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Review

Plant Pathology and Information Technology: Opportunity for Management of Disease Outbreak and Applications in Regulation Frameworks

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Abstract: In many European rural areas, agriculture is not only an economic activity, but it is strictly linked to environmental and social characteristics of the area. Thus, sometimes, a pathogen can become a social threat, as in the case of *Xylella fastidiosa* and olive trees (*Olea europaea* L.) in Salento. Fast and systemic response to threats represents the key to success in stopping pest invasions, and proves a great help in managing lots of data in a short time or coordinating large-scale monitoring coming from applying Information Technology tools. Regarding the field of applications, the advantages provided by new technologies are countless. However, is it the same in agriculture? Electronic identification tools can be applied for plant health management and certification. Treatments, agrochemical management or impact assessment may also be supported by dematerialization of data. Information Technology solution for urban forestry management or traceability of commodities belonging to "Food from Somewhere" regimes were analyzed and compared to protection from pests of a unique tree heritage such as olive trees in Salento.

Keywords: RFID; plant pathogen; health monitoring

1. Introduction

The widespread area of pests represents a difficult challenge for future agriculture. An enormous amount of plant materials (whole plants, propagative materials, fruits and vegetables, woods) are commercialized on the global market and the introduction of alien species is becoming an everyday threat. The European Union (EU) is a difficult territory to defend from "quarantine pests", due to multiple points of ingress of materials and frequent exchanges with worldwide producers. Tons of harbors, airports and customs need to be monitored constantly and countless health checks need to be carried out in order to protect the mainland. Moreover, in many European rural areas, agriculture is not only an economic activity, but it is strictly linked to environmental and social characteristics of the area. Thus, sometimes, a pathogen can become a social threat. This is the case for *Xylella fastidiosa* and olive trees in Salento (Apulia, South Italy).

The origin of the product is crucial for European olive oil and related foods, and the Salento peninsula is a paradigmatic contest of local production within a global market. Within sets of cultural dynamics, the mass market focuses on emphasizing cheapness, convenience and attractive transformations of food products with anonymous origins, but regional identities in agriculture such as Salento olive oil emerge. Indeed, the consumers of Apulia olive oil and related products are attracted by foods with opposite features, with significant social and ecological implications, and prefer retailers able to demonstrate the food origin and high quality, supporting regions such as the Apulia and Salento peninsula. In this context, a devastating pest such as *X. fastidiosa* that infects thousands of centenary trees should be considered as a natural disaster. Apart from pathogen-specific issues that can drastically increase the difficulty in quarantine pest management and that may be related to *X. fastidiosa* as well (i.e., occurrence in new hosts, uncertain in pathogenicity, unknown vectors, etc.), a fast and systemic response to the threat represents the key to success in stopping pest invasion. Typically, a great help in managing a large amount of data in a short amount of time or coordinating large-scale monitoring or activities, comes from the use of Information Technology tools. Regardless of the field of application, the advantages provided by new technologies are countless. However is it the same in agriculture? While phytosanitary certifications are mandatory for many plants and the need for risk management may promote Information Technology systems, at least in high cost cultivation systems, the lack of specific economic analyses may discourage farmers and investors [1]. Thus, Information Technology beyond use of personal computers for basic operations is still a chimera in most agricultural contests. Difficulty in permeation of Information Technology needs to be specifically detailed with regards to a single tool, but the radiofrequency identification (RFID) systems may represent one of the paradigmatic tools of Information Technology and may serve as case of study in agriculture.

Several studies indicate that the slow adoption of RFID systems in agriculture is due to the high investment and operational costs, especially for small or middle sized farms. This hurdle may be particularly difficult to overcome on traditional farms, where investments for crop management are generally low. It is difficult to propose not well-defined investments to farmers whose marginal profits are low and unstable over the years. The RFID system may require additional costs such as electronic tags for each tree (€0.20–1.50), implanting (€0.40–0.80) and the licensing fees for the software, which, again, is not typically included in economic plans of farmers. Thus, a change in vision is in order to implement these new and beneficial systems. Farm management information systems that can lead agriculture toward the future were defined [2], but some pre-requisites need to be established first, such as building the Information Technology infrastructures, at least, at a regional level, and analyzing the economic sustainability of this trial. It is not an easy task even in the industrial sector (commonly characterized by more controlled input/output processes) because benefits are difficult to identify and economically appraise even considering quantitative-related applications such as logistics [3]. The use of RFID can improve the management of stocks and reduce the margin of error involved. Similarly, the material flows are more efficiently generated beyond resource savings [4]. In agriculture, processes are less standardized, and it is difficult to model the activities in order to improve logistics. Some specific processes may be easy to monitor and economic sustainability should be assessed, such as work-related processes. For example, RFID could reduce harvest costs for fruit producers [5,6]. Ampatzidis et al. [7] developed a labor monitoring system that can track and record individual picker's efficiency during manual harvesting of specialty crops, utilizing RFID wristbands and tagged bins. The system is able to record the exact amount of fruit harvested by workers and measure worker efficiency in order to determine proper wages and promote fair work. Further positive prospects may be related to increased transparency and employee motivation, which are the main challenges in workload quantification and may play significant roles in agricultural applications.

2. Information Technology as Opportunity for Plant Health and Farm Management

2.1. Plant Protection

In medium or bigger scale farming or in high value production (i.e., nursery), the management of plant protection activities is a key-factor in disease control. A rational use of farm resources (workers, machinery, agrochemical) could have a significant impact in reducing costs. Similarly, large scale treatments, as well as multiple treatments or high-differentiated ones due to simultaneous cultivations of different plants, represent a challenge to farm management, in order to avoid delayed or wrong treatments. In these complex farming systems, Information Technology tools may support the management of multiple inputs and outputs. Thus electronic identification tools such as RFID can be applied for plant health management, in particular for plant health inspections and certifications [8], due to the link of useful data (i.e., plant identity, certification, etc.) to electronic tags inserted within the plant, avoiding misunderstandings or falsifications. Moreover, further data may be associated with this "electronic passport", such as treatments (voluntary or mandatory ones), supporting agrochemical management or impact assessment. It is the case of thermotherapy in grapevine nursery, an increasing practice in Europe to protect plants against phytoplasmas and relative vectors widespread. RFID tags were found to be useful for data storage regarding this specific treatment [9], in which plants are treated with hot water before selling throughout a voluntary-based protocol. In some important areas of North Italy, this practice is de-facto mandatory, due to the high incidence of phytoplasma, and region-based commission are appointed for checking treatments. Treatments may cause other beneficial effects such as killing the eggs of phytoplasma vectors. Thus, identification systems may increase trust in consumers toward onerous and voluntary treatments. Hot water treatments (HWT) were not relative to phytoplasma control, but they were recently proposed by European Food Safety Authority (EFSA) to protect grapevine from *X. fastidiosa* following precaution criteria [10]. The phytosanitary standard detailing the HWT conditions of 50 °C for 45 min against phytoplasma Flavescence dorée (FD) is provided by European Plant Protection Organization [11]. This same temperature/time regime is considered effective against *X. fastidiosa*, the causal agent of Pierce's decline, in both the French and Italian guidelines. Also outside the EU, similar HWTs are in use, such as in Australia, where an HWT of 50 °C for 30 min is mandatory for imported dormant grapevine cuttings, against both FD and Pierce's disease [12].

Digital management of phytosanitary treatments may also involve machinery in order to track conventional treatments. Peets et al. [13] suggests a pesticide label RFID, using existing national registration numbers as main product identifiers, store a minimum set of essential information on the label to make it usable independently, and reference existing national pesticide databases. Moreover, author's suggestions were not limited to tag design but the application of automatic recording systems so that it can provide an auditable trail of actions for the workers. Following this approach, the tracking of responsibility toward pesticides can be established because the system can prove that workers have followed the treatment plan from the agronomist or other qualified persons. Peets et al. [13] indicate that when using verified electronic labels of agrochemicals, some of the burden of responsibility can be removed from the operator and authenticated as they originate at the spray treatment stage. Authors underline the option to avoid further editing of agrochemical planning after compiling. Moreover, the implementation of pesticide databases in combination with digital signature technology provide a good opportunity to verify labels. The proposed systems were tested by mounting the RFID hardware, user interface, and controller on a sprayer while the operator carried out the experimental tasks that involved loading a set of test products, packed in containers equipped RFID labels compatibles with international standards i.e., International Organization for Standardization (ISO) 15693. Product identification cycles with RFID were carried out without failure, providing a true automatic record of the product containers used in the experiment.

RFID tags can also be used for monitoring agronomic pest control practices, such as soil solarization. Solarization consists of trapping solar radiation with plastic films laid over the soil, allowing the soil temperature to increase up to 50 °C near the surface [14,15], even if a higher temperature may be useful to control some pests such as viruses [16]. Temperature represents a key-factor in soil solarization success; the application of easy-to-use and cheap monitoring systems can help farmers in the decision making process. Long term treatments such as solarization may be prematurely stopped due to bad evaluation of environmental factors or being excessively extended. Thus, loss of effectiveness or increasing costs may occur. Thus, RFID sensor characteristics and tag distribution in soil were evaluated in order to overcome obstacles to tag readability due to soil interference in signal transmission. Compared to that in the air, the underground communication exhibits significant challenges for the development of wireless underground sensor networking [17].

Stuntebeck et al. [18] indicates that just 6 cm of wet soil causes a significant attenuation in signals. Appropriate sensor choice such as ultra-high frequency (UHF) tags (characterized by longer reading distance compared to low frequency ones) and correct orientation of the tags along the soil profile may lead to avoiding a soil layer thicker than 2.4 cm above the antenna [19]. Thus, real-time monitoring of soil temperature may be carried out, supporting farmers in effective evaluation of the treatment.

2.2. Digital Management of Data Derived from Plant Health Monitoring Programs

Thrane [20] stated that, with regards to pest management, there is increasing interest in implementation of Quality Assurance systems (QA-systems) in plant health diagnostic laboratories. In this approach, documentation (intended as steps in the diagnostic work, evaluation of results from proficiency testing and ring tests, audit reports, records of staff training, records of equipment maintenance, etc.) plays an essential role. Thus, sample labeling by barcodes ensures impartiality during testing and easy handling of samples. Moreover, a functional sample traceability can be established, limiting errors in final diagnostic results.

Dematerialization of data relative to health checks could lead to developing collaborative Web 2.0-based workspaces, promoting exchange information between users and laboratories [21]. Plant health management and environmental monitoring can be efficiently supported by RFID tags or other identification devices that are able to generate ecological feedback or improve automated systems. Generally, the dematerialization of data represents a common target of plant or agrochemical tagging; a useful feature that may be derived by data interchange and communications between labs during long-term trials or health monitoring at large-scale levels. Electronic tagging may reduce the loss in plant identification during repeated health checks of trees throughout the years; particularly due to damage of traditional labels that occur with accessions in the orchards. Electronic labeling reduced the workload for verifying the identity of plants during sampling. The quantity of documents sent or requested by researchers or plant health agents may be decreased if users recorded the data using workspaces. This approach may be particularly useful during pathogen outbreaks. Generally, retrieving information from samples or documents is more efficient and less time consuming when using RFID-labelling with workspace support. Web browser interfaces can provide most of the functionality achievable with a research-user interface [22], moving the implementation of lab systems from isolated data stations toward more effective and integrated laboratory automation [23].

While external labeling of items, such as containers or vials, is an easy task and issues related to post-labeling readings were limited, some uncertainties may be derived to direct association of microchips to samples and following storage in stressing physical or chemical conditions. Some RFID tags can be safely inserted within soil or water-based samples as well as within a medium of culturing, if covered by less than 5 cm of matrices. Thus, bag or vial labeling should be easily carried out just inserting tags. Devices are quite resistant considering thermal or chemical conditions in which samples are generally stocked, maintaining readability as reported by several authors during various agricultural applications [5,24,25]. As reported by Peets et al. [13], the key issue remains of what information to write on the tag or to be associated with the barcode in order to have a safe and effective system for identification of agrochemicals or samples with minimal cost.

2.3. Electronic Identification and Plant Disease Outbreak: Speculation about Olive Quick Decline Syndrome

The health status of an olive tree may be defined by olive certification schemes. In Italy, detailed protocols for virus infection assessments are applied with regard to categories of plant material. For primary source material, the absence of eight viruses among the 14 major viruses isolated from olive trees (*Olea europaea* L.) is mandatory. Considering the increasing number of viruses that have been isolated from olive trees [26], Luvisi et al. [27] describes a case of study on an RFID-based traceability system for virus-tested, certified, grafted olive trees. The aim is to support nursery management of plants and to provide a long-life identification tool for supporting health monitoring of transplanted trees. An easy-to-handle and inexpensive microchip was assembled using a UHF tag. Analysis of plant propagating materials for the production of certified olive trees leads to identifying four plant categories that are derived from candidate material: primary source, pre-basic material, basic material and certified plants. While grafted plants can be suitable for inserting the tag within trunk, external RFID systems such as wristbands can be implemented. Electronic UHF tags were associated with a digital identity card containing olive tree data. Analysis of the health monitoring procedures led to the definition of assays to be certified by UHF tag, while analysis of the information to be managed was performed by stakeholder identification, interviews, collecting data relative to regulations, farm rules and existing software for managing RFID-tagged plants. Data flow within the plant production chain was schematized and a unified modeling language (UML) diagram of the information system used for tag association was developed. Histological observations of olive tree tissues interested in tag implanting were corroborated by image analysis in order to avoid unacceptable damage or stress condition to plants due to tagging. Tests revealed that there was a reduction in functional vascular tissue around the microchip when the tag was inserted in 10- to 15-mm-diameter plants, compared with the olive trees that did not undergo the insertion procedure. The tagging procedures appear to be suitable in two- and four-year-old olive trees without negatively impacting the mortality or vegetative development of plants.

This approach, tested for virus monitoring in olive trees, was not transferred to marketable plants or used for concrete health monitoring programs. Probably due to the uncertainty about costs and limited interests in diseases affecting a plant species that were traditionally considered as tolerant to many biotic or abiotic stresses. Unfortunately, *X. fastidiosa* was recently reported under field conditions in Italy (Apulia region), associated with severe cases of an "olive quick decline syndrome" (OQDS) [28]. In October 2013, when systematic investigations for determining its aetiology were initiated, the affected acreage was estimated at ca. 8000 ha. In autumn 2015, many of the olive groves in an area of ca. 2300 km^2 were diseased. A year before that, the infected surface area given over strictly to olive (i.e., the totality of symptomatic groves taken together) was estimated to be ca. 10,000 ha, comprising about 1,000,000 trees [29]. Analogy in importance of centenary olive trees for environmental purposes and citizens may be found in urban forestry, in which the high value of a tree is not related to production but to people's lifestyle. A sort of communication can be established between people that benefit physiologically and psychologically from trees.

This communication is not based on a mere romantic contact between urban residents and their green neighbors but on a concrete approach to multifunctional green space management that can lead to a better organized plant protection and maintenance [30]. This approach can be easily transferred to centenary olive trees in Apulia, where their management may represent a key-factor for plant survival. Indeed, tree inventories are an essential tool to protect and enhance rural forests which help ensure healthy forests for generations to come [31]. They are useful to help maintain diversity in the tree population, assess the health of the urban forest, and communicate with property owners. Considering that inventories need to be updated regularly in order to help schedule tree health checks and manage invasive insects, maintenance works, and determine planting sites, RFID tags can be used as a safe system for tree identifications.

Moreover, the olive tree distribution in Apulia is not only related to countryside orchards; thus, further analogy can be found with urban forestry. Olive trees are frequently found along streets and other rights-of-way of Apulia as well as parks and residential yards, similarly to trees included in urban forestry definition [32]. In this case, geospatial tools such as GPS and the Geographical Information System (GIS) can provide timely and extensive spatial data to arrive at plant attributes that can be adapted for applications including data fusion, virtual reality, three-dimensional visualization, internet delivery, and modeling [33,34]. Thus, the opportunities in disease outbreak management are countless. The combination of GPS and computer-aided design (CAD) make it possible to easily record geographic profiles of fields and use them in CAD software to draw structural elements, virtualizing parks. Geostatistical approach can also involve application of environmental assessment such as the air pollution, biomonitoring networks, and related data modeling [35], particularly useful in prediction models for widespread disease. Moreover, combining decision support tools with recent computer visualization techniques may be a workable option, especially for monitoring quarantine pests such as *X. fastidiosa*. Falcão et al. [36] developed visualization tools that are able to produce dynamic simulations of prospective forested landscapes in which its connection to forest resources spatial decision support system is defined. Effectiveness in remotely monitoring trees may be derived by this approach thanks to management of data associated with the plants (e.g., identity, sanitary status, certification, and cultural practices, particularly using technical and plant health files). Further positive features may be related to durable, safe and detailed orchard or forest information maps. Moreover, mobile devices like netbooks, tablet-PCs or smartphones could represent optimal instruments for consulting and updating the virtual orchard from the field, while time-consuming operations can be carried out using desktop devices. Cunha et al. [37] described this strategy for contextualized vineyard management, where tags were placed in the field and decoded by mobile devices such as mobile phones or Personal Device Assistants (PDA), and no conceptual or technical limits should involve others plants such as olive trees.

3. Information Technology Applications within the Regulation Framework and Their Environmental Impact

3.1. Information Technology Could Support Application of Pesticide Regulations

Government agencies are responsible for regulating pesticides; they approve pesticides for use, set standards for the amount of pesticide residue that is allowed for various crops and establish the conditions in which the pesticides are safe (for human, animals and plants) to use. In the United States, the Environmental Protection Agency (USEPA) with the EFSA [38], the United States Department of Agriculture (USDA) and the Food and Drug Administration (FDA) establish the standards and regulations, and conduct human health risk assessments. As reported by Villaverde et al. [38], the European Union (EU) has enacted, through the Pesticide Regulation 1107/2009, the sustainable use of pesticides. The goal of the EU thematic strategy and of the Directive 2009/128/EC, which establish a framework for Community action to achieve the sustainable use of pesticides, is to achieve more effective treatments, which, in turn, allows for lower pesticide doses. With this background, the development of alternative pest control techniques may be a key to the implementation of Integrated Pest Management (IPM) practices in the EU. IPM is a strategy (combination of techniques) that can solve pest problems, reducing chemical pesticides and minimizing the risks to people and the environment. It is based on taking preventing measures, monitoring the crop and pests, assessing pest damage, using a combination of biological, cultural, mechanical and chemical management tools, and assessing the effect of pest management.

Standardized Information Technology solutions for management of treatments such as those suggested by Peets et al. [13] could support the harmonization of the risk assessment among EU Member States, an important goal of Pesticide Regulation 1107/2009 [39]. In fact, each Member State in a given territory is responsible for participating in risk management surrounding the use of pesticides, and harmonization will prevent a situation in which the risk-reduction efforts of one Member State are contrary to a divergent approach taken by a neighboring Member State [39]. Thus, the availability of harmonized methods for digital management of pesticides should help the application of these regulations, improving exchanges among EU members.

Dematerialization of data provided by Information Technology and availability of harmonized databases of pesticides may also support decision making processes of Member States. According to regulations, each EU member shall describe in their National Action Plans how they will ensure a rational use of plant protection products integrated with other practices and control measures (European Directive 2009/128/EC) [39]. To achieve this goal, the management of a large amount of data in a short amount of time or coordinating large-scale survey of control measures can be carried out using Information Technology tools. Information sharing approaches and collaboration between users via the web have been introduced through management system such as the Agricultural

Information Management System of Food and Agriculture Organization of the United Nations (FAO) (http://aims.fao.org/), suggesting as application of Web 2.0 tools is unavoidable in order to manage complex systems—for example, targets of 2009/128EC cover different areas of concern such as worker protection, protection of the environment, residues, use of specific techniques or use in specific crops: data in which storage in digital databases can be improved thanks to application of electronic identification tools to plants, pesticide containers, machineries, etc.

Further beneficial effects of Information Technology applications within the framework of Directive 2009/128/EC are linked to general objectives of the thematic strategy. Among them, contrast to the inappropriate use of compounds may be supported by the use of data mining tools working in digital national pesticide databases. Moreover, the application of digital farm systems push toward modernizing machineries and instruments, such as spraying equipment able to "read and store" treatments data, with positive effects on environmental impact of treatments [40]. Miller [41] describes the future role of electronics in limiting pesticide use by better matching applications to target requirements. Changes in pesticide applications can relate to the dose or volume applied, but may also concern the way in which a treatment is delivered in terms of parameters such as spray trajectory angle and droplet size distribution [41]. For example, for many weed species, there is evidence of patchy distributions in field situations, and weed patch detection is key to the performance of such patch spraying systems. Thus, Miller affirms that, as in widely spaced rowcrops such as vegetables (or olive tree orchards), for example, there is considerable scope for developing fully automated detection systems based on image analysis, and for the development of accurate guidance systems that apply pesticides only to the crop row [41]. Finally, the goal of the establishment of a system of information exchange at the EU Community level would be easier to achieve thanks to a national pesticide databases able to exchange data among EU members.

3.2. Environmental Impact of Information Technology Applications in Agriculture

Deng and Williams [42] state that the energy used to fabricate microprocessors or for their use, including the supply chain for the materials used to produce them, has decreased dramatically in the last decades, but unresolved concerns derive from secondary dematerialization, exposure to hazardous materials, and difficulties to recycle tags.

Dematerialization of data is one of the main features that drive the change toward digitalization of management activities. Dematerialization is defined as the technological process that can lead to significant reduction in the amount of materials that are involved in the production process [43]. Moreover, energy is an essential part of dematerialization and its reduction represents a further benefit. In this context, high value and utility tools such as microchips may represent a paradigm in the dematerialization process, due to the very low production weight and energy consumption. In particular, electronic tags tested in olive trees, or generally associated with plants are small and passive, thus a low mass of materials are involved and energy consumption is almost nullified. Further considerations are needed in order to evaluate the effective dematerialization impact of items such as a microchip [44]. To produce a very lightweight chip of just 2 g, 1600 g of fossil fuel is needed. A further 72 g of chemical inputs were estimated as part of the production process. Thus, the mass of secondary materials exceeded more than 600 times the mass of the final product, leading to a "secondary materialization" that cannot be ignored in order to define Information Technology sustainability, due to the economic and environmental impact of this sort of side effect. Exposure to hazardous materials cannot also be overlooked. Ancillary chemicals are consistently involved in high-tech processing such as the production of semiconductors, as well as brominated flame retardants being added to casings. The circuit boards in electronic ostensibly (to improve fire safety), increase exposure to workers of chemicals. Similar conclusions may be derived from energy evaluation. The production of a desktop computer and related monitor leads to more than 6000 MJ of energy consumption [45]. It is very difficult to estimate how improvements in the electronics industry have been changing the manufacturing process in recent years, but the energy and material impact of devices for electronic identification cannot be neglected. Even if manufacturing may be less energy intensive, the increase in production of digital devices is outstanding, probably overwhelming the manufacturing improvements. Moreover, the increasing level of computational capacity of mass-market devices and amount of peripheral devices are drastically increasing the energy need for workload. A large portion of organizations' electricity costs and concomitant greenhouse gas emissions is due to Information Technology energy use (e.g., office buildings, 26%; data centers, 95%) [46]. We can suppose that limited variability and quantity in input/output involved in plant management, compared to industrial processes, as well as the relatively low complexity of processes to track energy consumption, should be a less critical issue compared to other sectors.

If manufacturing of hardware for Information Technology applications rises, some concerns about environmental sustainability of dematerialization of data derived from waste materials and recycling. Conceptually, an effective dematerialization relay in the well-established and wide Internet of Things, in which plants, vehicles, inputs, outputs, and workers are connected. Computer recycling is a difficult task and may lead to potential exposure following the disposal of electronic devices [47]. Similarly to manufacturing, hazards may derive from metals, brominated flame retardants, and compounds generated or used during recycling. Moreover, the increasing amount of waste computers was partially due to the rapid improvements in performance, leading to updated digital devices every few years [48]. Finally, the use of different standards, such as Electronic Product Code (EPC) global and ISO for the RFID sector, do not promote practices such as the reselling of hardware, which can extend the lifespan of computers [48].

Computer recycling is carried out in many countries and is included in legal disposal of recycling, due to its importance and convenience. Conversely, other electronic devices such as electronic tags may be doomed to be scattered due to their low dimension, polluting the areas in which they are deployed. Moreover, their very low cost did not promote recovery actions that may result in being more expensive than the tag itself. The impacts of electronic tags on municipal solid waste recycling and disposal have been assessed, indicating that a specific recycling process to recover materials used for RFID labeling would not be feasible [49]. Anyway, with an increasing number of RFID labels in circulation, the question concerning the end-of-life disposal of RFID labels becomes important, in particular if they are used in green areas. Unfortunately, there is little information about the end-of-life issues related to RFID tags.

Debate in the European Commission [50] did not solve the problems, definitely due to the non-biodegradable properties of tags and presence of metallic components, plastic, or other petrochemical based materials. Moreover, as tags become smaller, the different parts of tags are difficult to separate and the recycling procedure is difficult. Plant health monitoring should represent a difficult challenge for recycling practices. While devices used for retrieving and storing data did not differ from widely used Information Technology tools, concerns may arise from tagging systems. As reported by Luvisi et al. [29], internal tagging may represent the best method in order to certificate plants and to guarantee health checks. The tag must be well inserted within plant tissues so that it cannot be removed easily. The portion of the trunk needs to be cut from the tree and further dissection of the plant tissues need to be taken out in order to extract the tag. This process could be time consuming and expensive. Conversely, external tagging did not need such a peculiar intensive procedure for tag retrieving after plant death or removal, creating less difficulties in recycling the tags.

Finally, some considerations may be derived by strategy types that drive firms to implement dematerialization tools and, more generally, "green" Information Technology solutions. Jenkin et al. [46] proposed a specific strategy that involves portraying an image of caring about the environment by publicly announcing environmental policies (espoused strategy), yet not implementing or carrying out these policies. Among organizations which follow that strategy, the authors identified organizations that may be concerned with their image, but not with the actual completion of environmental activities ("greenwashing" intentions) versus organizations that have authentic intentions but are unable to complete environmental activities due to organizational inertia or lack of resources and knowledge ("green" intentions). In the agriculture sector, where a "green" approach to production has a great impact on consumer's choices but implementation of Information Technology is difficult, the risk of "greenwashing" intentions should not be underestimated.

4. Conclusions

Economic and environmental uncertainties make Information Technology permeations in agriculture difficult. Thus, even if effective tools for plant pathology management or agricultural practices are available or could be optimized, they will be hardly implemented in the near-future agriculture or they will be limited to bigger farms. Information Technology may take advantage of some peculiarities of agricultural sectors, such as application in "Food from Somewhere" regimes.

The strong liberalization and commoditization of corporate supply chains, exemplified by harmonizing production standards and moving against regional identities to foods, resulted in what McMichael [51] termed the "Food from Nowhere" regime. However, compared to the earlier regimes, this one seems to have both enduring cultural framing (the era of cheap food) and an emerging acute problem of cultural legitimacy. Friedmann [52] describe Social Movement-inspired sites of resistance in a complex political dialectic with the emergence of 'green capitalism'. This tension between Social Movement-inspired critique and capitalist appropriation forms the heart of a posited 'corporate environmental' food regime that can actually operate at a global scale, driving mutation in regimes. Campbell [53] states that consumers in western countries are linking cultural status to foods that they be considered opposite to those "rooted within a set of cultural framings that emphasize cheapness, convenience, attractive transformation through processing and rendering invisible the origins of food products". Thus, some consumers are loyal to products that are socially and ecologically defined: "Foods from Somewhere".

It is interesting to note that as the Social Movement-inspired critique may play an essential role in defending and promoting typical production such as Apulian olive oil, as well as promoting cultivation and preservation of centenary olive trees, pests were never quite considered as a significant threat to regional identities in agriculture. Conversely, typical productions are frequently carried out in small and fragile eco-systems; cultivars may not be selected to resist to novel pests; pest control may be difficult to achieve due to limited resources of small farms; peculiar plants or cultivars may show different host/pathogen interaction, increasing difficulties in plant defense. The case of *X. fastidiosa* in Italy was emblematic of how difficult it can be to protect a unique plant heritage from pests. The huge territory infested by pests, the millions of trees in cultivated or abandon orchards, the fast widespread growth of bacteria, and the ubiquitous presence of vector requests a next-generation management approach. In Apulia, the "Food from Somewhere" regime is enhanced by further features because olive tree farming is not only an agricultural production choice, but represents the leitmotiv of landscapes, squares, courses, poetry, narratives, and the arts. The death of olive trees represents a terrible threat to conservation of biodiversity in a productive agricultural landscape, and protection requires increased research, policy coordination and strategic support to agricultural communities and conservationists [54]. In this context, the assurance of this regime, due to application of Information Technology tools such as electronic identification, should lead to indirect positive features such as digital monitoring of plants and relative pests.

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