *et al.*, 2019).

Design focuses on the problems technologies are supposed to address, on users' needs, and on potential risks. Depending on production approaches and business models, technology solutions can assume very different shapes: for example, multifunctional agriculture and agro-ecological practices need quite different solutions from those related to monocultural practices (Bellon Maurel *et al.*, 2022; Hilbeck, Tisselli, 2020). Different configurations, such as centralized systems providing subscription-based services (like Amazon or Google) or decentralized semi-autonomous localized application systems connected in broader networks (such as smart machinery for precision farming), can have different strengths and weaknesses. The issue of design is particularly relevant with AI and robotics, as they can make autonomous decisions with implications for safety and ethics (Coeckelbergh, 2020).

Access regards the endowment of infrastructures, human capital and financial resources that can affect the capacity to adopt digital technologies and create value with them. Different access conditions are at the root of different digital readiness of farmers (Pirola *et al.*, 2019). Inequalities in endowment of these capitals are at the root of the digital divide (Van Dijk, 2020). Different access conditions affect the digital readiness of potential users. In relation to rural areas, the digital divide has an external dimension (rural vs urban) as well as an internal one (Koutsouris, 2010). Access also has a dynamic nature (Van Dijk, Hacker, 2003): early adopters can gain cumulative advantages over late adopters. The removal of barriers to access digitalisation is one of the key aspects of sustainable digitalisation strategies, able to contrast the digital divide and intervene in its dynamics.

Complexity describes the systemic conditions for adoption and scaling up of digital technologies. As the key characteristic of application systems 4.0 is their interconnectedness, successful use of digital technologies for farmers implies being connected to a well-functioning socio-technical network. Lack of specific components (for example, of sufficient quantity and quality of data, advanced digital skills, system integrators), lack of key actors (for example, advisors or service platforms) or inappropriate relational configurations (for example, excessive centralization or decentralization of platforms) can generate unintended systemic consequences, such as structural inefficiencies, concentration of power, or systemic errors. One of the key systemic aspects to be considered is interoperability (Kerber, Schweitzer, 2017), which is the possibility to exchange, pool, integrate data between actors and devices. Interoperability requires regulatory conditions as well as governance and technical solutions (World Bank, 2021).

6. DIGITALISATION STRATEGIES AND FOOD SYSTEM TRANSFORMATION

Implementation of digitalisation strategies will give important insights into how public policies can orient these processes and will stimulate policy learning. However, it should be noted that the reflection on rural digitalisation policies is much less advanced than needed. In a recent overview document of the National Strategic Plans[10], the EU Commission analysed Member States' digitalisation strategies, and identified several shortcomings: a limited consideration of digital technologies as enabling tool for other CAP objectives (particularly for environment, climate and rural-related objectives), a scarce consideration of the needs of rural areas, and limited focus on the development of digital skills that can help to close the digital divide. Moreover, it is said that strategic plans fail to establish consistent links with dedicated interventions, and do not provide a clear picture in terms of planned financial support to digital-related investments.

If Member States have invested little and late in digitalisation strategies, it is to be considered that an EU-level policy framework for rural digitalisation, coherent

[9] https://desira2020.eu/

[10] Proposed CAP Strategic Plans and Commission observations: Summary overview for 27 Member States. June 2022. https://agriculture.ec.europa.eu/document/download/a376aab6-3a1d-4996-bb35-33c90b90c3bd_en?filename=csp-overview-28-plans-overview-june-2022_en.pdf

Tab. 1. A framework for sustainable digitalisation strategies

	Design	Access	Complexity
Directionality	Diversity, system management, relief of heavy and low added value tasks	A minimum level of digital readiness	Build conducive digital ecosystems; build European data spaces
Market articulation	Conditionality, interoperability standards, ethical codes	Incentives to users	Supporting data-based services
Reflexivity	Promoting Living labs	Systematic monitoring of the digital divide	Formative evaluation

with the Green Deal and the Long-Term Vision for the rural areas, is still under development. Table 1 provides an application of the DESIRA framework to transformative digitalisation strategies. The properties of transformative policies - directionality, market articulation and reflexivity (Weber & Rohracker, 2012) - are divided into the three dimensions of the socio-cyber-physical systems - design, access and complexity.

Directionality of *design* should encourage pathways for digitalisation fit to multifunctionality, agro-ecology, small and diverse farming, and adaptation of digital technologies to different contexts. This implies a thorough understanding of the needs related to these practices, which are related to the management of diversity, relief of heavy and unpleasant tasks, improved collaboration and network economies. *Directionality of access* could focus on combating the multiple dimensions of the digital divide. According to the DESI data[11], only 42% of people between 55 and 65 have basic digital skills, while this share raises to 71% in the segment of 16 to 24 years old, and the share of women between 16 and 74 is 52% compared with 56% of men. *Directionality of complexity* should be aimed at developing conducive digital ecosystems (Boiley, Chang, 2007) wherein all actors have the possibility to benefit from the use of data and to establish fruitful interactions with other actors. The specificity of digitalisation 4.0, in fact, is related to the interdependence of actors and technologies with related skills, so that the performance of individual actors depends strongly on to what and whom they are connected, and what are the conditions for exchange between them. Conducive digital ecosystems will depend on the combination of social, human and digital capital and on their relationship with the natural environment. Specific governance arrangements should aim at creating integrated data spaces sufficient to allow data use and re-use. Interoperability standards and clear rules for data sharing, use and reuse are necessary.

When it comes to *market integration*, strategies should be able to make transformative technologies competitive with conventional ones. This could occur in the field of *design*, where research fundings could specify required standards and prioritize application scenarios such as those of small size and marginal areas and focused on agro-ecological practices. In the case of *access*, strategies should guarantee the basic conditions of digitalisation. As seen before, rural areas lag behind urban areas in the parameters of digitalisation (connectivity, human capital, use of Internet). Lagging behind with these parameters implies the reproduction and broadening of inequalities. To keep rural areas within a level playing field, there is the need to be proactive, by constantly monitoring the digital divide, identifying the vulnerabilities, and addressing them with adequate tools. As far as *complexity* is concerned, policies can encourage the consolidation of data-related infrastructures and services, such as advisory service platforms based on specific quality standards. They can play a game changing role in the market, as they can harness the network economies related to the number of their connections.

Introducing *reflexivity* in design-related strategies could shape the characteristics of the design process. For example, the involvement of users in the design – such as in the Living Lab approach – supports adaptation to a diversity of contexts. Considering the anticipation of the impacts as an evaluation parameter could encourage researchers to link innovation to its outcomes. Policy tools should be designed to activate dynamics of transformation through networking and market integration. Operational Groups, Eco-schemes and Agro-Environment and Climatic measures can be designed in a way to encourage the fulfilment of environmental objectives while fostering the uptake of digital technologies in support of them. Reflexivity should also apply to *access*: given that the digital divide is a dynamic process, there should be systematic monitoring and adaptation of the strategies to its evolution. Finally, applying reflexivity to *complexity* would foster policy evaluation approaches aimed at improving the learning processes of all actors in the system, rather than just measuring outcomes, and building adaptive governance. Rural Digitalisation affects

[11] https://digital-agenda-data.eu/datasets/desi/visualizations

several sectors: infrastructures, training and education, data, regional policies, sectoral policies. Moreover, lack of jurisdiction for rural matters hinders coordination under a clear leadership. Governance arrangements should be capable of adaptation in relation to the feedback received from the policy implementation outcomes.

7. CONCLUDING REMARKS

To grasp the opportunities that digitalisation offers to transformative sustainable development policies are needed, organized into coherent strategies based on directionality, market integration and reflexivity, with a strong bottom-up approach. These strategies should be based on an understanding of digitalisation as a socio-technical process and should intervene in the process of technology development and diffusion by addressing critical points of design, access and complexity. As digitalisation can open up a multiplicity of pathways, real-life experiments are necessary to test the most appropriate socio-technical solutions to emerging problems, and the lessons learned at local level should be shared and elaborated to activate higher level learning processes.

Given the fragmented landscape of intervention in this field, a strong emphasis on governance is necessary. Rural digitalisation strategies should have the strength to make the components of several administrations act in a coordinated and coherent way, and institutional actors with strong legitimacy and authority should oversee their implementation. The Next Generation EU has provided a strong injection of resources in the system with a clear transformative purpose. It is now time that these purposes are clearly translated into appropriate governance and policy arrangements.

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Research article

Farmers' selection model in a club value chain: the case of the Agro-Pontino kiwifruit industry

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Abstract. Club varieties are protected horticultural varieties that farmers can grow only with the agreement of the intellectual property right holder (breeder). They contribute to the development of vertically coordinated value chains where breeders act as leading firms, because they can control both production and marketing of the protected variety. Despite the breeders' bargaining power, farmers find club contractual conditions more favourable than those usually offered for non-patented varieties. We hypothesize that breeders may have no incentive to contract all interested farmers in order to avoid expanding production and take advantage of the legal monopoly granted by current regulations. Thus, breeders are expected to select farmers according to an efficiency criterion instead of just licensing all applying farmers. Empirical results from the Agro-Pontino kiwifruit industry support this hypothesis. The results of a questionnaire, submitted to farmers, and of semi-structured interviews targeting key actors of the kiwifruit supply chains, confirmed the selection hypothesis and allow possible selection criteria applied to identify growers of yellow-flesh kiwifruit to be found. A logit-regression model was run using the questionnaire results, while information collected through the semi-structured interviews guided the identification of variables to be included in the model as well as interpretation of the results.

Keywords: Club varieties, kiwifruit, farmers' selection, innovation adoption, value chains.
JEL codes: Q13, Q18.

HIGHLIGHTS:

- Diffusion of protected varieties in the fruit sector to be grown by farmers only after signing a contract with the property right holder.
- Selection of farmers to be involved in the club supply chains according to an efficiency criterion instead of licensing all applying farmers.
- The results of a survey submitted to farmers helped identify the main factors used as criteria in the selection process.

1. INTRODUCTION

Protected varieties are those for which breeders holds intellectual property rights (IPR), under the TRIPS/WTO agreements or the UPOV 1991 Convention or the EU Community Plant Variety Right (CPVR). Supply chains organised around protected horticultural varieties are assuming a relevant role in the fruit sector (Noleppa, 2016; Sansavini, Guerra, 2015). Known as "club supply chains" (from club varieties), their development benefited from the regulation on Plant Variety Protection (PVP) approved in 1991, as a result of the reform of the Union for the Protection of New Plant Varieties (UPOV), considered a "sui generis" protection system particularly suitable for horticultural plants.

The 1991 UPOV regulation reform extended protection to harvested materials (art. 14, paragraph 2) and gave impulse to breeding programmes in the fruit sector and to the economic exploitation of protected varieties, expressed by the initiating of several club supply chains. The effects of UPOV regulation, however, are still considered controversial because of the implications that its provisions might have on the organisation of agriculture supply chains, in terms of distribution of power along the chain and of farmers' position and welfare (Tripp *et al.*, 2007). Breeders may claim their property rights on the harvest; when this happens, farmers might be subjected to production standards and delivery obligation. This implies that the breeders can extend their control on the marketing phase being at the same time input monopolist and harvest monopsonist for the farmers in the club. The reform of the legislation gives breeders the ability to influence both the upstream and downstream segments of the supply chain, by setting the quantity to be produced and imposing marketing control of the harvest (Di Fonzo *et al.*, 2019).

Club supply chains represent an example of the effects that PVPs can have on the organisation of supply chains. In a typical club supply chain, the rights holder acts as lead firm exerting the «power to set the conditions for the inclusion of smallholders and the gains that accrue to them» (Lee *et al.*, 2012). PVPs give breeders the possibility to influence management decisions of those farmers who want to grow protected varieties, because the right to use the variety can be conditional on contract agreements. These limits might go from paying royalties to joining a club supply chain. The latter might imply respecting production quotas decided by the breeder and adopting specific agricultural practices; thus, making relation-specific investments (Noleppa, 2016; Russo, 2020; Tripp *et al.*, 2007). Whether the right holders are breeders or third parties, the key element is that they represent the lead firm of the supply chain and, as such, control its set-up and organisation.

The most relevant examples of club supply chains can be observed in the kiwifruit and apple industries, but the trend in the use of protected varieties is growing in other industries (grapes, nectarines, apricots, pears), albeit with a lower level of complexity in their organisation (Legun, 2015; Sansavini, Guerra, 2015). Usually, in these other industries the exploitation of protected varieties is limited to the payment of royalties, per plant or per quantity produced, or as one-off payment. As for the club supply chains, the kiwifruit industry is considered a key example of development of club varieties (Di Fonzo *et al.*, 2019; Sansavini, Guerra, 2015).

The growing role played by protected and club varieties in the fruit sector raised interest in how these food chains are organised and structured. In relation to their organisation and the role played by breeders, the concept of excludability from the use of a certain good or service, as elaborated by the Theory of Clubs (Buchanan, 1965), becomes relevant. A club has been defined as «a voluntary group deriving mutual benefit from sharing one or more of the following: production costs, members' characteristics, or a good characterized by excludable benefits» (Sandler, Tschirhart 1980). The theory applies to those arrangements where excluding potential members from entering a club is possible. The accessibility of a club-good to non-club members would imply its use without paying the costs associated to membership. Hence, the flexibility of property arrangements represents an effective tool to exclude non-members from the use of the good (Buchanan, 1965). In the case of the kiwifruit clubs, the theory applies because the breeder and farmers achieve mutual benefits (large production volumes and higher prices, respectively) by voluntarily sharing the use of the protected variety and knowledge. Yet, unique characteristics emerge. Specifically, membership is awarded by the breeder, who also decides production volumes and practices, including quality standards of the harvest. The breeder's power to regulate access changes the nature of the innovation diffusion process from an innovation adoption model, where the innovation is adopted by any farmer who is willing to pay the price, to a supplier selection model where the innovation is accessible only to the farmers that the breeder decides to accept in the club. Breeders, in order to maximize their profit, will privilege more efficient farmers, capable of implementing the quality standards at a minimum cost. This might result in the exclusion of less efficient farmers from access to these new varieties, technical innovation and, potentially, higher profits.

Adoption and diffusion of innovation in agriculture have been extensively studied in economics and, more recently, in sociology, psychology and marketing; thus, there are multiple examples in the literature of innovation adoption models (Ajzen, 1985; Edwards-Jones, 2006; Rogers, 1962). Despite the differences between them and the variety of drivers used to explain the adoption and diffusion of innovation, a key element of them is the willingness of farmers and the interventions needed to support their adoption of innovations. The organisation of club supply chains, however, seems to entail the possibility that breeders might have a strong interest in selecting their suppliers; willing to pay the price to adopt the innovation might not be sufficient for farmers to join the club. In this respect, some insights might be offered by the literature dealing with the selection of suppliers, in particular explaining the mechanisms and potential criteria to be used to select the most suitable suppliers (Dey *et al*., 2015; Liu, Hai, 2005; Talluri *et al*., 2006). The definition of these criteria becomes key to select the most appropriate suppliers, considering that selecting "not-fit for the job" farmers might have negative consequences on the economic performance of breeders. The "market signalling" approach (Spence, 1973) might become a useful tool for breeders to set up the right criteria and correctly interpret them. Spence applied this approach to the job market, arguing that firms willing to hire employees with unobservable characteristics (such as work productivity) may solve the adverse selection problem by relying on "signals". Signals are observable actions (such as college degree or training) taken by the employees with a cost that is inversely correlated with the desired unobserved characteristics (for example, the cost in time and effort of a college degree is expected to be lower for a productive worker) (Spence, 1973).

If the signalling theory is transposed to the club supply chains, with the breeder being the employer and the farmers the employee, the same problem of information asymmetry applies. Breeders are not sure that farmers selected possess the right skills to implement the quality standards efficiently. They can become aware of farmers' skills and evaluate them once the business relationship is already in place and, if needed, they can terminate the contract, but this might bring negative consequences, because of the time required before the farm selected starts producing and the time to replace them. If the selection process fails in a relevant number of cases, the breeder might not be able to fulfil market demand. Knowing the complexity of the club variety to be produced, breeders might decide to select farmers and base this selection on a combination of observable indices and signals.

This paper analyses the case of the kiwifruit industry in the Agro-Pontino area, in central Italy. The objective of the study is to investigate whether the involvement of farmers in club supply chains can be considered as a model of adoption of the technical innovation by interested farmers or, as theory suggests, a model of selection of farmers by the breeder. This would allow it to be understood on which basis farmers are involved in club chains, if they can freely enter them and to what extent this process is controlled by right holders. Semi-structured interviews with key stakeholders and a survey submitted to farmers were used to collect information and data to conduct the analysis. Section 2 provides information about recent developments in the sector and the description of the main club and non-club chains identified in the Agro-Pontino area. Section 3 explains the empirical strategy used to conduct the studies in detail and sections 4 and 5 illustrate results and conclusions.

2. THE AGRO-PONTINO KIWIFRUIT FRUIT INDUSTRY

2.1. Development of protected varieties in the kiwifruit industry

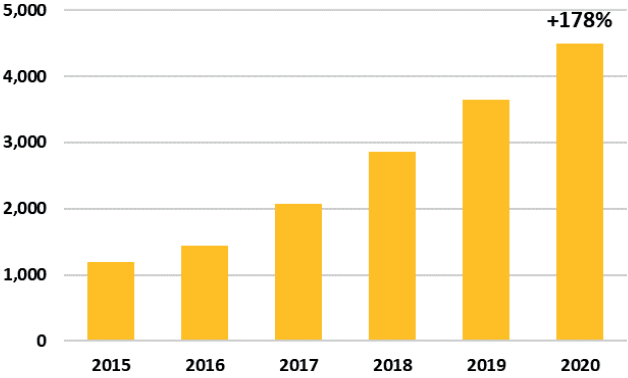
The importance of protected varieties in the kiwifruit industry has grown considerably in the past decade. Commercially, the yellow-flesh varieties are the most important, although some companies also recently started marketing red-flesh kiwifruit, always with the club formula. Green-flesh varieties, on the contrary, are mainly free; the most common free variety, Hayward, is also the most extensively cultivated both in Italy and abroad.

The development trends of the sector show that the club varieties are acquiring importance in terms of acreage and production, as evidenced by yellow-flesh kiwifruit registered within two of the main producing and exporting countries, namely New Zealand and Italy (https://www.csoservizi.com/; FAOSTAT). CSO

Figures 1 and 2 show the growing trends of acreage and production of yellow-flesh kiwifruit from 2015 to 2020 in Italy. Data refers to the main club varieties cultivated and marketed, that is Sungold (Zespri), Soreli, Dorì, Jingold (Jinyan and Jintao), and to the harvest that could be sold, net of waste and fruits not achieving the envisaged quality requirements. Acreage showed an increase of 178% in six years, reaching almost 4,500 hectares in 2020, while production increased by 346%, with 79,790 tons marketed in 2020.

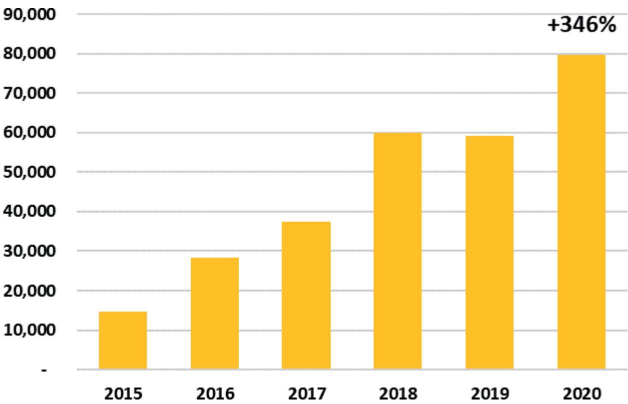
A comparison with the trend in green-flesh kiwifruit production shows that the latter is still widely

Fig. 1. Acreage (ha) of yellow-flesh kiwifruit in Italy from 2015 to 2020.



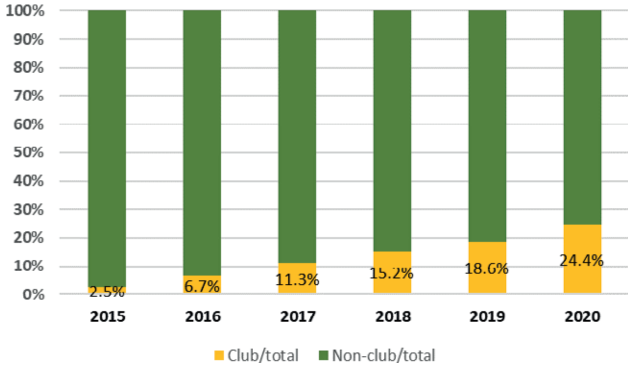
Source: Centro servizi ortofrutticoli.

Fig. 2. Production (t) of yellow-flesh kiwifruit in Italy from 2015 to 2020.



Source: Centro servizi ortofrutticoli.

Fig. 3. Marketed (%) club and non-club kiwifruit in Italy from 2015 to 2016.



Source: Centro servizi ortofrutticoli.

produced in Italy, as already pointed out, but shares of traded fruits have been decreasing constantly in the past six years, while the yellow-flesh one is increasing (Fig. 3).

Italy is the third main producer of kiwifruit worldwide and the main one in Europe, followed by Greece, whose production increased by 37% in the past six years (specific data about club varieties production is not available). The kiwifruit industry in New Zealand, second main producer of kiwifruit and first producer of yellow-flesh kiwifruit with Zespri (265k tonnes in 2019 and 5,480 hectares[1]), confirms the same trends observed in Italy, with a decrease in the production of green-flesh kiwifruit and a corresponding increase of yellow-flesh kiwifruit (+133% from 2015 to 2019[2]).

The growing role played by club varieties in the kiwifruit industry raises the need to focus on how these food value chains are organised and structured.

2.2. The kiwifruit industry in the Agro-Pontino area

The introduction of kiwifruit in the Agro-Pontino dates to the 1970s. It is the main production area of the country, with 26% of the national acreage in 2020. The area is considered highly specialised and is characterised by the cultivation of both free (mainly green-flesh Hayward) and protected varieties, in similar environments with respect to land quality, weather conditions, infrastructures and availability of services. The industry is characterised by a variety of supply chains. The first distinction is between club and non-club supply chains (Russo, 2020). The club chains trade mostly yellow-flesh kiwifruit (Sungold and Jingold varieties), while the non-club chains trade not protected varieties (Hayward green-flesh). Club supply chains are driven by breeders.

Two main club value chains can be identified in the Agro Pontino area; the major difference between them lies in the relationship the breeder has with Producer Organisations (POs). In one case, growers are members of the POs, and the breeder takes advantage of the knowledge POs have of their members to identify the most appropriate farmers to become club growers.

The club supply chains of kiwifruit in the Agro-Pontino can be split in three main areas, corresponding to input provision, production and marketing. The provision of input is directly controlled by the breeder or by a network of nurseries that grow and sell the materials in agreement with the breeder. Production is ensured by farmers, who join the supply chain upon signing a contract. They can be members of POs or independent

[1] Source: Centro servizi ortofrutticoli
[2] Source: Centro servizi ortofrutticoli

farmers. The marketing phase can be further broken into three layers, namely (i) buyers, (ii) other intermediaries; (iii) retailers. The distinction between the first two layers refers to buyers who directly buy from farmers, including POs, and buyers who buy from other breeders. The breeder is at the same time the supplier of the genetic input, the buyer of the harvest and the supplier who negotiates with retailers. The breeder controls the production, signs production contracts with farmers and provides farmers with technical assistance in order to reach the quality standard required to market the product with its brand. The contract signed by farmers includes the delivery of the entire harvest to the breeder. Farmers are usually allowed to grow other non-club varieties and they may or may not deliver the unprotected harvest to the breeder.

Two supply chains based on free varieties have been identified in the area. The main difference between them is the nature of buyers, who may be private traders or POs. POs, where present, collect the entire harvest of their members and usually provide them with the plant materials. They can be considered as "the lead firm" of the supply chain, even though they do not have the capacity to fully control production, unlike what happens in the club supply chains.

3. METHODS AND DATA

The investigation was conducted by using a farmer survey and semi-structured interviews targeting privileged actors involved in different ways in the club supply chains.

The farmer survey was originally designed to investigate the relevance of unfair trading practices within club value chains and to compare the difference in the occurrence of these practices between club and non-club supply chains[3]. Survey data were used to understand whether there are significant differences between farmers producing free kiwifruit varieties and those producing patented varieties and which farmers' characteristics can influence their opportunity to join club value chains.

The semi-structured interviews include three main sections:

1. The first investigates the factors determining farmers' participation in club supply chains. Questions about the following topics were included:
   a. Preliminary contacts. The process through which initial contacts were made between farmers and breeders is examined. Specifically: who takes the initiative and the role of possible intermediaries, such as POs and cooperatives in these initial exchanges; when POs or cooperatives are involved, additional questions are asked about how the process is managed within the PO/cooperative, to understand if farmers can propose themselves or if a strategy of the organisation exists to manage the process.
   b. Advanced contacts. The role of intermediaries is investigated in relation to the completion of contracts, in the case that the initial exchanges go further, and a business relationship is established. The relationship the breeder has with intermediaries is analysed, when they are involved, and what are the roles of both in the decision to include or not farmers in the club supply chain.
   c. Identification of prospective members. The process of involvement of farmers in the club chain is investigated. Questions about potential criteria to apply to this process are asked, including the role POs and cooperatives play in it.
2. The second section focuses on the characteristics of contracts signed between breeders and farmers and, where relevant, POs and cooperatives, or other intermediaries. This section aims to understand general content, length, presence of specific clauses related to, e.g., quantities to be delivered, price definition, quality standards to be achieved and possible penalties existing if they are not achieved, potential investments needed to make the farm adequate to grow the new variety, waste disposal, conditions to market productions, other possible obligations, conditions to exit the contract. The role of POs and cooperatives is also analysed, including the contract that the breeder signs with them, if present.
3. The third section deals with the organisation of the club supply chain and the strategic approach followed by the breeder in organising it. Distribution of tasks, responsibilities, specific requirements related to agricultural practices (e.g., training, access to advice), including investments. Nature and evolution of the relationships between different actors: breeders and farmers; breeders and POs and cooperatives, when involved; farmers and POs and cooperatives; farmers among them; retailers and farmers; retailers and breeder; retailers and POs/cooperatives. Additional questions investigate the presence of specific

[3] The data are property of the European Commission Joint Research Centre (JRC) and were collected for the research project *Pass-Through of Unfair Trading Practices in EU Food Supply Chains Methodology and Empirical Application*. The use of the data for this publication was authorized and the authors thank the JRC for the kind concession. A full description of the dataset is in Russo (2020).

risks linked to the participation in a club chain and organisation of the monitoring system, including information collection.

Based on the data collected by the survey, our objective is to estimate how the different farmers' characteristics, specialisation and farm size affect the opportunity to be selected to join a club supply chain. Thus, our dependent variable is a dichotomic variable, which can be expressed by being or not being a member of a club supply chain. Given the nature of the dependent variable a logit regression model with multiple regressors was applied, as follows:

$$\text{logit}\left[\pi(\mathbf{x})\right] = \log\left(\frac{\pi(\mathbf{x})}{1-\pi(\mathbf{x})}\right) = \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k$$

The equation with the dependent variable Kiwiclub and the regressors selected was formulated, as follows:

Ln(p/1-p) Kiwiclub= β0 + β1Age + β2Graduation + β3Fulltime + β4Kiwifarm + β5UAAkiwi + u

where the dependent variable "Kiwiclub" is a binary variable which equals 1 when the producer is a member of a club chain and 0 otherwise; the regressors, selected on the basis of the results of previous studies (Dey *et al*., 2015; Di Fonzo *et al*., 2019; Russo, 2020; Talluri *et al*., 2006) and of the key-informant interviews, are: age, level of education, extent of the agricultural activity (full time/part time), specialisation of the farm and kiwifruit UAA and u representing the random disturbance. The parameters βi are estimated by the maximum likelihood method. Furthermore, we estimate the marginal effect on the probability of being a member of a club when regressors change.

The questionnaire was submitted to 85 kiwifruit producers in the Agro-Pontino area, 19 of whom grow club varieties and the remaining 66 grow non-club varieties. These 85 farmers are representatives of 2,119 kiwifruit growers in the area considered (2010 Census). Table 1 reports farmers' characteristics and Table 2 variables and statistics of the selected sample.

60% of the sampled farmers are full-time farmers, 71% are male and only 21% are college graduates. Almost half of them are members of a cooperative or PO, and 63% are specialised in the production of kiwifruit, meaning that 22% of them grow club varieties, and all these 19 farmers are members of a PO. On average, they are aged 54 years and the kiwifruit UAA is slightly above 5 hectares.

Tab. 1. Farmers' characteristics.

Full time farmers	*60%*
Male farmers	*71%*
Graduated farmers	*21%*
Kiwifruit specialised farmers	*63%*
PO/Coop members	*49%*
Club varieties growers	*22%*

Tab. 2. Descriptive statistics of variables used in the analysis.

Variable/Statistics	Min.	Max.	Mean	Std Dev.
Age of farmers	25	73	54	9.60
UAA (ha)	1.50	170.00	11.01	21.90
Kiwifruit UAA (ha)	0.50	73.00	5.29	9.30

4. RESULTS AND DISCUSSION

Table 3 shows the estimates and marginal effects of the logit regression model. The overall fit of the model, measured by McKelvey and Zavoina R2, is 0.897, which represents a very high result for logit estimations, indicating that the variables included in the model explain a relevant part in the selection of farmers to be included in the club chains. These results are consistent with a selection of farmers by breeders, based on a combination of observable indices (age, sex) and signals (education, work experience, farm size) (Spence, 1973). Specifically, full-time farmers have 58% higher probability to be included in a club chain, while graduate farmers have 53% higher probability to be selected by breeders than farmers with a lower level of education. The specialisation of the farm is also valued as an important characteristic. Farmers growing only kiwifruit have 20% higher probability of being selected than those producing other fruit varieties, while farm size has less influence on the choice of farmers. Age, on the contrary, negatively influences the possibility to be part of a club chain. Younger farmers are preferred to older ones as club growers. However, this influence does not seem that important, and this can find an explanation in the average age of farmers being rather high in the area, as in the rest of the country.

Interviewees reported the availability of farmers to become part of the club supply chains, despite the condition of the contracts to be signed with the breeder being considered rather strict and so are the agricultural practices to be followed to achieve quality standards. Interviewees agreed on the fact that a selection is performed, and the model gives insights into the most relevant factors considered in this selection process.

Tab. 3. Results of the logit model.

	Coefficient	Std. Error	Significance	Marginal effects
(Intercept)	-3.60101	2.49177		
Age	-0.10470	0.04774	**	-0.0133
College diploma	2.86224	1.28013	**	0.5396
Full-time farmer	5.25047	1.61305	***	0.5828
Kiwi farms (specialised)	1.83766	0.89101	**	0.2044
UAA kiwi	0.49872	0.21836	**	0.0636

McKelvey and Zavoina R^2=0.897
Mac Fadden R^2=0.405
n: 85
N: 2,119

Breeders are concerned by the need to select the most "fit for the job" farmers. The results of the analysis confirm that breeders oriented their choices following signals such as education, work experience and professionalism/being a full-time farmer (Spence, 1973). This strategy has been confirmed by interviews with breeders, who mentioned the existence of a selection process, where education and experience of growers are valued as positive signals. The factors included in the selection can be associated with more efficient farmers. Breeders prefer to grant access to the club supply chain to more efficient and skilled farmers.

The data collected with the interviews also indicate the role of POs and cooperatives as being relevant in this selection process (Di Fonzo *et al*., 2019; Russo, 2020). They are involved in the selection process and, in at least one of the two club supply chains analysed in the Agro-Pontino area, farmers involved in it are all POs' members. The involvement of POs might be considered as an additional strategy to mitigate this risk for breeders. POs and cooperatives know their members and they might have a rather precise idea of which farmers are more skilled. Their involvement relates also to issues such as trust and reputation, which become more relevant within the perspective of a long-lasting business relationship, and of course can assist breeders in correctly "reading" growers' signals.

5. CONCLUSIONS

This investigation supports the conclusions that farmers' involvement in club supply chains can be defined as a farmers' selection rather than farmers' adoption model. Farmers cannot freely access a club supply chain and breeders exert the power to exclude farmers from growing their patented variety. Breeders apply selection criteria to recruit growers in the club supply chains, despite the willingness of farmers to become members. Cultivating protected varieties, though, entails following and meeting specific quality requirements, and this might need farmers to modify agricultural practices and invest in modernizing their farm structures.

Breeders seem to consider that professional farmers with a higher level of education might ensure production standards of club varieties. Full-time farmers have 58% higher probability to be included in a club chain, while graduate farmers have 53% higher probability to be selected by breeders than farmers with a lower level of education. Farmers specialised in the production of kiwifruit have 20% higher probability to be selected than those also producing other fruit varieties. Age negatively influences the possibility to be part of a club chain.

No detailed economic data are available to measure farm income from yellow-flesh kiwifruit production compared to green-flesh kiwifruit. Information about farm income was not filled in by farmers in the questionnaire. However, interviewees agreed on the fact that protected varieties allow, at least, to double farm income. This information would need to be confirmed by a quantitative analysis that could allow a comparison with the income of free varieties growers. This might be the subject of future research on this topic.

The results of the analysis suggest potential implications linked to the PVPs and the adoption and diffusion of innovations. The update of the UPOV regulation in 1991 influenced, to a certain extent, the incentives that breeders have to innovate and the process to manage the exploitation and diffusion of their innovation. Before the reform, the payment of royalties (per plant or per quantity produced, or a combination of them) was an adequate means to exploit new varieties. The royalty system incentivises the diffusion of new varieties. The breeder maximises his profit by increasing the diffusion of the protected varieties and, consequently, the amount of royalties received.

After the reform, the incentives for breeders changed. The extended protection of harvested materials opened up new exploitation possibilities, including that of registering trademarks associated to the new varieties and of controlling all phases of the supply chain, including marketing. These new economic incentives of breeders led to an interest in better protecting the investments on new varieties and the economic margin deriving from their exploitation. Protecting the variety from non-authorised growers combined with the need to achieve quality standards able to ensure good results in the marketing phase raised the importance of selecting farmers to be involved in the club supply chains, hence, influencing the process of adoption and diffusion of innovations.

Another potential implication of the diffusion of club supply chains concerns the access that farmers have to the new varieties. Our investigation suggests that the most efficient and skilled farmers are selected to be part of the club supply chain, which, according to interviewees, ensures higher profits. Inefficient farmers, on the contrary, are excluded from the club chains; they do not have the possibility to access innovation and increase their profits. This might have implications in terms of policy interventions to increase skills and knowledge of less efficient farmers. Of course, improving their efficiency would not ensure access to the club, since breeders will still apply the selection process.

The study has some important limitations. The high level of reticence of respondents and the difficulty in finding farmers and other actors available for interviews reduced the amount of data to be used in the analysis. The lack of previous studies on this topic and the lack of economic data about the spread of club varieties complicated the analysis. Another limitation of the study is that it refers only to the Agro-Pontino area and does not consider other areas in the country and abroad where yellow-flesh kiwifruit is grown, even though the area was chosen because of its homogeneity.

These results support the conclusion that further and more specific criteria and conditions might be set up by breeders to engage farmers. Additional research would be needed to better define these criteria and understand the farmers' position and perspective in the club supply chain, given the importance that they are assuming in the fruit sector. Additional research to quantify the differences in terms of farm income between club and non-club growers, to be extended also to other industries, might give important insights to judge the functioning of these supply chains and to understand if the limitations that farmers must accept to be part of them are balanced by an increased farm viability.

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Research article

A participative methodology for prioritising intervention logic in the design of the Italian CAP Strategic Plan

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Abstract. The new CAP implementation model requires each Member State to design a CAP Strategic Plan (CSP) to deliver operational actions under the two CAP pillars. Each CSP must be built from an evidence-based needs assessment that undergoes rigorous prioritisation to plan comprehensive and achievable interventions. In Italy, the institutional context requires all the Regions and Autonomous Provinces to express their preferences and to discuss the CSP collectively, both as regards identifying territorial needs and their prioritisation. In this framework, it became pertinent to introduce a specific instrument to facilitate participation in this process. The Italian Ministry, in collaboration with the National Rural Network, developed a participatory route to assess the prioritisation of the identified needs, to support the decision-making process in CSP drafting process. The process is primarily based on a voting aggregation technique called the Constrained Cumulative Voting method. The process identified makes it possible, on the one hand, to formulate a shared consensus on the level of importance of each need; on the other one, via the definition of natural breaks, to determine homogeneous groups of needs by importance of intervention. This process is in line with the European Commission's legislative proposals requiring a sound and well-founded logic of intervention.

Keywords: CAP, CSP, needs, prioritisation, governance arrangements.
JEL codes: Q18, O21, D7.

HIGHLIGHTS

- The process to define the CAP Strategic Plans for 2023-2027 requires Member States to identify territorial needs in a very participatory way.
- The National Rural Network proposed a well-structured, comprehensive and highly participatory prioritisation route, based on the Constrained Cumulative Voting method.
- The results of the prioritisation process were collectively discussed, evaluated and emended, and a final list of the priority levels was defined with a clear level of polarisation.

1. INTRODUCTION

The implementation of the Common Agricultural Policy (CAP) is structured around a New Delivery Model based on the CAP Strategic Plans (CSP), developed by EU Member States (MS). As stated in the new regulations, each MS must design a single plan following 9 specified objectives (Fair Income; Competitiveness; Food Value Chain; Climate Change; Environmental Care; Landscapes; Generational Renewal; Rural Areas; Food Health), from three General Objectives (economic, environmental, and social) (GO), plus one cross-cutting objective on knowledge and innovation (AKIS) (reg. (EU) 2021/2115, art. 6). The CSP is intended to offer MSs greater manoeuvrability to respond to their specific territorial needs and contexts; some experts (Carey 2019, Matthews, 2021, Cagliero *et al.*, 2021) suggest that this is the most crucial element contained in the new CAP regulations adopted in December 2021. The transfer of relevant responsibility to MSs allows them to design their own strategies to address specific national challenges, while still complying with objectives defined on an EU level.

This challenge requires the establishment of a consistent intervention logic, defined in the European Commission's Better Regulation Guidelines as «the logical link between the problem that needs to be tackled (or the objective that needs to be pursued), the underlying drivers of the problem, and the available policy options (or the EU actions actually taken) to address the problem or achieve the objective». It involves implementing a very robust process when it comes to designing the CSP: (i) diagnostic and context analysis, (ii) SWOT analysis and territorial needs assessment, (iii) prioritisation of needs, and (iv) the establishment of a strategy to integrate interventions and the set of targets (Carey, 2019). All the steps must be adequately defined using clear and transparent methods and the use of participatory approaches is recommended (Matthews, 2021; Erjavec *et al.*, 2018).

The introduction of a single plan represents a particularly significant challenge in countries where agricultural issues are decentralised to regional authorities. Indeed, several Member States constitutionally delegate their competencies over agriculture and rural development to subnational entities; in Italy, for example, the Regions and Autonomous Provinces (RAPs) hold several, fundamental competencies in agriculture and rural development. In the 2014-2022 planning period, the implementation of rural development strategies, i.e. the second pillar of the CAP, was structured as follows: 22 Rural Development Plans (RDPs) – one covering the national level and 21 regional or provincial – and a Rural Network Plan.

The Italian route to define an intervention strategy began in 2019, when the Ministry of Agriculture, Food and Forestry Policies (MIPAAF) launched a joint process with the RAPs. The aim was to assess context analysis as a diagnostic phase, with the technical support of the National Rural Network (NRN). Ten Policy Briefs related to the 9 EU-specific objectives and the AKIS objective were drafted and discussed in various technical meetings with the RAPs.[1] Consultation with economic and social partners and civil society stakeholders was also initiated in this phase. The consequent elaboration of SWOT matrices aimed to provide narrative synthesis of the Policy Briefs, but also to be consistent with the experience gained during the 2014-2022 planning period. Useful indications for the improvement of the Policy Briefs and SWOT matrices were provided during the technical meeting with the Commission's GeoHub (Pierangeli, 2020). The identification of the first list of 50 needs was conducted by NRN experts and discussed, in several rounds, with the RAPs (Angeli *et al.*, 2020).[2]

Based on these steps, Italy developed a specific, highly participative process for assigning different levels of priority to the identified territorial needs, starting from a Cumulative Voting (CV) approach. Cumulative Voting is a simple and transparent method for prioritising a list of items and, according to the literature, offers several advantages. It allows for a high rate of participation among stakeholders and the possibility of clustering results, rather than merely providing a list of priority values. Using the literature available, NRN experts developed a specific field-tested model of the technique, known as Constrained Cumulative Voting (CVV), to address the common weaknesses of the CV techniques and to cope with constraints arising from the COVID-19 pandemic. In addition, to make the results of the voting process more manageable and effective, they were aggregated into priority bands, through a clustering procedure (Jenks optimisation).

The results of the application of CCV were very positive and it was able to polarise the priority of needs as expected. These results were compared with the outcomes of a consultation phase with the stakeholders (Partnership). This comparison procedure supported and confirmed the outcomes of the application of CVV and made it possible to define the final framework for the priority bands of territorial needs that could subsequently be applied to the future CSP in Italy.

This participative approach is particularly unique because it also involved the RAPs and the Partnership

[1] https://www.reterurale.it/PAC_2023_27/PolicyBrief

[2] https://www.reterurale.it/flex/cm/pages/ServeAttachment.php/L/IT/D/a%252F1%252F9%252FD.6c3376f87cf067a519f9/P/BLOB%3AID%3D23075/E/pdf

Fig. 1. The Route to Validate the Needs and Priorities Assessed in Italy, by the Main Phases.

Phase	Steps	Method	Months
Phase A	**Step A.1** - The RAPs are called to express the degree of priority of the listed needs, split into altimetric areas (plain, hill, mountain)	Cumulative Constrained Voting	May/June 2021
	Step A.2 - NRN experts processed the individual indications vector into a consensus matrix, according into four qualitative levels: Strategic, Qualifying, Complementary, Specific.	Jenks natural breaks classification method	July 2021
	Step A.3 - Overall validation of the aggregation process of individual indications in the common consensus matrix	Traffic light	August/September 2021
Phase B	**Step B.1** - The members of CSP partnership are asked to fill a simplified online format for voting the same initial list of needs submitted to RAPs	Online voting	Early October 2021
	Step B.2 - NRN experts processed the votes to identify and compose the overall level of prioritization as expressed by the Partnership into four qualitative levels	Modal attribution	End of October 2021
Phase C	**Step C.1-** NRN experts cross-checked the two result matrices, highlighting the major differences, to define a common, definitive matrix	Gap and Discrepancy Analysis	Early November 2021
	Step C.2 - Final validation of needs and priorities with the RAPs	Plenary dscussion	End of November 2021

in the prioritisation process, while other regionalised Member States have predominantly used desk research techniques, applying multi-criteria methodologies. For this reason, the aim of the article is to describe the process and discuss the outcomes of the needs prioritisation phase in Italy.

2. THE PARTICIPATORY ROUTE TO PRIORITISING CSP NEEDS IN ITALY

Since 2019, the Italian Ministry has been developing an approach that would coherently combine CSP intervention logic with EU indications, in line with the four steps mentioned above: (i) context analysis, (ii) SWOT analysis and territorial needs assessment, (iii) prioritisation of needs, and (iv) the establishment of the CSP strategy. Other regionalised Member States, such as Spain, Portugal and France, followed a similar path: they used a participative approach up to the needs assessment step, while for needs prioritisation, they used desk research approaches, often built on multicriteria analyses, to define priority bands.[3] In compliance with the European Code of Conduct for Partnerships (Commission Delegated Regulation (EU) 240/2014), Italy opted to maintain a highly participative approach in the prioritisation step. The Ministry initiated a particularly unique approach, made up of various phases to create what is called the needs prioritisation route. A thematic working group, comprised of NRN analysts, identified the iterative process supporting the MIPAAF, the RAPs and the stakeholders in expressing a shared assessment of the prioritisation of the various items identified in the diagnostic process. The process is intended to involve and allow for feedback from stakeholders through various mechanisms, ensuring the involvement of a broad partnership and the active participation of actors with mandates on agriculture.

The prioritisation route was composed of three phases (Fig. 1): the first (Phase A), involved the Italian RAPs to define needs and priority levels based on a participatory cumulative voting approach; the second

[3] In Spain and Portugal, territorial needs are classified using a code system (+++; ++; +), while in France, they use "PSN indispensable; PSN utile; PSN pas indispensable".

(Phase B), involved the Partnership for CAP 2023-2027, with the aim of consulting partners and refining the picture emerged from Phase A; the third (Phase C), provided the final definition of the priority levels for each of the needs identified, by comparing and merging the results obtained from phases A and B.

Phase A: The Technical Feedback from the RAPs

The first phase of the prioritisation process was focused on the technical exercise carried out with the RAPs, stimulating a collective discussion to define and share the different levels of importance of the 50 needs identified from the context analysis, specified for each altimetric area (plain, hill and mountain).

In a two-stage selection process with feedback adjustment (Tang *et al.*, 2020), RAPs were called to express the degree of priority of the common needs in a constrained voting framework that led to the first list of prioritised needs. The voting mechanism allowed simplicity of application, flexibility and remote manageability. This aspect was particularly important, as the CAP planning phase took place during the period in which the restrictions on travel and in-person meetings due to the COVID-19 pandemic were particularly strict (Cagliero *et al.*, 2021). The result of this step was the collection of priority indications in cardinal terms by the participants.

Next, we proceeded to aggregate the individual indications gathered. To avoid rigid, ineffective cardinal ranking, while favouring a usable indication of priorities, we provided a priority bands scheme restitution of the overall aggregated matrix. Since it is crucial to obtain «clear break points that show which are the obvious high-priority items» (Dennison, 2000), we transformed the numerical indications for each need into qualitative levels or bands, via the Jenks natural breaks classification method. The Jenks optimisation is a common classification technique based on a K-means approach to define the minimum distance between data and the centre of a class, as well as the maximum distance between class centres (Mac Carron *et al.*, 2016; Khan, 2012). This means reducing the variance within every band and it maximises the variance between the bands. By extension, in this study, we set a priori four bands to subdivide the territorial needs and we applied the Jenks optimisation with an R® software routine by altimetry. The qualifications for the different priority bands have been set as follows (Mazzocchi *et al*, 2021):

- Strategic: these priorities lie at the heart of the strategy and should involve both specific actions and comprehensive approaches that also synergistically address other needs;
- Qualifying: these priorities refer to enabling areas of intervention to make effective responses to other needs, in particular, strategic needs;
- Complementary: theses priorities refer to spheres of intervention that synergistically complement strategic needs; they are not technically less relevant, merely more specific, of an enabling nature;
- Specific: to increase the effectiveness of the process, but with specific relevance to the Strategic Plan.

Once the first draft of the national matrix was defined, the feedback stage was conducted to reduce or eliminate inconsistency or dissatisfaction of individual participants with the overall grade. The measurement of consensus can be read as the deviation between the individual and the collective preference matrix and, despite the fact that decision-makers do not often easily accept a feedback mechanism, any contentious issues must be clearly identified and addressed (Wu *et al.*, 2018; Gu *et al.*, 2021). The RAPs were then called to discuss the overall estimated picture and they could confirm or propose a change in the priority levels allocated in the aggregative process conducted by NRN experts.

This feedback mechanism is based on a colour-coded voting system (Gibbons, 2019; Dennison, 2000), similar to a traffic light. The RAPs were asked to review each need and given the option to indicate if they agreed with its allocated priority band or believed it should be revised, using a system of coloured dots: GREEN = increase to the next priority level; WHITE = the level is correct; RED = reduce priority by one level. This step was conducted by applying a criterion of consistency in the observations and proposals. A change in priority levels was accepted when the proposed change was sufficiently represented in the overall tally of votes both in terms of number of votes and the direction (up or down by one level) of the change. In practice, this meant that at least one-third of the participants had requested an amendment to the priority assigned to a particular need and with a similar indication in the change to priority band (either increasing or decreasing).

Phase B: The Consultative Phase with the Partnership

From the outset, the MIPAAF initiated an open and collaborative discussion with the representatives of the competent institutions and environmental and socio-economic sectors, in line with reg. (EU) 240/2014. The Ministry has set up a specific Partnership, composed of representatives of the stakeholders (public authorities, economic, environmental, and social actors). The Partnership was asked to express its assessment of the priority levels of the needs by altitude (plain, hill, mountain).[4] The participants were asked to fill out an online questionnaire through which they could assign the possible priority levels for the 50 priorities. They were given the option to include qualitative comments in a separate section; this qualitative information mainly concerned specific territorial aspects and was organised by theme. All feedback was processed by the NRN experts, to identify the level of prioritisation as expressed by the Partnership for each need by altimetric area, under the four labels used by the RAPs (Strategic; Qualifying; Complementary; Specific). The most critical issue was the determination of an unambiguous level of priorities, while the indications gathered were in several cases discordant or not sufficiently polarised. The aggregation mechanism started from the modal value of the votes. The attribution in a priority band was set as follows: (i) at least 3/4 of the votes indicates the same priority level, (ii) if two votes represent together at least 2/3 of the tally votes, we attributed the priority level most voted between them.

Phase C: Recomposition of the Prioritisation Indications

The final phase was to collate the indications deriving from the two stages described above. NRN researchers crosschecked and compared the levels attributed by the RAPs, deriving from the CVV application, and those that emerged from the Partnership's indications, to validate the RAPs priority bands and compile an overall assessment.

As already described, the approach was primarily to maintain the attribution resulting from the technical path in Phase A. In this light, the RAPs' indications were confirmed in two different cases: (i) where the stakeholders' consultation led to a minor difference in votes, i.e., a difference of only one priority band level, (ii) where stakeholder consultation did not indicate a univocal assessment. On the other hand, where there was evident discordance, a revision of the priority band – limited to one level – was proposed and discussed again with the RAPs; e.g., if a Strategic band was indicated by the RAPs, but the Partnership assigned the Complementary band, we proposed the final Qualifying level.

During the discussion in Phase C, modifying the description and the labelling of certain needs was taken into consideration, but only in a very limited way, less than five needs. Following this, based on the discussion held and the elements collected, NRN experts were able to draw up a conclusive list of final needs and the relative priority levels by GO and altitude.

[4] https://www.reterurale.it/PAC_2023_27/TavolodiPartenariato

3. THE CONSTRAINED CUMULATIVE VOTING TECHNIQUE: A THEORETICAL BACKGROUND

Prioritisation Processes through Participatory Approaches: the Cumulative Voting Technique

The key challenge for using participatory approaches in prioritisation processes is to find a suitable way of deriving a collective preference vector from individual choices and of reaching a consensus (Tang *et al.*, 2020). Consensus-building processes among different stakeholders representing different economic, social, environmental interests and cultural values typically involve voting procedures by which to infer collective choice from individual preferences (Marcatto, 2021). Approaches based on prioritised decision-making do not result in a single chosen alternative, since they produce a list of options ranked from most to least important, where the ranking represents the preferences of an individual relative to other available options. More formal prioritisation processes are typically associated with working groups ("group prioritisation"), where multiple priorities from various individuals must be combined into a single priority list, as is required for the CSP. Cagliero *et al.* (2021) explored the main prioritisation taxonomies, as shown in Table 1, and highlighted the advantages and weaknesses of adopting a Cumulative Voting technique (Tab. 2).

CV is a simple and transparent method to prioritise a list of items. Each participant is given the same number of votes/points/dots to be allocated among a given number of options undergoing prioritisation (Vestola, 2010): the more points you give an option, the more its relevance in terms of priority increases. CV is generally considered an appropriate method for conducting prioritisation sessions, including those involving multiple stakeholders (Tufail *et al.*, 2019). It is easy to use and it allows voting with fine-grained information on voter preference intensity. The main benefit is CV's ability to handle many items with many participants.

However, there are some caveats worth mentioning. Used in a very basic form, CV presents some limits linked to tactical voting and is susceptible to "shrewd tactics" (Vestola, 2010), as indicated in Table 2. For example, if a stakeholder expects others to spread their points among many items, then s/he may assign all her/his points to one specific item in order to elevate its relevance on the aggregate priority list (called *plumping*). Although meeting face-to-face is useful for stimulating discussion, the practice of in-person CV entails certain risks, such as authority bias or HiPPO effects (i.e. participants assign a higher priority following the most influential group member), or bandwagon effects,

Tab. 1. The Main Taxonomies of Prioritisation Methods with a Participatory Approach.

Scale	Examples	Complexity	Ease of use	Accuracy	Statistics
Nominal scale	Top 10	Very easy	Yes	Yes	Mode and chi-square
	MoSCoW	Easy	Yes	No	
Ordinal scale	Numerical assignment	Easy	Yes	Yes	Median and percentile
	Ranking	Easy	N/A	N/A	
	Game Planning	Easy	Yes	Yes	
Interval scale	Wieger's Method (WM)	Complex	Yes	Yes	Mean, st. dev., correlation, regression, variance
	Requirement Uncertainty Prioritisation Approach (RUPA)	Complex	N/A	N/A	
Ratio scale	Value-oriented prioritisation	Complex	Yes	Yes	All forms
	Analytic Hierarchy Process (AHP)	Very Complex	Yes	Yes	
	Cost-value ranking	Easy	Yes	No	
	Cumulative Voting (CV; 100$)	Complex	Yes	Yes	

Source: Cagliero *et al.*, 2021.

Tab. 2. The Main Aspects of the Cumulative Voting Technique.

Strengths	Weaknesses/threats
It is a quick and easy way to prioritise a long list of options.	Too many options can be overwhelming (overchoice) and undermine the polarisation of indications.
It requires a clear choice to be made and does not involve vague or uninformed behaviour.	It is not possible to add new options once the process has started.
It allows participants to express a preference for more than one option at the same time.	Similar or related options are penalised (vote splitting).
It creates a sense of commitment and allows participants to be active in the decision-making process.	Participants may adopt opportunistic attitudes (shrewd tactics).
It allows for a cumulative and simple system of analysis of results.	There is a risk of bandwagon and HiPPO effects (leaders can influence the opinions of the group)
It has several possibilities for adaptation (sub-groups, different rounds, use of monetary values, ...).	It may not be possible to highlight whether an outcome represents a broad consensus or not; because of excessive dispersion or too much focus on votes.
Main Application Fields	**Attention Points/Customisations**
It is particularly useful for reaching a collective consensus with a large group of participants and a high risk of disagreement.	It is suitable for focusing the discussion on a subset of alternatives within a very broad set.
It is particularly useful for choosing between several potential options.	It is necessary in order to reach a group decision within an acceptable time frame (potentially as short as possible).
It is particularly useful for narrowing down a policy design.	It is necessary in order to favour the anonymisation of votes and non-sharing of partial results.
It is particularly useful for classifying arguments to be discussed.	It is useful for randomising the voting procedure.
It is particularly useful for gathering information to create a priority matrix.	It is useful for applying software tools for remote voting, instead of face-to-face meetings (in particular, as regards the COVID-19 pandemic).

Source: Mazzocchi *et al.*, 2021

where participants voting later are more inclined to vote for an alternative that had been previously voted for by others (Asch, 1951; Kohavi, *et al.*, 2007; Nadeau *et al.*, 1993) In addition, CV requires some cognitive effort when used for lists with many options. However, according to some authors (Skowron *et al.*, 2021; Mazzocchi *et al.*, 2021), the gains in expressiveness outweigh the cognitive burden and the well-known and aforementioned disadvantages.

The Proposal of the Constrained Cumulative Voting Technique

To overcome the critical issues reported, Cagliero *et al.* (2021) tested and proposed a strengthened version, as compared to the basic application of the method, called Constrained Cumulative Voting. Based on the CSP regulation requirements (reg. (EU) 2021/2115), the process aims to be:

- transparent, both in the expression of individual preferences and the computation of the final aggregation;
- easy to understand and execute, thus, avoiding being a burden;
- software-based, so that various participants can take part remotely as/when required;
- flexible enough to be used with small, medium and large sets of items to be prioritised and by the required number of participants;
- able to run iteratively, in the case of using multiple rounds to refine evaluations, as well as limiting time-wasting in the process.

The final determination of the voting model took place after two rounds of testing on different formulations, both in terms of the number of votes and the weighted values for votes, with the collaboration of NRN regional experts. The improved model contains some upgrades to the standard CV technique: it is software-based, it counts non-fixed votes and it enhances the ability to explain prioritisation variability. From an operational point of view, the CCV runs on a Microsoft® Excel® application and includes five spreadsheets, containing the needs related to each General Objective, plus the AKIS transversal objective and a summary sheet containing an overview of the values allocated for each need.

We proposed a specific voting format, including different weights of votes to compile individual preference vectors to then be aggregated into a collective preference vector (Tang *et al.*, 2020). This voting shape is characterised by a very limited quantity of high-value votes, to simplify the process and nudge voters towards the clear polarisation of options (Achimugu *et al.*, 2014). Following Amrhein (Amrhein, 2019), the definition of the number of votes was assigned based on the following relationship:

$$N = \frac{[(T/2) * T]}{P} \tag{1}$$

where T is the number of issues or topics, in the present analysis the number of territorial needs, P is the number of participants and N is the number of dots required for each person. For the testing phase, we considered 50 needs to be prioritised and 23 voters (one per each of the 22 RPDs and the NRN Plan), thus the number of dots was estimated as 50-55 votes for each participant. The form of the *voting portfolio* was: 5 dots of value 10, 7 of value 5, 35 of value 1. Each participant had to distribute the full amount of 50 votes by geographical level, i.e.: 120 points for the plains, 120 for the hills, 120 for the mountains (Fig. 2).

Once the individual levels of prioritisation from participants were gathered, it was possible to compose the overall national picture. This aggregation was carried out by NRN experts, after the single RAPs expressed their indications individually and separately, without potentially knowing each other's intentions as regards voting. The resulting matrix comprises three territorial aggregates (plain, hill and mountain) and is related to CAP objectives.

4. MAIN RESULTS FROM THE PRIORITISATION PHASES

In this section, the results from the phase led with RAPs and consultation of stakeholders are presented.

Fig. 2. The final shape of the voting pattern by number and value (Constrained Cumulative Voting, CCV).

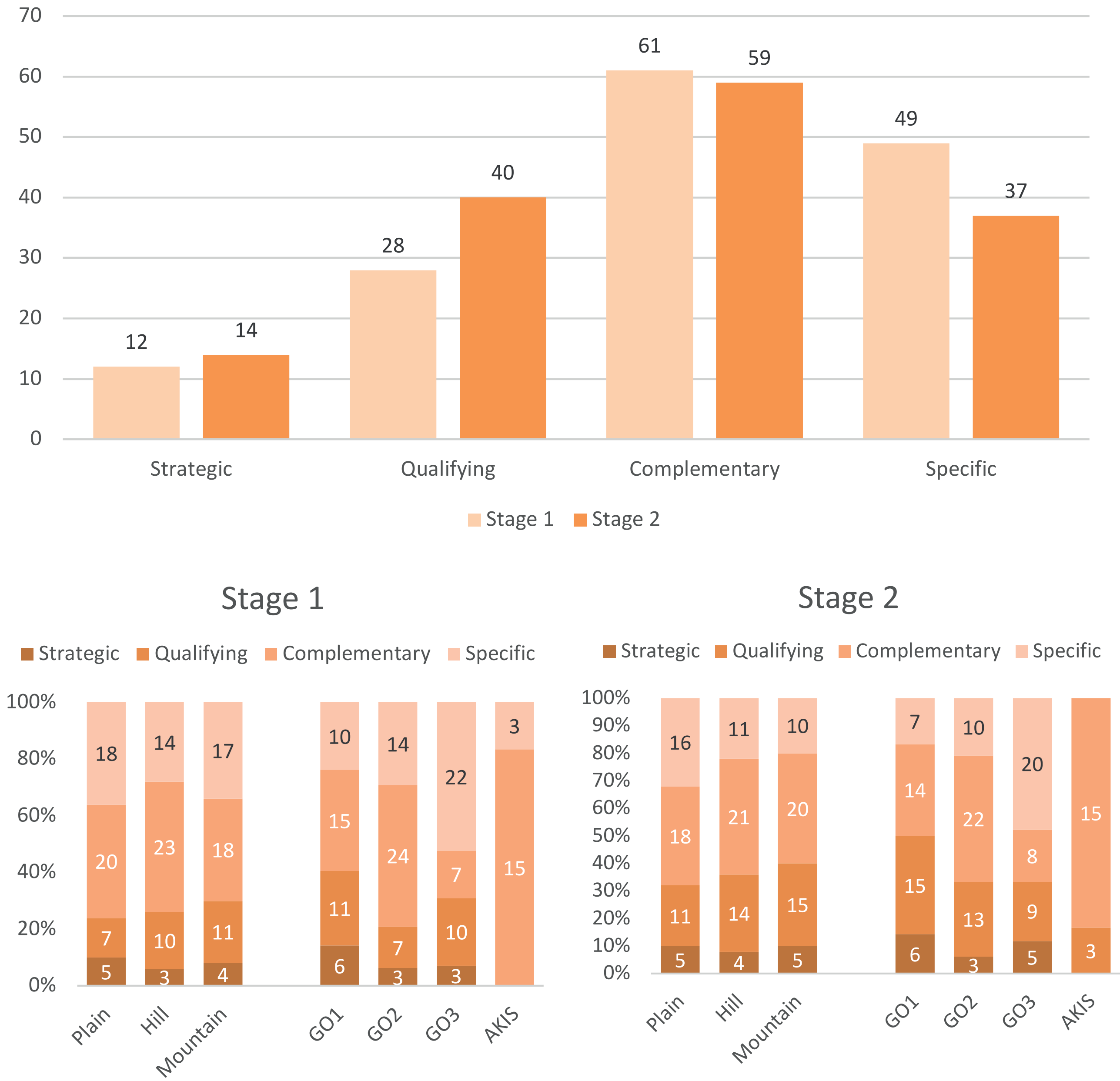
Furthermore, the final definition of needs prioritisation deriving from the merging of the two rounds is shown.

Phase A: The Indications of the RAPs

In Figure 3, the results of the prioritisation process conducted with RAPs, via CCV and the Jenks optimisation method, are presented. Stage 1 and Stage 2 represent the two moments before and after the discussion and review phase with the RAPs in the two-stage selection process.

The results of Stage 1 show the consistent polarisation of allocations, as intended to be achieved with the application of the CVV. Out of the 150 options to be voted on (50 needs for 3 altimetric areas), just over one-tenth were judged to be at the Strategic level, less than a fifth at the Qualifying level, almost 40 per cent at the Complementary level and the remainder at the Specific

Fig. 3. The Outcomes of the Technical Phase with RAPs – Phase A (frequency).



level. In terms of altimetry, we can see a slight majority of Strategic level for the lowlands, while for the hills and mountains, there is a higher level of defined Qualifying priorities; however, the distribution of attributes is relatively homogeneous for the three areas. Considering GO, we can see that Strategic priority levels are more present for GO1, Complementary priorities are particularly present for GO2 (environmental issues), while GO3 (rural area issues) is characterised by more Specific needs (52%). For the AKIS objective, only Complementary or Specific levels are indicated. Only three needs are Strategic across all three altimetric areas, one for each GO: Increasing the profitability of farms, agri-food and forestry (GO1); Supporting organic farming and animal husbandry (GO2); Promoting entrepreneurship in rural areas (GO3).

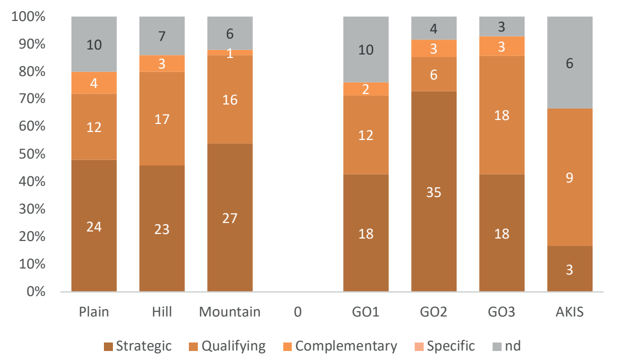
In Stage 2, we applied the mechanism of feedback and adjustment to the outcomes of Stage 1. The RAPs received the overall priority vector by bands, and they could suggest possible changes, by justifying them, if they found a significant distance from their individual priority vectors. Generally, emendations led to a more balanced representation than in Stage 1 and the number of Strategic and Qualifying needs were increased, while Specific needs were reduced. These adjustments cut across all altimetric areas, while they particularly affected the AKIS objective. The new bands for General Objectives confirm the relevance of the Strategic needs for GO1 and confirm the weight of the Complementary needs for GO2. The Strategic needs for GO3 increased and all the AKIS needs became complementary, at the least, although the absence of Strategic needs remained.

Phase B: The Partnership's Priority Assignments

Nearly 70 participants responded to the consultation with a proportionate representation of all stakeholders in the CSP drafting process and included in the Partnership, nominated by the MIPAAF (Mazzocchi *et al.*, 2021).

The results of this stakeholder's consultation show that out of the 150 options, half were considered to be Strategic, about one-third Qualifying, the remainder Complementary and none were deemed Specific (Fig. 4). The prevalence of high priority levels was expected, and this is due to the simplified methodological choice not to subject the vote to an overly constrained and technically complex modality. As regards level of altitude, the distribution by priority band seems similar, albeit with some variability, with more than 40% of the needs defined as Strategic for each GO, about one-third as Qualifying and the remainder unclassifiable. In contrast, the

Fig. 4. The Outcomes of the Stakeholder's Consultation - Phase B (frequency).

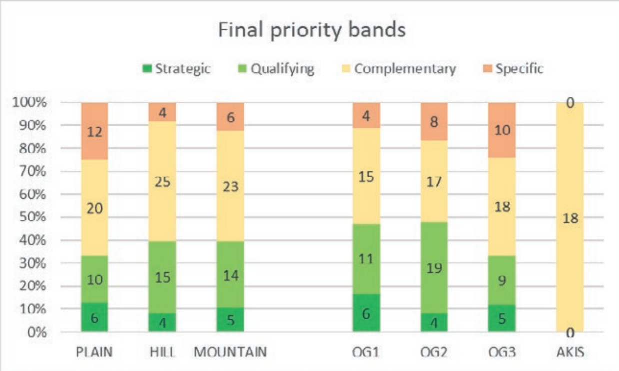


presence of Strategic needs for GO2, i.e., environmental issues, is much more evident than in the other GOs, while for AKIS, Strategic needs are particularly low. Overall, a clear and unambiguous assessment of the level of priority was not possible in almost 15% of the cases.

Phase C: The Merging of Feedback from both RAPs and Partnership

The cross-analysis of estimated bands from both RAPs and Partnership revealed cases, albeit not numerous (less than 10%), where the evaluation in the two previous phases diverged considerably. Where the estimations were very discordant, we revised the level of priority, proposing a new attribution. For example, this was the case for a few needs related to rural development and the level of assessment of the needs under the AKIS objective, where a homogeneous Complementary band was proposed. From the qualitative information gathered in all the steps, the necessity to merge some needs emerged, which were indicated as being too similar in the comments of the participants. To avoid the dispersion of the level of priority, we proposed a new interpretation of the needs concerned in an aggregated way. These cases were mostly related to supply chain issues. In summary, 41 needs were confirmed in the priority bands determined from the application of the CCV technique in Phase A. 3 needs were re-evaluated in their priorities, while 6 needs were reformulated and aggregated into 2 needs only. 2 more needs were added to this revised grouping, at the request of the participants: a need specifically dedicated to the sustainable use of phytosanitary products and one concerning the fight against the exploitation of workers. The final number of territorial needs to be addressed by the Italian CSP is, therefore, 48 (Appendix).

Fig. 5. The Final Priority Bands from the Prioritisation Route in Italy (frequency).



In Figure 5, we represent the final results of the needs' prioritisation process. The picture confirms the ability of the process to determine an adequate and polarised allocation of priorities.

The most represented priority band is Complementary, for almost half of the needs expressed by altimetry. About one in four needs is held to be Qualifying, while 10% are Strategic and 15% Specific. The attribution of priority bands is substantially homogeneous for the three altimetric areas, even though a greater presence of Specific priorities for the lowlands can be noted. In relation to the General Objectives, a certain homogeneity and balance can be observed but, for GO3, there is the particular presence of the Specific band. As already described, for the horizontal objective AKIS, it was decided to apply the Complementary level for all needs, given the instrumental nature of the issue. For GO1, the need for income support and equity in farm support was highlighted, as well as the need for integration and aggregation, i.e., issues addressed by Pillar 1 interventions (direct payments and market measures). Moreover, the need to modernise the sectors is also particularly high. As regards GO2, the needs related to environmentally-friendly production and breeding methods, sustainable forest management and the sustainable use of plant protection products were highlighted. Finally, the promotion of entrepreneurship in rural areas and the implementation and enhancement of telematics infrastructure were highlighted in GO3.

5. DISCUSSION AND MAIN CONCLUSIONS

Italy has identified a participative and sound route in order to define priority bands for the needs to be included in the CSP, based on two central points: a robust methodology and a high level of participation. The proposed approach presents interesting practices in terms of sharing and review/feedback procedures, especially in reaction to the crisis due to the COVID-19 pandemic, to facilitate the possibilities of interaction. The pandemic emergency profoundly marked the process of prioritising the identified needs for CSPs (Erjavec, 2020) and, in this sense, the NRN experts modified some steps in the analytical phase with remote iteration techniques (Cagliero *et al.*, 2021; Mazzocchi *et al.*, 2021). The publication of all the documentation and presentations made during the diagnostic steps[5] was another important aspect to reinforce the overall transparency of the process. This certainly facilitates the inclusion of all stakeholders in general, not just the competent bodies.

To technically prioritise CSP needs, a two-stage exercise was carried out with the Regions and Autonomous Provinces, aimed at encouraging discussion and sharing the identification of the different relevance levels of the needs under consideration. The Italian proposal, unlike other regionalised Member States, is highly coherent with the participatory and collaborative approach followed in the diagnostic phases, i.e., Policy Briefs, SWOT analyses and the first list of needs. Cumulative Voting is the most common approach used in this type of participatory process and it is a relatively simple technique for assigning levels of priority. It is considered particularly appropriate in the case of collective and participatory decision-making processes, although it shows some weaknesses and the potential risk of skewed outcomes. Following the advice of the literature, the tailored CCV model we adopted is capable of overcoming many of the crucial issues in Cumulative Voting models. The CCV model also made it possible to remotely undertake the participative process during the COVID-19 pandemic. In this light, CCV is an appropriate technique for defining needs prioritisation in the process of creating an intervention logic plan.

The CCV exercise was the crucial step within the prioritising route and was aligned with the overall process implemented by the Italian Ministry of Agriculture. However, it is important to underline that it is not the only way of expressing levels of priority and that it must be accompanied by adequate stakeholder consultation (Matthews, 2021; Erjavec *et al.*, 2018; Cagliero *et al.*, 2021). CCV is primarily a technical instrument rather than political, and it needs to be coupled with other mechanisms to understand and represent the complexity of a prioritisation process in defining the logic of a plan. In this light, an important challenge is how to compare

[5] https://www.reterurale.it/PAC_2023_27

and compile the outcomes of different steps of stakeholder consultation.

The results of the entire prioritisation process are of significant interest both as regards descriptive capacity and in operational terms, as they are the basis for the application of the CSP. The resulting picture is adequate to identify the actual needs for CAP support in Italy. The central objective was to determine bands of priority that would allow a polarised and clear distribution of the identified needs, going beyond the determination of a mere ranking. The choice of prioritising the needs by bands and not by a numeric ranking has also been made by other Member States (i.e., Spain or Portugal), but those classifications are based only on a gradient of relevance. In Italy, the priority bands were also aggregated in relation to the different functions and potential synergies of the needs identified. Indeed, to address the relatively small group of Strategic needs, it is necessary to systematically consider their synergy with the more numerous Qualifying Complementary needs. We can say that the CCV model was able to lead to a clear identification, which was subsequently discussed and compared by all the stakeholders at different stages, of a complex scenario, in which the needs to be addressed were related to each other and included in an actual strategic framework.

We are conscious that it is not possible to make a direct comparison between the needs identified for the 2023-2027 and those included in the 2014-2022 RPDs. Indeed, the latter was planned and implemented on a regional basis and concerned only second pillar interventions, while the CSP, which will be drawn up by each Member State, also includes first pillar support. This difference is deeply relevant, but from the analyses made by the NRN during the diagnostic phase, it is possible to draw an estimation of the aggregate priority distribution of the needs of the 2014-2022 RDPs (Cagliero *et al.*, 2021; Mazzocchi *et al.*, 2020). We can appreciate two main outcomes. The first is a consistent level of continuity between the two planning periods in identifying a small but clear group of strategic needs. Second, we appreciate a certain similarity in the overall shape of prioritisation, with a common vision of integration and complementarity.

In defining the CSP, each intervention must be combined with one or more prioritised needs. At the time this article was written, it was not possible to have a consolidated picture of the resources assigned to each intervention. Therefore, it is not possible to provide an assessment of the consistency between priority levels and the actual allocation of resources. This could be the subject of future research, which could also compare the consistency between priority levels and resources assigned in other Member States.

In addition to this, it is important to recognise that the prioritisation process carried out in Italy had the important role of stimulating initial debate on the contents that should be incorporated into the CSP through the various forms of intervention. In fact, in addition to the comparisons that took place on the national institutional tables, each RAP undertook regional paths to identify and evaluate regional priorities, helping to stimulate the debate on the CAP among public administrations and stakeholders. In some RAPs, Regional Partnerships were conducted to identify the priority levels of needs, the results of which were then transmitted to the NRN and fed into the overall national assessment.

This complex approach (a common participative route with several integrated steps) proposed in Italy may answer many of the criticisms against the prioritisation process, as it can provide (1) higher quality in the strategic planning process; (2) robustness of the design of diagnostic phases via a clear prioritisation of needs; (3) transparency of criteria for the future link between measures, needs and targets; and (4) evidence of the steps required to establish a robust intervention logic. Flexibility, transparency and robustness will also be important to handle the new CSP delivery model and its rigidities for setting targets, allocating resources, and constructing a monitoring system. The more the intervention logic can be tailored to specific national and regional needs and conditions, the more the CSP could enhance its efficiency and effectiveness.

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APPENDIX. LIST OF NEEDS BY GO, ALTIMETRY AND PRIORITY BAND.

General Objective 1: to foster a smart, competitive, resilient and diversified agricultural sector ensuring long-term food security.

1.1 Increase the earnings of agricultural, agri-food and forestry companies	Plain Hill Mountain	Strategic Strategic Strategic
1.2 Promote the market orientation of agricultural companies	Plain Hill Mountain	Strategic Qualifying Qualifying
1.3 Favour income diversification of the agricultural and forestry companies	Plain Hill Mountain	Specific Qualifying Qualifying
1.4 Facilitate the access to credit by agricultural, agri-food and forestry companies	Plain Hill Mountain	Complementary Complementary Complementary
1.5 Reinforce the quality and accessibility to the infrastructure networks	Plain Hill Mountain	Specific Qualifying Qualifying
1.6 Promote processes of integration and aggregation of businesses and the offer	Plain Hill Mountain	Strategic Qualifying Complementary
1.7 Support the creation and consolidation of local supply chains and direct sales channels	Plain Hill Mountain	Specific Complementary Qualifying
1.8 Reinforce the systems of certification, recognised quality and voluntary labelling	Plain Hill Mountain	Qualifying Complementary Complementary
1.9 Improve the penetration and positioning on the market	Plain Hill Mountain	Complementary Complementary Complementary
1.10 Promote the activation and access to tools for the management of risk and market risks	Plain Hill Mountain	Qualifying Complementary Complementary
1.11 Support to the profitability of companies	Plain Hill Mountain	Specific Qualifying Strategic
1.12 Promote the legality and respect of the rights in agriculture	Plain Hill Mountain	Complementary Complementary Complementary

General Objective 2: to support and strengthen environmental protection, including biodiversity, and climate action and to contribute to achieving the environmental and climate-related objectives of the Union.

2.1 Conserve and increase carbon sequestration capacity of farmlands and in the forestry sector	Plain Hill Mountain	Qualifying Qualifying Qualifying
2.2 Favour the reduction of greenhouse gas emissions	Plain Hill Mountain	Qualifying Qualifying Qualifying
2.3 Stimulate the production and use of energy from renewable sources	Plain Hill Mountain	Qualifying Complementary Complementary
2.4 Implement plans and actions aimed at increasing resilience	Plain Hill Mountain	Complementary Complementary Complementary
2.5 Reinforce the agrometeorological services and the development of monitoring and alert systems	Plain Hill Mountain	Complementary Complementary Specific
2.6 Support organic farming and livestock rearing	Plain Hill Mountain	Strategic Strategic Strategic
2.7 Favour the safeguarding and promotion of animal and plant biodiversity and natural biodiversity	Plain Hill Mountain	Complementary Qualifying Qualifying
2.8 Safeguarding, promotion and restoration of the rural landscape	Plain Hill Mountain	Complementary Qualifying Complementary
2.9 Support and development of agriculture in areas with natural constraints	Plain Hill Mountain	Specific Complementary Qualifying
2.10 Promote the sustainable use of phytosanitary products	Plain Hill Mountain	Strategic Qualifying Qualifying
2.11 Promote the active and sustainable management of forests	Plain Hill Mountain	Specific Complementary Qualifying
2.12 Favour the conservation and restoration of soil fertility	Plain Hill Mountain	Qualifying Qualifying Complementary
2.13 Make the use of water resources more efficient and sustainable	Plain Hill Mountain	Qualifying Complementary Specific
2.14 Safeguard surface and deep waters from pollution	Plain Hill Mountain	Qualifying Complementary Specific
2.15 Reduce the emissions of ammonia and gasses from agriculture and livestock rearing	Plain Hill Mountain	Qualifying Complementary Specific
2.16 Favour the diffusion of voluntary marketing systems of ecosystem services	Plain Hill Mountain	Specific Specific Complementary

General Objective 3: to strengthen the socio-economic fabric of rural areas.

3.1 Promote entrepreneurship in rural areas	Plain Hill Mountain	Strategic Strategic Strategic
3.2 Implement and/or strengthen the telematics and digital infrastructure	Plain Hill Mountain	Specific Strategic Strategic
3.3 Create and support occupation and social inclusion in rural areas	Plain Hill Mountain	Complementary Qualifying Qualifying
3.4 Promote innovation for sustainable and circular bio-economics	Plain Hill Mountain	Complementary Complementary Complementary
3.5 Increase the attractiveness of the territories	Plain Hill Mountain	Specific Qualifying Qualifying
3.6 Raise the level of the quality of life in rural areas	Plain Hill Mountain	Specific Complementary Qualifying
3.7 Support integrated planning in rural areas	Plain Hill Mountain	Complementary Qualifying Qualifying
3.8 Improve the planning capacity and the participation of local actors	Plain Hill Mountain	Specific Specific Complementary
3.9 Promote elevation of the quality and healthiness of agri-food and forest productions	Plain Hill Mountain	Complementary Complementary Complementary
3.10 Promote consumer knowledge	Plain Hill Mountain	Complementary Complementary Complementary
3.11 Reinforce the links of the sector with the territory and the types of direct relationship	Plain Hill Mountain	Specific Specific Specific
3.12 Favour the evolution of livestock rearing towards a more sustainable and ethical model	Plain Hill Mountain	Qualifying Qualifying Complementary
3.13 Reinforce the production of healthy and nutritious foods.	Plain Hill Mountain	Complementary Complementary Complementary
3.14 Reinforce management techniques and methods orientated towards the reuse of by-products	Plain Hill Mountain	Complementary Specific Specific

Horizontal Objective: AKIS

A.1 Promote cooperation and integration between the different AKIS components	Plain	Complementary
	Hill	Complementary
	Mountain	Complementary
A.2 Promote the gathering and diffusion of information adequate for the companies' needs	Plain	Complementary
	Hill	Complementary
	Mountain	Complementary
A.3 Improve the information and training offer	Plain	Complementary
	Hill	Complementary
	Mountain	Complementary
A.4 Promote training and the consultation system (public and private)	Plain	Complementary
	Hill	Complementary
	Mountain	Complementary
A.5 Promote the use of digital instruments	Plain	Complementary
	Hill	Complementary
	Mountain	Complementary
A.6 Stimulate the participation of companies in the setting-up of innovations	Plain	Complementary
	Hill	Complementary
	Mountain	Complementary

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Research article

Econometric analysis of choice drivers and willingness to pay for certified forest biomasses for energy

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Abstract. In the field of fuels generated from renewable resources, woody biomasses have found fertile ground for labelling. Indeed, several certification schemes have been developed, covering not only the sustainability of forest management, but also the chain of custody, allowing the traceability of products at different stages, from production to purchase. This study aims to investigate whether there is a willingness to pay for forest products for energy purposes with sustainability or quality certifications (FSC, PEFC and ENplus certifications) and what determines it, using pellets as reference product for the study. To do so, an exploratory analysis has been conducted, firstly using Principal Component Analysis (PCA) for a dimensional reduction and, subsequently, an ordered logistic regression. The results show that more than 30% of consumers are mainly willing to pay up to 10% more for PEFC and FSC certified pellets than for non-certified products, indicating a strong attention by consumers towards environmental issues, the quality certifications that can be adopted for pellets, and the attitude of consumers towards local and recycled products.

Keywords: pellet, sustainability certification, willingness to pay, quality label.
JEL codes: M31.

HIGHLIGHTS

- Consumers are willing to pay a premium price for quality or sustainability-certified forest biomasses for energy purposes.
- Not only does price influence pellet consumers; label knowledge and environmentally-friendly habits are also the most significant drivers of certified pellets WTP.
- The level of knowledge about certification schemes positively influences certified pellets WTP.

1. INTRODUCTION

In recent decades, the term *bioeconomy* has been used to describe the production and trade of products derived from renewable biological resources, such as crops and forests (European Commission, 2012). Given the growth of the global population and the overconsumption of many resources, together with the ongoing climate change (Perone, 2019), the bioeconomy seems to be a solution to the scarcity of non-renewable resources, such as oil products (European Commission, 2018), and the related increase in prices, which in 2022 are reaching historical highs.

The road towards the so-called bioeconomy has been paved since the 1970s, when the environment became an issue of discussion (Welford, 1995). However, it was only in the last decades of the 20th century that the issue of sustainable production of renewable biomasses arose (Ros *et al.*, 2010). The issue has grown into a social concern and, since then, has shaped the general attitude of consumers towards sustainably-crafted products (United Nations Environment Programme, 2018). This new attitude has also put pressure on businesses to adopt environmentally sound practices (Bradley, 2021); indeed, nowadays, consumers increasingly demand that biomass production (ISPRA, 2010) complies with *minimum standards* of social and environmental responsibility (European Commission, 2018). For example, in 2020, the Italian consumption of certified quality pellets – a biofuel made of compressed untreated sawdust – reached 1.1 million tonnes out of a total of 3.4 million tonnes of national consumption, showing a marked positive trend compared to previous years (Associazione Italiana Energie Agroforestali, 2021). The same concern is expressed in many other sectors through an increase in so-called ethical consumer purchases, regarding the environmental and social spheres of products (Blanc *et al.*, 2021). Many forms of labelling have consequently been established since the late 1990s to inform consumers about the link between the product and its origin and processing phases (Paluš *et al.*, 2021). Product labelling has also been used to identify those products deriving from environmentally-friendly productions and chains of custody (Tikina, Innes, 2008). Indeed, the label is the most immediate tool to help consumers compare certified products with other non-certified ones of the same category, allowing them to express their preferences towards more sustainable consumption.

In the field of fuels generated from renewable resources, woody biomasses have found fertile ground for labelling. Indeed, several certification schemes have been developed since the end of the 20th century, covering not only the sustainability (economic, environmental and social) of forest management, but also the so-called *chain of custody*, allowing the traceability of products at different stages, from production to purchase.

Among these certification schemes, the most widely used in the field of forest sustainability are the *Forest Stewardship Council* (FSC) and the *Programme for the Endorsement of Forest Certification* (PEFC). Both apply to any forest product (and recently to forest services as well), including forest biomasses. FSC is an international, independent, non-profit organization established in 1993 to promote responsible forest management and later introduced in Italy in 2001. This certification covers 230 million of hectares and also deals with chain of custody, allowing consumers to evaluate the path of the product (FSC, 2022). PEFC is a voluntary certification that covers both the management of the forests and the chain of custody. The certification was developed in Europe in 1999 to meet the needs of wood producers and subsequently introduced in Italy in 2001. Currently PEFC certification covers more than 326 million of hectares in the world and 888,494 in Italy (PEFC, 2022).

On the other hand, in the specific field of product quality, the ENplus certification establishes technical specifications such as calorific power, durability and dust that allow for better product quality (ISO/IEC 17065:2012 — Conformity Assessment — Requirements for Bodies Certifying Products, Processes and Services, 2012), being especially dedicated to pellet fuel. This certification was established in 2011 and was based on international ISO standards but adopting more stringent requirements. Currently ENplus certifies more than 13 million tons of pellets representing the most important quality certification for this product (ENplus, 2022).

Given the widespread nature of this type of labels, several studies have investigated consumer attitudes towards certified product purchase, in particular the willingness to pay (WTP) a premium for certified wood products (Paletto, Notaro, 2018). It has been shown that consumers are willing to pay a price premium ranging from 1% to 39% of the base price for a certified product (Cai, Aguilar, 2013). In more detail, recent research has shown that, while in the past older people with a good income were the main purchasers of labelled products, in the last few years this trend has been changing and the main buyers of eco-labelled products are the younger, more environmentally-aware generations (Higgins *et al.*, 2020). Another interesting result related to the consumption of forest products is that the base price of a product is usually negatively correlated with consumers' WTP, meaning that the buyers are willing to pay a higher premium price for cheaper products (Cai, Aguilar, 2013). This result ties with Teisl (2003), who found that WTP is higher for more frequently-used products, due to the belief that frequently-purchased wood products have a greater impact on the environment. Finally, knowledge of and trust in an eco-label also influence consumers' attitudes and their WTP (Panico *et al*., 2018), which is why companies and policy makers should implement targeted information campaigns on ecolabels and environmental issues (Panico *et al*., 2022).

As consumer awareness and propensity to pay a price premium for labelled forest products for energy purposes is a relatively unexplored field of research, even when considering the different meanings people give to sustainability. This study aims to investigate whether there is a willingness to pay for forest products for energy purposes with sustainability or quality certifications and what determines it, using pellets as a reference product.

The choice of pellets as case study can be related to different aspects. Based on the latest specific data published on pellet utilization, this product is used by more than 4% of Italian families to heat domestic environments (ISTAT, 2014) and its consumption steadily increased from 2012 (AIEL, 2020). In particular, by considering regional aspects, pellet utilisation seems to be more important in Northern Italy, where households have twice the consumption of Central Italian households and four times that of Southern Italian households (ISTAT, 2014).

To do so, a multi-section survey was developed using Google form and subsequently shared online. Following data collection, an exploratory analysis was conducted, first using Principal Component Analysis and subsequently an ordered logistic regression to highlight different patterns of consumer perception and behaviour of sustainability, and to elicit information about the main drivers of consumer WTP.

The objective of the study was pursued by answering the following specific research questions:

1. How do consumers approach and behave about the topic of sustainability? What is their level of knowledge about sustainability and quality labels?
2. Are consumers willing to pay a premium price for a bag of pellets with a sustainability or quality certification?
3. What drives consumers' willingness to pay for this labelled forest product?

The paper is structured as follows: I) the methodology section presents how data were collected through an online survey and subsequently analysed with the *Principal Component Analysis* (PCA) and the ordered logistic regression tools; II) the results section includes the main findings about the dimensional reduction with the PCA and the main drivers of sustainability or quality labelled pellets WTP; III) the discussion section tries to explain these main findings, like the lower quota of respondents who are willing to pay a premium price for labelled pellets, or the main determinants of WTP emerged from the ordered logistic regression, e.g., label knowledge, product origin, sustainability perception. age and level of education of purchasers; IV) finally, the conclusion section includes further research that can be developed and possible market and policy implications of the study and its main limitations.

2. METHODOLOGY

2.1. Data collection and questionnaire structure

In order to collect information about consumers' knowledge and opinion on sustainability and their pellet purchasing process, a self-compiled questionnaire was designed. It consists of three parts: the first one deals with consumers' behaviour and attitudes on sustainability and their level of knowledge on the main sustainability and quality pellet certifications. The survey was presented in the online data collection as specific to pellet consumers. To avoid response bias, a filter question was used where respondents were asked whether they were actually users of this product, if so they were redirected to the compilation

Starting from the first part, based on what is already known in the literature, several questions on the perception of sustainability were administered, as shown in Table 1. In particular, the section about sustainability perception focuses on what consumers think about environmental sustainability (attitude) and on how consumers act in relation to sustainability issues (behaviour). These two items were explored through questions based on the literature. No validated attitudinal scales were adopted, trying to build different constructs about attitude (Minton, Rose, 1997; Moser, 2016) and behaviour (Liobikiene, Juknys, 2016; Paco, Lavrador, 2017).

Regarding the evaluation of consumers' specific knowledge about the main certifications linked to sustainability (PEFC and FSC) and quality (ENplus), a three-item construct based on subjective knowledge was designed and adapted as indicated by Pieniak *et al.* (2010).

The second section focuses on the pellet purchase process and consumption, where extrinsic and intrinsic characteristics are considered, and on the WTP for sustainability certification or quality-labelled pellet bags.

The last section deals with the socio-demographic aspects of the respondents such as age, gender, education, family members and monthly household income.

Tab. 1. Constructs used in the questionnaire to explore behaviour, attitude and knowledge about sustainability.

Category	Variables	Source
Behaviour	Differentiate waste even though it is not mandatory	Liobikiene, Juknys, 2016
	Use of energy-saving light bulbs	Liobikiene, Juknys, 2016
	Short distances without a car	Paço, Lavrador, 2017
Attitude	Woody and agricultural biomass as a valuable source of energy	-
	Prefer to buy local products	Moser, 2016
	Favourable to stop buying from polluting companies	Minton, Rose, 1997
	Prefer to buy recycled products	Minton, Rose, 1997
	In favour of paying more taxes to reduce pollution	Minton, Rose, 1997
	Current environmental measures are adequate	Moser, 2016
Knowledge	ENplus level of knowledge	Adapted by Pieniak *et al.*, 2010
	FSC level of knowledge	
	PEFC level of knowledge	

All questions included in the questionnaire are closed-ended, either binary questions (Yes/No) or five-point Likert scales, where 1 means "Not important/Never/Totally disagree" and 5 means "Very important/Very often/Totally agree" depending on the specific context.

The questions dealing with the WTP for PEFC, FSC or ENplus labelled pellets are structured with five different options, starting from a base price of 4.50 €/bag: 0%, up to 10%, up to 20%, up to 30% and more than 30% of the base price.

The questionnaire, which was written using easily understandable terminology, was first tested with a user panel and then distributed online, using the Google Form tool. To reach as many consumers and interested people as possible, it was shared through specialised forums and social media, during the period between 2020 and 2021, collecting 254 valid interviews which were then coded and recorded in a database. Socio-demographic characteristics of the Italian consumers interviewed are reported in Table 2.

In order to group the observations into different age cohorts, the classification proposed by Brosdahl, Carpenter (2011) was adopted, resulting in the following categories: Younger generations (between 1982 and 2000, also including those few people born after 2001), Generation X (between 1961-1981) and Older generations (between 1925 and 1960, grouping the Baby boomers and Silent generation cohorts).

Tab. 2. Socio-demographic characteristics of the sample (n=254).

Variables	Category	Frequency (n)	Percentage
Gender	Male	156	*61.42*
	Female	98	*38.58*
Age cohort	Younger generations	112	*44.10*
	Generation X	101	*39.76*
	Older generations	41	*16.14*
Family members	1-2	92	*36.22*
	3-4	133	*52.36*
	>4	29	*11.42*
Educational level	Elementary and middle school	35	*13.78*
	High school	126	*49.60*
	University	69	*27.17*
	Higher education	24	*9.45*
Monthly household income (€)	Up to 2000	68	*26.77*
	2001-3000	81	*31.89*
	3001-4000	40	*15.75*
	> 4000	19	*7.48*
	No answer	46	*18.11*

2.2. Principal Component Analysis

The next step in the analysis was the simplification of the dataset, in order to reduce the number of covariates, through a PCA. This procedure performs a dimensional reduction of the data with a slight loss of explained variance (Gewers *et al.*, 2021). Moreover, it can highlight any latent relationships between the included covariates, grouping them into a new set of orthogonal variables (Capitello *et al.*, 2016) and making the information level more effective.

The 12 original variables included in the analysis are those reported in Table 3, which refer to consumer behaviour and attitude towards sustainability in a comprehensive view, and to the subjective knowledge of the main labels used to assess the sustainability or quality of pellets.

Tab. 3. Variables included in the Principal Component Analysis (n=254).

Category	Variables	Mean	St. dev.
Behaviour	Differentiate waste even though it is not mandatory	4.44	0.95
	Use of energy-saving light bulbs	4.38	0.85
	Short car-free distances	3.99	1.17
Attitude	Woody and agricultural biomass as a valuable source of energy	4.28	1.01
	Prefer to buy local products	3.94	0.98
	Favourable to stop buying from polluting companies	3.73	1.17
	Prefer to buy recycled products	3.35	1.12
	In favour of paying more taxes to reduce pollution	3.13	1.33
	Current environmental measures are adequate	1.86	1.03
Knowledge	ENplus level of knowledge	2.85	1.57
	FSC level of knowledge	2.63	1.41
	PEFC level of knowledge	2.31	1.33

Only principal components (PCs) with eigenvalues greater than 1 were considered for further analyses, as factors with a lower value could be considered unreliable (Kaiser, 1960; Cliff, 1988). Finally, Varimax rotation was implemented to simplify the interpretation of the results (Kaiser, 1958; Abdi, Williams, 2010). Thus, results and subsequent discussions will refer to rotated factor scores with a value greater than |0.400|, which is considered appropriate for the sample size of the dataset (Hair *et al.*, 1998; Pituch, Stevens, 2012).

The last step of the dimensional reduction procedure involves the adequacy and reliability tests. To check whether the sample size is adequate, the Kaiser-Meyer-Olkin (KMO) test was used: results up to 0.600 are considered reliable (Kaiser, Rice, 1974). Secondly, Bartlett's sphericity test was applied to check whether the correlation matrix is adequate for carrying out factor analysis (Dziuban, Shirkey, 1974).

Finally, Guttman's lambda test was implemented to check the internal consistency of the factors and of the overall model (Gliem, Gliem, 2003). Internal consistency coefficients below 0.600 are considered inadequate to be used in subsequent analyses; therefore, similarly to Giampietri *et al.* (2016) PCs with similar values will be excluded.

2.3. Ordered logistic regressions

To estimate how the willingness to pay a premium price for the bag of pellets with a sustainability or quality label, was performed through a series of ordered logistic regressions, one for each proposed label (FSC, PEFC, ENplus), similarly to what has been done in recent studies (Capitello *et al.*, 2016; Merlino *et al.*, 2020; Giampietri *et al.*, 2021).

The ordered logistic regression implies that the observed ordinal dependent variable *Y* is a function of another latent variable, *Y**, which is unobserved and continuous (Wooldridge, 2012). The values of *Y** will be compared with the different cut points calculated by the model, highlighting the probability that the observation falls into one specific ordinal category or another (Williams, Quiroz, 2020). The ordinal dependent variable is the willingness to pay (WTP) a premium price for a pellet bag with a sustainability or quality label, with five responses ranked (1-5), as reported in section 2.1.

Only the sign of the coefficients obtained from the model estimation can be discussed directly: in order to highlight the magnitude of the covariates, odds ratios were calculated.

The ordered logistic function, derived from the model, is structured as follows (1):

$$Y_i^* = \alpha\ PC1\ldots n_i + \lambda Sociodemographics_i + \sigma Intr/Extr\_char_i + \varepsilon_i \quad (1)$$

where Y_i^* is the latent variable for the *i* observations, $PC_{1\ldots n}$ are the factors obtained from the PCA deemed suitable for the logistic analysis, *Sociodemographics* corresponds to the variables Age cohort, Gender, Family members, Education, Monthly household income, and *Intr/Extr_char* are the intrinsic/extrinsic attributes of pellets, reported in Table 4, considered by consumers during the purchase process. Finally, ε_i is the stochastic error.

The goodness of fit of the three models was estimated through the *Pseudo* R^2 value, whereas the proportional odds assumption of the ordered logistic regression was tested through the likelihood-ratio test (Mehmetoglu, Jakobsen, 2017; Giampietri *et al.*, 2021).

Tab. 4. Attributes included in the ordered logistic regression (n=254).

Variables	Mean	St. dev.
Price	4.13	1.05
Wood species	3.51	1.55
Absence of Residue	3.13	1.28
Local origin	2.68	1.42
Label	2.37	1.42

All the analyses were performed using STATA 17.0-SE (StataCorp, 2021) statistical software.

3. RESULTS

The descriptive analysis of WTP a premium price for certified pellets by consumers in Table 5 allows some preliminary considerations to be made. First of all, it is evident that most of the respondents are not willing to pay an additional premium for sustainability certifications compared to ENplus certification. Furthermore, more than 30% of consumers are mainly willing to pay up to 10% more for PEFC and FSC certified pellets than for non-certified products. ENplus, compared to sustainability certifications, has fewer consumers willing to pay up to 10% or not willing to pay, in favour of the classes with higher WTP. From these descriptive considerations, it can be deduced that quality certification is slightly more appreciated by consumers.

3.1. Principal Component Analysis

With the adoption of the PCA, a dimension reduction was obtained starting from the original twelve regressors (Table 3) and obtaining a four PCs model, whose characteristics are presented in Table 6. The principal components, as indicated in the methodology earlier, represent a new set of variables obtained by saving most of the variance carried by the original variables; in particular, the model explains 58% of the total variance. The adequacy was met on the basis of the significance of Bartlett's test and value of the KMO test higher than 0.6. However, to select suitable components for the regression analysis, a second step was conducted to check the consistency of the grouped variables, using Guttman's lambda test. This analysis indicates that three components were sufficiently reliable (PC1; PC2; PC3), while the fourth was excluded at this stage. Table 6 shows, in addition to the PCs, the results of the model adequacy and reliability tests as well as Guttman's lambda for internal factor consistency.

The first PC explains 19.2% of the total variance and groups together many variables related to the approach to sustainability, indicating a strong attention of consumers towards environment issues. This consideration stems from the combination of the factor loading of the variables; in fact, from the coefficients, a positive correlation can be observed between the *differentiation of waste, even if not mandatory*; the *preference for walking rather than using a car for short distances*, the *purchase of recycled products*, the *propensity to pay more environmental taxes*, the *attitude toward biomasses* and *to avoid products from polluting companies*. This combination suggests that consumers may associate multiple aspects that contribute to environmental sustainability. Indeed, for the respondents such aspects can be combined in a new factorial dimension. They recognise a certain complexity in the sustainability issue that can be addressed on the basis of several combined actions, such as waste separation and environmental taxes. Based on these considerations and on the number of variables correlated, the PC can be related to broad attention to the main aspects of sustainability, the name *Holistic approach to sustainability* was chosen for this component.

The second dimension accounts for 16.4% of the variance derived by the original covariates. This PC collected the variables related to knowledge of the certification schemes, in particular, the self-reported knowledge of FSC, PEFC and ENplus certifications. As expected, the positive coefficients of the original variables indicated a certain degree of correlation between consumer knowledge of sustainable and quality certifications that can be adopted for pellets by providing a strong factorial dimension including just the variables related to consumer knowledge. The relationship described by the component suggests that there is some degree of association between the certifications, indicating that informed consumers are likely to be familiar with more than one certification scheme. Furthermore, the association between PEFC and FSC is stronger compared to ENplus, probably because these certifications

Tab. 5. Frequency distribution of Consumers' willingness to pay for certified pellets.

	PEFC	FSC	ENplus
0%	48.8	45.7	41.3
up to 10%	31.9	35.0	29.5
up to 20%	15.0	14.2	21.7
up to 30%	3.5	4.3	5.5
more than 30%	0.8	0.8	2.0

Tab. 6. Results of the Principal Component Analysis.

Variables	PC 1	PC 2	PC 3	PC 4
Differentiate waste even though it is not mandatory	0.547			
Short distances without a car	0.472			
Use of energy-saving light bulbs			0.867	
Prefer to buy local products			0.559	
Prefer to buy recycled products	0.536		0.426	
In favour of paying more taxes to reduce pollution	0.743			
Woody and agricultural biomass as a valuable source of energy	0.453			0.493
Favourable to stop buying from polluting companies	0.721			
Current environmental measures are adequate				0.721
PEFC level of knowledge		0.907		
FSC level of knowledge		0.858		
ENplus level of knowledge		0.513		0.477
Bartlett's test of sphericity	Chi-square = 614.225		Df = 66	Sig = 0.000
KMO's test	0.685			
Guttman's lambda (PCs)	0.709	0.680	0.603	0.201
Guttman's lambda (Overall model)	0.717			

* Only factor loadings > |0.400| were considered for the analysis.

are both related to sustainability aspects and in the mind of consumers a certain degree of overlapping of confusion between them may occur. Concerning the ENplus that deals mainly with quality aspects, the relation found with the other variables related to FSC and PEFC indicate that correlation exists between quality and sustainability aspects. For these reasons the PC was named *Subjective knowledge of sustainability and quality labels*.

The last PC considered reliable – on the basis of the internal consistency test – explains a total of 12.8% of the variance. It contains the variables related to sustainable energy use (*using energy-saving light bulbs*) and to the *purchase of sustainable products*, due to the attitude toward local and recycled products. Factor loadings indicate a positive relationship among these elements, suggesting that the use of sustainable energy and the attitude towards local and recycled products are tied, probably because the latter are also related to saving energy and resources, with positive impacts on environmental sustainability. In fact, this PC is mainly related to the purchasing intention of sustainable products and the avoiding of energy waste. Considering these aspects, this component was named *Sustainability linked to purchasing and consumption habits*.

3.2. Ordered logistic regressions

As indicated in the methodology, three different ordered logistic regressions were performed to highlight which drivers affect the WTP an additional premium price for certified pellets and whether there are differences between the models, as shown in Table 7.

Starting with the PCs used as covariates, *Holistic approach to sustainability* and *Subjective knowledge of sustainability and quality labels* were significant in each regression. The component *Sustainability linked to purchasing and consumption habits* was only significant when describing WTP for PEFC certified products. These results suggest that both knowledge of certifications and environmental concern are important in placing a higher value on products bearing sustainable or quality certifications, particularly for PEFC certifications, since the PCs related to environmental attitude were both significant only in this regression.

Moving on to socio-demographic predictors, the age cohort was negatively related to the additional premium price for PEFC, FSC and ENplus, suggesting that older people are less interested in these certifications. The odds ratio quantified this attitude in terms of probability ratio, indicating that older people are 0.662 times less willing to pay for PEFC, 0.668 for FSC and 0.722 for ENplus. Gender was positive and significant in PEFC and FSC models, indicating that women are more interested in such certifications and willing to pay more for them, respectively 1.935 time more and 1.859 times more. Education level is positively related with FSC certification, with more educated people being 1.479 times more willing to pay a premium price for pellet-bearing FSC.

Tab. 7. Ordered logistic regression results (n=254).

Covariates	PEFC			FSC			ENplus		
	Coef.	Odds ratio		Coef.	Odds ratio		Coef.	Odds ratio	
PC 1	0.529	1.697	***	0.531	1.701	***	0.459	1.582	***
PC 2	0.559	1.749	***	0.550	1.734	***	0.286	1.332	**
PC 3	0.264	1.302	*	0.222	1.248		0.156	1.168	
Age cohort	-0.413	0.662	**	-0.403	0.668	**	-0.326	0.722	*
Gender	0.660	1.935	**	0.620	1.859	**	0.366	1.442	
Family members	0.001	1.001		0.037	1.038		-0.065	0.937	
Education level	0.226	1.254		0.391	1.479	*	0.199	1.220	
Monthly household income	0.021	1.021		-0.020	0.98		0.198	1.219	*
Wood species	0.055	1.057		0.028	1.029		-0.038	0.963	
Price	-0.216	0.806	*	-0.120	0.887		-0.206	0.814	*
Local origin	0.175	1.191	*	0.203	1.225	**	-0.074	0.920	
Label	-0.019	0.981		-0.049	0.952		0.125	1.133	
Absence of residue	0.040	1.040		0.067	1.069		0.152	1.164	
/cut 1	-0.022			0.514			-0.365		
/cut 2	1.798			2.508			1.093		
/cut 3	3.583			4.120			2.866		
/cut 4	5.356			6.083			4.302		
Log-pseudolikelihood	-257.491			-260.652			-301.248		
Chi-square	62.13			64.75			52.17		
prob. Chi-square	0.000			0.000			0.000		
Pseudo R^2	0.123			0.128			0.083		

p-value levels of significance * < 0.1; ** < 0.05; *** < 0.01.

Turning to pellet attributes, price was significant in PEFC and ENplus models, suggesting that people who place more importance on price are less willing to pay for these certifications. Another insight related to this outcome suggests that PEFC and ENplus buyers are more price sensitive than people interested in FSC. Finally, the role of local origin was only significant for sustainability certifications schemes. This result suggests a relationship between these certifications and the importance attached to the origin of timber, indicating that the role of PEFC and FCS is at least partially recognised by consumers.

4. DISCUSSION

Woody biomass has been recognised as an important element in combating the climate crisis and promoting renewable energy, since – in addition to being the main source of bioenergy in the EU (Šupín *et al.*, 2019) – its emissions appear to be climate neutral (Luick *et al.*, 2022). Among the woody biomass products, pellets have gained strong interest in the global market, becoming one of the best-selling products, as reported by Nuramin *et al.* (2020).

Given the increasing volume of pellet imports from non-EU countries, such as the United States (Fingerman *et al.*, 2019), and the high exploitation of forests to meet the high market demand (Luick *et al.*, 2022), the importance of introducing eco-labels that guarantee the quality, origin and sustainability of the product seems evident.

Based on these considerations, this study tried to investigate the demand side, the WTP a premium price, and the factors that motivate a consumer to buy a bag of certified pellets.

Three key findings emerged in the light of our analysis:

1. concerning the perception of sustainability by pellet consumers, three clear components emerge. A first component based more on attitudes and defined as a *Holistic approach to sustainability* in which a strong focus on environmental issues, their complexity and actions to face them emerges. In the literature, several authors state that environmentally-conscious consumers are positively inclined to buy green prod-

ucts (Chaudhary, Bisai, 2018; Carfora *et al.*, 2019; Rahman *et al.*, 2020). A second component linked to knowledge of the certification schemes adopted in this study and named *Subjective knowledge of sustainability and quality labels* was highlighted. In a study by Tan *et al.* (2019) on Chinese consumers' preferences in purchasing certified wood flooring, the importance of knowledge of eco-labels was recognised. Finally, a last component called *Sustainability linked to purchasing and consumption habits* in which sustainable behaviours emerge, such as the purchase of recycled, local and sustainable products and a responsible and sparing use of energy was identified.

2. Almost half of the consumers are not willing to pay a premium price for the three certifications analysed. About 30% would be willing to pay 10% more than the base price and only a small fraction would be willing to pay more than 20%, more for quality certification than for sustainability. Although the WTP varies depending on the products studied and the location under analysis (Wan *et al.*, 2018), the obtained WTP ranges for certified pellets remains consistent with those reported in the meta-analysis of Cai, Aguilar (2013) for certified forest products, that is between 1 and 39%. This result, which is in contrast to the statement made by Vásquez Lavin *et al.* (2020) on the low possibility of paying a premium price for certified forest products, is also in line with the findings of García *et al.* (2021) for firewood, suggesting that it is forest products intended for energy use that are susceptible to a premium price.
3. The factors leading consumers to pay a premium price for a bag of certified pellets are multiple and are to be found in some components of the perception of sustainability, such as attention to environmental issues and knowledge of labels. Notaro, Paletto (2021) in a study conducted on the WTP, attitudes and preferences of Italian consumers towards wood fibre bio-textile report that environmental issues are among the main drivers of green purchasing behaviour. Concerning label knowledge, Panico *et al.* (2022) in a study conducted on the purchasing behaviour of Italian consumers for certified forest products, state that certification has a positive effect on the WTP, while they had no significant results concerning the factors "trust" and "environmental attitude" of consumers. Other factors that lead consumers to pay a premium price for certified pellets are found in the sociodemographic domain. Our results partly support what Higgins *et al.* (2020) stated about sociodemographic predictors of WTP for eco-labelled forest products. Indeed, age, particularly youth, and level of education are key predictors. Indeed, age, in particular the younger generation, and level of education are strong predictors of consumer behaviour since they were significant in all models. Gender is a good predictor of behaviour only for sustainability certifications while income was not significant in the models. In the literature, however, Zhang, Dong (2020) report that women are more likely to make green purchases and several authors of studies on the use of alternative energy sources for households have emphasised the importance of income as a key variable for WTP (Streimikiene *et al.*, 2019; García *et al.*, 2021; Nduka, 2021). Finally, pellet attributes such as local origin for sustainability certifications and price for PEFC and ENPlus certifications are also important factors for the WTP of certified pellets. Specifically, our results show a negative relationship between price and WTP, in fact the lower the price, the higher the propensity to purchase the certified product, thus agreeing with a study by Luo *et al.* (2018) on Chinese and Japanese consumers' willingness to pay for modern wood structures, according to which the base price of the product influences the consumer's WTP. This result can probably be attributed to the fact that pellets are a non-durable good.

5. CONCLUSIONS

5.1. Main findings

The objective of this study was to explore if, and how, consumers attach importance to different sustainability and quality labels about woody biomasses for energy purposes, and whether this importance translates into a willingness to pay for such attributes. To do so, three research questions were proposed, focusing on the pellets market.

Concerning the first one, the results highlighted a certain propensity of consumers towards an ecological behaviour and attitude, considering both their daily actions and their opinion on energy consumption and pollution. Despite their positive leanings, consumers also declared a relatively average level of knowledge on the sustainability and quality certifications of forest products proposed in the study (PEFC, FSC and ENplus), suggesting that they do not distinguish the labels and their meanings well.

Focusing on the second research question, the majority of respondents are not willing to pay a premium price for a bag of sustainable or quality labelled pellets. Among those who are in favour of paying more for a certified product, it seems that both sustainability labels behave similarly, again confirming the scarce differentiation between PEFC and FSC by consumers; moreover, the quality scheme received a higher WTP than the others, considering the increasing importance given by buyers to quality standards.

After confirming the presence of a quota of consumers willing to pay a premium price, the third research question tried to explore the main drivers of this answer. What emerges is that label knowledge and approach to sustainability positively influence the propensity to pay a premium price, particularly in the case of PEFC. Turning to socio-demographics data, age cohort, and gender were the most relevant, followed by education level and monthly household income (significant for only one label respectively). Finally, considering the characteristics of the product, only price and local origin were found to play a role in WTP.

5.2. Limitations and future research

The main limitation of the study is linked to the national dimension of the survey: although the sample is adequate for the analysis conducted and is also representative of the Italian situation, it does not reflect the international scene, due to the difficulty of comparing different markets and consumers. In this direction, further research could increase the scientific reliability of this analysis, by adopting an international scale in the survey of woody biomass purchasers.

The second issue that can be improved regards the method of investigation of the willingness to pay. In fact, the present research performed a deeper analysis on the drivers of WTP, and further studies on the premium prices that purchasers give to certified forest biomasses like pellets are needed. In this way other econometric tools like choice models or experimental auctions could be implemented on the certified pellets market.

Moreover, the issue related to the evaluation of sustainability and environmental friendliness has been explored by adopting different literature sources: further research could implement validated psychometric scales, obtaining a more reliable estimation of consumer attitudes. In fact, the adoption of constructs or attitudinal scales already validated in the literature and implemented with a confirmatory factor analysis could enrich further in-depth studies, better highlighting the role of consumer's behaviour, attitude, and knowledge spheres on forest biomasses' WTP. Likewise, Principal Component Analysis is not supported by a structured model including latent constructs, as in the case of Exploratory or Confirmatory Factor Analysis, making the interpretation of the components more difficult. In this direction, the methodology approach itself could be improved, e.g., by the adoption of the Partial Least Squares Structural Equation Modelling (PLS-SEM) technique, to better explore complex structural models with more detailed cause-effect relationships.

Finally, among the further developments of this exploratory study, there is also the link between safety of pellet stoves emissions and quality certifications of the product. An in-depth exploration of consumers' awareness of health risks of emissions and the quality of forest biomasses could provide a more comprehensive scenario about forest biomasses market dynamics and requirements.

5.3. Market and policy implications

This is one of the first times that the drivers of willingness to pay for certified forest biomasses for energy purposes are assessed through an econometric model.

The market implications could be relevant given that almost 40% of people are not willing to pay an additional premium for certifications, companies could invest in consumer awareness and knowledge of the environmental implications of PEFC, FSC and ENplus. This is particularly interesting in the case of quality labels, since consumers seem to be more sensitive to product quality and safety standards. The adoption of private certifications could meet people's requirements for quality and, at the same time, could increase the company's economic margins.

The study also highlighted that there is not enough differentiation between the different meanings of the certifications. Policy makers can act in this direction by promoting the adoption of and knowledge on sustainable and quality certification schemes, enhancing people's environmental awareness and helping forestry and energy companies that are adopting private labels on the final product or that are certifying their production chain. From the long-term perspective, this awareness-rising action could also promote the adoption of sustainable production criteria at an international level, with positive environmental and economic repercussions on a larger scale. Finally, the question of the large-scale use of pellets and their origin acquires even greater relevance in this historic moment of energy crisis and the considerable increase in heating costs. The price on the market, which has reached peaks of 10 €/bag during the second half of 2002, is an indication of the greater prominence that this forest biomass is acquiring as a substitute for gas heating, but it could lead to less control, and therefore less sustainability of the supply chain and safety standards, of the material marketed, with possible repercussions for consumers in both economic and health terms.

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Research article

Crop Diversification, Agricultural Transition and Farm Income Growth: Evidence from Eastern India

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Abstract. This paper examines the role of crop diversification in agricultural transition towards high-value crops as well as farm income growth in Odisha, Eastern India. The empirical analysis reveals some crucial facts: first, a stagnant and relatively low level of crop diversification in Odisha agriculture. Second, there is an insignificant agricultural transition due to the negative *area substitution effect* for most of the crops, along with a *weak expansion effect* over the last two decades from 1995-2018. Third, a declining contribution of productivity growth coupled with an insignificant contribution of crop diversification to the farm income growth over the years. Hence, we conclude no or an insignificant agricultural transition from traditional to high-value modern agriculture in Eastern India, causing unsustainable farm income growth. This calls for an urgent need to promote a mixed cropping pattern and colossal investment to encourage the farmers to transition towards high-value crops, stimulating farm income growth. Furthermore, massive efforts are required to make farmers aware of the advantages of diversification.

Keywords: crop diversification, farm income, agricultural transition, Odisha.
JEL codes: C10, Q17, Q18.

HIGHLIGHTS

- There is stagnant or little crop diversification in Odisha agriculture, causing insignificant transition to modern commercial agriculture.
- The low level of diversification is on account of the negative area substitution effect for most crops, along with weak expansion effect over the last two decades.
- The contribution of diversification is insignificant while the yield effect is almost nil in farm income growth.
- It is only price effect that sustains the slight growth in farm income.

1. INTRODUCTION

In smallholder-dominated agrarian economies, diversification of the cropping system performs multiple functions. It reduces farmers' exposure to downside risks (Birthal, Hazrana, 2019; Paut, Sabatier, Tchamitchian, 2019), conserves natural resources, regulates climate change, and provides ecosystem services (Bertoni *et al.*, 2018; Matthews, 2020; Tamburini *et al.*, 2020; Bertoni *et al.*, 2021), and generates additional income and employment (Joshi *et al.*, 2007; Basantaray, Nancharaiah, 2017). On the whole, crop diversification contributes to the sustainability of agricultural production systems and growth (Birthal *et al.*, 2006; Nayak, Kumar, 2019; Akber, 2022), food and nutrition security (Pandey, Sharma, 1996; Satyasai, Viswanathan, 1996).

The literature on economic development indicates that the structural transformation of an economy is preceded by the diversification-led productivity growth in agriculture (Gollin, Parente, Rogerson, 2002; Emran, Shilpi, 2012; Bustos, Caprettini, Ponticelli, 2016). As the economy grows, the demand for high-value commodities[1] increases, which encourages farmers to diversify their production portfolios towards crops that generate higher returns with better market prospects and potential for value addition through processing and storage (Timmer, 2009; Sharma, 2005; Reardon, Timmer, 2007; Anwer, Sahoo, Mohapatra, 2019). Timmer (2009) argues that a sequence of progressively broader diversification steps defines a successful agricultural transformation as part of the broader structural transformation of the economy. Further, to deal with persistent agrarian distress, we require strategic intervention to reinvigorate the growth of farmers' income and farm sector growth at the aggregate level. Hence, diversification of the farm sector towards high-value crops (HVCs), including fruits, vegetables, spices, oilseeds and condiments, has proved quite effective in augmenting farm income and reducing rural poverty (Birthal, Roy, Negi, 2015; Michler, Josephson 2017). Moreover, HVCs are highly remunerative compared to the widely grown staple crops (Birthal *et al.*, 2020).

There is sufficient evidence that agricultural growth has a larger impact on poverty reduction than similar growth in the non-farm sector (Christiaensen *et al.*, 2011; Dutt, Ravallion, Murgai, 2020). This paper aims at understanding the sources of agricultural growth in Odisha, one of the poorest states in India, and explores whether crop diversification could be a pathway for agricultural transition to a higher growth trajectory. Agriculture in Odisha is dominated by smallholders and is under excessive employment pressure. It contributes about 22 percent to the state's gross domestic product and engages 62 percent of the workforce. The farm sector is plagued by low labour productivity, sluggish growth and high instability, rendering agriculture-based livelihoods unsustainable (Paltasingh, Goyari, 2013; Senapati, Goyari, 2019). Notably, landholdings in the state are small — approximately three-fourths of the total 4.87 million landholdings are of a size less than or equal to one hectare (OAS, 2018-2019). Again, over 41 percent of the rural population lives in poverty (Sahoo *et al.*, 2020). Against this backdrop, this study attempts to analyze the extent and pattern of crop diversification, its contribution to farm income growth, and future prospects for diversification-led growth. This has implications for (re)allocation of resources among crops and thus probes into a vital research question "whether or not the crop diversification can lead to agricultural transition".

The rest of this paper is divided into four sections. The following section deals with the data and methodology for quantifying the contribution of crop diversification to agricultural growth. Section 3 discusses the sources of growth. The final section summarises key findings and provides a few policy prescriptions to accelerate crop diversification.

2. DATA SOURCES

The secondary data used in the study have been taken from *Odisha Agriculture Statistics* (OAS), published annually by the *Directorate of Agriculture and Food Production*, Government of Odisha (GoO). This is the only reliable dataset from the state government on various aspects of Odisha agriculture. The dataset mainly publishes, for each year, district-wise area, productivity, and production of different crops, land utilization pattern, use of fertilizers, farm mechanization, and weather parameters such as rainfall, humidity, irrigation, and so on. We have used annual crop-wise data on area, production, productivity and prices from 1993-1994 to 2018-2019. Furthermore, major crops such as cereals, pulses, oilseeds, fibres, vegetables, spices, sugarcane, tobacco, fruits and flowers have been compiled for our analysis by clubbing together crops that fall under these headings. The historical series on "farm harvest prices" (FHP) for

[1] High-value farm commodities include profitable cash crops like fruits, vegetables, pulses, and dairy products, poultry, fish, and processed food (Ravi, Roy, 2006; Birthal *et al.*, 2007). Basically, a high-value crop is one that enjoys a high demand in the market with relatively higher price than staples. In this study, we consider pulses, vegetables, oilseeds, sugarcane, fibres and floriculture as high-value agriculture. It also includes horticulture, animal husbandry and aquaculture, etc., which fetch higher income for the farmers.

each crop has been collected from the *Directorate of Economics and Statistics* (DES), GoO.

Temporal changes in the cropping pattern and expansion of the area under cultivation of different crop groups *prima facie* provide an initial indication of the extent and pattern of crop diversification. Hence, we compare these indicators at different time points: triennium ending (TE) 1995-1996, TE 2001-2002, TE 2009-2010, and TE 2017-2018. The selection of these time points has been guided by data availability and structural breaks in agricultural growth. The complete dataset on agricultural indicators at the district level is available from 1993-1994 onwards. This initial time point coincides with the beginning of economic reforms in India; hence it serves as a proper reference to understand the dynamics of agriculture in the post-reform period. The next time point, i.e., TE 2001-2002, is considered on the grounds that the year 2002-2003 was a drought year in India, including the state of Odisha. Therefore, the period after 2002-2003 is considered a period of outstanding performance of agriculture. Interestingly, the year 2008 witnessed a global food price spike, but India's food economy was not much influenced by it (Acharya *et al.,* 2012).

3. EMPIRICAL STRATEGY

Several measures can be used to understand the degree of diversity in the cropping pattern. We use the Herfindahl index, a widely used measure[2]. It can be expressed as:

$$HI = \sum_{i=1}^{n} P_i^2 \tag{1}$$

where $P_i = A_i / \sum_{i=1}^{n} A_i$ and P_i is the proportion of area under ith crop in the total cropped area. The value of HI lies between 0 and 1; 0 indicates complete diversification, and 1 shows complete concentration.

3.1. Diversification and Agricultural Transition: First Decomposition

Crop diversification can be defined as a shift of resources, especially land, from low-value to high-value crops to maximize income gains from cultivation (Birthal *et al.*, 2007; Joshi *et al.*, 2007; Dasgupta, Bhaumik, 2014). We can observe this transition in land use by decomposing the change in the gross cropped area as an "expansion effect" and a "substitution effect" (Dasgupta, Bhaumik, 2014). Formally, it is expressed as:

$$\Delta A^i = A_t^i - A_0^i = \left[\left(\frac{A_0^i}{A_0}\right)(A_t - A_0)\right] + \left[(A_t^i - A_0^i) - \left\{\left(\frac{A_0^i}{A_0}\right)(A_t - A_0)\right\}\right] \tag{2}$$

where, A_t is the gross cropped area (GCA) in year *t*, A_0 is the gross cropped area in the initial year, and A_t^i and A_0^i stand for the cropped area under ith crop in year *t* and initial year, respectively. The first bracketed term on the right-hand side of Eq. (2) represents the expansion effect (defined as the share of ith crop in GCA in the initial year times the change in GCA between year t and the initial year. In other words, it is the increase in area under ith crop because of an increase in GCA. The second bracketed term, the residual between the total change in area under a crop and its expansion effect, gives the substitution effect, indicating land diversion from low-value to high-value crops. Thus, there would be a strong and positive substitution effect for incoming crops and a strong negative substitution effect for outgoing crops (De, 2003; Dasgupta, Bhaumik, 2014). A strong positive substitution effect, together with the expansion effect, suggests a transition from traditional to modern commercial agriculture.

3.2. Sources of Farm Income Growth and Diversification: Second Decomposition

We follow the decomposition method developed by Minot (2003) that provides for the contribution of area expansion, yield improvements, price increases and area reallocation (or diversification) to farm income growth[3]. Some recent studies, like Joshi *et al.,* (2006) and Pandey & Kumari (2021) have adopted this method.

Denoting the area under ith crop as A_i, its real price as P_i and yield as Y_i, the total farm income/revenue (R) from "n" crops can be expressed as:

$$R = \sum_{i=1}^{n} A_i Y_i P_i \tag{3}$$

Expressing $a_i = A_i/\sum_i A_i$, i.e., the share of ith crop area in the gross cropped area, the Eq. (3) can be rewritten as:

$$R = \left(\sum_{i=1}^{n} a_i Y_i P_i\right) \sum_{i=1}^{n} A_i \tag{4}$$

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[2] There are other measures of diversification like the Simpson Diversity index, Margalef index, Gini-Simpson Index, Ogive index, Berger-Parker index, Shannon index, Entropy index, etc. But, Herfindahl index is used because it is the simplest and most widely used measure of crop diversification. This measure is closely associated with the Simpson index.

[3] Gross farm income is defined as the income from the crop production as the value of crop production. Since some portion of the total output is not marketed, this includes both cash and in-kind income.

Now, the change in gross farm income, taking the total change on both sides, can be expressed as:

$$\Delta R \cong (\sum_{i=1}^{n} a_i Y_i P_i)\Delta(\sum_{i=1}^{n} A_i) + (\sum_{i=1}^{n} A_i)\Delta(\sum_{i=1}^{n} a_i Y_i P_i) \quad (5)$$

Eq. (5) provides approximate contributions of different sources to agricultural growth as it ignores the contributions of interactions of different sources. The second term on the right-hand side of Eq. (5) can be further decomposed from a "change in sums" to the "sum of changes".

$$\Delta R \cong (\sum_{i=1}^{n} a_i Y_i P_i)\Delta(\sum_{i=1}^{n} A_i) + (\sum_{i=1}^{n} A_i)\sum_{i=1}^{n} \Delta(a_i Y_i P_i) \quad (6)$$

Further manipulation of the second term in Eq. (6) gives the following equation:

$$\Delta R \cong (\sum_{i=1}^{n} a_i Y_i P_i)\Delta(\sum_{i=1}^{n} A_i) + (\sum_{i=1}^{n} A_i)\sum_{i=1}^{n}(a_i Y_i \Delta P_i) + (\sum_{i=1}^{n} A_i)\sum_{i=1}^{n}(a_i P_i \Delta Y_i) + (\sum_{i=1}^{n} A_i)\sum_{i=1}^{n}(P_i Y_i \Delta a_i) \quad (7)$$

The first term on the right-hand side of Eq. (7) denotes the change in gross farm income due to the change in total cropped area or GCA. The second term represents the effect of change in real price, and the third term indicates the effect of change in crop yields. Finally, the fourth term shows the effect of area reallocation, and if this term is positive, then there is diversification from lower-value to higher-value crops.

4. CROPPING PATTERN AND GROWTH DYNAMICS OF ODISHA AGRICULTURE

4.1. Changes in cropped area

Let us begin with an analysis of the changes in cropping patterns (Tab. 1). Overall, the GCA has been shrinking but erratically. The area under foodgrain crops witnessed a slight increase, and that under non-food grain crops a marginal decrease. The area under oilseeds, vegetables, spices, sugarcane and tobacco has declined. On the other hand, the area under fruits and fibres has increased. In fact, fruits have gained substantially in their area share, from 2.7% in TE 1995-1996 to 3.6% in TE 2001-2002, and further to 6.4% in TE 2017-2018. The area share of fibre crops more than doubled, from 0.8% in TE 1995-1996 to 1.8% in TE 2017-2018. The change in share of foodgrains initially registered an increase but subsequently declined. In TE 1995-1996, it stood at 73.9%, which increased to 77.9% in TE 2001-2002 but after that decreased continuously, reaching 74.5% in TE 2017-2018. Despite these dynamics, the area share of foodgrains has, by and large, remained stable.

Foodgrains occupy a significant chunk of cultivable land in Odisha; hence, we further look into the dynamics of change in different foodgrain crops. Appendix Table A.1. shows that cereals account for about 70 percent of the total area under foodgrains and pulses the rest. Amongst cereal crops, rice is the dominant crop and shares more than 62 percent of the foodgrain area. Among other crops, green gram, black gram, horse gram and arhar are important pulses grown in the state.

It is generally perceived that crop diversification happens when there is an increase in the area share

Tab. 1. Change in Cropping Pattern in Odisha.

	Average Area (in '000 hectares)				Share in Total Cropped Area (%)			
Crop Heads	TE 1995-1996	TE 2001-2002	TE 2009-2010	TE 2017-2018	TE 1995-1996	TE 2001-2002	TE 2009-2010	TE 2017-2018
Food –Grains	7173.8	6544.1	6905.6	6284.3	*73.9*	*77.9*	*76.3*	*74.5*
Oilseeds	1127.9	801.6	822.3	621.6	*11.6*	*9.5*	*9.1*	*7.4*
Vegetables	827.8	468.1	675.0	651.2	*8.5*	*5.6*	*7.5*	*7.7*
Fruits	266.8	302.4	369.2	540.1	*2.7*	*3.6*	*4.1*	*6.4*
Fibres	74.3	98.8	93.0	151.8	*0.8*	*1.2*	*1.0*	*1.8*
Spices	178.4	149.0	147.2	160.9	*1.8*	*1.8*	*1.6*	*1.9*
Sugarcane	43.3	30.7	37.6	27.8	*0.4*	*0.4*	*0.4*	*0.3*
Tobacco	9.8	5.5	3.7	0.8	*0.1*	*0.1*	*0.04*	*0.01*
Non-foodgrain	2528.3	1856.0	2148.0	2154.3	*26.1*	*22.1*	*23.7*	*25.5*
GCA*	9702.1	8400.1	9053.6	8438.6	*100*	*100*	*100*	*100*

Note: TE implies a Triennium ending. The asterisk (*) indicates that GCA includes the area under fruits.
The sum of shares is 100, which is calculated by taking the broad groups.

of non-foodgrains high-value cash crops. But some foodgrains like pulses and basmati rice are considered high-value crops. Appendix Table A.2. presents broad categories of non-foodgrain crops, such as oilseeds, fibres, spices and vegetables, with significant shares in the total cropped area. Oilseeds have the highest share in the total non-foodgrain areas, but their share has continuously declined, from around 50 until TE 2001-2002 to 42.4 percent in TE 2017-2018. The area share of groundnut, linseed and mustard has remained almost stagnant within the oilseeds, while that of sesamum and niger declined. On the other hand, the area share of fibres increased considerably from 3.3 percent in TE 1995-1996 to 8.1 percent in TE 2017-2018. This was driven by cotton. The area share of vegetables and spices (e.g., chilly and turmeric) also increased.

4.2. Dynamics of Agricultural Growth

Table 2 presents production of different crop groups and growth therein. Between TE 1995-1996 and TE 2001-2002, the growth rates in production of all crop groups were negative, except for spices and sugarcane. Production of pulses, oilseeds, vegetables and fibres declined faster. Nonetheless, the trend reversed in the subsequent period, and most crop groups experienced positive growth between TE 2001-2002 and TE 2009-2010. The production of cereals and pulses grew at an annual rate of 3.4% and 5.6%, respectively. Vegetables grew at 7.4% and spices at 4% during the same period. The growth in production of most crops decelerated in the recent period.

Combining the observations from Tables 1 and 2, we can draw certain inferences. First, the area under foodgrains' growth rates is lower than the growth rate of foodgrains' production between TE 2001-2002 and TE 2009-2010, and between TE 2009-2010 and TE 2017-2018. It may be due to an increase in the productivity of foodgrains. Similar phenomena are observed in the case of oilseeds, vegetables and spices, which imply an increase in these categories of crops' productivity. Second, as far as fibres are concerned, the production growth rate is higher than the area's growth rate between TE 2001-2002 and TE 2009-2010, suggesting an increase in fibres' productivity during this period. On the other hand, between TE 2009-2010 and TE 2017-2018, the growth rate of area is very high compared to the growth rate of fibres' production, suggesting a decrease in productivity.

5. EMPIRICAL RESULTS AND DISCUSSION

5.1. Extent of Diversification and Agricultural Transition

Table 3 reports the values of the Herfindahl index (HI) for the agriculture of Odisha. Excluding the area under fruits and flowers, the value of HI reveals that the level of crop diversification in Odisha's agriculture has fallen marginally over time. HI's value was 0.25 in 1995-1996 but increased to 0.32 in 2001-2002, implying a significant diversification decline during this period. Since then, it has improved slightly as the HI value reached 0.29 in 2009-2010 and further declined to 0.27 in 2017-2018, implying a slight improvement in the extent of

Tab. 2. Average production and compound growth rates of different crop groups.

Crop Group	TE 1995-1996	TE 2001-2002	TE 2009-2010	TE 2017-2018	GR between 1995-1996 & 2001-2002	GR between 2001-2002 & 2010-2009	GR between 2009-2010 & 2017-2018
Total Cereals	6887.1	6058.2	7910.2	8261.7	*-2.1*	*3.4*	*0.71*
Total Pulses	1154.4	619.2	955	1003.4	*-9.9*	*5.6*	*0.72*
Foodgrains	8041.5	6677.5	8865.2	9265.1	*-3.1*	*3.6*	*1.28*
Oilseeds	852.1	493.7	666	553.4	*-8.7*	*3.8*	*-1.92*
Vegetables	6996.6	4812.7	8512.1	9006.5	*-6*	*7.4*	*2.03*
Fibres*	473.1	311.6	383.8	478.5	*-6.7*	*2.6*	*4.07*
Spices	194.3	200.3	274	588.9	*0.5*	*4*	*10.73*
Sugarcane	289.2	1940	2652.1	2035.6	*37.3*	*4*	*-2.86*
Tobacco	5.9	3.4	2.8	0.5	*-8.9*	*-2.5*	*-9.14*

Note: (1) * is in '000 bales. Other quantities are in '000 tonnes. (2) GR is the average annual compound growth rate defined as $g = e^{\left(\frac{1}{t} * Ln\left(\frac{Y_T}{Y_0}\right) - 1\right) * 100}$; Y_T and Y_0 are starting and ending values of the concerned variable, and "t" represents the number of years between two time periods (in our case TE periods). For spices, sugarcane and tobacco, production data for 1995-1996 is the average of 1994-1995 and 1995-1996 data due to their data unavailability for 1993-1994.

Tab. 3. Extent of crop diversification in agriculture of Odisha.

TE Periods	HI excluding Fruits & Flowers	HI including Fruits & Flowers*
1995-1996	0.25	0.24
2001-2002	0.32	0.30
2009-2010	0.29	0.26
2013-2014	0.28	0.23
2017-2018	0.27	0.25

Note: * TE 1995-1996 & 2001-2002 includes the area under fruits only since the area under flowers is not available for these periods. TE 2009-2010 onwards consists of both fruits and flowers area.

diversification. However, it is still less than the level it used to be at in 1995-1996. After including all crops, the HI estimates that the extent of diversification naturally came out higher. The initial value was at 0.24 in 1995-1996 but increased to 0.30 in 2001-2002. However, it grew to 0.26 in 2009-2010 and then further decreased to 0.23 in 2013-2014 but again increased to 0.25. So, in recent times, the extent of agricultural diversification has declined. This result has been supported by Nayak & Kumar (2019). They argue that the wide use of high-yielding varieties (HYVs) and access to irrigation in coastal districts have rendered crop diversification sluggish in Odisha agriculture.

From the preceding analysis, we obtain the extent and pattern of agricultural diversification over time, suggesting that it was around 0.75 during the mid-1990s and then started falling. However, recently it increased but still below the level of the mid-1990s. So, we can conclude that there is a marginal decline in diversification. Here, we analyze the source of diversification, i.e., whether the change in area is from the expansion of gross cropped area or intercrop substitution of area. Table 4 gives the decomposition of the total change in the area into expansion and substitution effects. It is important to recall that the GCA in Odisha was 9747.29 thousand hectares in 1993-1994, which declined to 8636.59 thousand hectares in 2003-2004 and became 9054.07 thousand hectares in 2009-2010, which again fell to 8206.94 in 2017-2018. It can be seen from Table 5 that, between 1993-1994 and 2003-2004, the total change in area under all crops except fibres and fruits is negative. However, there is a strong positive substitution effect in the case of cereals, fibres and total fruits, which indicated that farmers were substituting other crops with cereals, mainly paddy. There was a significant decline in the area under pulses, oilseeds and vegetables, where there was a substantial negative expansion as well as a substitution effect. In the more recent period, between 2003-2004 and 2013-2014, the total change in area under pulses was positive with sizeable positive expansion and substitution effect. At the same time, the total change in area under cereals fell with a strong negative substitution effect. During this period, the total change in area under fibres, vegetables, spices and fruits increased positively, with positive expansion as well as substitution effect. This implies that these crops, along with pulses, were substituting other crops in Odisha. In the most recent period between 2013-2014 and 2017-2018, total area change for almost all crops was negative. However, cereals and pulses experienced a positive substitution effect, but a strong negative expansion effect outweighed it. This means that these crops were replacing other crops even though the total area under these crops was falling. We observed similar dynamics in crop

Tab. 4. Decomposition of the total change in area in Odisha (area in ‘000 ha).

Crop Groups	TE 1993-1994 to 2003-2004			TE 2013-2014 to 2003-2004			TE 2017-2018 to 2013-2014		
	EE	SE	TC	EE	SE	TC	EE	SE	TC
Cereals	-578.0	431.2	-146.8	238.1	-495.4	-257.3	-436.8	76.6	-360.1
Pulses	-242.6	-244.0	-486.7	79.4	366.2	445.6	-195.4	73.4	-122.0
Oilseeds	-127.1	-192.5	-319.7	38.5	-82.2	-43.7	-70.4	-60.4	-130.8
Fibres	-7.6	23.3	15.7	4.0	65.9	69.9	-14.2	14.1	-0.1
Vegetables	-97.0	-109.5	-206.5	31.2	1.2	32.4	-63.4	37.3	-26.1
Spices	-19.7	-8.6	-28.3	29.9	-11.8	18.2	-14.5	15.8	1.3
Sugar Cane	-4.4	-5.7	-10.1	1.4	5.2	6.6	-3.3	-4.2	-7.5
Tobacco	-1.1	-3.6	-4.7	0.3	-3.9	-3.6	-0.2	0.2	0.1
Total Fruits	-32.5	114.8	82.3	17.7	138.8	156.6	-49.0	-160.2	-209.2
Total Flowers*	--	--	--	0.02	4.9	4.9	-0.5	1.8	1.3

Note: (1) EE-expansion effect, SE-substitution effect, and TC-total change. (2) NA-not available.
Odisha.

area changes in the case of fibres, vegetables and spices. Surprisingly, the area under fruits fell with negative expansion as well as substitution effect.

Thus, this analysis demonstrates a negligible agricultural transition from traditional food crops to the modern state of non-food crops by substituting the crop area. But as such, there is no change in the degree of diversification. Banerjee & Banerjee (2015) and Nayak & Kumar (2019) also found the same in the case of Odisha. So, Odisha agriculture continues to be in a low growth state with the static spread of cropping patterns over time. This fact makes Odisha agriculture unsustainable because without expansion of gross cropped area with the static spread of crops does ensure a high exposure of farmers to various types of farming risks such as market/price risks, income risks as well as climatic risks (Paltasingh, Goyari, 2011; Birthal, Hazrana, 2019).

Again, this low degree of diversification causing a negligible agricultural transition towards high-value agriculture is deleterious to Odisha agriculture. Because the state's agricultural sector is replete with smallholders but substantial surplus labour, this transition could be a boon for the smallholders to augment their income as most of these high-value commodities are labour-intensive with low gestation periods that give quick returns (Birthal *et al.*, 2007; Barghouti *et al.*, 2004). We also have credible evidence of an inverse relationship between farm size and productivity in the case of high-value crops (Birthal *et al.*, 2014), which is absent in the case of other crops. Hence, Odisha agriculture could highly benefit from this move. Diversification is also a major driver of farm investment and farm productivity (Akber, Paltasingh, 2021). In this context, we have success stories in other Indian states like Punjab and Andhra Pradesh (IFPRI, 2007). In Punjab, there is diversification towards the dairy sector, though the rice-wheat system still dominates. But Andhra Pradesh has been more diversified toward fisheries, poultry, fruits and vegetables, replacing the core cereals and, to some extent, rice.

5.2. Sources of Farm Income Growth & Diversification

Table 5 presents the decomposition of farm income growth into various sources: total cropped area, yield, prices and crop diversification. Here, we observed the contribution of different factors in farm income growth during two decades: TE 1995-1996 to TE 2007-2008 and TE 2007-2008, and TE 2017-2018. Initially, the contribution of the growth of real price and the growth of yields, and the combined contribution (interaction effect) significantly determined farm income growth. First, there was a significant price effect, followed by the yield effect.

Tab. 5. Contribution of various components to farm income growth for crop groups (in %).

Changes in Gross Crop Income due to	Between TE 1995-1996 to TE 2007-2008	Between TE 2007-2008 to TE 2017-2018
ΔTotal Cropped Area	*-25.9*	*-5.4*
Δ Real Price	*96.1*	*69.4*
Δ Crop Yields	*14.1*	*12.0*
Δ Area Composition	*3.7*	*2.2*
Interaction	*12.0*	*21.8*
Total	*100*	*100*

Note: (i) Major crops include paddy, wheat, ragi, maize, mung, Biri, Kulthi, mustard, groundnut, til, jute, sugarcane and potato; (ii) Share of these commodities in total cropped area of Odisha for TE 1995-96, TE2007-08, and TE 2017-18 stood at 87 percent, 83 percent, and 81 percent, respectively; (iii) District level data on Farm Harvest Prices (FHP) for calculation of the value of these crops are used as the value of Odisha agriculture. This dataset is available on https://agriodisha.nic.in/Home/staticstics. (iv) We calculate the weighted average FHP for each crop for Odisha by taking each district's crop-wise production as weight.

In the subsequent decade, i.e., TE 2007-2008 to TE 2017-2018, farm income growth was also mainly determined by the same set of factors, but the interaction effect turned out to be a major one. There is a slight decline in yield effect that may be attributed to the declining contribution of yield in crop income growth on account of a reduction in yield growth for most crops, including rice, as evident earlier (Tab. 3). Pandey & Kumari (2021) also evidenced the same in the case of Jharkhand, another poor state in Eastern India. They found a significant price effect (41%) in the later period. Joshi *et al.*, (2006) also found the same at the aggregate level of Indian agriculture. However, the effect of diversification was meagre in the initial period, which again declined. This is in line with earlier results observed that there is a decline in the degree of diversification. So, we obtain a negative contribution of crop diversification. It implies that the agriculture of Odisha has been static, and there is no transition towards high-value crops. Again, the decline in yield effect poses a serious question about the viability of output and farm income enhancement. Because the improvement in crop yields represents technological advancement (Birthal *et al.*, 2014; Pandey, Kumari, 2021), while the price effect signifies the market contribution in a narrow sense, this suggests that farm income is increasingly and mainly driven by only the price increases, not by technological improvements or diversification. When market contribution is necessary, technological advancements (yield effect) and agricultural transition (diversification towards high-value crops) make farm income growth sustainable and stimulates higher farm investment (Akber, 2022). But in Odisha agriculture, both are missing as it is significantly out of rising real prices. As observed earlier, the negative area effect further exacerbates the condition. Therefore, farm income growth is not sustainable in state agriculture, which calls for urgent policy intervention.

6. CONCLUSION AND POLICY IMPLICATIONS

From the above analysis, we observed a fall in the total cropped area. However, the extent of the decline in the area under non-foodgrains is relatively lower than that of foodgrains. Again, there is hardly any change in the relative share of area under foodgrains and non-foodgrains in the total cropped area over the years. The cropping pattern in Odisha, primarily biased towards cereals, has remained static over the period. In the case of area occupied, rice, among cereals, is still the dominant crop in Odisha. Maize and Ragi are the other two significant cereal crops.

The value of HI, including fruits and flowers, was at 0.24 in 1995-1996 and increased to 0.312 in 2002-2003. But since then, it has declined, first to 0.26 in 2009-2010 and then further to 0.25 in 2017-2018. So, in recent periods, fruits and flowers have led to a marginal increase in the extent of crop diversification in Odisha. But overall, there is a moderate to low degree of diversification in the agriculture, and much worse is the fact that it has remained stagnant over the last two decades. Hence, the agricultural transition looks gloomy because of marginal crop diversification due to increased area under vegetables, fruits and flowers. Therefore, the transition from traditional to modern high-value agriculture is almost absent. The substitution effect is negative for nearly all crops, while the expansion effect is relatively weak (only fibres, fruits, vegetables and flowers).

In fact, the agriculture of Odisha continues to reel under the traditional form where a heavy bias towards rice is found, making it highly vulnerable to both biotic and abiotic risks. Again, crop income growth in the agriculture is majorly determined by the unsustainable price effect. When the contribution of yield growth is not that substantial, the role of crop diversification in farm income growth has been meagre over the last two decades. It's only because of the static cropping pattern, which renders the agriculture of Odisha a subsistence sector.

The paper suggests some policies for the development of Odisha agriculture along with directions for future research. First, the low and almost stagnant level of crop diversification in agriculture should be addressed. The farmers need to be encouraged through various schemes, awareness programmes, and farmers' field schools (FFS) about the importance of diversification in their cropping pattern. Second, the declining contribution of yield and diversification must be viewed seriously in the policy circle because both have been declining over the years. Hence, there is a huge need for public investment in irrigation, transport, marketing, storage, etc. Because this will stimulate private investment at farm level in the form of the adoption of modern yield-enhancing technology, as well as encourage farmers to adopt a mix of cropping patterns to reduce risks. Again, traditional indigenous cropping patterns consisting of pulses and millets should be promoted in dry uplands. Recently, a programme called "millet mission" was launched, but it should be promoted massively in dry regions of the state. Diversifying towards a remunerative crop mix augments rural farm income, creates more employment opportunities, and empowers the downtrodden, especially rural women (Pingali, Rosegrant, 1996; Ryan, Spencer, 2001; Joshi *et al.*, 2006). Third, the already weakened agricultural extension and market information system must be emphasized to achieve all this. Fourth, other institutional arrangements must be implemented to enhance all markets' vertical coordination, adequate crop procurement, and arrest crop losses due to their perishability.

This study can be considered as the basis for further research on various issues relating to crop diversification, such as why there is a low level of crop diversification in the state's agriculture. How can it be promoted, and is diversification towards high-value crops effective in augmenting farm income, reducing rural poverty and coping with climatic shocks? These are some of the research issues that can be addressed.

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APPENDIX

Tab. A.1. Crop-wise distribution of total food grain area in Odisha (in %)

Crops	Share in Total Food grain Area			
	TE 1995-1996	TE 2001-2002	TE 2009-2010	TE 2013-2014
(A) Cereals	*70.0*	*75.6*	*70.9*	*69.0*
Rice	*62.9*	*68.8*	*64.3*	*61.7*
Wheat	*0.3*	*0.3*	*0.3*	*0.2*
Jowar	*0.3*	*0.2*	*0.1*	*0.1*
Bajra	*0.1*	*0.1*	*0.0*	*0.0*
Maize	*2.3*	*2.6*	*3.2*	*4.2*
Ragi	*3.2*	*3.0*	*2.7*	*2.6*
Small Millets	*0.9*	*0.6*	*0.3*	*0.3*
(B) Pulses	*30.0*	*24.2*	*29.1*	*31.0*
Arhar	*2.3*	*2.1*	*2.0*	*2.1*
Mung	*10.6*	*8.8*	*11.3*	*12.6*
Biri	*8.3*	*7.5*	*8.9*	*9.0*
Kulthi	*5.2*	*4.3*	*3.7*	*3.5*
Gram	*0.5*	*0.4*	*0.6*	*0.6*
Fieldpea	*0.3*	*0.4*	*0.4*	*0.5*
Lentil	*0.1*	*0.2*	*0.2*	*0.2*
Cowpea	*0.3*	*0.4*	*1.1*	*0.8*
Other Pulses	*2.4*	*NA*	*1.2*	*1.7*
Total Food grains*	*7171.8*	*6544.0*	*6884.6*	*6600.0*

Note: * Figures are in '000 Hectares; NA- not available

Tab. A.2. Crop-wise distribution of total non-food grain area in Odisha (in %).

Crops	Share in Total Non-Food Grain Area			
	TE 1995-1996	TE 2001-2002	TE 2009-2010	TE 2013-2014
(A) Oilseeds	*50.0*	*51.6*	*46.2*	*42.4*
Groundnut	*14.1*	*15.0*	*14.1*	*14.7*
Sesamum	*16.5*	*16.5*	*16.6*	*12.7*
Caster	*1.2*	*1.3*	*1.0*	*0.7*
Niger	*9.0*	*9.4*	*5.8*	*4.2*
Sunflower	*0.1*	*0.5*	*1.0*	*1.4*
Safflower	*0.2*	*0.2*	*0.1*	*0.0*
Linseed	*1.4*	*1.5*	*1.5*	*1.3*
Mustard	*7.4*	*7.2*	*6.2*	*7.3*
(B) Fibres	*3.3*	*6.3*	*5.2*	*8.1*
Jute	*0.9*	*0.9*	*0.6*	*0.6*
Mesta	*1.5*	*1.7*	*1.1*	*0.8*
Sun hemp	*0.6*	*0.7*	*0.5*	*0.4*
Cotton	*0.3*	*3.0*	*3.0*	*6.4*
(C) Vegetables	*36.7*	*30.1*	*37.9*	*38.5*
Sweet Potato	*2.3*	*2.6*	*2.7*	*2.4*
Potato	*0.4*	*0.5*	*0.5*	*0.8*
Onion	*2.1*	*2.0*	*1.7*	*2.0*
Other Vegetables	*31.8*	*25.0*	*32.9*	*33.3*
(D) Spices	*7.8*	*9.6*	*8.3*	*8.7*
Chilly	*4.4*	*5.2*	*4.2*	*4.3*
Coriander	*1.1*	*1.1*	*1.1*	*1.1*
Garlic	*0.8*	*0.8*	*0.6*	*0.7*
Turmeric	*1.0*	*1.7*	*1.4*	*1.6*
Ginger	*0.5*	*0.6*	*0.9*	*1.0*
(E) Sugar Cane	*1.8*	*2.0*	*2.1*	*2.1*
(F) Tobacco	*0.5*	*0.3*	*0.2*	*0.1*

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Short communication

The 7th Italian Agricultural Census: new directions and legacies of the past

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Abstract. The release of the new Italian Agricultural Census shows many features in line with the previous decades and also some novelties, which shall be properly investigated in the upcoming future. The reduction in number of farms was largely announced and in line with the overall declining trend. However, in 2020 the average farm size has grown, showing a slowdown of land abandonment and soil consumption in agriculture and a reorganization of the farm structures. In this paper the main economic, social and functional transformations are analysed, by aggregating some of the most relevant trends in evidence. More in-depth analyses from scholars, stakeholders and policymakers are advocated, with the ultimate goal of highlighting and interpreting the long-term paths of Italian agriculture.

Keywords: farm structures, farm size, on-farm diversification, young farmers, contract services.
JEL codes: Q10, Q12.

HIGHLIGHTS

- The new Census shows relatively few large professional farms integrated into the global supply chain and many small farms surviving despite their sharp decline.
- Large farms introduce innovations and diversification of activities that become an increasing part of their production and market orientation.
- Italian agriculture still suffers from a lack of a new generation of younger farmers taking over from the older generation.

1. INTRODUCTION

The Agricultural Census contributes to describing, analysing and measuring the overall economic, social and environmental changes occurring in the Italian primary sector alongside the European model of agriculture. It also shows the specificity of agricultural and rural areas as a privileged lab of the interactions amongst the structural changes occurring and the policies.

Many specific dynamics started in the past decades and were caught by the latest Census for different reasons: the growing attention to the environmental aspects of farming, which look at agriculture as both a polluting agent and also as an activity influenced by pollution; the increasing sensitivity of the sector to climate change and the higher frequency of extreme meteorological events; the growing multifunctional role of agriculture and its capacity to produce goods and services different from and conjoined to the primary products (food and fibres); the change in European policies supporting farming activities and putting them back at the centre of market relationships and global economic forces that act directly and indirectly on agriculture.

The primary function of agriculture has deeply and rapidly changed in the last decade, with an ongoing segmentation that is not secondary to what is happening in less mature branches of the economic system, and thanks to which we can see a combination of differentiated products originated in the same territories: from high quality products and designations of origin to products perfectly integrated into the value chains and international markets, organic products, those for niche markets, traditional local products, and so on. Such coexistence is particularly evident moving from the North to the South of Europe and it is also the result of the progressive articulation of the EU agricultural and rural policies from a top-down one-size-fits-all approach to a subsidiary, bottom-up and participatory approach (Ortiz-Miranda *et al.*, 2013). This process has progressively allowed Member States to better fit policies to the needs and characteristics of their agricultures and this has been particularly relevant for those countries, mostly in the South of Europe, where the traditional Common Agricultural Policy (CAP) of the past was not fully accessible (Henke *et al.*, 2018).

Another relevant consideration is the evidence of an increasing process of on-farm diversification that introduces new elements of analysis and classification in the statistical taxonomy (Van Huylenbroeck, Durand, 2003; Henke, Salvioni, 2008; Henke *et al.*, 2014). Such changes involve the whole universe of farms to different extents according to their size, location and specialisation, and their functional role in the agri-food system (Sotte, 2006).

The analysis proposed here does not intend to provide a paramount picture of all the processes and changes occurring in the Italian primary sector, also because at the time of writing only a certain number of data and information are available[1]. We rather focus on three main directions of change, after a general introductive picture of the "new agriculture" emerging from the Census:

1. Economic transformations, looking at the evolution of the connections to markets and to the composition of revenues;
2. Social transformations, in terms of labour, young farmers, new entrepreneurs, age and education of farmers;
3. Functional transformations, looking at on-farm diversification generating income, contract services and digital innovation.

2. THE MAIN PICTURE: CHANGES AND CONTINUITY

At each new Census a wide scientific production attempts to give correct answers to the crucial questions: what are the economic and social roles of contemporary farming? As shown by some distinctive works (Fabiani, Scarano, 1995; Marinelli *et al.*, 1998; Arzeni, Sotte, 2014; Russo, 2014), this is not an easy question, mainly because the relatively small number of professional farmers coexists with a large number of non-professional farmers with whom they share the use of land, access to the same family of policies, the production of some public goods and many social and environmental functions. Arzeni and Sotte (2014) used a selected number of variables (economic dimension, yearly workdays, self-consumption and outsourced services) to identify several categories, from small non-professional farms to large professional ones. According to the 6th Census (2010), the former category prevailed in the south and centre of Italy while the latter were concentrated in the north.

The issue of the number of units and their size has always received a lot of interest from scholars and stakeholders. In the latest Census 1,133,023 farms were recorded, with a loss of almost 500,000 units (-30%) (Tab. 1). Such a reduction was largely announced as a turning point of Italian agriculture; however, this is totally in line with what happened in the previous decades. The process of restructuring has been going on for a long time and the real switch can be identified in the first decade of the 21st century (Spinelli, Fanfani, 2012; Arzeni, Pecci, 2012). Overall, in 40 years, more than 2 million farms have vanished, a higher number than the ones survived. At the same time, the slowing down of

[1] The 2020 Census data available at the time of this note can be found, together with a Report by ISTAT, at the following link: https://www.istat.it/it/archivio/274950. For some very relevant topics, such as livestock or other specialisations, the current set of data offers only an instant picture, since there is no comparison with the past. For other issues such as organic farming, smart farming and so on, data are only partially available and reported together with the information on young farmers, whose detailed information is one of the biggest novelties of the Census.

Tab. 1. Evolution of Farms and UAA in Italy.

Year	Absolute figures			Variations on the previous decade			Average size (UAA) (ha)
	Farms (n)	UAA (ha)	TAA (ha)	Farms (n)	UAA (ha)	TAA (ha)	
2020	1,133,023	12,535	16,474	-29.9	-2.5	-3.6	11.1
2010	1,615,590	12,856	17,081	-32.5	-2.5	-9.0	8.0
2000	2,393,161	13,182	18,767	-16.0	-12.3	-13.2	5.5
1990	2,848,136	15,026	21,628	-9.1	-5.1	-3.4	5.3
1982	3,133,118	15,833	22,398	-	-	-	5.1

Source: elaborations on ISTAT data.

the consumption of soil (for alternative uses) and land abandonment (re-naturalisation) can be associated to a process of land consolidation, with fewer but larger units as a result. However, it is quite evident that the whole universe of Italian farms in 2020 does not exclusively include "market-oriented farms", as indicated by the European institutions, but also many small non-market-oriented units, which are mainly residences and hobby farms and that altogether still cover a significant share of the UAA (Matthews, 2021; Giacomini, 2022). While farms up to 10 hectares hold around 20% of the total UAA, a relatively small number of farms larger than 50 hectares (4.5%) hold almost 50% of the Italian UAA.

Between 2010 and 2020 the farm size categories up to 30 hectares all decreased, with different but high percentages: 50% of farms under 1 hectare of UAA are gone, as are 35% of those under 2 hectares. In total, of the around 500 thousand units missing, roughly 380 thousand are smaller than 2 hectares. Looking at the other side of the coin, farms larger than 100 hectares grew by 17%, while those from 50 to 100 hectares grew by 11%. All the categories up to 30 hectares feature a reduction in the number of farms, while the higher size categories show an increase, particularly relevant for the farms over 100 hectares.

The change in the UAA, altogether reaching -2.5%, is in line with the change of the previous decade and much less than the change that occurred in 2000 (-12.3%). Once again, it seems that the last decade is seeing the tail end of a process that started much earlier. The cumulative share of hectares of farms up to 10 hectares equals less than 20%, while it was 24.4% in 2010. The already small amount of land attributed to micro-farms (equal to or less than 2 hectares) almost halved from 2010 to 2020. The highest reduction in the UAA in 2020 is shown in the south of the country, -4%. Overall, the average size of Italian farms increased quite substantially, from 8 to 11 hectares. Despite a generalized increase, the average size hides quite a differentiated picture in different parts of the country: in the north it is quite in line with the size of other European countries and certainly with the European average, while the mainland south is still quite far from that, at 7 hectares.

To complete the picture, it is worth looking at land use, which decreases for all the main categories, included the wood farms and with the only exception being pasture farms (+3.8%). In terms of area, the reduction includes all types of products, with the only exception being arable crops (+2.7%).

The slow professionalization of agriculture also emerges from the change in the legal status of farms: there is a clear increase in corporations (+42%) and a significant increase in partnerships (+15%). However, figures are still quite low, so that individual business and family farms still dominate the sector (93.4%), although in sharp decline (-32%). This is because most of the reduction of farms in the decade is of that category of holdings. At the same time, the share of UAA for these farms is "only" 73% and the reduction equals -7%.

Given this very preliminary description of the main dynamics, what kind of general picture can one draw?

Overall, the restructuring process of the primary sector in Italy is still ongoing, alongside the socio-economic transformation of the country that demands a different and multifunctional role from the primary sector and farmers, but also driven by the process of long-term policy reform.

A very interesting element is the progressive slow reduction of dualism, which has historically characterized the Italian structures, between micro-farms and large farms. Small farms are still a large share of the Italian structures, but their reduction in number coincides also with a different and renovated function for them, from residual and marginal productive structures to mainly residential and hobby farms (Sotte, 2006; Salvioni *et al.*, 2010; Arzeni, Sotte, 2014). Large farms are integrated in the supply chain, but they also contribute to the production of secondary goods and services. So, it seems that the relevant dichotomy is no longer about size but rather about economic, social and environmental functions. However, the geographical dualism between north and south seems to resist compared with other historical ones: micro vs. large, capitalistic vs. family farms, part-time vs. full-time and so on. Some of the issues characterising past studies seem to have lost importance as analytical categories in favour of others: such as the multifunctional role of agriculture, income diversification and the rate of integration of farms into the supply chain (local, national, international) (Arzeni, Pecci, 2012; De Benedictis, 1992; Fanfani, Montresor, 2000; Mantino, 1995).

In this view, it is interesting to further investigate the changes occurring in Italian agriculture according to the Census following three main directions: economic, social and functional. The availability of data only allows some general considerations that should be further analysed once the full set of data are available, such as the classification according to the economic size or the single farm data. Other issues, such as innovation, digitalisation, environmental aspects would also be very interesting to explore, but at the moment data available do not allow a comprehensive vision of such changes. All in all, the agriculture that stems from the Census only partially overlaps with the latest narration of the sector in society and to a limited extent matches the expectations of the EU about the renovated role of agriculture in contemporary societies, as announced in the Farm to Fork strategy and, in general, in the EU Green Deal. However, it does not fully support other crucial aspects, such as the agri-food Made in Italy, of which the primary sector is a key element. As such, it should be supported by an adequate statistical database able to interpret the ongoing dynamics.

3. ECONOMIC TRANSFORMATIONS

Many aspects about the economic transformations occurring in Italian agriculture can be further investigated once ISTAT releases the data on the economic dimensions of farms. However, some relevant issues of the performance of farms can be observed here, thanks also to the evidence from previous studies.

To start with, the high percentage gaining no revenues at all from any agricultural activity is still quite relevant (Tab. 2), although in reduction when compared with the previous decade. In the 2010 Census, the topic was investigated in a much more direct way, referring to self-consumption (full or a relevant share of the total production); while in 2020, the question was less direct and could create some misinterpretation from the farmers. In any case, a good quarter of the total farms declare not to gain any revenue or receive any support from the policies. Such a share hides quite a substantial difference according to geographical areas, with a share of 13% in the north-east and of over 30% in the centre. Surprisingly enough, the southern regions are not, as in the past, the ones with the highest share of farms without revenues or subsidies.

With regards to the other share of the universe (Tab. 2), all farms record a significant share of revenues from non-agricultural activities or from public subsidies. In the table, for each component of the total revenues the simple mean of the shares of source of farms' revenues is reported. In such a rather complicated way, the Census adds precious information on how relevant each component is in the composition of revenues (take note that the shares do not add up to 100, due to the fact that each column shows the share for the group of farms declaring such a specific source*)*. Among farms declaring to gain revenues from the sales of agricultural products the share goes from roughly 83% in the north to less than 74% in the south. As for the other gainful activities, for farms that take that diversification path the share is quite relevant, from 39% in the north-east to around 45% on the islands. Equally, the average share of subsidies is quite significant everywhere, however it is far more relevant in the south than in the north. This confirms the primary sector to be significantly supported by public policy, no matter the position, size and direct relationships with markets.

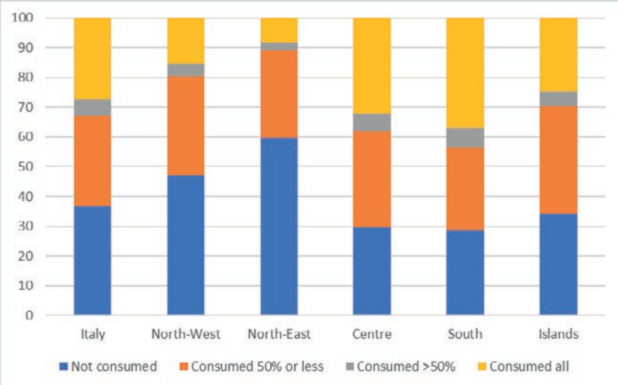
Another element of interest is the share of products consumed within the farms (Fig. 1). This share is particularly high in Italy according to the Census, mostly in consideration of the micro-farms included in it and

Tab. 2. Share of farms with and without revenues and average composition of revenues - 2020.

	No revenues/ subsidies	With revenues/ subsidies	Average composition of revenues*		
			Sales agr. products	Sales other products	Subsidies
North-west	20.3	79.7	82.9	40.2	28.1
North-east	13.4	86.6	83.3	39.1	27.3
Centre	32.3	67.7	72.9	43.8	49.7
South	28.3	71.7	73.7	43.3	60.6
Islands	27.0	73.0	75.0	44.8	46.8
ITALY	25.4	74.6	77.2	41.5	47.7

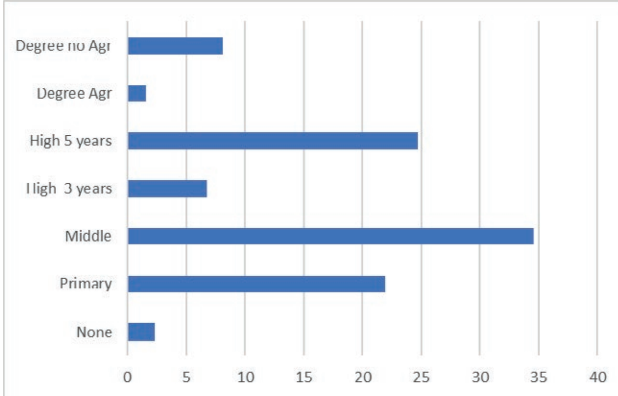
*Each share is the simple mean of the farms declaring a revenue from each of three different sources. Farms can have revenues from all, two or only one of the recorded sources. For this reason, the shares do not add up to 100.
Source: elaborations on ISTAT data.

Fig. 1. Farm composition according to the use of final production – 2020.



Source: elaborations on ISTAT data.

Fig. 2. Share of farms by farm holders' education – 2020.



Source: elaborations on ISTAT data.

often connected to the remoteness of the farms and the rural areas, which only allows for limited regular connections to the markets.

On average, in Italy 27% of farms consume all their products, which means, consequently, that they declare not to have any regular connections to the markets. Conversely, 37% of farms do not at all consume their own products. In between, there is a shady area in which around 36% of farms have "some" relationships with the markets, therefore gaining some revenues from the agricultural activities. This information is quite relevant for the share of farms producing regularly for the markets and integrated into the national and international value chains, which could, at a first glance, amount to about 60% of the total (between 600,000 and 700,000). The remaining units are oriented to residential, self-consumption, hobbyist functions, which if on the one hand do not contribute significantly to the integrated agri-food system, do, on the other, have a relevant role in terms of environmental, territorial and social functions.

Once again, the average scores in Italy are a combination of different features in the different parts of the country: the share of farms fully oriented to self-consumption is particularly high in the southern regions and in the centre, while the highest share fully oriented to production for the markets is in the north-east.

4. SOCIAL TRANSFORMATIONS

With regards to the social changes occurring in the primary sector, rather than trying to cover all the issues emerging from the new Census (such as gender issues, or the presence of foreign workers and rural-urban relationships), we chose to focus only on a few relevant aspects that somehow interlink also with other aspects investigated here: age, education and work force in agriculture.

The element of ageing of Italian farmers is common to other European countries (Cagliero, Novelli, 2012; Cardillo *et al.*, 2022). The reduction in absolute terms of the number of farms managed by young farmers (less than 40 years of age[2]) in the last 20 years also reflects a reduction of the share (from 10.3% in 2000 to 9.3% in 2020), which is probably due to the continuing process of ageing of farmers. This is certainly a bit worrying if one considers the implementation of policies in favour of young farmers and the support offered to new and innovative forms of entrepreneurship in agriculture. Such policies have as a main scope to insert new, more skilled and educated and strongly motivated forces in the primary sector, able to enhance and improve a new entrepreneurship in agriculture and rural areas (Davis *et al.*, 2013; Sargani *et al.*, 2020).

With regard to the education and skills of farm holders, the picture of Italian agriculture does not seem very different from that of the past: around 25% of farm holders do not have any form of education or a primary one; most of them have a "middle school" or "high school" education but few have a degree and even fewer a specialist degree (in agricultural science). This implies that, as in the past, the primary sector is still managed without a specialist education and specific skills coming from proper training are an option, and not a requirement, as in other sectors. Such specificity is to be related to the still high presence of elderly farmers, formally retired.

[2] The threshold of 40 years is traditionally chosen as the limit to access the measures in favour of generational change of the Common Agricultural Policy (CAP).

With regard to on-farm labour, the role of family work is key and predominant over wage-earning labour in Italy, and this is confirmed by the latest Census. However, it emerges that the contribution of the rest of the family (spouse, sons and daughters, others) is less relevant than in the past, concentrating especially on the farm holders. In fact, although some family labour is present in more than 98% of farms, the number of family members involved suffers a significant reduction (-50.3%), as does the total number of days worked by other members (equal to only 22.3% of the family total). This leads to a situation of near equivalence between family and non-family workers, which is reduced by looking at the standard working days, of which only about 30% come from non-family workers (whose contribution is often underdeclared). There is a sort of "professionalisation" of family farms too, so that the days of work of the other components of the family seem limited only to integrating that of the holder and non-family workers. Such a dynamic is very interesting not only for the quality of on-farm work, but also for the evolution of other possible sources of income. This topic will be developed further in the following pages.

5. FUNCTIONAL TRANSFORMATIONS

The first data from the 2020 Census allow us to analyse some strategic dynamics implemented by farms, as a reaction to the need to enhance and protect incomes from market fluctuations, both of final products and intermediate consumption. They are seen as a means of contrasting difficulties due to, on the one hand, the presence of a significant share of elderly farmers among agricultural entrepreneurs; on the other, to the technological challenges imposed by more advanced forms of management, which require both investments and the possibility to access IT technologies.

The diversification of on-farm activities – defined as the aggregation of two types of multifunctional activities: services and secondary conjunct activities – represents one of the most characterizing and significant strategies adopted by Italian farms in recent decades. This emerges not only from the periodical Census (Henke, Povellato, 2012; Fanfani, Sardone, 2017), but also from national agricultural accounts data which estimate the weight of diversification at around 20% of the total value of Italian agricultural production (Sardone, Monda, 2019; ISTAT, CREA, 2022). By 2020, the number of farms with secondary activities shows a decline (-14.5%), following the trend of general reduction, but the weight of diversified farms on the total rises from 4.7% to 5.7%[3]. Therefore, the role of these activities increases, showing how diversification has been able, at least, to contain the reduction of farm units.

There are a total of 21 multifunctional activities of diversification recorded by the Census, among which the most common are: agri-tourism, chosen by 37.8% of diversified farms (up on 2010, +27.4%); contract services, which involves a share of 14.5%, but in sharp decline (-52.2%); the production of energy from renewable sources, which shows a very rapid growth (+200% of farms involved in 10 years), where the solar source represents the most relevant (13.7%), followed by energy produced by biomass (1.8%), mostly located in the northern area; finally, the processing of farm products (first processing and processing of vegetables, milk and meat), although a decline comparable to the general agricultural trend, still ranges from around 8% to 10% of total diversified farms.

The production of renewable energies, although growing rapidly in all areas, still has a very unbalanced geographical spread, as shown by the fact that the south and islands count just 16.5% of farms equipped with solar plants, both for supplying internal demand for energy and/or for selling, while being the areas that can benefit from the greatest periods of sunshine.

In general, the territorial distribution of diversification does not follow that of farms; indeed, about three quarters of Italian farms with at least one multifunctional activity are in the northern and central area (Tab. 3). While in the north-west and north-east these activities involve 12% and 10.3% of total farms, the weight of diversification drops to just 2.4% and 3%, in the south and on the islands. The diversification processes, therefore, offer a dichotomic picture, with the central-northern area, more advanced, and the southern area less able to seize the opportunities coming from alternative production paths for strengthening and stabilizing the farm income (Aguglia *et al*., 2009).

It is to be noted that the diversification functions exceed the number of diversified farms (+32%), since several activities can be carried out simultaneously within the same unit. These different activities can be reorganized into two macro aggregates (van der Ploeg, Roep, 2003; Henke, Povellato, 2012): the "deepening" activities that keep together the closest and more interlinked functions to the proper agricultural business (such as on-farm processed and prepared food) and the "broadening" activities, for which there is a distance from the traditional agricultural activities (such as agri-tourism or other on-farm recreational activities). On the national

[3] It is worth noting that for farms run by owners under 40 years of age the share doubles (11.6%).

Tab. 3. Farms with activities of diversification - 2020.

	Farms with at least one diversified activity		% Farms with diversification	Functions		% Distribution of functions		
	Number	% Distribution	on total farms	Number	% Distribution	Deepening	Broadening	Others
North-west	13,697	*21.0*	*12.0*	18,373	*21.4*	*28.5*	*62.7*	*8.8*
North-east	19,369	*29.7*	*10.3*	26,424	*30.8*	*25.6*	*65.9*	*8.4*
Centre	15,266	*23.4*	*8.5*	19,654	*22.9*	*21.1*	*73.0*	*5.8*
South	11,022	*16.9*	*2.4*	14,112	*16.5*	*35.3*	*55.3*	*9.4*
Islands	5,772	*8.9*	*3.0*	7,222	*8.4*	*35.7*	*51.5*	*12.8*
ITALY	65,126	*100.0*	*5.7*	85,785	*100.0*	*27.7*	*63.9*	*8.5*

Source: elaborations on ISTAT data.

average, the deepening activities saw their weight dropping to 27.7%, against 38.6% in the previous decade. Conversely, the broadening activities rose to around 64%, compared to 58.1% in 2010. In this context, the southern area remains grounded on the more traditional diversification processes that have been present for a long time.

In the opposite direction to diversification, we find disactivated farms that outsource all or part of their management to external parties, who operate on behalf of the landowner/holder (Arzeni, Sotte, 2014). The total number of farms employing contract services has been declining over time, pushed down by both the progressive exit of small farms, whose size often limits the possibility of making investments in innovative machinery and technologies, and the lack of a generational change in many farms run by elderly farmers, who have used such services for postponing the (inevitable) exit from professional farming.

In 2020, farms run under contract services accounted for 27.6% of the total; a figure considerably lower than that recorded in 2000 (51%) and declining in comparison with 2010 (33.3%). The use of external services is very different among geographical areas: in the north-east over 45% of farms outsource tasks to external professionals, while in the south only 22% of farms adopt this mode of management, using considerably fewer average hours. The main part of the hours worked (58%) is provided by professionals, with higher shares in the north and centre, whereas in the south over half of the total hours are provided by other farms supplying agricultural services, within the above-mentioned diversification processes.

However, in the last decade the area fully managed by contractors increased, as a national average, from 6.2% in 2010 to 9.6% in 2020 (equal to 1.2 million hectares), with peaks close to 14% and 11% in the north-east and centre but falling to 7% in the south. Even the areas under "partial management" show an increase in UAA involved by one or more external operations (+12% on 2010). The composition of the functions (hectares) changes over the period: harvesting and first processing remain dominant, despite declining from 60% to 48%; fertilization and "other processes" gain in importance, witnessing an evolution in the needs expressed by farmers, likely related to other evolutions occurred in the meantime (such as the reinforcement of farm machinery).

A further element characterising farms and the gap between the north and south is the propensity of farms to invest in technological innovations. The Census data are a novelty of this survey and refer to investments in the period 2018-2020. As a national average 11% of farms have introduced new technological or management solutions, a figure that doubles in the northern areas (rising to around 22%) and drastically decreases in the south (around 6%). The relevance of farms with innovations rises rapidly as the size increases – expressed in Annual Working Units (AWU) –, reaching the national average of 58% for farms with more than 10 AWU, a share that rises to around 70% in the north.

Most of the recorded innovations are in the category of mechanization, well over 50% of farms in all areas, with the only exception of the islands. In general, the innovations adopted mainly involve certain types of crop operations (planting and sowing, soil tillage and irrigation, between 23% and 17%), but also the renovation of buildings (13%). Managerial innovations or those linked to sales and/or marketing involve fewer farms (7.6% and 5.5%), in both cases with a rather homogenous distribution among regions.

During the 2000s, the emphasis placed on digitalisation in agriculture has grown considerably, as an essential tool for helping farms towards more sustainable management models. The 2020 Census indicates that 15.8% of Italian farms are equipped with IT, compared to 3.8% in 2010 and about 1% in 2000, with a very significant growth that almost everywhere sees the total number of farms triple or more. Here again, territorial differences are relevant: in the north, computerisation involves a more than double share of farms (33%), the centre ranks on the national figure, while in the south the share is half the average. It follows that many of the computerised farms are in the north (55.8%) – especially in the north-east (34.8%) – and the remainder are divided between the centre (16%), south (17.3%) and islands (11%).

It is worth underlining that the importance of digitalisation is greater in larger farms, expressed in terms of AWU. In fact, in farms with over 10 AWU, computerization involves more than 78% of Italian farms (the same share falls to less than 9% for farms with less than 1 AWU). The same share rises to 90% for the northern area, while in the south less than two thirds of units in the same size category are equipped with IT. In summary, larger Italian farms, and especially northern ones, seem better equipped to take advantage of management innovation opportunities arising from IT endowments.

6. CONCLUDING REMARKS

The release of a new Census is not only an opportunity to investigate the structural evolution of an economic sector, given how fast the changes in economic systems occur, but also an occasion to discuss about what is the real object of investigation, what are the interlinks among the different components, what is relevant to the sector in order to design and enhance the more appropriate public policies.

With the publication of the preliminary data of the 2020 Census, a few relevant issues emerge, which will require a more in-depth and wider discussion among scholars, civil servants and stake holders.

First of all, the reduction in the number of small and micro units confirms an ongoing trend that reached its peak in the previous decade. Such a trend affirms the double nature of Italian farms: a relatively small number of large and professional units that are integrated into the global supply chain; a relatively large number of small farms that survive despite their sharply declining trend but have less or nothing to do with markets and are not business-oriented, being rather residences or hobby farms mostly or exclusively devoted to self-consumption. Even if micro farms are relevant in avoiding marginalisation of territories and land abandonment, it is the larger farms that contribute significantly to the multifunctional and diversified activities, and to the diffusion of innovations, in a way that becomes relevant for the sector as a whole. For micro and small farms, the physical size is often a constraint to grow and develop new activities, together with the entrepreneurial skills and the lack of a new generation taking over the farm management.

Diversification, although relevant in some cases and in some territories (for example, agri-tourism and energy production) is not booming as was expected and is still limited to a small number of farms. This is partly due to some size constraints, partly to the external socio-economic conditions, partly also to the missed generational change in agriculture, something that was largely announced and desired, but has not happened in significant numbers. There are certainly many virtuous experiences and some very successful ones, but it does not seem to be the rule, especially in the south, despite the way change in agriculture is often narrated and advocated by policy makers.

Of all the existing and traditional dichotomies within the Italian primary sector, the one still clearly represented by the new Census is the north-south one, in terms of size, functions, innovativeness, integration in the supply chain, and so on. Years of convergence policies and specific sectoral policies have not yet filled the gap, which has actually grown larger and presented new challenges (as in technology).

Finally, do we obtain the right picture of the primary sector from the Census? Does it catch all the dynamics, the many transformations it is going through and especially the necessary reshaping required by the new CAP and the main strategies of the European Union? To answer the question properly, more detailed information at the sub-regional level and innovative data integration are necessary. In conclusion, another more general question arises: what kind of Census do we really need? The answer comes from ISTAT itself, when the Italian Statistical Institute announced the end of the decennial survey and introduced the so-called Continuous Census. Such an innovation in the surveys should help to draw a clearer and more in-focus picture of such a dynamic sector, and to better represent the paths of economic, social and functional transformations that have already clearly emerged in the overall picture of Italian agriculture.

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