Georgofili Academy – Advisory Committee on Digitization in Agriculture

The prospects for digitalisation for the sustainable development of rural areas

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1. introduction

With this document, the Advisory Committee on Agricultural Digitization of the Academy of Georgofili intends to propose a conceptual framework, some elements of empirical evidence and the first reflections on the prospects for digitization in agriculture and rural areas. The contents of the document are oriented towards the objectives of European (Council of the European Union, 2020) and national (Department for European Policies, 2021) policies, which show a strong focus on digital transformation processes: a key to the sustainable modernisation of agriculture and rural areas.

1.1. *The state of rural digitization in Italy*

As you know, Italy ranks among the last positions in Europe in terms of the level of digitization. This unencouraging position is mainly related to the human component of the indicator used in the European Digitisation Report (DESI, 2020), as shown in Figure 1.

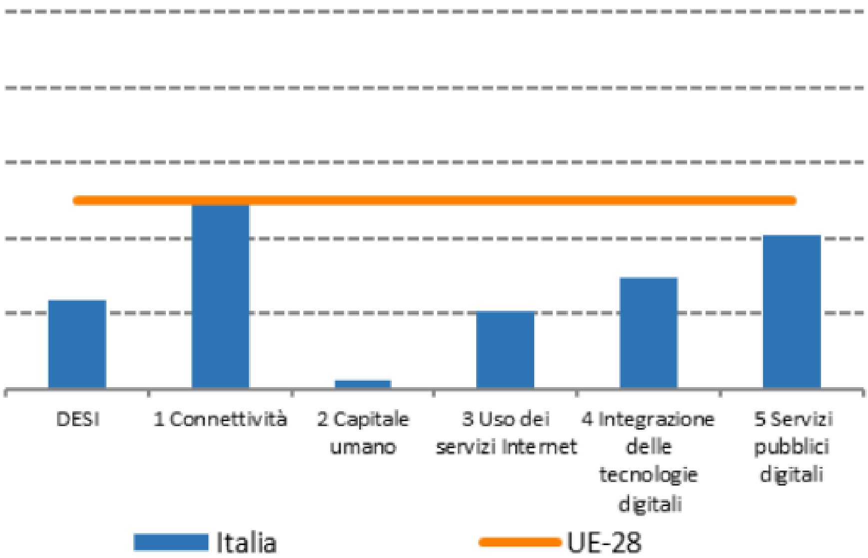
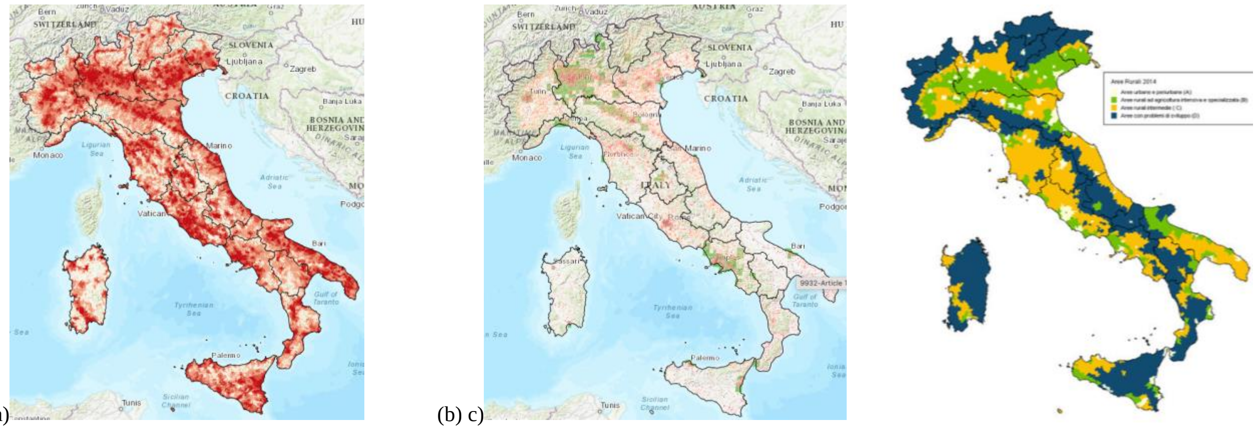


Figure 1 – Digitisation indicators for Italy (Source: DESI 2020)

Moreover, the lack of data on the state of digitization in rural areas does not allow a precise assessment of the level of the digital divide compared to urban areas in Italy. Figure 2 shows, in accordance with the Italian map of rural areas, how both 4G coverage, i.e. the mobile infrastructure that allows an adequate connection speed, and the various fixed connection technologies, cover a portion of land still limited to population centers, while large rural areas do not enjoy any coverage.



(a) (b) c)

Figure 2 – Map of 4G coverage a) and fixed b) (Source: AGcom, www. maps.agcom.it)and Rural Areas of Italy (Source: National Rural Network, www.reterurale.it)

Despite the high offer of digital solutions by companies specialized in IoT, in accordance with the last ISTAT survey in 2016, only one-fifth of Italian farms used electronic devices and digital control of management or communication and promotion was limited to 5% of the survey sample (Table 1).

Table 1 - Percentage of farms using digital technologies (Source: ISTAT SPA 2016,www.ISTAT.it)

region	**Use of electronic devices (PC, Smartphone, tablet)**	**Use of internet connections**	**Software use for management control**	**Web use for communication and promotion**
Italy	19	18	5	5

CREA's Policy Brief in preparation for the National Strategic Plan for Rural Development (National Rural Network, 2021) reports, on the basis of a sample analyzed by the Smart-agrifood Observatory of the Politecnico di Milano (www.osservatori.net), data showing the impact of the main technologies in the agricultural field. 'Smart' machines account for 39% of the technologies adopted, followed by management software (20%) and connected machinery (14%).

The above data, still very poor compared to the needs of a careful analysis of these processes, show a clear delay of the Italian system observed in a European context. Given its importance, digitalisation should become a priority for the whole system, to be pursued through an exceptional effort, putting into practice active policies to remedy market failures and at the same time direct the system on paths that direct digitalisation to sustainable development of rural areas.

We need to overcome the current digital divide that penalizes rural areas by intervening both in grey areas and especially in white areas[1], for which the economic intervention of the public body is required to create broadband or ultra-broadband connectivity, as no operator in the sector is willing to intervene. The number and time taken to authorize ultra-broadband infrastructure in rural areas must also be reduced.

1.2. Digitalisation in rural areas and agriculture: the potential

Digital technologies change a large number of aspects of daily life, from communication to mobility, from shopping to leisure, from care to entertainment. These trends, which have accelerated their evolution in the aftermath of the pandemic, are bound to profoundly change the way rural people work, live the place and consume. For rural areas, digitalisation could be the tool for filling the development gap between urban and rural areas, addressing key elements such as distance and isolation, environmental sensitivity and socio-economic disadvantages. Digital services – teleworking, telemedicine, e-commerce, e-government – could allow many people to reside in rural areas without the disadvantages of which normally rural areas suffer, and development strategies focused on digitalisation could rebalance city-country relations.

In agriculture, digitalization promises many positive changes. First of all, it allows a qualitative change in the access to information and social communication. With regard to production aspects, digitalization allows the improvement of efficiency, the reduction of inputs, the possibility of preventing biotic and abiotic adversities to crops, the strengthening of quality analysis tools, commercial disintermediation, the possibility of improving the company image and promoting farm products at limited costs, the reduction of transaction costs with administrations and with other companies. The automation of production processes frees physical work from the most tiring and risky operations.

In animal husbandry, digital applications allow real-time monitoring of animal health and welfare conditions, collect data on feeding and on milk production, allow high levels of automation, surveillance in open spaces, better epidemiological management of the presence of animals on the territory and more accurate control of aspects related to product quality and traceability of productions, as well as the planning of supply chain activities.

In open-field crops, 'smart' machines have long been available on the market, collecting a large amount of data, allowing communication between all components of a system, including software, and having functions such as assisted driving and variable-rate fertilization. Systems for autonomous driving or for operations such as weeding are already on the market, and the 'Internet of Things' will allow the integration of data collected from sensor networks with management software capable of supporting decisions in the cultivation sector. Artificial intelligence allows the recognition of plant diseases and the indexing of the quality of fruits through analysis of the acquired multispectral images and on the target investigated.

In greenhouse cultivations, where digitization has had an earlier diffusion, the control of production processes mainly concerns irrigation, fertilisation (fertigation and use of ‘speciality’ fertilizers, e.g. controlled release fertilizers), antiparasitic protection (monitoring of the health of crops) and intelligent control of environmental conditions in greenhouses through air conditioning systems (heating, cooling, shading, carbon fertilizer, etc.).

In the irrigation field, digitalization has had a significant impact on the two main irrigation management protocols applicable both to the local scale (plant, company) and to broader scales (farm, basin). The first management protocol uses model-based digital tools (forecast-based management), which solve the mass and/or energy water balance of the vegetate surfaces and return information regarding irrigation variables. The second management protocol uses digital sensory-based tools (management based on retroactive control), usually specialized in monitoring the water content of the soil. The implementation of these protocols, together with automation of irrigation systems, leads to a considerable efficiency gain in the use of the company's water and energy resources and, moreover, could potentially cancel the number of working hours to be allocated to hydraulic operations.

In rural areas, digital technologies can also help predict, prevent and mitigate the damages caused by natural and/or man-made disasters: floods, pollution, droughts and fires. Applications of predictive risk models or decision-making of the practice, together with a local (environmental sensors) and/or distributed awareness (prescription maps and/or remote images) of the risks, can currently instruct operators (including robots) in the protection or restoration of the environment of the site.

Digital technologies can also facilitate the development of tourism through the disintermediation of the tourist supply, the integration between local businesses and the provision of innovative information and services functional to an improved experience of the place. Interactive maps, augmented reality and virtual reality tools will allow to integrate tourist use by enriching the turist offer, extending periods of stay and improving accessibility to the price of services.

Table 3 shows some of the possible applications of digital technologies available in agriculture and rural areas (Bacco et al. 2020).

Table 3 – Possible applications of digital technologies in agriculture and rural areas

<table>
<tr><th>Digital technology</th><th>Example in rural areas</th><th>Example in agriculture</th><th>Impact in rural areas</th><th>Impact in agriculture</th></tr>
<tr><td rowspan="3">Social media and social networks and web-based technology</td><td colspan="2" rowspan="3">Access to online services and connection to the market</td><td colspan="2">access to information</td></tr>
<tr><td>Consumer access to shops</td><td>Consumer access to farms</td></tr>
<tr><td>Access to administration; Socialization; teleworking</td><td>Peer-to-peer learning</td></tr>
<tr><td>Local and remote detection</td><td>Advanced monitoring capabilities in areas of interest and inaccessible</td><td>Advanced monitoring capabilities applied to crops and livestock</td><td colspan="2">Detailed information in time and space; More accurate and prescribed system prediction; Calibrated and prescribed actions in space and time</td></tr>
<tr><td rowspan="2">Cloud/edge computing</td><td rowspan="2">Retroactive monitoring and management of sensitive sites in the territory</td><td rowspan="2">Expert management of time-sensitive production processes</td><td>Improved real-time support and reduced decision latency to sensitive scenarios</td><td>Automation of retroactive control production processes; Better support for sensitive scenarios in real-time thanks to the continuity of service</td></tr>
<tr><td colspan="2">Increased resilience</td></tr>
<tr><td rowspan="2">Data analysis</td><td colspan="2">Information from data collected to support decision-making</td><td colspan="2" rowspan="2">Increased productivity; Loss reduction and optimization of inputs; Improvement of monitoring and intervention services and activities</td></tr>
<tr><td>Multifunctional modelling of the landscape</td><td>Integrated modelling of agricultural systems</td></tr>
<tr><td>Distributed ledger (in some cases also referred to as blockchain)</td><td colspan="2">Traceability and smart contracts; Insurance</td><td colspan="2">Reduction of transaction costs; Confidence reaction in the value chain</td></tr>
<tr><td>Augmented reality / virtual reality (AR/VR)</td><td colspan="2">Instruments of education, training and decision support; The structure of the territory; Entertainment systems</td><td>Information integration and tourist attraction</td><td>Integration of information into the decision-making process; Better knowledge of the business ecosystem and business risks</td></tr>
<tr><td>CAD and 3D Printing</td><td colspan="2">Design and printing of customized parts and small equipment</td><td>Industrial decentralization</td><td>Decentralization of technology;</td></tr>
<tr><td rowspan="2">artificial intelligence</td><td colspan="2">Computational systems for bigdata; Support system for decisions; Simulation of development scenarios</td><td rowspan="2">Communication with the public administration; Surveillance and alarm systems with reference to sensitive sites</td><td rowspan="2">Efficiency of company resources; Reduction in production costs</td></tr>
<tr><td>Intelligent planning systems</td><td>Systems for the recognition of critical conditions of the crop</td></tr>
</table>

Autonomous systems and robotics	Transport systems	Systems for the collection of data and the autonomous execution of agricultural practices; Strengthening the physical capacities of operators	Waste management; Local mobility	Better knowledge of agroecosystem and farmed animals; Riction of labour costs; The establishment of unpleasant/dangerous jobs,and the possibility of managing processes in the absence of labour

1.3. Digitalisation in rural areas and agriculture: barriers

Faced with the potential of digital technologies, there are clear barriers to digitalisation. These barriers are of three types:

- factors that restrict access to them;
- the responsiveness of technologies to the real needs of users;
- limited communication between technologies.

The factors limiting users' access to digital technologies can be physical (connectivity), cognitive (the skills needed to access them) and economical (cost). In agriculture and rural areas, the three dimensions of access contribute to maintaining, and in some cases, increasing the digital divide. Moreover, in view of the fact that technological innovation processes have exponential growth over time (Kurzweil, 2012), it should be considered that the persistence of these factors of inequality will contribute more and more to the increase in the digital divide.

As far as technology design is concerned, a distinction should be made between technologies that are consistently fit to current practices and technologies requiring a change in these practices. In the first case, where, for example, innovation is incorporated into an 'improved' product or service compared to the one normally used, as in the case of satellite-guided machines, the benefits are clear as is the relationship between benefits and costs. The use of digitalization is sought when the added value is evident, like in the case of the mitigation of risks due to pathologies in the wine supply chain, where control units and DSS are now a diffused endowment. However, systems are often complicated and farmers do not fully exploit their possibilities. For example, so-called 'climate computers' that are now at greenhouses such as car navigators (i.e. they are part of the basic equipment and are not optional) are often used in basic functions, i.e. as a simple control unit such as those we use at home to regulate the ignition of the heating system in 24 h.

In the second case, however, the benefits that digital technologies can generate depend on a rethink of the farm organization, expansion of skills, or a change in the business models. In other words, the adoption of digital technologies does not imply only the purchase of some tools but comes to the end of a real cultural revolution in the way of running a company. It, therefore, seems appropriate to analyse the adequacy of innovation to the host context, which in the case of agricultural eco-issues cannot be reduced to a simple economic comparison, but must include adaptation to demand for intangible added value (environmental and social sustainability, saving and improvement of water use, air and soil, safety and collective well-being).

The third limiting factor is the need to coordinate the technologies and skills necessary for their use. Added to this is the fact that among the many innovation proposals, most have a limited level of readiness and are not supported by ancillary but essential services and skills. Many companies complain about dependence on the supplier: it is not possible to turn to other suppliers to solve problems even – apparently - trivial. Some control irrigation and fertigation systems are presented as tailor-made solutions and developed by small (sometimes start-up) companies. They are very similar devices at least in theory but in practice, they are not equal; after a few years, you will no longer find spare parts, firmware updates for interfacing or even there is no longer the company that installed the device.

A major problem in field operations and other production structures is the non-standardisation and interconnectivity of systems and applications because proprietary software is used. The problem must be tackled based on a development of innovation that is territorial and involving the whole ecosystem linked to agriculture: manufacturers who are suppliers of products, service providers, infrastructures, consultants, the education training system for human capital, governance.

1.4. Digitalisation in rural areas and agriculture: the risks

In addition to the potential that the application of digital technologies offers, it is important to analyze its limits and possible risks, which can be distinguished into risks that may have technical, economic, social, and legal implications. Among the problematic profiles that emerge most often are those concerning:

- the vulnerability of data and its systems;
- transparency and/or obscurity of technique, methods and results;
- the maturity or otherwise of the instruments available on the market;
- validation of techniques and results;
- the ‘openness’ of technologies;
- "maternity" and data ownership;
- user autonomy in systems management;
- the loss and/or development of knowledge, the decentralization and/or centralisation of knowledge, the social acceptability of techniques.

It should be remembered that many of the digital solutions have been patented, engineered, and then applied in sectors quite different from the primary sector. Therefore, the rural world and agriculture should be able to harmonise the huge flow of digital innovative solutions that manufacturers (including military and aerospace industries) very often propose to agriculture after they have become functionally obsolete and have lost intellectual property rights. The introduction of technologies with a high degree of innovation in rural areas very often needs a long period of adaptation, as is the case in other sectors such as those for which the innovative solution has been studied. The impossibility of observing a clear return in the term of progress is linked not only to the physical complexity of the rural system but also to the multifunctionality of the rural system, which includes very diverse contexts that are not very suitable for the introduction of rigid solutions.

2. Digitalisation as a systemic change: land conditions for a sustainable transition

The effects of adopting digital technologies depend not only on how they are designed but also on how they fit into social, economic, and ecological systems. The potential of digital technologies lies above all in the possibility of completely reorganizing processes, and reorganization normally generates winners and losers. It is, therefore, necessary to pay close attention to the way in which digital transformation is encouraged, and an effort is needed to anticipate its systemic effects. If the best-known example is that of job losses linked to automation – which becomes a problem when labour is plentiful, and alternatives are scarce – the sustainability objectives on which European policies are committed to requiring attention to be paid to the relationship between efficiency and pressure on resources.

An example of possible tension between the two objectives is the increase in water consumption in the territories where a particular digital technique has spread that has led to a gain in water efficiency of individual companies (Grafton et al., 2018). In the absence of governance systems capable of limiting water consumption at the basin level, massive support for the adoption of technologies aimed at improving efficiency could lead to an increase and/or increase (through the introduction of water-intensive crops) the irrigated area, generating water consumption equal to, if not higher than, that of the status quo ante. Similarly, it has been observed that in some contexts the applied dose of fertilizers, sized on the basis of only the information given to the map of production per plant, has increased as farmers increased the administration of fertilizers in the less productive areas of the field (Basso & Antle 2020). These examples make clear the need to plan incentives for innovation within a systemic approach that considers the effects on different levels of spatial scale.

The consideration of opportunities and risks leads to the need to analyze the conditions that allow technologies to generate social value and the consequent preparation of intervention tools able to guarantee these conditions.

2.1. Digitalization at the service of the needs of the territory

The example of the role of digital technologies in water management shows that technology incentive policies should be consistent with the more general objectives of territorial development, in the awareness that a higher rate of adoption of digital technologies does not automatically contribute to an improvement in territorial performance. In this regard, it should be expected that digitization strategies will be based on planning that allows all interested actors to express their voice and that sees passages of close interaction between research, users, and policymakers.

2.2. Active digital inclusion policies

The adoption of certain digital technologies can permanently widen the gap between companies and create dangerous economic concentrations. Faced with this risk, it is not enough to rely on the rules of the market: policies must be put in place that can identify vulnerabilities and intervene to promote the inclusion of even those unique agricultural realities on certain production segments (for example local typicality) and /or subject to the multifunctionality of the territory of competence.

2.3. Directionality of innovation

Digital technologies fully embody those factors of 'creative destruction' that Schumpeter talked about (Knell, 2021). However, to prevent creative destruction from becoming a 'destructive creation', the development of technologies must be geared towards sustainable paths. Digital technologies are flexible enough to adapt to different business models and purposes. The most effective solutions can be achieved through user involvement, as in the case of the multi-actor operational groups promoted by rural development plans. The synergy between the skills of researchers, companies for the supply of technologies and agronomic, marketing and environmental respect needs can guide development towards sustainable paths.

2.4. The creation of digital ecosystems

The starting point of this analysis could be the development of a conceptual framework that outlines the characteristics of a 'digital ecosystem' in which actors for agricultural/rural development are having fun with each other, exchanging information to expand their knowledge and skills, thus trying to arrive at the best operational solution to be implanted.

This digital ecosystem could be schematic as a pyramid structure at the top of which lies the *basic skill level*, which constitutes the interface with the farm. This level of action, embodied in preferably human decision-makers, is instructed through the use of the tools and know-how that we find cascading distributed in the pyramid: complex information user interfaces suitable for user characteristics (e.g. smartphones are more suitable for country operators than personal computers), digital services, platforms for access to services, advanced and specialized skills for the provision of services, knowledge and technology integrators, application systems appropriate to the needs of the context, integrated databases, connectivity infrastructures.

3. Proposals for digitalisation for sustainable development

To put the principles considered above into practice, some operational proposals are put forward here.

Rural proofing: to tailor all strategies for digitization to the development needs of rural territories. This can be achieved through the commitment to the rural characterization of digitization data, the identification of ad hoc performance indicators and appropriate monitoring mechanisms.

Development of human capital: Coordination between secondary, higher, and vocational training for the development of basic and advanced knowledge. Revision of university curricula for the training of technicians with advanced skills.

Governance: Strategic coordination of digitization interventions. Participation of territories and users to the definition of strategies, focus on specific needs and problems, zonation of rural territories according to *the logic of land suitability/capability*, impact analysis.

Support for innovation based on users' needs: Strengthening interactive innovation models, such as Operational Groups and Living Labs, and transdisciplinary research.

Development of digital ecosystems: Identification and training of subjects capable of acting as integrators of knowledge and technologies; encourage data sharing and communication between application systems; strengthening support for innovation operational groups and other participatory forms of knowledge dissemination; support for the creation of networks and consortia for the sharing of data and digital technologies.

Promotion of brokerage systems: Support for the digital transformation of technical assistance systems in agriculture; support for 'digital innovation intermediaries' between research and business; identification of the minimum skills needed by 'digital innovation intermediaries' to support the digital transition. Support to bodies - such as rural digital innovation hubs - able to monitor the state of the art of the technological offer, evaluate the best performing digital solutions and relate them to the emerging needs of rural territories.

Conditionality in investment aid: priority to companies developing data management projects, for example using management software and integration with intelligent and sensory machines. Audit and ecolabelling of the company on the sustainable use of digital technology.

Open source: strong priority to open solutions, able to allow the dissemination and integration of IT tools.

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