Participatory approach for developing knowledge on organic rice farming: Management strategies and productive performance

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A R T I C L E   I N F O

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Farm-led research
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A B S T R A C T

Rice is the third grown crop worldwide and responsible of significant environmental impacts. Nevertheless, there is a lack of knowledge concerning the organic rice’ performance and management, probably due to the limits encountered by the reductionist approach in studying complex systems such as an organic paddy. The study proposes a knowledge-intensive and qualitative research methodology based on researcher-farmer participatory approach, with the aim to improve the state of knowledge on organic rice, explore the yield potential and variability, and identify the successful agronomic practices. A wide range of cropping systems placed in North Italy were monitored and analysed during three years by a multi-actor network. Knowledge was generated from collected data and information, integrating the scientific and empirical knowledge on the basis of the DIKW hierarchy and through mutual learning and knowledge sharing tools. The organic rice field proved to be a complex and difficult to predict system, which evolves over the time, under the on-going pressure of the bottom-up innovations, and whose performance depends on many interacting elements. The results highlighted three main knowledge-intensive management strategies, not involving universal recipes but a range of agroecological principles and flexible solutions that the farmers adapt to the time- and space- variability through an active adaptive management. Yield showed a wide variability (0–7 t/ha) and normal distribution (median 4 t/ha). The lower, middle and upper quartiles of yield showed a mean of about 2, 4 and 6 t/ha, respectively, with high variance associated with upper and lower quartiles. The variability sources related to the management and effectiveness in weed control have mainly determined the productivity gap, “Know-how” (suitability of the chosen management plan), “optimization” (timely and accuracy of interventions) and “seed bank” (previous operations and land uses affecting the weeds dynamics) were responsible of the low yield in 77%, 54% and 31% of the cases, respectively, drowning out the impact of climate, soil and variety.

Results are useful to drive further scientific inquiries and evaluations consistently with the faced reality by the farmers, and suggest that improvements in the farmer’ know-how and skills can lead to further yield increase and variability reduction. The participatory research, adopted to explore complex systems, has worked in this direction, fostering the co-creation of knowledge and innovation and the social cohesion. However, the methodology showed constraints mainly related to the time-consuming surveys and its nature affected by human component.

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1. Introduction

1.1. State of knowledge on organic rice

Italy is the first rice producer in Europe, accounting for the 52% of the European rice area (FAO, 2016), with 234,000 ha. The latter are mainly based on high-input monoculture and concentrated in one of the most profit-yielding rural area of Italy, between Lombardy and Piedmont regions. In the recent years, the national rice sector was involved in environmental and socio-economic issues. Public authorities (Ispra, 2018) reported the higher degradation of water quality in rice production areas, due to contamination by pesticides, with concerns for the integrity of the environment and public health. In the same time, a significant price decrease occurred for conventional rice due to the competition with imported quantities (e.g. in 2017, Copa Cogeca, the European Association of Farmers and Agri-Cooperatives, asked for the declaration of state of crisis and special subsidies for rice farmers). In this context, organic agriculture can be a solution, in favour of both environmental and economic sustainability, avoiding the use of herbicides, and then reducing the impact on water quality, and providing the farmers an alternative based on higher price paid by the market for organic products.

However, organic agriculture is a novelty and a challenge for this sector. Farmers, who are familiar with industrialized and high-input agriculture, perceive the conversion to organic as difficult to implement, risky and uncertain in terms of productive performance. They are reticent to significantly change the management practices, operation schedules and farm structure (e.g. introduction of crop rotation or cover crop, purchase of new machines for weed control). The lack of skills, necessary to control weeds without the use of herbicides, and the uncertainty, concerning the organic rice cropping system (ORCS) performance and behaviour, are the main constraints. All this is accompanied with the absence of systematic knowledge and external supporting expertise as technicians or researchers.

In fact, weed control remains the major challenge for organic systems (Shennan et al., 2017). Rice is particularly prone to weed issues and the intense weed competition is the main constrain to realize the potential production (Hazra et al., 2018), in addition, the weed incidence is reported as the main causes of yield variability and yield gap with conventional rice in Mediterranean organic paddies (Delmonte et al., 2011).

Nevertheless, few scientific publications have addressed this topic, resulting in a lack of knowledge about the strategies for weed control and the resulting yield. Most of the scarce literature on organic rice is focused on the dynamics of nutrients with organic manures, the greenhouse gas emissions balance and the genotype (Hazra et al., 2018). While, systematic researches on the practices, productive inputs and performance of the ORCS are lacking (Huang et al., 2016). Only 17 recent papers (since 2004) were found by SCOPUS entering the key words “organic rice”, “yield”, “weed”, while 1,389 papers (since 1952) entering the key words “rice”, “yield”, “weed”. The missed understanding of the management strategies for the ORCS, and the corresponding yield potential and variability, is a constraint in encouraging the conversion of conventional farmers. This condition makes the organic rice cultivation a niche activity, carried out by few pioneer farmers with a self-help approach. As shown by the literature, the diffusion of organic farming in a new productive sector or countries is a slow process, mainly driven by the farmers themselves (Padel, 2001; Kroma, 2006; Ortolani et al., 2017). Farmers are the first innovators and experimenters, developing on-farm new techniques and skills, with a trial-and-error approach. Therefore, in organic agriculture, the innovation development often follows the “bottom-up” paradigm, instead of a “top down” linear process.

1.2. Research approach for complex systems

Researchers could have a pivotal role in speeding up the transition process toward organic agriculture, supporting the dynamics of “bottom-up” innovation, but a profound change is required in the practice of research, since the organic farming and its management differ a lot than the conventional farming. The industrial agriculture tries to do the same in different places and in the same places (e.g. monoculture, universal agronomic recipes), involving simplified and specialized cropping systems managed with a short-term approach and based on the fast action of external inputs. On the other hand, organic agriculture involves complex systems, regulated by long-term biological processes and cumulative and non-linear effects (e.g. humus formation, weed seed bank dynamics), where the effectiveness of an agricultural practice is time- and site- specific and greatly dependent on the historical causality of each production situation (Duru et al., 2015).

Facing the above mentioned uncertainty, an active and adaptive management may underlie the decision making process of the organic farmers, with a deliberate plan for learning about the managed system (Shea et al., 2002). The adaptive management is pointed out by the agroecological studies, as the farmer’ response to across time- and space- variability (Bell et al., 2008), based on common ecological and agronomic principles that underlie a variety of practices, rather than on a unique and standard management and context-independent recipes. Therefore, the farmer’ decision making process leads to agricultural practices highly variable in time and in space, depending on the site-specific features of the farm and the cultivation environment, and on the contextual occurrences during the growing season. The ORCS management is complex, as complex is the addressed system, and in accordance with the agroecological vision (Bell and Bellon, 2018), the pioneers of this sector are trying to do different things in different places, and different things in the same place (e.g. crop rotation, wide range of agronomic solutions and variants of the same practices). The adaptive management is farmer-centred and involves will-known complex practices, which can be acquired through direct experience, or mutual-learning and sharing experiences within other farmers. However, this knowledge is difficult to validate within the prevailing institutional norms of research that accords value to objective and standardized knowledge (Kroma, 2006).

In this context, the research, traditionally targeted to solve the industrial agriculture issues, is based on a reductionist approach that is uncomfortable in studying complex systems characterized by many interactions and variability sources (Drinkwater, 2002; Ponzio et al., 2013; Duru et al., 2015; Döring, 2017). The factorial experiments aim to deconstruct the complexity of the system, reducing the variability and isolating the causal relationships among few elements. This approach could be unable to predict the performance of the whole agroecosystem, leading to incorrect conclusions or results that are not replicable or confirmed by the reality on the ground (Drinkwater, 2002; Baker, 2016; Carberry, 2001; Sadras and Denison, 2016; Hazra et al., 2018). As shown by Kravchenko et al. (2017), in conventional farming, the recorded yields in experimental plots are often in line with those obtained in the farm’ fields under the same management treatment, while in the organic farming a persistent yield gap can be observed between them. The challenges that associated with weed control and the timeliness of the management interventions were found to be the cause of the lower yield of the organic fields. Similarly, Stoop et al. (2009) highlighted the weakness of the results coming from the rice trials performed by IRRI (International Rice Research Institute), targeted to find standardised solutions suitable for a linear technology transfer process among farmers. This approach neglects the variability and diversity encountered in the real-world farming environment, excluding the interactions between experimental and non-experimental
factors. The latter factors, kept constant during the experiments, play instead a critical role in determining the rice yield. The authors highlight the limits of the current research, asking to scientific community for more flexible solutions originated from knowledge-intensive agronomic practices.

In order to produce suitable agronomic solutions and comprehensive results for organic farming, the research in agriculture need to be reconsidered, moving beyond the plot-scale, toward a holistic vision, on-farm studies, the action research (Bengtsson et al., 2005; Shennan et al., 2017; De Ponti et al., 2012), and the use of interdisciplinary tools and participatory approaches (Rockström et al., 2009; Drinkwater, 2002; Ponzio et al., 2013). In particular, higher level of farmers' participation into the research, and the integration of farmer’s expert knowledge into a bottom-up innovation process are required (Carolan, 2006; Ingram, 2008).

However, agricultural research is still far from integrating the traditional tools with a holistic and interdisciplinary vision, and unable to cooperate with farmers in a process of peer-to-peer knowledge exchange and mutual learning (Kroma, 2006; Méndez et al., 2015). On the other hand, agroecology has well-recognized this need, and thus proposes the participatory networks of farmers and scientists as main tool for understanding the complexity of agroecosystems and food systems (Warner, 2008; Méndez et al., 2013, 2015; Berthet et al., 2016). Many studies showed as the participatory approach and the incorporation of local knowledge into the process of scientific inquiry, led to a more complete understanding of natural and agricultural systems, in favour of their sustainable management, starting from the assumption that people can have well-founded understanding of their own environment. Especially in wetlands, where water adds an upper level of complexity, the research' need to recur to helpful perceptions from the local community, seems to be exacerbated (Calheiro et al., 2000; Rasmussen, 2000; Barzmann and Desilles, 2013; Stoop et al., 2009). In accordance with the five levels of change toward agroecology (Gliessman, 2016), the participatory research proved to be able to foster the transition beyond the field and farm level. As shown by successful researches in plant breeding (Murphy et al., 2005; Mancini et al., 2017; Ortolani et al., 2017), food network building (Guzmán et al., 2013) and rural development (e.g. FAO projects), the participatory approach supports the sustainable development of local and global food systems, social innovation, and farmers' empowerment. Lilja and Bellon (2013) highlight how participatory studies are needed when the agriculture development requires a holistic vision (i.e. change of the whole cropping system, rather than one technology at a time), and the crop growing conditions vary widely among farmers and sites. This approach was often tried after the failure of the traditional scientist-designed research programmes in the complex and risk-prone contexts of the poor and marginal agriculture, characterized by high variability and the need to improve the natural-resource management. Today, the participatory research can be a valuable tool also for the organic agriculture of the industrialized countries that has many features in common with the low-input farming systems of the developing countries.

However, the methods of participatory research are not commonly employed to develop innovation in agriculture and the scientists remain sceptical of formally incorporating the knowledge of local people. As result, a substantial research gap exists in the understanding of complex farming systems, such as those of flooded organic rice fields, and in aligning of modern agricultural techniques with them, in order to support solutions useful for organic farmers (Hazra et al., 2018).

1.3. Precondition of the participatory research

The present study addresses the rice’ cultivation area of North Italy. This case study provided an encouraging context for a farmer-researcher participatory exploration of complex systems. The researchers’ intention to improve the current state of knowledge on the ORCS (i.e. input, management and performance), in order to perform further evaluations (e.g. environmental, economic and agronomic) coherent with the real-world farming environment, met the needs of the local organic farmers. The latter demonstrated the will to improve their management, through the experiences and skills sharing, and to contrast the widespread scepticism among the scientific and rural community, which can be represented by the following sentences “Producing rice without herbicides is impossible”, “Organic farming is unable of satisfactory economic returns”, “Organic farming increase the environmental polluting, because the fuel consumption for mechanical weeding and the lower yield”. These farmers represent for scientists a precious source of knowledge, generated by the active adaptive management, through the learning of suitable practices by trial and error over the years and the implementation of locally relevant empirical knowledge.

1.4. Study goals

Starting from the needs of scientists and farmers, the present study addresses the challenge of integrating the farmers' insights, perceptions and knowledge into the process of research, exploring the complex agroecosystem of organic rice field. At this aim, a methodological framework, based on the Data-Information-Knowledge-Wisdom (DIKW) hierarchy (Ackoff, 1989) and participatory tools, is proposed. For three years, ten farmers were actively involved in the research on ORCS, and in a multi-actor network (namely: the organic rice network; OR-Net) composed of other farmers, scientists and sector’ technicians. Farmer-led experiments were monitored and evaluated by the OR-Net, taking into account real agro-ecosystems, with different features in terms of farm size, crop management, and constraints faced by the farmer.

The main study goal was to improve the state of knowledge on the ORCS, providing results useful to develop, without approximations and contextually, any further evaluations (e.g. economic, productive or environmental), and to make the transition to organic agriculture less uncertain. The following sub-goals were addressed:

i) Define and evaluate the most promising management strategies (identifying the agricultural practices, input, functional principles, and performing a participatory SWOT analysis).
ii) Explore the productive performance of a broad range of ORCSs (analysing the yield range and the main sources of the variability).
iii) Make considerations (opportunities and constraints) on the participatory approach for the explorative study of complex agro-ecosystems.

2. Materials and methods

2.1. Organic rice network: farmers and farms features

During the growing seasons (i.e. 2016, 2017, 2018), ten farmers, that grow organic rice in North Italy, were involved into the participatory research on ORCSs. The related farms are placed between the provinces of Vercelli (Piedmont region) and Pavia (Lombardy region), where the main Italian rice production is concentrated (i.e. 67% of the national harvests; Istat, 2016). Farmers were identified on the basis of the information framework on the local reality of organic sector, coming from: i) agronomists and technicians with a deep knowledge of the territory, because in charge of further farm’ inspections, beyond those carried out by the certification body (involved in plans to limit fraud in organic sector, by private companies and regional authorities); ii) local pioneers of the organic rice cultivation, with a pre-existing relationship of trust with the research team (i.e. ex-student); iii) the farmers, progressively included into the OR-Net, since nobody like the organic farmers know which farmers embrace the organic agriculture, beyond the economic reasons, to support a system of values (i.e. environment protection and new models of food production). Then, farmers available to collaborate for a common purpose in favour of
A heterogeneous sample of 50 ORCSs were monitored (i.e. 15 in 2016, 22 in 2017 and 13 in 2018). The management, planned by the farmers on the basis of their adaptive strategies, has been kept unaltered. Each ORCS was thus evaluated as a whole agroecosystem, using a holistic approach, closely aligned with the study of natural ecosystems. Since the variables of the system and the sources of variability were not isolated, a knowledge-intensive and qualitative research methodology option was used for the assessment (see section 2.3, 2.4).

The ORCSs’ features are shown in Table 2. The fields have been chosen on the basis of their representativeness in terms of management practices adopted by the farmer, and excluding those usually characterized by yield above or below the farm’ average for reasons due to soil properties or other external factors.

Direct seeding of rice and the flooded conditions of growth were common elements for all the ORCSs. Three main strategies were used to manage the ORCSs, mainly targeted to weed control (see Table 2. Testing techniques: SD = Stale seedbed in Dry paddy, mainly using comb harrow; SF = Stale seedbed in Flooded paddy, using different types of machines; CC = use of green mulch from different Cover Crops). The strategies were used as unique treatment or in combination. The ORCSs differed also by the used varieties: the japonica genotype “Rosa Marchetti” (Callegarin et al., 1994) was grown by five farmers out of ten, while the “Ronaldo” (Ilieva et al., 2017) was grown by other three. In each rice field, soil sampling (5 sampling points of the upper soil 30 cm) and the related standard physical analysis were carried out. Results confirmed those of other authors (Tanaka et al., 1973), revealing the tendency of rice fields placed in Pavia Province to have a higher percentage of sand (i.e. prevalence of sandy-loam soils), while a decrease of sand percentage and an increase of silt for paddies placed in Vercelli Province (i.e. prevalence of silty soils).

### Table 1
Features of monitored farms. Legend: P = Pavia Province (Lombardy); V = Vercelli Province (Piedmont); M = male; F = female; UAA = Utilised Agricultural Area; Y = yes.

<table>
<thead>
<tr>
<th>Farm ID</th>
<th>Site</th>
<th>Gender</th>
<th>Testing organic since</th>
<th>UAA (ha)</th>
<th>Organic crops (% UAA)</th>
<th>Rice (% UAA)</th>
<th>Set-aside</th>
<th>Rotation</th>
<th>Rotational Crops</th>
<th>Legumes</th>
<th>Cereals</th>
<th>Other crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P</td>
<td>M</td>
<td>1976</td>
<td>476</td>
<td>29</td>
<td>Y</td>
<td>Y</td>
<td>soybean, pea, rapsedeed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>P</td>
<td>F</td>
<td>2006</td>
<td>106</td>
<td>30</td>
<td>Y</td>
<td>Y</td>
<td>soybean, bean, barley, spelt, triticale, wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>P</td>
<td>M</td>
<td>2008</td>
<td>13</td>
<td>12</td>
<td>Y</td>
<td>Y</td>
<td>bean, pea, maize</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>P</td>
<td>F</td>
<td>2008</td>
<td>29</td>
<td>24</td>
<td>Y</td>
<td>Y</td>
<td>soybean, pea, mile, spelt buckwheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>P</td>
<td>F</td>
<td>2016</td>
<td>103</td>
<td>18</td>
<td>Y</td>
<td>Y</td>
<td>alflafa maize</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>P</td>
<td>M</td>
<td>2016</td>
<td>210</td>
<td>40</td>
<td>Y</td>
<td>Y</td>
<td>soybean maize, barley, rye</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>V</td>
<td>M</td>
<td>2015</td>
<td>125</td>
<td>80</td>
<td>Y</td>
<td>Y</td>
<td>soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>V</td>
<td>F</td>
<td>2015</td>
<td>82</td>
<td>46</td>
<td>Y</td>
<td>Y</td>
<td>soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>V</td>
<td>M</td>
<td>2015</td>
<td>33</td>
<td>64</td>
<td>Y</td>
<td>Y</td>
<td>soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>V</td>
<td>M</td>
<td>2016</td>
<td>64</td>
<td>50</td>
<td>Y</td>
<td>Y</td>
<td>soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

organic sector were recognized, avoiding possible distortion in the study results due to the inclusion of fraudulent farmers.

Those farmers were involved into the multi-actor network OR-Net, which its core composed of the farmers themselves, three technicians and three researchers in agronomy. During the study, the OR-Net progressively involved scientists from other disciplines (i.e. in agreements with the research’ needs of expert knowledge) and other farmers, in order to extend the debate and exchange of opinions on ORCS.

The high level of farmers’ participation, needed for generating new knowledge (Lilja and Bellon, 2013), was assured. Peer-to-peer relationships from collaborative to collegial were established between researchers and farmers, both partners in the research process. The informal and local R&D system was encouraged, as well as the knowledge sharing and mutual-learning system, underlying the methodological approach (sections 2.3, 2.4).

The main features of the ten farms involved in the study are listed in Table 1. Four out of the ten are managed by women, a significant share, considering that the local agriculture is mainly managed by men (e.g. in Lombardy 78.2% of farm’s heads are men; Istat, 2010). This is in accordance with the active role of women, highlighted by Padil (2001), in developing and sharing innovation for organic farming. The farmer’s experience level in organic cultivation was different: four farmers (i.e. farm ID 1, 2, 3, 4) with at least 8 years of experience in organic farming, and the remaining at their early stage (i.e. in 2016: three farmers were at the first year, and three farmers at the second year of experience). The farm Utilized Agricultural Area (UAA) ranges between a maximum of 476 ha and a minimum of 13 ha, with half farms having UAA more than 100 ha (i.e. farm ID 1, 2, 5, 6, 7), and the remaining below. Most of farmers are testing organic system in the entire farm, except one (i.e farm ID 7) who maintains a mixed organic-conventional regime. Most of farmers introduced crop rotation with no more than two-thirds of UAA dedicated to rice, except one (i.e. farm ID 7) who alternates rice growing in monoculture with set-aside land. The four oldest pioneers (i.e. farm ID 1, 2, 3, 4) adopt complex plane of crop rotation, with the introduction of cereal and minor crops in addition to legumes, while most of remaining farmers alternate a year of rice with one year of legumes, mainly soybean.

### 2.2. Organic rice cropping systems

A heterogeneous sample of 50 ORCSs were monitored (i.e. 15 in 2016, 22 in 2017 and 13 in 2018). The management, planned by the farmers on the basis of their adaptive strategies, has been kept unaltered. Each ORCS was thus evaluated as a whole agroecosystem, using a holistic approach, closely aligned with the study of natural ecosystems. Since the variables of the system and the sources of variability were not isolated, a knowledge-intensive and qualitative research methodology option was used for the assessment (see section 2.3, 2.4).
purpose, in order to be useful, providing answers to “who” “what” “where” and “when” questions (i.e. information as “Know what”). Knowledge mainly deals with the understanding of the patterns (i.e. parts as a whole). Knowledge is a property of people, generated from the integration of contextual data and information with expert opinion, skills, training, own or other experience, perception, common sense and the background knowledge. Therefore, knowledge involves the prior understanding and accumulated learning, and the reflection and synthesis of information from multiple sources over time. During the knowledge generation process new insights are internalized by establishing links with already existing knowledge; these links can range from firmly characterized relationships to vague associations. Finally, knowledge involves as a potential for action “the know-how”, which is originated from the transformation of data and information into guidelines, and then results in a valuable asset useful for decision making and to increase the capacity to take effective action (i.e. knowledge as “actionable information” or “information combined with understanding and capability”). Knowledge provides answers to “how” questions (i.e. knowledge as “Know how”).

Along the continuum from data to information to knowledge (Fig. 1; y’ axis on the left), the amount of human contribution, needed to perform the transition from a level to another, increases (Fig. 1; y” axis on the right). According with the literature (Rowley, 2007), data and information are characterized as phenomena in the universal domain, while knowledge as phenomena in the subjective domain. Consequently, the tools used to perform the shifts toward the knowledge (see paragraph 2.4) involved an increasing level of participation among actors, namely among the OR-Net (Fig. 1, x axis in the middle).

Finally, the participatory model involved important component of a feedback loop from the research to its outputs, since that the process of research was adjusted to produce more relevant and appropriate outputs (Lilja and Bellon, 2013). Therefore, the outcomes, at each level of the hierarchy, represented feedbacks, on the basis of which to adapt and re-design the tools and processes involved at all levels (Fig. 1, arrows of “feedback-and-adaptation cycle” on the left), in order to target the activities to the study goal. After the first year, the questionnaire for the interview was implemented with further open-ended questions and dialogue techniques more close to those used during the group fields monitoring. Starting from the results of the previous activities, the interviews shifted also in the “information’ domain” of the DIKW pyramid, with the aim to capture information about the ORCS response to some elements highlighted as relevant. Similarly, after the first year, the system thinking, used during group fields monitoring and plenary meetings, capitalized the previous results, contributing to confirm or put in doubt the information and knowledge previously obtained.

As highlighted by other authors (Bruges and Smith, 2008; Berthet et al., 2016), the participatory approach is in allowing participants to further their goals as that themselves define them, while any limitation to the influence of participants in determining the goals risks limiting the method effectiveness. Therefore, this “feedback-and-adaptation cycle” pathway was applied with a certain extension also to the overall research process, i) leaving the farmer free to set the strategies to test for the ORCS during each growing season, ii) and giving space to the development of further studies targeting purposes beyond those shown in the present work. Thanks to this, other relevant issues have arisen and pointed out by the OR-Net, and consequently the OR-Net

### Table 2

Features of monitored organic rice cropping systems. Legend: SA-LO = sandy-loam; SI-LO = silty-loam; LO-SA = loamy-sand; SI = silt; Y = yes; SD = Stale seedbed in Dry paddy, in combination with comb harrow; Stale seedbed in Flooded paddy, in combination with minimum tillage machines; CC = Flooding of green mulch from different Cover Crops.

<table>
<thead>
<tr>
<th>Farm ID</th>
<th>Rice varieties</th>
<th>Soil texture</th>
<th>Testing techniques</th>
<th>Monitored fields (n.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rosa Marchetti, Ronaldo, Baldo</td>
<td>SA-LO</td>
<td>Y Y Y</td>
<td>2 2 2</td>
</tr>
<tr>
<td>2</td>
<td>Rosa Marchetti, Ronaldo, Loto</td>
<td>SI-LO</td>
<td>Y Y Y</td>
<td>3 3 3</td>
</tr>
<tr>
<td>3</td>
<td>Ronaldo, Loto, Tondo cerere</td>
<td>SA-LO</td>
<td>Y</td>
<td>1 1 1</td>
</tr>
<tr>
<td>4</td>
<td>Carnaroli, Ermes, Venere</td>
<td>SA-LO</td>
<td>Y</td>
<td>2 2 1</td>
</tr>
<tr>
<td>5</td>
<td>Sant’Andrea, Baldo</td>
<td>SA-LO</td>
<td>Y</td>
<td>0 4 2</td>
</tr>
<tr>
<td>6</td>
<td>Sant’Andrea</td>
<td>LO-SA</td>
<td>Y</td>
<td>1 1 0</td>
</tr>
<tr>
<td>7</td>
<td>Rosa Marchetti, Pato</td>
<td>SI</td>
<td>Y Y</td>
<td>2 3 1</td>
</tr>
<tr>
<td>8</td>
<td>Carnaroli</td>
<td>SI-LO</td>
<td>Y</td>
<td>3 3 2</td>
</tr>
<tr>
<td>9</td>
<td>Rosa Marchetti, Pato</td>
<td>SI-LO</td>
<td>Y</td>
<td>0 2 1</td>
</tr>
<tr>
<td>10</td>
<td>Rosa Marchetti, Carnise</td>
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![Fig. 1. Conceptual chart on the methodological approach: the DIKW Pyramid levels (on the left); the corresponding processes to shift from a level to another (on the right); and the tools used in practice to perform the shift (in the middle). Legend: 
- = data realm; 
- = information realm; 
- = knowledge realm; 
- = overlapping, transition zone between levels.](image-url)
incorporated new experts, approaching the interdisciplinary study of ORCSs, as shown in the conceptual chart of Fig. 2. The DIKW pyramid was implemented through practical discussions (see section 2.4) that occurred in interactive and informal environments. On-farm experiences were compared and explained, fostering the critical analysis and the ability to gain general principles from a wide range of case studies. This process occurred in horizontal and non-systematic way, giving space even to spontaneous extensions of further multidisciplinary researches and common actions, beyond the beginning goals.

2.4. The tools

Tools were used to realize a participatory system thinking that allowed to capture and validate in the research process the cumulative knowledge of the farmers, implementing the DIKW hierarchy and its key processes: the interpretation and understanding of the data meaning (toward information), and the linkages and integration with the past experience, accumulated learning, scientific literature, existing empirical and scientific knowledge (toward knowledge).

Interviews were conducted with the farmers in three phases of the growing season (i.e. at beginning, mid and end). The interviews were performed immediately after the application of the agronomic practices, to avoid the collection of incorrect or approximate information due to long time elapsing between the actualization of the practices and the interview. At least the first interview was conducted face-to-face and, depending on the complexity of the management strategy, the others were conducted using other communication channels (i.e. phone interviews, emails, messages via smartphone). Data were collected concerning: field size, tillage (e.g. machines, depth, schedule), irrigation (e.g. flooding depth, schedule), sowing (i.e. date, dose, variety, modality: depth or direct seeding, dry or water seeding, in-row or broadcast seeding), harvest (i.e. date, total harvest, grain moisture), and the crop residues management. The harvest data were converted into grain yield (t/ha at the commercial moisture, 14%). Data on the previous land use over the latest four years was collected (i.e. prior cover crop, year of set-aside with grass meadow or bare soil, crop rotation), as well as details on the cover crop management if there was (i.e. tillage, species, sowing), and related biomass management (i.e. lodged or shredded).

Group fields monitoring was carried out by groups of researchers and farmers (at least one researcher and one other farmer, besides the one who manage the farm), from two to three times per field, depending on the complexity and key periods of the management strategy. The field tour represented an opportunity of opinions comparison and participative brainstorming. The group members tried to find the nexus between yield, crop growth and weeds control (i.e. species’ presence and incidence) on one hand, and the management or other element variables (i.e. soil, climate, etc.), on the other hand, sharing reflections, insights and suggestions (i.e. constraints of the chosen management, possible mistakes, corrective measures).

Plenary meetings were organized with the OR-Net members three times per year during the cropping season (i.e. at beginning, mid and end). One of the three annual meetings was extended also to other actors, inviting: i) experts with specific skills, useful to improve the ORCS understanding and knowledge (e.g. on compounds produced by the fermentation of cover crop, allelopathy between species, etc.) (Fig. 2), ii) other farmers, that shared their experience and were encouraged to join the OR-Net. During the plenary meetings the researchers schematically shown in presentations (i.e. PowerPoint) data and information related to each ORCS case study, also with the documentary support of videos and photos (all the materials were shared with the OR-Net through a folder on google drive). This encouraged the actors of OR-Net to share their expert opinions, performing the linkages between the collected data and information, and the existing wealth of experience and knowledge. Thanks to these focus groups over three years, the most promising managements were progressively characterized, identifying the functional principles underlying the strategies for weed control, and highlighting the positive and critical aspects, via SWOT analysis (Strengths, Weaknesses Opportunities and Threats). The productive responses of the ORCSs were analysed and shown by the researchers as quartiles (Q1 contains the lowest 25% of the data, Q2 in the median of the data and contains 50%, Q3 contains the upper 25% of the data), together with the descriptive statistic for each quartile (i.e. mean, standard error, standard deviation, variance). Then, the differences between ORCSs belonging to different quartiles were discussed, using dialogue techniques.

The interviews to the farmer were the main effort in data collecting, concerning the agricultural practices and the associated yield. The group fields monitoring was an opportunity mainly to enhance the interpretation of field data, with the understanding of the relationships between the ORCS performance and the agricultural practices or other environmental variables, producing information on the ORCS’ responsiveness to the management choices. During the plenary meetings data and information were chorially discussed, operating the linkage with experiences and skills, and contrasting the opinions with the current scientific and empirical knowledge. This results in a progressive advancement in the state of knowledge of ORCS, and in the definition of successful management strategies and mistakes not to commit.

The responses chorially approved by the OR-Net were grouped according the potential causes of low yields, and in parallel, the key elements of successful decision making were pointed out. The researchers through careful listening, understanding and conversing with the OR-Net’ members, learned the main sources of variability impacting the ORCS production. Table 3 shows exemplificative case studies of the ORCSs associated to the lowest yields of three farms. The table describes the process of analysis, based on the implementation of the DIKW framework that allowed to identify the variability sources and generate know-how among the farmers. “What data says”: the data
Three promising management strategies for the ORCs were identified. They are not distinct by strict boundaries, since the adaptive management can lead to adopt a combination of more than one strategies in the same field, exploiting more than one functional principles for weed control. Each strategy does not represent a universal recipe, but it can be declined with a wide range of variants, maintaining the basing functional principles, but shaping the practices to the case specific needs.

What was observed in the present study is well commented by Bell et al. (2008): the organic farmers see their farming as something more than a process of recipe adoption. The real meaning of their management seems to be working with variation, across space and time, rather than against it, avoiding universal practices, proper of a reductionist approach: the farmer asks to agroecology help in identifying the driving ecological and agricultural principles, and, in the same time, space for her/his genius and contextual creativity.

The main agronomic practices and innovative aspects of each strategy are listed below.

**Stale seedbed in dry paddies, in combination with minimum tillage machines (SD).** The strategy is based on the well-known technique of the stale seedbed (Ferrero, 2003). The weed germinated after the false seeding are removed with the comb harrow. The latter is used on dry soil, both before and after the rice sowing (i.e. 2–7 passages with fine spring tines; 3–4 cm of tillage depth). The effectiveness of comb harrow is conditioned by appropriate devices that allow to mechanically impact the weeds, without damage rice seedlings (e.g. suitable field levelling and regulation of tractor speed and tines’ tillage depth to assure the uniformity and precision of comb harrow action; promptness intervention before the young weeds rooting). After the rice dry sowing (i.e. at 4–6 cm depth), the paddy field dry conditions are protracted (e.g. 20–30 days), in order to allow the comb harrow passages. The comb harrow is a novelty for the European rice production. Its use for rice is reported in less mechanized and low-industrialized agricultural contexts of Asian countries (i.e. studies talk about “indigenous” or “locally designed” comb hovers; Verma and Dewangan, 2006; Pande et al., 1994; Callilung, 1985).

**Stale seedbed in flooded paddies, in combination with minimum tillage machines (SF).** In this strategy, the stale seedbed is followed by the field flooding, then the weeds eradication occurs in water through minimum tillage (i.e. 2–3 interspersed passages). For this operation the farmers use innovative machines, realizing them by themselves, “ex novo”
(e.g. “rotolama”, Valsesia et al., 2009), or modifying existing machines (e.g. adding tines to a bar normally used for field levelling). The management of flooding and the regulation of the water level need to be accurate, in order to ensure the removal through water of the eradicating weeds floating up to the surface. After the minimum tillage, the broadcast sowing of rice occurs. As the literature revealed, the weed control is performed not only mechanically, but also by the “puddling” effect; the tillage in saturated conditions destroys the top soil structure, and within the resulting mud, the weeds remain knead, finding anaerobic conditions, able to kill the young individuals and delay the seeds germination (Bhagat et al., 1996). The “puddling” technique is practiced in tropical agriculture of lowland rice, and effects in weeds’ reduction are reported (Ponnamperuma, 1981; Bhagat et al., 1996; Sharma and De Datta, 1985; Sureshkumar et al., 2016). However, the adoption of minimum tillage in this context is a novelty. In Asian agriculture the “puddling” is used with the main aim to reduce the percolation and softens the soil for rice transplanting, and it is realized through high energy intensive operations (i.e. deep tillage machines: plough, harrow or rototiller).

Flooding of green mulch from different cover crops (CC). A cover crop is introduced before rice (e.g. Lolium multiflorum Lam.). The rice is sown on the cover crop plants. Then, the cover crop is chopped, lodged or standing, and flooded, activating an anaerobic fermentation of its biomass. The fermentation has negative impacts on weeds germination, and, to a lesser extent, also on rice. Therefore, fermentation’ intensity and duration are key aspects, controlled by many factors (e.g. temperature, biomass quantity). Many agronomic variants are tested by the farmers in order to increase the weed control and decrease the impact on rice. Mainly the farmers tested two different pathways: the broadcast sowing of rice, immediately followed by flooding (i.e. the cover crop fermentation occurs at rice germination growth stage); or the rice dry sowing, followed by a protracted dry conditions (e.g. 20–30 days) (i.e. the flooding and fermentation occur at rice leaf development growth stage 3°-4° leaves unfolded). The CC strategy is completely innovative and there are no references in literature concerning its use. It is based on complex dynamics and requires further studies (e.g. competitiveness and allopathic relationships between weeds and cover crop species, green mulching effect, weeds and rice susceptibility to the organic acids of the fermentation, etc.). This strategy was evaluated by the OR-Net as the most promising, since it showed wide room for improvement and is in line with the farmers’ agroecological vision.

The underlying techniques and functional principles of each management strategy, and the results of the SWOT analysis are summarized in Table 4.

### 3.2. The productive performance

The yield of the “ORCSs population” showed a normal distribution (Skewness = -0.33; Kurtosis = -0.01) (Fig. 3; Fig. 1a and b in supplementary material), and high variability, ranging from 0.0 t/ha (i.e. harvest failed) to 7.1 t/ha, with: mean of 3.7 t/ha, median almost 4 t/ha, standard error of 0.23, standard deviation of 1.6, and variance of 2.6 (Fig. 4) (Table 1a and 1b in supplementary material). Table 5 shows the mean and different measures of variability for the three yield quartiles, while the box plots of Fig. 5 show for each of them the area within which 50% of the data are distributed and the position of the median.

The highest variance was found for the lower quartile Q1, followed by the upper quartile Q3, highlighting the wide yield fluctuations associated with the unsuccessful production (i.e. Q1), as well with the greatest productive performances (i.e. Q3), while the medium quartile Q2 shows a certain yield stability and data homogeneity.

Concerning the Q1, the OR-net has identified, firstly, the weed competition, promoted by management errors (i.e. strategy or technique unsuitable for the cultivation condition, lacking punctuality and timely of the interventions), as the main cause of the yield decline, in
accordance with the literature (Delmotte et al., 2011; Shennan et al., 2017; Hazra et al., 2018), and secondarily, the pests attack (i.e. water weevil, *Lissorhoptrus oryzophilus*; rice blast, *Pyricularia oryzae*), promoted by the weather conditions and susceptible varieties. Concerning the middle quartile Q2, the median yield was 4 t/ha, and its position, far from the centre of the box plot (Fig. 5), indicates the tendency of the included data to be close to the bottom threshold of the box, while few data contribute to increase the top threshold, and thus the mean. These yields are in line with the productivity of organic rice recorded in the European countries (i.e. without the use of hand weeding): Bacenetti et al. (2016) showed an average yield of 4.5 t/ha in a farm located in the same Italian rice area, and Delmotte et al. (2011) found on average 4.3 t/ha by analysing an extensive database for similar rice district in France (i.e. Camargue). Regarding the upper quartile Q3, the position of the median (Fig. 5), far from the centre of the box plot, indicates the tendency of the included data to be close to the bottom threshold of the box, while few data contribute to increase the top threshold, and thus the mean.

The highest yields of Q3 (e.g. 6–7 t/ha) were close to those observed for conventional rice in the same area (i.e. 6.8 t/ha; Bacenetti et al., 2016), and in line with those shown for organic rice in China, where the weeds competition was almost totally controlled with hand weeding: Huang et al. (2016) and He et al. (2018) report average yields of 6.1 t/ha and 6.3 t/ha (grain moisture at 14%), respectively. The highest yield values observed in this study give an idea about the potential production that could be reached by the ORCS, opening up the prospect that organic rice of European countries could reach in the long-term a productivity similar to conventional systems or to the Asian organic systems based on hand weeding.

Finally, the results invite the scientific community to consider the ORCS as a farming system that is evolving over the time, under the ongoing pressure of the bottom-up innovations and know-how generation among farmers’ community, and then to not evaluate the ORCSs as a group of unchanging and static systems. The researchers that carry out environmental (e.g. LCA, carbon or water footprint) or economic evaluations in this area of study, with different outcomes depending on the agronomic inputs and the harvest per hectare, should become aware about the existing heterogeneity within the ensemble of ORCSs. Concerning this, different scenarios with a range of possible results should be implemented, basing on the wide range of management options, as farmer response to the time- and space-variability (see section 3.1), and the harvest fluctuations.

### 3.3. The variability sources affecting the yield

The identification of the factors that determine yield variability and productivity gaps between organic and conventional farming is an important step towards the design of more ecologically intensive rice cropping systems (Delmotte et al., 2011). Concerning this, the obtained results allowed to understand the large yield variability observed among the ORCSs (see Section 3.2), identifying the main variability sources (VS) affecting the production. The progressive implementation of the DIKW framework during the three-year participatory study led to highlight the causes underlying the best and worst yields and show the ORCS as a complex and difficult to predict system, whose performance depends on many interacting and interconnected VS, as described below.
The know-how (A): the main factor affecting the ORCS performance was identified in the farmer skills, i.e. in capability to develop know-how about the ORCSs. An agronomic solution cannot be successfully repeatable in any productive context, since its feasibility is conditioned by site-specific features (e.g. water supply, soil hydrology and texture; Table 4). The farmer capability to understand the peculiarities and needs of the cultivation environment and, on these bases, to identify ad-hoc agronomic solutions (e.g. choose, adapt, eventually modify or invent context-specific practices) is currently the key element to reach satisfactory yields. The know-how depends on the direct experience of the farmers, and then on their capacity to learn through the adaptive management, using creativeness, intuitive ability and improvisation skills to address the uncertainty. The know-how also depends on the indirect experiences, transmitted by other farmers, and then on the farmer inclusion into a system of knowledge sharing within the rural community. The farms’ distribution in Q3 (upper quartile of yield; Tab. 1b in supplementary material) confirms the influence of the farmer know-how on the ORCS’ productivity: the farm ID2, characterized by a long-term experience in organic agriculture and led by one of the farmers’ leader of the OR-Net, is present five times out of 12.

The optimization (B). After the identification of the suitable management techniques (A), these need to be applied by the farmer with the required accuracy. The ORCS performance showed high susceptibility to small changes in the timely and punctuality of the operations. Then, the agronomic practices need to be optimized in time and in space, doing the right thing at the right time and in the right place. For example, small changes in the tillage’ depth and dates, in the flooding time and duration, in the soil levelling accuracy, can compromise the successful of a suitable strategy, hampering its effectiveness and the functionality of the underlying agronomic principles working in weed control.

The seed bank (C). The expression of the soil weed seed bank depends on the dynamics of the annual plants population, which is complex and difficult to predict (Borgy et al., 2015). It depends on many factors, many of which in turn are included in the other VSs (e.g. management’ effectiveness: A, B; soil and climate’ conditions: E, F). Then, the VS, here defined “Seed bank”, concerns the historical causalities of the field that, beyond the current rice growing season, promote or not the weed development. The seed bank expression depends on the endemic characteristics of the agroecosystem, the previous land use (e.g. crop rotation, set-aside), and the past operations (e.g. tillage). The negative impact, that was observed associated to the continuous cultivation of rice (for more than two or three years) or to the lack of ploughing in the past seasons (minimum tillage), pointed out the key role of the long-term effects in the complex environment of the ORCS.

The variety (D). The variety affects the yield in different ways, also on the basis of the interaction between the genotype’ traits and the other VSs: taller varieties can show higher competitiveness with the weeds, short-cycle varieties better fit with management strategies that involve rice sowing delays, genotypes with higher potential yield lead to better harvest in favourable weather seasons, while with climate favourable to pest attacks show lower yield than that obtained with low-yielding but pest resistant varieties.

The climate (E). The climate and the weather trend affect the rice grow and the incidence of biotic (e.g. pest) and abiotic (e.g. thermal stress) damages, and impact the effectiveness and scheduling of some management operations (Table 4). Beyond the annual trend, a substantial difference in productivity was observed between the fields in Vercelli and Pavia Province. The coldest agro-environment of Vercelli and Pavia Province, showed a quite stable production, with average yield ranging between 6.9 (in 2016 and 2017) and 6.6 (in 2018). This suggests that, at the early development of organic rice farming, soil (F), climate (E) and variety (D), that usually play a key role in determining the conventional farming performance, cover a secondary role instead. Their effects on yield are mostly hidden by the strong impact of the other VSs mainly related with the field management and its effectiveness on weed control: the suitability of the chosen strategy and agronomic solutions (A), the optimal application of the practices (B), the past operations and land uses (C). The participatory study showed as, in the beginning of the Italian rice sector, these VSs are predominant in driving and affecting the performance of the ORCS.

These results are confirmed by the inter-annual average trend of yield observed for the ORCSs. Thanks to the improvement over time in the farmers’ know-how, management skills and techniques refining, an increasing average yield, accompanied by a decreasing standard deviation were observed. Compared to 2016 (mean = 2.85 t/ha, standard deviation = 1.77) the average yield of the ORCSs showed an increase of 34.7% in 2017 (mean = 3.84 t/ha, standard deviation = 1.47), and of 61.6% in 2018 (mean = 4.61, standard deviation = 1.13). On the other hand, the trend of conventional rice yield, reported by the national statistics (ISTAT, 2016-2018) in the study area (Vercelli and Pavia Provinces), showed a quite stable production, with average yield ranging between 6.9 (in 2016 and 2017) and 6.6 (in 2018). This suggests that the increasing productivity, observed in the ORCSs during the three years, is related to dynamics not in common with the other farming systems (i.e. preponderance of A, B, and C impacts, instead of those of D, E and F).

The results suggest the crucial role of the bottom-up innovation and the knowledge-intensive agronomic practices development for improving the management and yield in the ORCS. These processes were supported by the knowledge sharing among the OR-Net’ members. The three years of participatory study led to a better understanding and farmers’ awareness about the relationships between the management choices and the ORCS yields, toward an overall improvements of the performance.
In this context, it is reasonable assume that the current framework about the variability sources weight is only temporary. Further developments in innovation, know-how, and management skills, can lead to minimize the impact due to A, B and C, a then to a progressive increase of the relative weight of D, E and F. This in the future, can lead to reshape the frequencies distribution curve for the yield shown in Fig. 3, shifting it forward (i.e. increase of mean yield) and shrinking its width (i.e. decrease of yield variability).

3.4. Reflections on the participatory approach

A knowledge-intensive and qualitative research methodology was applied, mainly based on researcher-farmer dialogue techniques and a collective system thinking among different actors. This turned out to be a useful approach for studying complex systems, when the study is in the early stage and starts from poor background knowledge. The participatory study allowed to make sense of collected data through the experience of the farmers, overcoming the gap between scientific and empirical knowledge. Tangible improvements occurred in the state of knowledge on the ORCS, its management practices, inputs, and performance. These results will be useful to drive further scientific inquiry and evaluations. Others positive externalities of the participatory research were observed:

- It supported the spreading and sharing among the farmers’ community of agroecological principles and flexible agronomic solutions, instead of unsuitable universal receipts. As consequences the farmers’ know-how and organic rice yield increased.
- It promoted the connections between the farmers’ and scientific community (see Fig. 2) giving space to further research extensions, targeting the sector needs. Currently, following farmers’ advices, specific studies are ongoing on the allopathic relationships between weeds and crops, and on all-encompass environmental evaluations (i.e. GHG emissions balance, flora and soil biodiversity).
- Above all else, it generated social innovation. Meetings and interactions among the OR-Net members, and the three years’ collaboration for a common aim fostered trust relationships, and the social cohesion among farmers. As result, in the early 2019, the farmers have founded a group of producers legally recognized: the farms’ network “Noi Amici della Terra” (means “We Friends of Earth”). This is an aspect extremely innovative for the Italian rice sector that lacks of any aggregation forms among producers. The farms’ network allowed to build a group entity in the market, facilitating the scouting of new sales channels and advantageous agreements, strengthening the farmers’ power in the food supply chains.
- It has built a system of mutual-learning, knowledge sharing and co-action, that is continuing to exist, and is independently implemented by the farmers with exchanges of news and information (e.g. suggestion, field pics, discussion the techniques within animate whatsapp OR-Net group), and coordinated actions to address specific issues (e.g. work tables on economic or legislative issues).

On the other hand, the applied methodology was also characterized by constraints and weakness. The DIKW pyramid implementation mainly occurred in a horizontal and non-systematic way, despite the attempt, since the beginning, to follow an organized scheme and timetable for the ORCS monitoring. Data, information and knowledge were obtained in many cases following a flexible path, conditioned by the farmer timing and based on the use of different supports for the farmers’ communications (e.g. updates sent by farmer with notes, pictures or videos via email or whatsapp, face-to-face dialogues, questionnaires form, phone calls, etc.) and the researcher’ documentation (e.g. writing on field notebooks, voice recordings, photos, videos, etc.). Then, the subsequent effort in synthesis and in organizing all the resulting data, information and knowledge was great and time-consuming.

Moreover, the researcher had to spend long time living the reality of the farm, constructing a common agronomic vocabulary with the farmers (i.e. “talk the same language”), dialoguing with them, participating in the decision making processes. In this context, the reaching of a systemic vision of the ORCS and its dynamics, is similar to compose a puzzle. At least one researcher had to follow all the steps involved in the DIKW pyramid, in order to track, reorder and understand the “pieces”, obtaining an overview (i.e. to study the puzzle pieces and then compose the whole framework). This results in a limited possibility to alternate the researchers in the activities, with the risk to overloading a single person, especially during the overlapping of the fields monitoring in the key periods for the ORCS. On the other hand, the possibility that two researchers can monitor together all the ORCSs, mutual-helping each other, is constraints by the excessive effort in terms of human resources.

Finally, the successful of the participatory research was conditioned by the presence of some preconditions (i.e. matching of farmer and researcher needs and wills; see section 1.3), and by the availability of farmers, that share ethical values and collaborative spirit, and researchers able to strength skills in social relations (e.g. approaching farmers through peer-to-peer relationships and learning that it is an important way to gain their respect and trust). Then, the human component intrinsically present in the participatory research adds elements of uncertainty. In other words, the results obtained applying the same methodology to other case studies could be different, affected by the partially unpredictable evolving of human interactions and personal expertise in this field.

4. Conclusion

The study proposed a knowledge-intensive and qualitative research methodology based on the participatory approach between researcher-farmer and on the integration between scientific and empirical knowledge to fill the knowledge gap about organic rice, which is resulted from the current reductionist research approach uncomfortable in studying complex agroecological systems.

The research led to an improvement in the state of knowledge about the organic rice, describing the performance and the main variability sources affecting the production at the early stage of organic agriculture development in the Italian rice sector. The research also identified the agronomic principles, practices and innovative aspects of the successful management strategies resulting from the bottom up innovation process led by a small group of pioneers. The results will be useful to make less uncertain the challenge of the transition toward organic agriculture, supporting the conversion of conventional farmers, in a hardly encouraging rural context, where high-input and mono-cropping systems prevailed. Moreover, the results will provide to the scientific community a framework on the ORCS useful to drive further scientific inquiries and evaluations coherently with the reality faced by the farmers, and then taking into account the wide variability that characterizes the management and the in time evolving of the productivity, under the pressures of the know-how and innovation generation. The participatory research showed also the capability to generate social innovation, leading to the creation of an innovative form of aggregation among organic rice producers that was based on the peer-to-peer and trust relationships established during the three years’ study. However, even if the methodology proved to be useful for an explorative study of unknown complex system, the revealed weakness highlighted the need to make more systematic and schematic the data, information and knowledge collection and to integrate the present results with further study performed with the traditional research approach. Moreover, the study pointed out as the main constraints of the participatory approach the time-consuming of the research activities and to the unpredictable component related to the human contribution, intrinsically belonging to this type of approach.
Acknowledgments

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.agsy.2019.102739.

References


