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How Can Innovation in Urban Agriculture Contribute to Sustainability? A Characterization and Evaluation Study from Five Western European Cities

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Abstract: Compared to rural agriculture, urban agriculture (UA) has some distinct features (e.g., the limited land access, alternative growing media, unique legal environments or the non-production-related missions) that encourage the development of new practices, i.e., "novelties" or "innovations". This paper aims to (1) identify the "triggers" for novelty production in UA; (2) characterize the different kinds of novelties applied in UA; (3) evaluate the "innovativeness" of those social, environmental and economic novelties; and, (4) estimate the links between novelties and sustainability. The study was based on the evaluation of 11 case studies in four Western European countries (Italy, Germany, France and Spain). The results show that the trigger and origin of new activities can often be traced back to specific problems that initiators were intended to address or solve. In total, we found 147 novelties produced in the 11 case studies. More novelties are produced in the environmental and social dimensions of sustainability than in the economic. In most cases, external stakeholders played an important role in supporting the projects. The analysis further suggests that innovativeness enhances the overall sustainability in urban agriculture projects.

Keywords: urban food systems; innovation; sustainability; city farming; rooftop farming; urban horticulture

1. Introduction

Historically, the question of how to feed our cities has always been a concern for the organization of towns and settlements. The phenomenon of urban agriculture (UA) is therefore not new, and activities related to UA have always been part of urban activities [1,2]. During the last century, in the global North, urban gardens were often implemented as an adaptation to crises, and they have sometimes held a permanent place in these cities since then [3,4]. The so-called "war gardens" and "victory gardens" secured the provision of vegetables and fruits not only during the first and second world wars but also throughout further periods of limited food access [5,6].

Currently, UA projects reflect a broad variety in terms of the size, motivation, goals and actors. UA activities range from educational projects (e.g., school gardens) and food security- and community-directed projects (such as neighborhood gardens) to commercial farming ventures.

Goldstein et al. [7] defined UA as follows: "Most broadly, urban agriculture refers to growing and raising food crops and animals in an urban setting for the purpose of feeding local populations." Guided by this definition, we focus our research on this type of agricultural or horticultural production that is taking place either within the city or in very close proximity to it.

1.1. UA as an Innovation

Despite the early origin of UA in cities, it has often been considered an "innovative" way to address current urban problems. Therefore, this raises the following question: If UA is not new, why is it so often considered innovative? Pfeiffer et al. [8] indicated that many aspects of urban agricultural production are indeed very similar to those of small-scale rural farms and not entirely new, while other factors set UA apart from traditional agricultural operations. In their study, Pfeiffer et al. also described the distinct features of UA, such as the limited and nontraditional land access, the usage of urban soils and alternative growing media, the unique legal and political environments, the non-production-related missions, and the involvement of nontraditional farmers, which force the development of new practices. Prain and De Zeeuw [9] confirmed and complemented those findings by elaborating that the key factors for innovation in UA are those factors, such as multiple livelihood strategies, lower community cohesion, fewer possibilities for integrated agriculture, and quick market access, which differentiate urban from rural agriculture. They identified a direct correlation between urban settings and innovation processes in UA. Those specific conditions and characteristics drive urban operations to develop unique new practices adapted to the urban context.

1.2. UA as a Sustainable Practice

Today's cities are facing pressing challenges in terms of sustainable development [10]. Making future cities resilient and sustainable has been addressed as one of the Sustainable Development Goals by the United Nations (SDG 11); the goal of responsible consumption and production was similarly designated by the United Nations (SDG 12). Along with the increase of the world population, pressures on land within and outside cities have led to the development of new approaches that hold the potential to address or even solve many of those problematic issues. The contemporary academic literature considers UA a possible cornerstone to improve sustainable urban development [11].

In the past, scholars have addressed the sustainability aspects of UA. Most studies concluded that UA has multiple functions and produces a range of non-food and non-market goods that may have positive impacts on the urban setting [12–14]. Studies on UA identified potential benefits as well as risks and problems in all three dimensions of sustainability [15]. On the social level, UA appears to be advantageous for the provision of education, for linking consumers to their food sources, and for improving the general food security of neighborhoods. With regard to the environmental dimension, UA creates environmental benefits resulting from the reduction of food miles and transport emissions as well as the saving and recycling of local resources [16,17]. In economic terms, UA can potentially strengthen local economies and small businesses and provide commodity outputs. At the same time, major risks and concerns related to UA remain [18]. In an analysis of urban rooftop farming, a whole range of UA practice-related risks was identified [19], including risks associated with urban integration, the production systems, the food products, environmental issues and economic issues.

Previous studies dealing with UA in the field of innovation have mainly focused on either social, technological or economic aspects. However, in presenting these studies along those three foci, we acknowledge that interrelationships and overlaps exist between those dimensions. Nevertheless, for operational reasons, we made decisions on how to assign the respective literature and cases.

The first group of studies deals with *social innovations* in UA [20,21]. This comparably large group treats UA as a field where social innovation and new networks are created. Jarosz [22] suggested that UA falls under the group of so-called "alternative food networks (AFN)". Following Zoll et al. [23], those new networks represent efforts to re-spatialize and re-socialize food production, distribution, and consumption. What makes them particularly innovative is that new consumer-producer relations come to the forefront. Those interactions between consumers and producers open up specific learning channels and enhance the consumers' learning about food and agricultural production [24].

The second group of studies focuses on *technological innovation* targeted to reduce the environmental impacts of UA [25,26] and to exploit opportunities to optimize resource flows. This is realized by achieving an overall better input-output-ratio through either the minimization or the improvement of the resource inputs (by either the reduction of or using more sustainable input sources) or through the maximization of the positive outputs. This group of studies focuses very much on presenting best-practice examples in improving or closing water, nutrient and energy cycles. Scholars describe approaches for the following: dealing with polluted or insufficient water resources [27,28], supporting the recirculation of water [29,30], improving local waste recycling [31,32] by using local organic waste as a resource [33,34] or increasing the energy-efficiency by making use of urban waste heat for UA purposes [35].

The third group looks at innovation in the *economic dimension* of UA and focuses on the creation of new business models in UA [36,37]. Scholars present concepts for micro-level entrepreneurial agriculture, revenue improvement, and the transformation of gardens into innovative UA enterprises [38,39]. Van der Schans [36] concluded that due to the ultra-short distance between the farm and the target audience, UA businesses are capable of staging a unique experience and that their innovativeness stems from the fact that "they can create a much more direct and much more exciting interaction in the city between nature and culture, green space and grey buildings".

Just as UA, in general, has been addressed as a solution to contribute to sustainability in all three dimensions, the above-described social, technological, and economic innovations should have a positive impact and should better prepare cities for future sustainable development. A study by Opitz et al. [40] investigated the UA innovation drivers and their potential contribution to sustainable development and concluded that some of the novelties in UA have the potential to open up opportunities for social learning processes and contribute to societal change. At the same time, innovative practices are not sustainable practices per se, and the literature also points to potential UA innovation risks and negative impacts, which can be caused by factors, such as inappropriate cultivation techniques, the use of non-sustainable materials or high energy demand [19].

1.3. Aims and Objectives

As laid out in the previous section, a large body of literature deals with the sustainability aspects of UA and studies the effects of UA and the respective social, environmental, and economic impacts. In the context of innovation, existing studies that look into UA largely focus on one specific field of innovation in UA: these studies address either social innovation or technical innovation for environmental improvement or address economic innovation such as new business models. Opitz et al. [40] and Berges et al. [41] investigate the link between innovation and sustainability in UA by using a qualitative approach.

The goal of this paper is to expand the previous research and characterize and evaluate the innovations in different types and levels of UA across Western Europe while taking into account the contribution of these innovations in the three dimensions of sustainability [35]. We aim to reflect the diversity of UA by focusing on projects that are producing food for either commercial or community purposes. The technological approaches range from traditional horticultural practices to those that experiment with high-tech methods.

To characterize and evaluate innovation in UA, we first tested a framework developed by Hartmann et al. [42] to evaluate the level of innovation ("innovativeness") of social, environmental, and economic novelties in UA. To break down the complexity of the innovation process, Hartmann et al. evaluated best-practice examples by dividing their innovation process into the three subprocesses of invention, adaptation and adoption. They invented a simple criteria system, in which the novelties were factored against the innovation subprocesses carried out in the respective project. We applied the basic idea of this criteria system and developed it further to refine it to our own purposes (as displayed in Section 3.3).

We then looked into the specific innovations within selected case studies around Western Europe and identified their links to sustainability aspects (both positive and negative). The following research questions were explored in the case studies:

- What are the initial motivation and main trigger for UA activities?
- What role do (external) stakeholders play in promoting innovation in UA?
- What types of novelties are produced in the selected UA case studies?
- How "innovative" are those novelties? What kind of activities promotes elevated levels of innovativeness?
- Is there a linkage between different types of innovations and their sustainability effects?

2. Theoretical and Analytical Framework

2.1. Defining the Theoretical Background

The development of the theoretical framework was based on information obtained from selected publications on "innovation". As Johannesen [43] noted, nearly every definition of innovation focuses on the concept of newness. He suggested that "in order to isolate a useful definition and measure of innovation, we need to address three newness-related questions: what is new, how new, and new to whom?". Based on this basic definition, for newness, he proposed six categories: (1) new products; (2) new services; (3) new methods of production; (4) opening new markets; (5) new sources of supply; and (6) new ways of organizing. This understanding goes far beyond classical, linear, and exogenous innovation conceptions where innovations basically consist of new technical arrangements.

While innovation is defined as the process of something new being created, its inner core is a novelty. Van der Ploeg et al. [44] defines a novelty as "a modification of, and sometimes a break with existing routines." Novelties are often perceived as a potential critique of current performances. Novelties are a "new way of doing or thinking—a new mode that carries the potential to do better" [44]. Following this definition, innovation again exceeds technological innovation: every change in products, production methods, services or organization can be considered a novelty. As suggested by Van der Ploeg, this understanding of novelties, which we applied in our study, is very broad and allows us to designate changes of many different kinds as "novelties".

Within the innovation process, as a study of Biggs et al. [45] revealed, institutional support and stakeholder engagement are of crucial importance. Biggs et al. also pointed to the fact that the starting point (trigger) of innovation is usually a specific problem or even a crisis accompanied by the recognition that existing approaches would not adequately address it.

2.2. Analytical Framework to Characterize and Evaluate Innovation in UA

According to Jaeger-Erben [46], the *innovativeness* of alternative social practices describes the degree of change introduced by different practice elements (new meanings, materials, settings, competences) in contrast to the established routines. To grasp, as Jaeger-Erben puts it, this "degree of change", based on an innovation and "innovativeness" assessment that was introduced by Hartmann et al. [42] and Berges et al. [41] and building on the findings of Biggs et al. [45] and Jaeger-Erben [46], we developed our analytical framework (Figure 1).

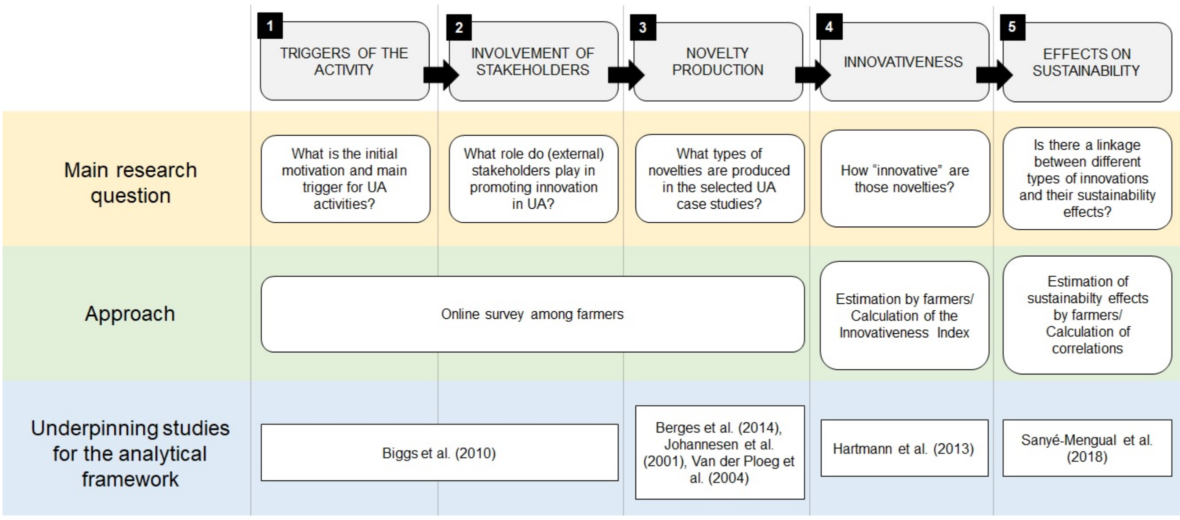

Figure 1. Analytical framework to characterize and evaluate innovation in UA.

(1) In a first step, we identified the "triggers" for innovation in UA.
(2) Second, we assessed the level of involvement of external stakeholders, as suggested by Biggs et al. [45].
(3) Third, based on the social, environmental, and economic novelty categories developed and presented by Berges et al. [41], we surveyed the novelties produced in the case studies.
(4) Forth, we measured the "innovativeness" of novelties by using a refined classification method that assessed novelties [42] as either of the following:

   a. INVENTION, which is defined as the creation of a totally new practice, i.e., a novelty that occurs at the beginning of each innovation process;
   b. ADAPTATION, indicating an existing idea or application adapted to different needs and requirements; and
   c. ADOPTION, denoting an existing novelty taken and applied without any further changes.

The classification of the novelties regarding the level of innovation allowed us to design and implement an innovativeness metric for assessing the level of innovation at the UA-experience level.

(5) Last, a statistical analysis was conducted to explore the links between innovation in UA and sustainability.

3. Materials and Methods

3.1. Case Studies

Eleven case studies from four European countries were evaluated in this study. To represent the heterogeneous development of UA in Western Europe (Table 1), different cases were selected according to their inclusion of the following:

- different social, technological and business innovations;
- diverse UA forms, from community-supported ventures to individual farming activities;
- the use of different spaces of the city, from the peri-urban fringe to rooftop agriculture;
- diverse potential cultivation techniques employed in UA, from organic soil-based UA to soil-less cultivation solutions; and
- different goals, from social inclusion to technological development,

paired with a general willingness to participate in research studies and provide data for the assessment.

The goal in the selection of the sample was to include different types of UA (e.g., rooftop greenhouses and community-supported initiatives). Due to the different scale of the projects (domestic-scale and business-scale), aquaponics was represented in two different cases.

Table 1. By type of innovation, the case study, city, urban space, and main innovation activity of the case studies under assessment.

	Case	City	Space	Main Innovation Narrative
	CASES FOCUSING ON SOCIAL INNOVATION			
S1	Community rooftop garden	Bologna	Roof	Community-managed activity towards community building
S2	Social coop farm	Bologna	Peri-urban	Local and organic production creating inclusive jobs
S3	Community-supported peri-urban farm	Bologna	Peri-urban	Community supported agriculture (CSA) model with prepaid annual membership
S4	Peri-urban farm	Bologna	Peri-urban	Local and organic farming with direct selling to consumers
S5	Home garden	Padua	Urban	Self-sufficiency model
	CASES FOCUSING ON TECHNOLOGICAL INNOVATION			
T1	Peri-urban high-tech greenhouse	Bologna	Peri-urban	Protected soil-less production with integrated heat and water recirculation
T2	Indoor farming	Bologna	Building	Resource-efficient LED production
T3	Domestic-scale aquaponics	Dortmund	Urban	Domestic scale resource-efficient food and fish production
T4	Business-scale aquaponics	Dortmund	Urban	Business scale resource-efficient food and fish production
T5	Open-air rooftop garden	Paris	Roof	Integration of diverse urban wastes in soil production
T6	Integrated rooftop greenhouse	Barcelona	Roof	Integrated flows between the greenhouse and the building

Most of the cases were located in Bologna (Italy), where the core of the scientific project took place, while case studies were also selected in Padua (Italy), Barcelona (Spain), Dortmund (Germany), and Paris (France). In general, the resulting selection of case studies displayed the diverse innovations and the development of UA in different European regions (Figure 2).

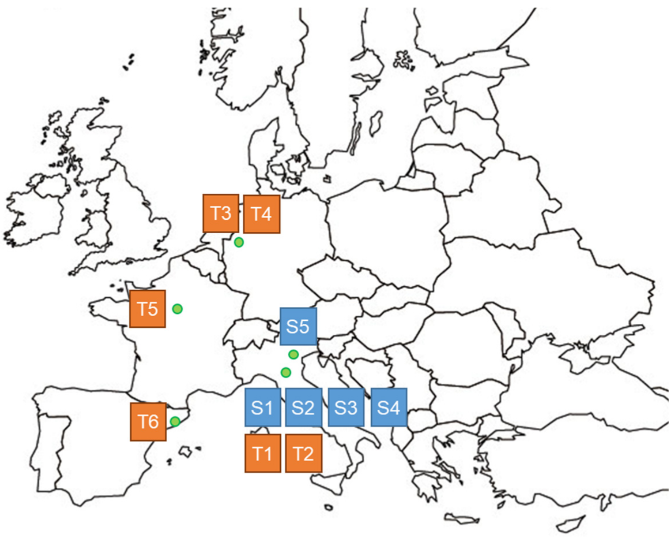

Figure 2. Location of the case studies of social innovations (blue) and technological innovations (orange). The case study number refers to the list from Table 1.

3.2. Data Collection

Data collection was performed in April and May 2018 through a questionnaire answered by representatives (e.g., manager or employee) of each UA initiative. The questionnaires were mainly filled out via an online format. In a few cases in Italy, where the representatives were not comfortable with online tools (due to their older age), the identical questionnaire was filled out in a paper-and-pencil form through an onsite visit. The questionnaire included open, yes/no and scale answers and was divided into three main sections: (a) general description of the activity, (b) novelties within the activity, and (c) sustainability aspects.

The first section 'General description of the activity' explored the trigger that initiated the activity and whether this was a response to a specific problem, whether and how stakeholders were involved and specified the external support to the activity (i.e., legal support, specific program, provision of resources, provision of space, funding programs, others).

In the second part of the questionnaire, we asked the representatives to identify and evaluate the novelties taking place in the UA activity. Here, in this framework, we still follow the broad definition of "novelty" (see Section 2.1): "every change in products, production methods, services or organization can be considered a novelty". Altogether, a total of 22 novelties were presented in the three sustainability dimensions (seven environmental, nine social, and six economic actions). The representatives were asked to identify whether novelties were present in their activity and by differentiating among invention, adaptation and adoption, as defined in Section 2.2, to identify the novelties' level of innovation.

Finally, the survey respondents were asked to identify whether different sustainability aspects (both positive and negative) are observed in their UA activities. The list of sustainability aspects was adapted from the stakeholder-based study of Sanyé-Mengual et al. [15] and included the following: 19 environmental benefits, five environmental risks, 20 social benefits, five social risks, 16 economic benefits, and four economic risks. Due to the completeness of the list of sustainability elements and the involvement of stakeholders in the definition of sustainability aspects, this study was chosen as the basis for assessing sustainability.

Once the questionnaire was designed, four pretests were performed to guarantee the understanding and the completeness of the questionnaire. To ensure the understanding among different profile groups, the pretests were given to the managers of the UA projects, the UA researchers, and the general public. The vocabulary and survey mechanisms were adapted based on the pretests feedback.

3.3. Assessing the Innovativeness of UA Activities

For a UA experience, to assess an activity's innovativeness based on the level of innovation of each of the novelties present in the activity, we designed the Innovativeness Index (InnIn) (Equation (1)). This is based on the innovation level framework in which an innovation can be classified as an invention, an adaptation, or an adoption. The InnIn is the average level of innovation of the novelties occurring in the assessed UA activity per sustainability dimension (environment–*env*, social–*soc*, economic–*eco*). The InnIn considers that the novelties occurring in the three dimensions of sustainability have the same relevance (i.e., a weighting factor of 1/3 is applied for this purpose). For the calculation of the InnIn as a quantitative metric, the level of innovation obtained from the questionnaire response is assigned a numerical value as follows: 3 (invention), 2 (adaptation) and 1 (adoption). This scale has been defined by the authors in order to provide a hierarchy to the levels of innovation and considers a 3:1 value between invention and adoption, thereby providing the same scale distance between the three levels of innovation. Although a higher value ratio could be applied, by its definition, each innovation should be valued individually, as the implementation of a novelty as adoption or as an invention is a specific type of implementation. Therefore, this quantitative scale ranges between 0 and 3, with a value of 0 being less and a value of 3 being highly innovative. In this sense, the higher the value of the InnIn is, the higher the innovativeness of the UA experience.

$$Innovativeness\ index\ (InnIn) = \frac{1}{3}x\left(\frac{\sum_i^n level\ of\ innovation_{env}}{n_{env}} + \frac{\sum_i^n level\ of\ innovation_{soc}}{n_{soc}} + \frac{\sum_i^n level\ of\ innovation_{eco}}{n_{eco}}\right). \quad (1)$$

3.4. Statistical Analysis

To quantitatively analyze the responses of each UA-venture representative, we constructed several new variables by adding positive responses in relevant questions to create a numerical measure of the various aspects. In this way, the following variables were created: diversity of support, number of environmental novelties, number of social novelties, number of economic novelties, total number of novelties, number of adaptations, number of adoptions, number of inventions, innovativeness index, number of positive environmental aspects, number of negative environmental aspects, number of positive social aspects, number of negative social aspects, number of positive economic aspects, number of negative economic aspects, number of positive sustainability aspects, and number of negative sustainability aspects. The statistical analysis consisted of two parts: the development of the descriptive statistics of the variables of interest and the investigation of the relationships between them. To see whether the constructed variables differ significantly by specific aspects and characteristics of the UA interventions, we use a *t*-test [47]. The specific aspects are all coded as binary "yes/no" variables and each *t*-test examines whether any of the constructed variables are higher (or lower) when a specific aspect is present. The correlations between the constructed variables themselves are assessed by calculating the Pearson correlation coefficient and testing its significance by obtaining *p*-values via the asymptotic *t* approximation. The statistical analysis is performed in R software [48], and the level of significance used across all tests is 5%.

4. Results

In this section, the results of the study are shown: for the UA experiences evaluated, we describe the innovations' characteristics, including the triggers and the societal involvement, and assess the level of innovativeness and the resulting positive and negative impacts on sustainability. The significant results from the statistical analysis are integrated into the descriptive statistics results.

4.1. The Triggers of Innovation in UA

The representatives were asked whether the starting point of the UA activity was a response to a problem (Figure 3). On average, according to the information collected, a specific problem was the trigger in 63% of the cases. This percentage was slightly higher for cases related to technological innovation (67%) than for those related to social innovation (60%). The respondents were asked to detail the trigger of the UA activity. On one hand, urban planning and the technological aspects of the agronomic activity were the main issues for originating a technologically innovative experience, as the representatives specified the causes "Lack of green space in the urban environment", "High energy use in indoor cultivation", "Accumulation of urban brownfields", and "Lack of success in urban gardening". On the other hand, some representatives asserted that socially-oriented activities enabled them to tackle socioeconomic issues, such as "Market differentiation from other conventional food suppliers", "Food sovereignty", and the "Lack of social interaction among inhabitants".

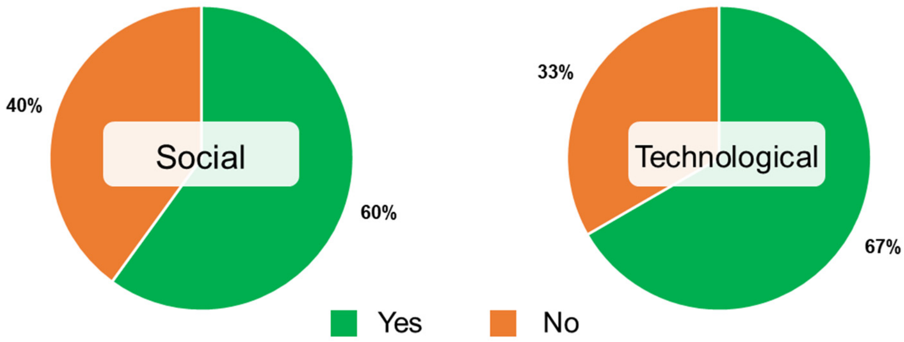

Figure 3. By type of UA activity (social or technological cases), share of UA initiatives that were created as a response to a specific problem.

The statistical assessment unveiled that the UA experiences that were implemented as a response to a specific problem are linked to both a larger number of inventions and a high level of innovation (p = 0.049) (see Section 4.4).

4.2. Stakeholders Involvement and Support for Innovative UA Experiences

To evaluate the involvement of society and external support in the development of UA experiences, the representatives of the cases were asked whether stakeholders have been involved (Figure 4a), what type of stakeholders has contributed to the UA initiative (Figure 4b), and what type of external support has been received throughout time (Figure 4c).

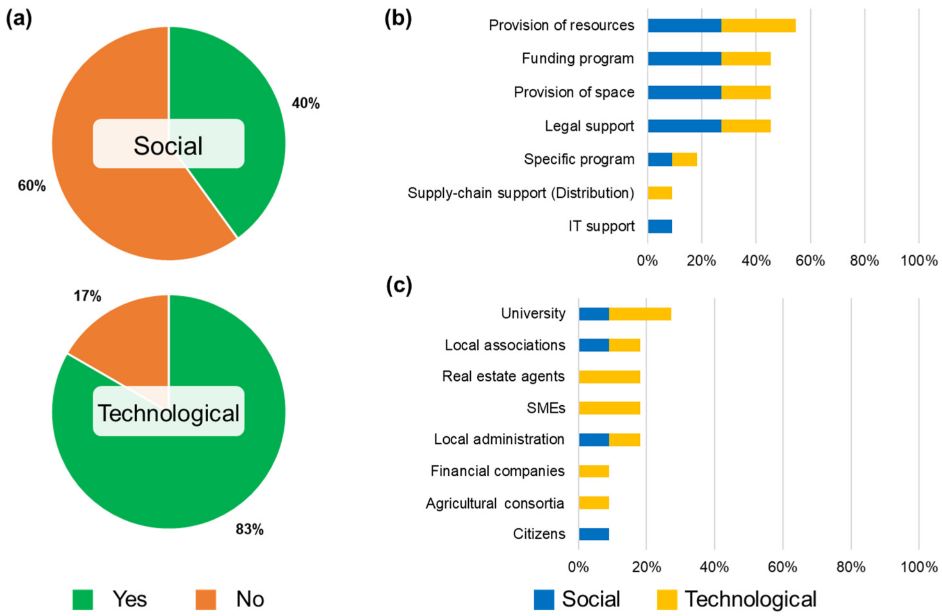

Figure 4. Involvement and external support in social and technological case studies: (**a**) Involvement of stakeholders, (**b**) type of external support received and (**c**) type of stakeholders involved.

Regarding the role of stakeholders and the external support, stakeholders were involved in 64% of the cases. Involvement was higher in the technological experiences (83%) than in the social ones (40%). In the former, higher education institutions, companies, the local administration, and business consortia supported the implementation or development of the UA activity; the local administration, higher education institutions, local associations, and the citizens were mainly involved in social UA activities.

For the development of their experiences, the case studies had different types of external support: the provision of resources was the most common (55% of the cases), followed by legal support (45%), provision of space (45%), and the provision of funding from a program (45%). The least common ones were IT support (1 case) and supply-chain support, where a business consortium was taking care of the distribution of the product (1 case). On average, each UA project received two different types of external support. Social projects received a higher number of external support per case (2.6, on average) than did the technological ones (1.7, on average). Three cases (two technological cases and the home garden) received no support at all.

According to the statistical results, the involvement of stakeholders in UA experiences was related to a higher level of innovation (i.e., number of novelties) (see Section 4.4).

4.3. Novelties Produced in Urban Agriculture

A total of 147 novelties were identified in the 11 case studies, and for each case study, there was an average of 13 novelties (Table 2). The number of innovative actions per UA experience ranged between 5 (S5—home garden) and 20 (S3—community-supported peri-urban farm).

As far as the novelty level is concerned, the most common innovative action among the assessed case studies was the 'Building of capacities, know-how, knowledge' (10 cases), followed by 'New ways to improve the overall resource efficiency', 'New ways to improve the crop efficiency', 'New ways to improve the water efficiency', 'New ways to improve the nutrient use efficiency', 'New ecological practices (e.g., organic, biodiversity)' and 'Introducing new products and practices to urban areas' (nine cases). Among the different environmental novelties tackling efficiency, energy efficiency was the least common in the case studies (six cases) and took place in only one case of the social UA ventures. On the other hand, the least common novelties were 'New ways of "leading"' (two cases) and the 'Remediation (ecological improvement) of urban land' (three cases). In fact, the latter was not present in any of the social UA cases analyzed. The presence of each novelty among the assessed case studies can be observed in Table 2 as well as the proportion of cases where a novelty was present: this proportion ranged from 0.18 and 0.91 (corresponding to 18% and 91%). On average, a novelty was present in 61% of the analyzed UA activities.

Differing between social and technological case studies, the average number of novelties was slightly higher in the technological cases (14.0 per case study) than in the social ones (12.8 per case study). All the social experiences included the novelties 'New ecological practices (e.g., organic, biodiversity)' and 'Building of capacities, know-how, knowledge'. Conversely, 'New ways to improve the overall resource efficiency', 'New ways to improve the crop efficiency', 'New ways to improve the nutrient use efficiency' and 'Development, use and testing of new technologies' were novelties occurring in all the technological cases.

Table 2. Ranked by total value, novelties by case study, typology (social—S; technological—T) and sustainability dimension.

	S1	**S2**	**S3**	**S4**	**S5**	**S**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T**	**Total**	**Average**
New ways to improve the overall resource efficiency	X		X		X	3	X	X	X	X	X	X	6	9	0.82
New ways to improve the crop efficiency		X	X	X		3	X	X	X	X	X	X	6	9	0.82
New ways to improve the water efficiency	X	X	X	X		4	X	X	X	X		X	5	9	0.82
New ways to improve the nutrient use efficiency	X		X		X	3	X	X	X	X	X	X	6	9	0.82
New ecological practices (e.g., organic, biodiversity)	X	X	X	X	X	5	X		X		X	X	4	9	0.82
New ways to improve the energy efficiency			X			1	X	X		X		X	4	5	0.45
Remediation (ecological improvement) of urban land						0	X			X	X		3	3	0.27
Total environmental novelties	4	3	6	3	3	19	7	5	5	6	5	6	34	52	4.73
Building of capacities, know-how, knowledge	X	X	X	X	X	5	X	X	X	X	X		5	10	0.91
New networks	X	X	X	X		4			X	X	X		3	7	0.64
Work and employment experiences (youths and adults)	X	X	X	X		4	X	X			X		3	7	0.64
New/alternative ways of spreading/distributing knowledge	X	X	X	X		4	X				X		2	6	0.55
New services (service novelties)		X	X	X		3				X	X		2	5	0.45
New ways of community life/get-togethers	X		X			2	X		X			X	3	5	0.45
New community spaces	X		X			2					X	X	2	4	0.36
New forms of participation	X		X			2			X	X			2	4	0.36
New ways of "leading"			X			1			X				1	2	0.18
Total social novelties	7	5	9	5	1	27	4	2	5	4	6	2	23	50	4.55
Introducing new products and practices to urban areas	X	X	X	X		4	X	X	X	X	X		5	9	0.82
New options for utilization of urban space	X		X		X	3		X	X	X	X	X	5	8	0.73
Development, use and testing of new technologies		X		X		2	X	X	X	X	X	X	6	8	0.73
New cooperation/alliances for product distribution	X	X	X	X		4	X			X		X	3	7	0.64
Use of set-aside urban areas/brownfields	X		X			2	X	X	X	X	X		5	7	0.64
New economically viable businesses		X	X	X		3	X	X		X			3	6	0.55
Total economic novelties	4	4	5	4	1	18	5	5	4	6	4	3	27	45	4.09
Total	15	12	20	12	5	64	16	12	14	16	15	11	84	147	13.36
Average per dimension	5	4	7	4	2	21	5	4	5	5	5	4	28	49	4.45

All the case studies included novelties in the three dimensions of sustainability. The sustainability dimension where the assessed UA activities showed the largest number of novelties was the environmental dimension (a total of 52 and a mean of 4.73 per case), followed by the social dimension (50, 4.55) and, last, by the economic dimension, in which the smallest number of novelties occurred (45, 4.05). Considering the total amount of novelties per sustainability dimension, the social UA cases showed more novelties in the social dimension (42%, 27 out of 64), while the technological UA cases reflected more novelties in the environmental dimension (40.5%, 34 out of 84) (Table 2). The average number of environmental novelties differed significantly between the technological UA experiences and the social UA experiences (5.8 versus 4, *p*-value = 0.044).

Economic novelties were the least present in social projects (28%, 18 out of 64 total present novelties), while social novelties were the least present in the technological cases (27%, 23 out of 84 total present). Indeed, the only type of novelties with a greater number in social UA ventures than in technological ventures was comprised by social novelties (on average 5.4 social novelties versus 3.8 per case study). The average number of novelties ranged between 2 (S5, home garden) and 7 (S3, peri-urban CSA) per sustainability dimension (Table 2).

The *t*-test results provided evidence for the following statistically significant differences:

- A significantly higher average number of environmental novelties were observed for the study cases that had "New ways to improve the overall resource efficiency" (*p*-value < 0.001), "New ways to improve the energy efficiency" (*p*-value = 0.004) and "New ways to improve the nutrient use efficiency" (*p*-value < 0.001) as environmental novelties.
- Similarly, a significantly higher number of social novelties was shown for the study cases that replied "yes" to questions related to the presence of "New networks" (*p*-value = 0.002), "New forms of participation" (*p*-value = 0.045), "New alternative ways of spreading and distributing knowledge" (*p*-value = 0.023) and "Introducing new products and practices to urban areas" (*p*-value = 0.004).
- The case studies that replied "yes" to questions related to the presence of "New economically-viable businesses" had a significantly higher number of economic novelties than did those that replied no (*p*-value = 0.047).
- A higher number of overall novelties in the UA experience were related to the social novelty "New forms of participation" (*p*-value = 0.018) and the economic novelty "Use of set aside urban areas, brownfields" (*p*-value = 0.027).

This analysis individuates those novelties that reflect a higher number of novelties per sustainability dimension and a higher overall number of novelties. Unlike the descriptive statistics (i.e., statistics that identify the presence of novelties in the different case studies regardless of the total amount of novelties per case study), this assessment identifies those novelties that are common among the case studies and that reflect a higher number of novelties.

4.4. Assessing the Innovativeness of the Novelties

When assessing the innovativeness level and its composition (Figure 5), we see that 'New networks' (4 inventions), 'New ways to improve the overall efficiency' (3), 'New development, use and testing of new technologies' (3) and 'New cooperation/alliances for product distribution' (3) had the highest number of inventions. In contrast, there were no inventions in 'New ecological practices (e.g., organic, biodiversity)', 'Remediation (ecological improvement) of urban land', 'Work and employment experiences (youths and adults)', 'New ways of "leading"', and 'New/alternative ways of spreading/distributing knowledge'.

No novelties were categorized only as adoptions (the lowest level of innovation), but a mixture of adoptions, adaptations, or inventions was found in all the novelties, meaning that UA activities tend to also adapt or invent novelties rather than just adopt novelties present in other examples around the globe. These results suggest that there is room for a higher level of innovation in UA activities: as several novelties were not categorized as invention, the level of innovation found in this sample could be higher. Furthermore, as rather novel urban economic activities, economic sustainability novelties reflected high levels of innovation.

According to the statistical analysis, the UA experiences for which the representatives replied "yes" to the question regarding their ability to obtain support from a "Funding program" had a higher innovativeness index (p-value = 0.040) than those experiences for which representatives replied "no" to the same question. Regarding the relation between the level of innovation and specific novelties, the presence of the social novelty "Use of set aside urban areas, brownfields" was associated with a higher number of adaptations: (p-value = 0.033) and inventions (p-value = 0.049).

When considering the level of innovation of the different novelties taking place, the average innovativeness index (InnIn) was 1.9 (Table 3). InnIn varied between 1.0 (S5—Home garden) and 2.4 (S1—Community rooftop garden and S3—Community-supported peri-urban farm). The range of the innovativeness level was slightly larger within the group of social UA experiences (1.0 to 2.4) than within the technological group (1.7 to 2.1), suggesting a higher variability of innovativeness in social UA ventures.

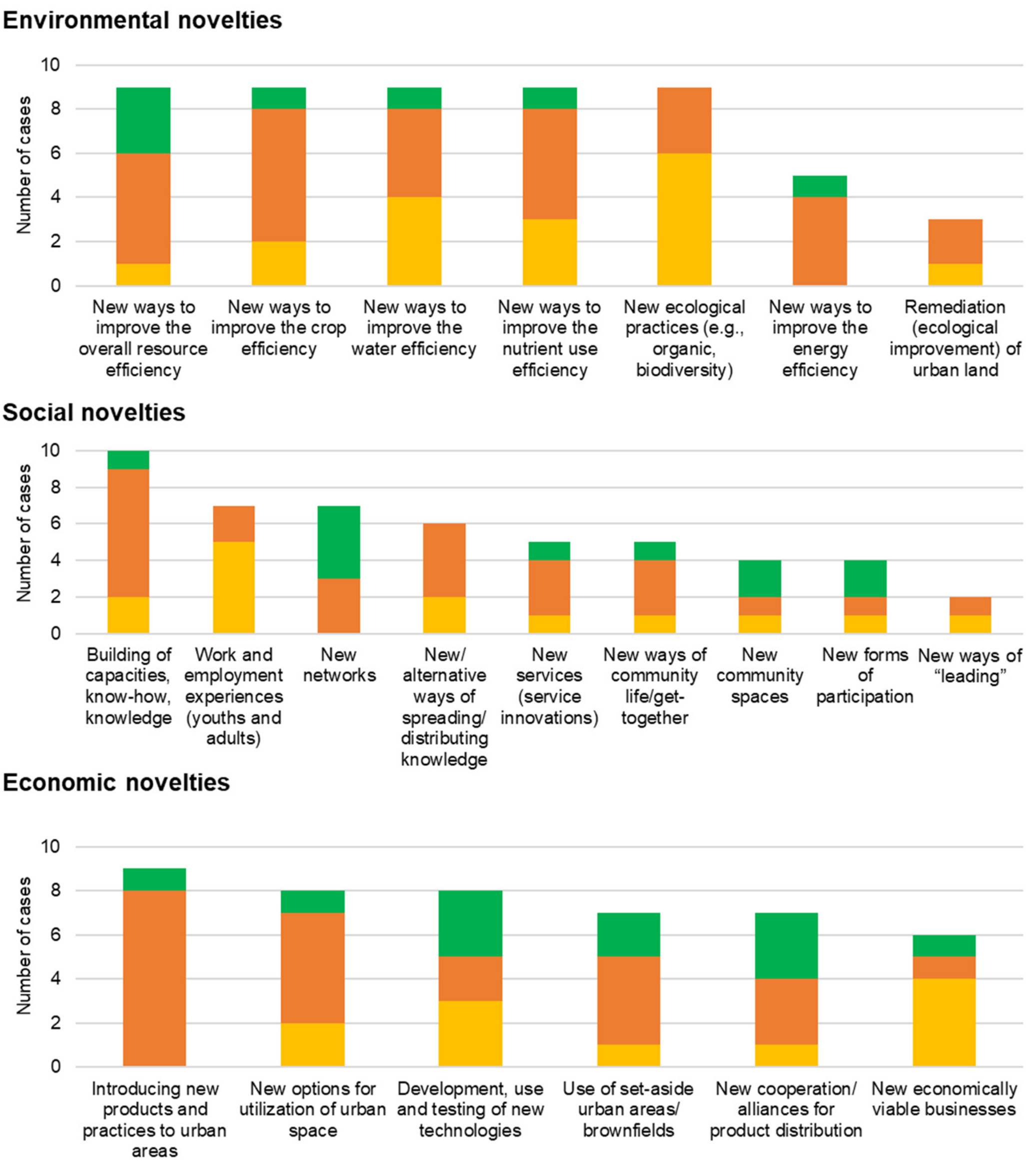

Figure 5. Innovativeness level of environmental, social and economic novelties: invention (green), adaptation (orange) and adoption (yellow).

Table 3. Average level of the novelties' innovativeness by sustainability dimension, innovativeness index (InnIn), and case study. InnIn value ranges from 1 (= not innovative at all) to 3 (= highly innovative).

Case Study		Environmental	Social	Economic	InnIn
Social cases	S1	2.3	2.7	2.3	2.4
	S3	2.0	2.3	3.0	2.4
	S2	1.3	1.8	1.8	1.6
	S4	1.3	1.8	1.8	1.6
	S5	1.0	1.0	1.0	1.0
Technological cases	T2	3.0	1.5	1.8	2.1
	T1	2.0	2.0	2.0	2.0
	T4	1.8	2.0	1.8	1.9
	T5	1.8	2.0	1.8	1.9
	T3	1.6	1.6	2.3	1.8
	T6	1.8	1.5	1.7	1.7
Average		1.9	2.0	2.0	1.9

In two instances, namely, the case for the economic dimension for S3 (Community-supported peri-urban farm) and the environmental dimension for T2 (Indoor farming), all of the case study's novelties occurring in one sustainability dimension were classified as inventions: therefore, the average level of innovation for the sustainability dimension in these cases was 3. In contrast, all the novelties of S5 (home garden) were classified as adoption.

Among the sustainability dimensions, the social (2.0) and economic (2.0) dimension had a slightly higher average innovativeness than did the environmental one (1.9). Twenty-four percent of the economic novelties were classified as inventions (i.e., the highest level of innovation), while only 13% of the environmental novelties were inventions. However, 55% of the environmental novelties were adaptations where novelties were adapted to the specific context of the experience (i.e., middle level of innovation). Adoptions (i.e., the lowest level of innovation) were more characteristic of the environmental dimension (32%) and the social one (28%) (Figure 5).

The overall number of novelties (p-value = 0.027), the number of adaptations (p-value = 0.033), and the number of inventions (p-value = 0.049) are higher in the cases with stakeholders' support. Those UA activities with the presence of social novelties such as "New networks" (p-value = 0.018), "Work and employment experiences" (p-value = 0.049), or "New alternative ways of spreading, distributing knowledge" (p-value = 0.008), as well as of the economic novelty "Introducing new products and practices to urban areas" (p-value = 0.049), were associated with a higher average number of types of support provided than were those UA activities without these novelties. In contrast, less diversified support is evident in the presence of the environmental novelties ("New ways to improve the overall resource efficiency", a p-value = 0.005; New ways to improve the nutrient use efficiency, a p-value = 0.050).

4.5. Boosting Sustainability through Innovation in Urban Agriculture

The representatives were asked to indicate whether different sustainability benefits and risks were associated with UA activities. A statistical analysis was used to explore the links between innovation in UA and sustainability. Figure 6 displays by sustainability dimension, the specific sustainability benefits or sustainability risks identified in each case study.

Figure 6. Frequency of case studies showing specific sustainability aspects by sustainability dimension. Blue bars represent the positive aspects (benefits), while orange bars represent the negative ones (risks).

More environmental benefits were associated with the case studies than were social and economic ones. On average, each case study provided seven environmental benefits, 5.8 economic ones and 5.7 social ones. Within the environmental dimension, in all the case studies, representatives declared that they were increasing the resilience of the environment (in terms of improved knowledge and food production capacity). Among the assessed UA activities, the 'Reuse of spaces' (10 cases), 'Reduced food transportation' (nine cases), 'Increased biodiversity and habitat for pollinators' (eight cases), 'Microclimate regulation' (eight cases), 'Increased resource efficiency' (eight cases), and 'Reduced carbon emissions' (eight cases) were the most common environmental benefits. Conversely, the least common environmental benefit was denoted by 'Reduced paved areas' (three cases).

On the social dimension, all the representatives indicated that their UA experiences increased their knowledge of agri-food systems and sustainability. 'Training opportunities' and 'Improved access to healthy food' (10 cases), as well as 'Increased consumption of fruits and vegetables' (nine cases) were the other most common social benefits provided by innovative UA experiences. However, only one case highlighted 'Increased the neighborhood's safety' as a benefit of the UA experience.

Finally, concerning economic aspects, the 'Development of food short-chains' (nine cases), 'Reduced costs due to self-production' (eight cases), the 'Diversification of the local economy' (eight cases) and 'Employment opportunities' (eight cases) were the most mentioned economic benefits. None of the cases indicated that the 'Reduced costs due to environmental externalities (subsidies, taxes)' was a benefit: this was probably due to the lack of related environmental policies that monetize such benefits.

In terms of risks (i.e., negative impacts on sustainability), the highest number of risks was associated with the economic dimension. On average, while posing only 1.6 environmental risks and 1 social risk, each case study posed more than three economic risks. The most common economic risk was the 'High price of products' (six cases). On the environmental dimension, 4 cases were concerned about the 'Large water consumption' related to their crops. 'Health risks (e.g., pollution)' and 'Implementation without considering the local context' were the most present social risks (two cases each). None of the UA activities identified 'Social exclusion' and 'Land access disparities (injustice in distribution)' as social risks.

Finally, the statistical assessment outlined the association between the presence of specific sustainability aspects and the positive and negative aspects of environmental, social and economic sustainability, as well as of the overall sustainability. In general, the presence of the following aspects, namely, "Increased biodiversity, habitat for pollinators" (p-value = 0.017), "Reduced air pollution" (p-value = 0.048), the "Creation of green barriers, pollution" (p-value = 0.003), "Microclimate regulation" (p-value = 0.003), "Soil preservation" (p-value = 0.005), "Carbon sequestration" (p-value = 0.030), "Community cohesion and development" (p-value = 0.032), "Community self-organization" (p-value = 0.042), "Cultural exchange" (p-value = 0.004), "Maintenance of cultural heritage" (p-value = 0.009), "Improved mental health" (p-value = 0.048), "Economic stability" (p-value = 0.001), and "Reduced costs due to self-production" (p-value = 0.018), were shown to be related to higher levels of sustainability (i.e., higher number of positive sustainability aspects).

Conversely, the presence of other sustainability aspects, namely, "Urban regeneration" (p-value = 0.039), "Business opportunities" (p-value = 0.010), and "Ethical work" (p-value = 0.042), were found to be related to a higher number of negative sustainability aspects. However, the presence of the "Development of short food chains" as a positive environmental aspect in the UA projects is linked to a significantly lower number of negative sustainability aspects (p-value = 0.031). A detailed assessment by the sustainability dimension is included in Appendix A.

In total, 341 sustainability benefits were identified by the assessed case studies, while only 26 risks were observed (Table 4). Thirty-nine percent of the benefits targeted environmental sustainability, 33% targeted social sustainability, and 28% targeted economic sustainability. Thus, the contribution to sustainability was quite balanced among the three dimensions. However, the distribution of the sustainability risks generated by the UA experiences was more unequal, as 50% of them were economic risks.

Table 4. By case study, sustainability benefits and risks by sustainability dimension and overall sustainability. Benefits-risks ratio is shown at the overall sustainability level (B/R ratio).

Case Study	Environment		Society		Economy		Sustainability		
	Benefits	Risks	Benefits	Risks	Benefits	Risks	Benefits	Risks	B/R Ratio
S1	13	0	16	0	3	1	32	1	32.0
S2	15	1	13	0	13	2	41	3	13.7
S3	15	0	18	0	14	0	47	0	-
S4	16	1	12	0	14	2	42	3	14.0
S5	12	0	7	0	3	0	22	0	-
Total social UA cases	71	2	66	0	47	5	184	7	26.3
T1	15	0	10	0	9	0	34	0	-
T2	10	0	5	0	9	1	24	1	24.0
T3	7	0	12	1	7	3	26	4	6.5
T4	5	1	6	0	9	2	20	3	6.7
T5	13	2	11	2	4	0	28	4	7.0
T6	13	3	4	2	8	2	25	7	3.6
Total technological UA cases	63	6	48	5	46	8	157	19	8.3
Total	134	8	114	5	93	13	341	26	13.1

At the case study level, S3 (community-supported peri-urban farm) was the experience providing the largest number of sustainability benefits (47), followed by the other two social activities: S4 (peri-urban farm) (42) and S2 (peri-urban social cooperative) (41). With reference to risks, the activity that posed larger risks to sustainability was T6 (integrated rooftop greenhouse) (total number of risks of 7). However, when one considers the trade-off ratio (benefits/risks), the activities least beneficial were the technological ones: T3 (domestic-scale aquaponics), T4 (business-scale aquaponics), and T5 (open-air rooftop garden) (benefit-risk ratios of 6.5, 6.7 and 7.0 respectively). Differentiating between social and technological activities, the average number of sustainability benefits per case was 40% higher for social projects than for technological ones (36.8 versus 26.2 benefits).

4.6. Unveiling the Link Between Innovation and Sustainability

The results of the questionnaire were statistically analyzed to observe the relation between the innovations of the case studies (in terms of the diversity of support, the number of environmental novelties, the number of social novelties, the number of economic novelties, the total number of novelties, the number of adaptations, the number of adoptions, the number of inventions, and the innovativeness index) and the sustainability aspects found in each case study. For the analyzed sample, some significant differences, which indicated relationships between sustainability aspects and external support, innovation and innovativeness, were unveiled (Appendix C).

To observe the overall association between innovation and sustainability, Pearson correlation coefficients were calculated for the main constructed variables (e.g., the total amount of novelties implemented per UA experience). Five key messages regarding innovation in the evaluated UA projects and its relation to sustainability aspects emerged from the statistically significant correlations (see Appendix D, Table A1):

- The relationship between innovativeness and environmental, social and sustainability aspects is statistically significant (as a larger number of negative aspects is evident when the InnIn is higher). On the other hand, no statistically significant correlation was observed between negative economic aspects and innovativeness.
- Innovation in the social dimension of sustainability is the only dimension showing a significant correlation with positive social aspects and overall sustainability aspects (Pearson's r equal to 0.88 and 0.62, respectively).

- Environmental innovation is statistically significantly correlated with economic innovation (Pearson's r = 0.62).
- Adaptation is shown to be statistically correlated with the number of environmental novelties (Pearson's r = 0.61), social novelties (Pearson's r = 0.69), economic novelties (Pearson's r equal to 0.65) and the total number of novelties (Pearson's r = 0.84). Therefore, the greater the number of adaptations applied by a UA project is, the larger the number of overall novelties implemented.
- Finally, negative environmental aspects are statistically significantly correlated with social negative aspects (Pearson's r = 0.77).

5. Discussion

5.1. Innovation in UA

In everyday discussions and in media portrayals, UA is often addressed as something "new" and "innovative", even though not each and every component or practice applied in UA projects is actually new. Even if the general approach of a UA project has already been applied in previous cases (such as other CSAs or rooftop farms), two important issues need to be considered when thinking about newness or innovation. The first one is that even if the approach is not new per se, there is still "a new way of doing or thinking" and a specific way of managing it for those who apply it. New practices were consequently a novelty to the interviewees and were therefore also designated as such by them. The second thing is that even if the general idea of a project may not be new (such as establishing a rooftop farm), it may still contain innovative elements. Those novelties within the project and the sum of novelties produced within a project build the core of the innovation.

As our analysis has revealed, a high number of novelties were produced within the investigated UA projects, and we even showed that some of these novelties could be characterized by a very high level of "innovativeness" (e.g., having a level of innovation characterized as an invention). This confirms the findings of Berges [49] who concluded that UA is not an innovation in its entirety but that the different types of UA have very innovative elements. Berges et al. [41] further described innovativeness as a direct outcome of the need to adapt to the specific spatial, economic, ecological, and social conditions in urban spaces.

Regarding innovation, we found that the conditions for the cultivation and the marketing of products in UA are so different from those in rural agriculture that the UA operators have to invent new practices. This view on innovation in UA is also in line with the findings of Pfeiffer et al. [8] and Prain and De Zeeuw [9], who also detected that techniques and procedures from rural agriculture cannot be simply transferred to urban environments, creating the need for innovation. Innovation in UA, therefore, includes a great deal of testing, experimenting, and failure.

Our study further illustrates that the produced novelties entail all kind of routines, behaviors, and practices throughout all three dimensions of sustainability. This follows the view of Johannesen [43] and van der Ploeg [44], according to whom innovation is not only technological innovation but goes far beyond that. According to Opitz et al. [40], new products, concepts, and practices can be understood as an expression of innovation processes in UA. Confirming Biggs et al.'s [45] theoretical considerations on innovation, our results also point to the fact that the starting point (trigger) of innovation is usually a specific problem. As Berges et al. [49] formulated: "Space, water, energy and nutrients are precious goods in our society, especially from a sustainability perspective". Much of the attempts of our investigated UA cases dealt with overcoming shortages, while novelties were developed to better address those needs.

5.2. Delving into the Most Common Novelties in UA

Environmental novelties are widely used in UA initiatives, which usually promote a local and green marketing identity to differentiate these novelties from conventional options. For example, aquaponics companies often claim that the nutrient recirculation for plant cultivation in their aquaponics system avoids the toxic environmental run-off that characterizes current aquaculture practices (e.g., Oko Farms, New York, USA, http://www.okofarms.com/). The most common environmental novelties in the case studies were new ways to improve efficiency (focusing on overall resources, crop, water, or nutrient use) and new ecological practices (e.g., organic, biodiversity).

Most of the cases focused on increasing overall resource efficiency and involved introducing a local food product with a minimized supply-chain and improving the economic cost-benefit balance of the activity by enhancing the implementation and the efficiency of crop management techniques. In terms of crop efficiency, the integrated rooftop greenhouse (T6) enlarges the crop period for summer products (e.g., tomatoes), as the location of the greenhouse on the top of a building and the use of the building's residual heat for the greenhouse ensures viable year-round temperatures for producing the crop without additional energy input [35]. Furthermore, the integrated rooftop greenhouse (T6) employs rainwater harvested on the roof of the building to satisfy the water demand of the crop [29]. Regarding water efficiency, the two aquaponics case studies (T3 and T4) are also an example of a novelty that boosts water efficiency by combining the water flow for two systems, i.e., crop production and aquaculture, thereby decreasing the overall water demand of the two systems [30,50].

Increasing the nutrient use efficiency was a novelty shared by multiple cases. The combination of aquaculture and hydroponics in aquaponics (T3 and T4) leads to improved nutrient use efficiency, as wastes in the water outflow from the fish production are assimilated by the plants as nutrients. Beyond this opportunity, aquaponics offers the chance to close the water metabolism and recirculate the water outflow from hydroponics back to aquaculture. However, this circular system fully benefits the water cycle rather than the nutrient one, as water from hydroponics needs to be treated to eliminate nutrient residues before being used in the aquaculture production [35]. Indoor farming using LED lighting (T2) also enhances nutrient use efficiency by optimizing the plant metabolism through specific red-blue light ratios [51,52]. The most efficient experience assessed in this paper is the community-supported peri-urban farm (S3), which employs a crop rotation cycle leading to a 0 requirement of nutrients beyond the natural cycles. In this sense, the community-supported peri-urban farm (S3) is also one of the examples of the implementation of organic and ecological practices that build on the reciprocal interactions in the soil-plant ecosystem. To satisfy the nutrient demand of the crops, other case studies reflected the use of organic fertilizers, such as the use of manure in the peri-urban social cooperative (S2) or the peri-urban farm (S4) or the use of urban compost in the open-air rooftop garden (T5) [16,17].

Social novelties associated with the building of capacities, know-how or knowledge were found in all the case studies except the home garden case study. In the different cases under assessment, the knowledge arising from the experience was shared with other stakeholders: this is a common output from UA initiatives [53]. In some of the activities, such as the open-air rooftop garden (T5) or the community rooftop garden (S1), a large involvement of universities led to experimentation (new knowledge generation) and training opportunities for students. Other activities, such as the peri-urban high-tech greenhouse (T1) or the community-supported peri-urban farm (S3), offered onsite visits to citizens or specific professional groups. Finally, some experiences, such as the peri-urban farm (S4) and the peri-urban social cooperative (S2), involved an engagement with the general public in debates on the food system in cities or meet-the-farmer events.

The novelty of creating networks was already pointed out by Opitz et al. [40], where linkages were not only considered with city-wide groups of urban agriculture activists but also with networks with a specific purpose (e.g., surplus food distribution, donations and bartering, community building and knowledge exchange). In the evaluated cases, the peri-urban farm (S4) performs direct marketing, while also participating in a local food producer network that allows them to join farmers' markets, food fairs and meet-the-farmer events. This type of network enables the peri-urban farm to spread the knowledge of their brand and their products among citizens (i.e., potential new customers), while also enabling them to receive feedback from consumers and to exchange knowledge and experiences with other local farmers. The peri-urban social cooperative (S2) and the community-supported peri-urban farm (S3) are members of "campi aperti"("open fields"), a network of farmers and plant growers that self-organizes farmers' markets in capitalism-resistant spaces of the cities (e.g., squatted spaces, public areas) and that also promotes alternative values, such as fair trade and social inclusion, which are beyond those embraced by local food supply-chains. The domestic-scale aquaponics case (T3) was promoted by a local association that works to enhance the multicultural, creative and active use of the public space and that is part of a network of stakeholders involved in the decision-making around the public space of cities (e.g., local administration, architects, local farmers). The mentioned networks are comprised of not only farmers but also multiple stakeholders and citizens that are activists in urban movements. Belonging to a different type of network, other cases, such as the LED indoor farming (T2) or the peri-urban high-tech greenhouse (T1) cases that interact with other companies or researchers linked to the specific crop technology under use, are part of strictly professional networks.

Finally, another common social novelty was the generation of work and employment experiences (for both youth and adults), which is a common aspect of professionalizing UA [53,54]. The peri-urban social cooperative (S2) mainly employs the population at risk of social exclusion (e.g., drug addicts and former convicts) and youth. The peri-urban farm (S4) was created by just-graduated agronomists, and the new job opportunities have also promoted the inclusion of new graduates looking for their first professional experience in the job market.

Concerning the economic dimension, most of the cases claimed to be introducing new products and practices to urban areas. Beyond the provision of food as a product, most of the UA experiences offer services as a way to differentiate their activity (e.g., equestrian services, room rental and sports activities, gastronomy services) [54]. The peri-urban social cooperative (S2) has developed the Spazio Battirame (Battirame space), where a restaurant, a training school, meeting rooms and a handcraft workshop space are hosted. In addition, the Spazio Battirame has been used for the hosting of food-related events, such as cooking workshops, a recurring farmers' markets and thematic dinners. The peri-urban farm (S4) was not the first UA company to offer home-delivered vegetables and fruits boxes in Bologna, but they differentiated themselves with a service that included a free-choice basket composition and a guaranteed morning-harvested and afternoon-delivered service. As an alternative to the mainstream capitalistic system, the community-supported peri-urban farm (S3) offered their members a new way of producing food in cities.

Some of the cases reflected innovation in the way the urban space was utilized. The recent development of UA has included new urban food production forms, such as the integration of agriculture in and on buildings [14,55]. In Bologna, several UA experiences were deployed by the city council or developed by the citizens to regenerate urban spaces [56]. Some of the assessed experiences take place on roofs (S1, T5, T6) and within greenhouses (T2, T3, T4). The latter systems can be designed to be performed within buildings, such as former warehouses (i.e., indoor farming). In the case of LED farming (T2), the case simulated a greenhouse in a real indoor situation (i.e., closed growing boxes that could be placed inside of buildings). The two aquaponics systems required LED lighting to perform within a building with the same efficiency, as the cases were originally developed within a greenhouse. These experiences, such as the two aquaponics systems (T3, T4) or the LED indoor farming (T2) project, are also related to the development, use and testing of new technologies.

5.3. Contrasting the Evidence of the Most Frequent Sustainability Aspects of Innovative UA

Concerning the sustainability aspects linked to the UA experiences evaluated, the literature generally supports those aspects that were also in the present study more common, i.e., taking place in six or more cases (Figure 6). Regarding environmental benefits, an increased environmental resilience due to life-long learning was identified as a strength of the UA experiences in Bologna [56]. Additionally, UA was indicated as a potential urban strategy for food production and self-sufficiency not only at the household level [57] but also at the city level [58]. In recent decades, the reuse of spaces has been highlighted in renewed UA activity where new and unused spaces of the city, such as rooftops and indoor spaces of buildings or their facades [13], including not only residential buildings but also industrial parks [59] or retail parks [60], have been adapted to food growing. Previous research compared the use of rooftops for food production and photovoltaic energy production and highlighted that when producing electricity, the environmental benefits could be 6.6 times higher in terms of savings of greenhouse gas emissions [61]. However, this study only focused on the environmental dimension, and further research including the economic and social dimensions would provide data to shed further light on this debate. In fact, some UA experiences on roofs combine food production and photovoltaic systems to satisfy the energy demand of the activity [59]. Reduced food transportation and reduced food waste were highlighted as a benefit in studies employing life cycle assessment (LCA), where the entire supply chain of products is evaluated [61,62]. Depending on the type of UA, the product and the agronomic practices, such reductions result in the decrease of the environmental impact in the LCA indicators related to carbon emissions and air pollution associated with the food product [15,25,62,63]. However, the logistics of UA can lead to less efficient distribution models (e.g., smaller truck capacity, consumer transportation to the farm or to the pick-up point), and the environmental benefits depend on the logistics model implemented in each specific case [64]. Highlighting the positive aspects of the vegetative structure, the inclusion of diverse native plants and the re-naturalization of urban areas for sustaining biodiversity and pollination ecosystem services, Lin et al. [65] reviewed the literature regarding biodiversity and UA. Gasperi [66] evaluated how a rooftop garden in Bologna could improve the microclimate conditions and the resulting comfort of humans. Sanyé-Mengual et al. [60] assessed how rooftop agriculture with greenhouses can be coupled with rainwater harvesting to not only cultivate water self-sufficient crops but also to improve rainwater drainage systems. Although the employment of organic waste in UA depends on the agronomical practices, Grard et al. [34] demonstrated that the potential use of urban organic waste as a substrate for UA could also enhance the urban circular economy. Orsini et al. [58] highlighted the role of UA in increasing urban green areas (i.e., by transforming built rooftops into green gardens) and in implementing ecologic corridors, since new urban green spaces would be able to connect large external green areas in the outskirts with small urban parks and gardens within the city. However, the literature has not provided data on how UA improves the management of the territory. Moreover, although carbon balances were considered in the LCA studies of UA, due to the short life cycle of food and the emission of carbon when food is digested or when plant residues are managed, carbon sequestration was not included. Although the sustainability role of carbon sequestration and been demonstrated in urban parks [67], this sustainability aspect has not yet been quantified and demonstrated for UA.

Large water consumption was the most frequently mentioned negative environmental sustainability aspect. Water requirements strongly depend on the cultivation technique implemented in UA [25]. Although direct water consumption in the garden can be larger than that in conventional agriculture (i.e., where the economy scale allows for adopting improved technologies), the overall water use along the supply chain can result in a better water balance. In addition, rainwater harvesting can be integrated into UA systems, thereby reducing the water consumption requirements [25,60,62]. Furthermore, compared with traditional open-field or greenhouse production systems, urban indoor growing systems may present increased water usage efficiencies. McDougall et al. [68] also highlighted the need for UA projects to properly manage other resources beyond water (e.g., energy, chemicals) in order to be environmentally efficient activities.

Regarding the social dimension of sustainability, the existing literature reveals the contribution of UA to an increased knowledge of agri-food systems and sustainability [40,69], including the role of school gardens [69,70] and the associated training opportunities [53] (e.g., community gardens [71]). Several studies have proved that engaging in UA improves the access to healthy food as well as the consumption of fruits and vegetables [72–74], while positively contributing to the mental health of the participants [75,76]. Providing improved access to affordable food, UA has a positive role in low-income communities, in food deserts and in the context of economic crises [77,78]. The engagement in UA experiences by citizens from different cultural backgrounds enhances the cultural exchange among individuals [79–81]. The food production spaces in cities are also valued as new areas of recreation for citizens [82–84]. Finally, the business potential and the professional opportunities of UA initiatives are linked to self-employment [54].

Regarding the negative aspects in the social dimension, health risks can arise from soil contaminated by previous uses [85]; however, these problems can be solved through the use of raised beds and cultivation media or through rooftop gardening [86,87]. The fact that the "remediation of urban land" is one of the least common novelties may indicate that there might be low concern or knowledge of soil pollution. Even though soil contamination is generally acknowledged as one of the major health risks in UA, there seem to be minor efforts to address this specific issue in the cases displayed in this study. Furthermore, UA implementation without considering the local context was highlighted as an issue in the UA experiences in Bologna, where the low involvement of stakeholders in the design and implementation was considered as a weakness [56].

The positive sustainability aspects associated with the economic dimension have been less evaluated in the literature. Due to a higher proximity between producers and consumers, the development of short food supply chains is an identity of UA. In fact, the direct marketing of short supply chain food products has been a way to differentiate UA projects from conventional food supply chain projects [54]. UA is also related to business and employment opportunities [13,53,54,88]. The enhancement of innovation has been evaluated in some studies [8,40,89], which have highlighted how UA activities need to adapt to the urban environment and to focus on looking for alternative ways to reach consumers in order to avoid the economic competitiveness within the conventional market. Finally, reduced costs due to self-production depend on crop management and the crop species [25,57]. Although no studies have evaluated the diversification of the local economy as a whole, a research study on the business models of professional UA activities has highlighted the diversification of the activities not only in terms of products but also of services [54]. Furthermore, the role of UA in boosting the local economy, the ethical quality of UA jobs, and the cooperation (sharing production factors) between UA activities has not yet been assessed. Moreover, the literature has not yet quantified the reduced costs related to food waste prevention and the healthy food provision (i.e., the public health system's economic benefits due to a healthier diet and the improved mental and physical health of gardeners) associated with UA.

The main negative aspect within the economic dimension was the high price of urban food products. The price strongly depends on the production costs, whose dependence on the available technologies, products, and climatic conditions [25,57,62] may limit the viability of UA activities. The strong price pressure of the food market was indicated by Pölling et al. [54] as a driver for adaptations in UA professional activities (e.g., specialization, diversification, differentiation) but also as a cause for a decreased number of urban farms in the last decades.

5.4. Limits and Shortcomings of the Study

Relying on 11 selected case studies, our analysis can be read as a seminal study, which may not represent the entirety of UA. The study results rely on single cases, which are influenced by specific impeding and supporting local frame conditions. The statistical assessment aimed to unveil significant differences and relationships within the analyzed sample. However, due to the limited size of the sample and the sampling method (i.e., convenient sample), no generalization of the results can be extended to UA in general or to the entire region of Western Europe. To do so, a random sampling from an extensive list of UA projects and a larger sample would be required.

Another limitation may lie within the framework employed in this study itself. First, the evaluation of the innovativeness grade of the novelties and the sustainability effects of the UA activities might be subjective evaluations based on the perspective of the representative of the activity. Further research might perform an objective evaluation, such as including an experts' judgment, to contrast the results. Second, when setting up the risk/benefit ratio, one major weakness was that risks and benefits were not offered in an equal share, as from the beginning, the benefits outnumbered the risks. Thereby, we unintendedly created a bias leading to an expectably higher number of benefits compared to the number of risks. Third, as we applied a very broad definition of novelty ("new ways of doing or thinking") (see Section 2.1), many things, which in an everyday understanding may not have been labeled as a novelty, were labeled as novelties.

In this study, the applied statistical analysis allowed the formation of conclusions on significant differences and trends, although the findings based on the limited sample used for data collection should be further confirmed by use of a larger survey that would enable the application of the hereby developed methodology to a larger population of UA experiences.

Finally, further studies of different types of UA activities (e.g., business-scale rooftop farms) and in different regional areas (e.g., North America) might shed further light on the innovation and sustainability effects of UA experiences at the global scale. Moreover, the objectives targeted by UA activities in cities in the Northern part of the world vs. those targeted by UA activities in cities in the Southern part of the world [90] may substantially alter the associated innovation potential. Consistently, the variability in the access to technologies and agricultural input in the different World regions as well as the main functions that are locally associated with UA (ranging from food production and income generation to social and environmental objectives) will call for different innovations.

6. Conclusions

The analysis of the initial motivation and main trigger for UA experiences revealed that most UA experiences were started to overcome urban planning, agronomic, and socioeconomic problems occurring in cities. Highlighting the relevance of UA in contestation and resilience, in more than 60% of the cases, the trigger resulted from a response to a specific problem [81]. The stakeholders' involvement (including universities, local associations, real estate agents, local administration, SMEs, financial companies, agricultural consortia and citizens) was high in the UA activities (over 60%) and was mainly focused on the provision of resources, legal support, space (45%), and funding. The involvement of stakeholders in UA experiences was related to a higher level of innovation, i.e., a larger number of novelties and the funding support was associated with a higher innovativeness index.

Regarding the characteristics of the novelties taking place in the assessed case studies, innovation was more intense in the environmental and social dimensions of sustainability than in the economic one. Achieving efficiency (including crop, water, and nutrient use efficiency), implementing ecological practices, capacity building (know-how, knowledge), and introducing new products and practices to urban areas were the most prevalent novelties among the UA experiences. Innovation in terms of the number of novelties was however very variable between UA activities. In this study, the number of novelties varied between 5 (home garden) and 20 (peri-urban community-supported farm). Differentiating between technological and social experiences, the average number of novelties was slightly higher in the former, where environmental novelties were the most relevant. Finally, the results showed a correlation between environmental and economic novelties, suggesting their link, particularly in technology-oriented cases, when implementing innovations in UA.

The developed Innovativeness Index (InnIn) that considers the level of innovation of each individual novelty (classified as invention, adaptation, or adoption) allowed evaluating the innovativeness of the UA activities. It was based on a scale from 1 (lower innovativeness) to 3 (high innovativeness). The average InnIn was 1.9, ranging between 1 (home garden) and 2.4 (Community rooftop garden, Community-supported peri-urban farm). The social cases showed the highest values of innovativeness but also had the largest variability within the group. Community-supported experiences and high-tech solutions (e.g., indoor farming) showed the highest levels of innovation. Among the different sustainability dimensions, the largest share of inventions (i.e., the highest level of innovation) (24%) were reflected in economic novelties. At the case study level, adaptations (i.e., second level of innovation) reflected the largest number of novelties (i.e., higher innovation)

There is a link between innovation and sustainability, as the results from the statistical assessment unveiled. Innovativeness had a significant positive effect on sustainability, with the exception of the economic dimension. Innovating in the social dimension was associated with positive social and sustainability aspects. There was a correlation between negative environmental and social aspects, suggesting that trade-offs can take place when only economic goals are pursued in UA.

Regarding policy-making and planning, the urban policy-making actors have a key responsibility to develop wise strategies for the future and to react to the challenges posed by climate change. As our study showed, UA has the potential to serve as a cornerstone to meet these future demands. Policy-making further needs to develop guidelines to guarantee food supply, social justice and the careful use of natural resources. Our study revealed that UA has the potential to contribute to positive changes, which are moreover driven by an engaged, involved and active civil society. To unfold its full potential, UA needs to be included as a key part of relevant urban development strategies and concepts. UA should be integrated as a key element in policies, such as in the food planning, water efficiency, energy efficiency, education, health, and biodiversity policies. If UA obtains that type of institutional support and backup, the civil society actors could even assume responsibility in sustainable urban governance and planning and play a central role in making future cities more sustainable.

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Ethics Statement: The questionnaire addresses facts of the activity, and the respondents were representing the activity as representatives rather than as individuals. Furthermore, the results were displayed in an anonymous way. The respondents were informed about the scope of the study and were given the opportunity to finish the questionnaire at any time.

Appendix A Statistical Results—Sustainability Aspects per Sustainability Dimension (*t*-Test)

In addition to the results presented in the main text, several other statistically significant relationships were evident:

- Positive environmental aspects, namely, "Increased biodiversity, habitat for pollinators" (p-value = 0.033), "Creation of green barriers, pollution" (p-value = 0.020) and "Soil preservation" (p-value = 0.010), were present. The positive social aspects, namely, "Social inclusion" (p-value = 0.046) and "Maintenance of cultural heritage" (p-value = 0.027), and the positive economic aspect "Economic stability" (p-value = 0.023) were linked to a higher average number of positive environmental aspects. The UA projects that did not identify "Limited wage" as a risk had a higher average number of positive environmental aspects (p-value = 0.036).
- The presence of the positive environmental aspect "Reduced food transportation" (p-value = 0.035) and of the positive economic aspects, namely, "Employment opportunities" (p-value = 0.047) and "Business opportunities" (p-value = 0.047), were associated with a higher average number of negative environmental aspects.
- Positive environmental aspects, namely, the "Creation of green barriers, pollution" (p-value = 0.003), "Microclimate regulation" (p-value = 0.005), and "Carbon sequestration" (p-value = 0.039), were present. The positive social aspects, namely, "Community cohesion and development" (p-value = 0.002), "Creation of community places" (p-value = 0.027), "Community self-organization" (p-value = 0.006), "Cultural exchange" (p-value < 0.001), "Maintenance of cultural heritage" (p-value = 0.007), "Increased physical activity" (p-value = 0.019), "Improved mental health" (p-value = 0.002), "Recreation" (p-value = 0.009) and "Governance, political self-empowerment" (p-value = 0.004), were present. The positive economic aspect "Reduced costs due to self-sufficiency" (p-value < 0.001) was associated with a higher number of positive social aspects.

- When positive environmental aspects, such as “Improved rainwater drainage management” (p-value = 0.023) and “Soil preservation” (p-value = 0.004), were present, a statistically higher number of positive economic aspects were observed. Projects where the representatives that replied “yes” to questions related to the presence of many positive economic aspects, such as “Employment opportunities” (p = 0.022), “Alternative economic models” (p-value = 0.004), “Economic stability” (p-value = 0.001), and “Ethical work” (p = 0.001), had a statistically significantly higher number of positive economic aspects.
- A higher average number of negative economic aspects were associated with the positive economic aspect “Boost of the local economy” (p = 0.0028) and the negative economic aspects “High price of products” (p-value = 0) and “Low efficiency of crop yields” (p-value = 0.014).

Appendix B Statistical Results—Sustainability Aspects Related to Specific Novelties (*t*-Test)

In general, a higher number of positive sustainability aspects were linked to the UA experiences reflecting the following novelties: “New ecological practices, e.g., organic, biodiversity” (p-value = 0.020), “Work and employment experiences, youth and adults” (p-value = 0.007), “New alternative ways of spreading and distributing knowledge” (p-value = 0.004), “New cooperation, alliances for product distribution” (p-value = 0.044), and “Introducing new products and practices to urban areas” (p-value = 0.026). In addition, the UA experiences that did not reflect the novelties “New ways to improve the overall resource efficiency” (p-value = 0.001), “New ways to improve the nutrient use efficiency” (p-value = 0.001) and “New options for utilization of urban space” (p-value = 0.025) were associated with a larger number of positive aspects concerning sustainability. Alternatively, the novelties “New ways to improve the crop efficiency” (p-value = 0.041) and “Development, use and testing of new technologies” (p-value = 0.008) were linked to higher negative sustainability aspects.

The social novelty “New alternative ways of spreading and distributing knowledge” (p-value = 0.023) was related to a higher number of positive environmental aspects. Alternatively, statistical evidence showed the opposite for the environmental novelties, namely, “New ways to improve the overall resource efficiency” (p-value = 0.011) and “New ways to improve the nutrient use efficiency” (p-value = 0.011), and the economic novelty “New options for utilization of urban space” (p-value = 0.009). Concerning the negative environmental aspects, the novelty “New ways of leading” (p-value = 0.035) was associated with a lower amount of negative sustainability aspects, while the novelties “New ways to improve the crop efficiency” (p-value = 0.035) and “Development and testing of new technologies” (p-value = 0.033) were associated with a higher risk.

The environmental novelty “New ecological practices, e.g., organic, biodiversity” (p-value = 0.003) and the social novelties “New networks” (p-value = 0.014) and “New alternative ways of spreading, distributing knowledge” (p-value = 0.007) were related to a higher number of positive social aspects.

The environmental novelties “New ways to improve the crop efficiency” (p-value = 0) and “New ways to improve the water efficiency” (p-value = 0.001) and the economic novelty “New economically viable businesses” (p-value = 0.002) were related to a higher number of positive economic aspects. On the other hand, those UA experiences that did not reflect the environmental novelties “New ways to improve the overall resource efficiency” (p-value = 0.011) or “New ways to improve the nutrient use efficiency” (p-value = 0.001) showed a larger average number of positive economic aspects. A lower number of negative economic aspects were linked to the environmental novelties “New ways to improve the overall resource efficiency” (p-value = 0.001) and “New ways to improve the nutrient use efficiency” (p-value = 0.028), while a higher average number of negative economic aspects were associated with the environmental novelty “New ways to improve the water efficiency” (p-value = 0.003).

Appendix C Statistical Results—*T*-Test Results between Sustainability Aspects and External Support, Innovation and Innovativeness

The results of the questionnaire were statistically analyzed to observe relations between the innovations of the case studies (in terms of the diversity of support, the number of environmental novelties, the number of social novelties, the number of economic novelties, the total number of novelties, the number of adaptations, the number of adoptions, the number of inventions, and the innovativeness index) and the sustainability aspects found in each case study.

External support and contribution to sustainability:

Regarding the support received by the UA experience, a higher number of positive environmental aspects were associated with the presence of "legal support" (*p*-value = 0.047), a lower number of positive economic aspects were associated with those UA cases that received support from a "Specific program" (*p*-value = 0.001), and a larger number of negative sustainability aspects were related to those cases that participated in a "Funding program" (*p*-value = 0.048) than to those that did not.

Innovation and sustainability aspects:

Concerning the number of novelties, a larger number of novelties were observed for the UA projects that replied "yes" to questions related to the presence of the aspects "Social inclusion" (*p*-value = 0.026), "Food sovereignty" (*p*-value = 0.003), and "Self-employment" (*p*-value = 0.027) and replied "no" to questions related to the presence of the aspects "Large water consumption" (*p*-value = 0.036). Differentiating between the three dimensions of sustainability, specific relations were unveiled. A lower average value of environmental novelties was observed for the UA projects that answered "yes" to questions related to the "Recreation" aspect (*p*-value = 0.020). A higher number of social novelties were associated with the presence of certain positive sustainability aspects: "Creation of green barriers, pollution" (*p*-value = 0.038), "Community cohesion and development" (*p*-value = 0.003), "Community self-organization" (*p*-value = 0.026), "Cultural exchange" (*p*-value = 0.017), "Maintenance of cultural heritage" (*p*-value = 0.045), "Improved mental health" (*p*-value = 0.028), "Co-design and participatory design" (*p*-value = 0.031), "Governance and political empowerment" (*p*-value = 0.002), "Self-employment" (*p*-value = 0.017) and "Reduced cost due to self-production" (*p*-value = 0.006). Finally, a higher average number of economic novelties were linked to the presence of the economic aspect "Diversification of farm work" (*p*-value = 0.047) and to the absence of the environmental risk "Large water consumption" (*p*-value = 0.026). Appendix B details the statistical assessment regarding the relation between sustainability aspects and specific novelties.

Innovativeness and sustainability aspects:

A higher number of adaptations were linked to the presence of social aspects, such as "Community cohesion and development" (*p* = 0.014), "Social inclusion" (*p*-value = 0.049), "Cultural exchange" (*p*-value = 0.037) and "Self-employment" (*p*-value = 0.007), and to the presence of positive economic aspects, such as "Cooperation, shared production factors" (*p*-value = 0.040) and "Reduced costs due to self-sufficiency" (*p*-value = 0.022). The presence of "Governance, political empowerment" (*p*-value = 0.043) was statistically significantly associated with a higher number of inventions. Finally, innovativeness was associated with the presence of the environmental risk "Large water consumption" (*p*-value = 0.028).

Appendix D Statistical Results—Pearson Correlation Coefficient between Pairs of the Main Constructed Variables

Table A1 shows the Pearson correlation coefficient between pairs of the main constructed variables as well as the *p*-value of the test to determine whether the correlation coefficient is equal to zero (no correlation). Indicating that the variables are likely to be correlated, the correlation coefficients that differ statistically significantly from zero are shown in the table.

Table A1. Pearson correlation coefficient and *p*-value for selected pairs of the main constructed variables. The level of significance is 95% (*p*-value < 0.05).

Variable 1	Variable 2	Pearson's Coefficient	*p*-Value
n° environmental novelties	n° economic novelties	0.62	0.041
n° environmental novelties	n° adaptations	0.61	0.047
n° social novelties	n° adaptations	0.69	0.019
n° social novelties	n° positive social aspects	0.88	0.000
n° social novelties	n° positive sustainability aspects	0.62	0.043
n° economic novelties	n° adaptations	0.65	0.030
n° novelties	n° adaptations	0.84	0.001
innovativeness index	n° negative environmental aspects	0.69	0.020
innovativeness index	n° negative social aspects	0.69	0.020
innovativeness index	n° negative sustainability aspects	0.60	0.049
n° negative environmental aspects	n° negative social aspects	0.77	0.006

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