Universitat Autònoma de Barcelona

OPEN GRANARIES: PREVENTING TRADITIONAL AGROECOLOGICAL KNOWLEDGE EROSION AND ENCLOSURE IN THE ERA OF OPEN SCIENCE

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PhD THESIS

OPEN GRANARIES: PREVENTING TRADITIONAL AGROECOLOGICAL KNOWLEDGE EROSION AND ENCLOSURE IN THE ERA OF OPEN SCIENCE

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Universitat Autònoma de Barcelona

November 2019

Granaries are places where seed is kept and stored. But granaries need to be somewhat open and breathe so that the seeds do not rot, safeguarding them for the next planting season.

Every year, seeds are brought in and taken out of the granary. New seeds from other farmers might come in, or seeds from your own plants that have been modified by crossbreeding. You might also give seed from your granary to other farmers in exchange. This is what guarantees future crops for you and others.

As seeds, knowledge also needs to breathe, be freely exchanged and cross-pollinated to guarantee humanity's capacity to know, innovate and adapt.

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SUMMARY

In the past decades, traditional agroecological knowledge (TAeK) has suffered a rapid process of erosion and privatization, especially in industrialized contexts. As a response to this situation, numerous TAeK conservation initiatives have emerged, including initiatives engaging in local TAeK revitalization (*in situ* o contextualized knowledge conservation) and initiatives engaging in global TAeK documentation and inventorying (*ex situ* or decontextualized knowledge conservation). On another level, emerging efforts coming from the open science and post-normal science movements are trying to include multiple epistemological standpoints in the production of knowledge, pushing for recognizing the validity of locally grounded expertises. However, these complementary approaches to restoring the perceived legitimacy of TAeK are not always linked together.

This thesis advances our understanding of the nexus between the conservation of TAeK, public participation in science, and knowledge co-production and co-management in digital environments by exploring the potential of digital citizen science to become a participatory tool for traditional knowledge conservation. Specifically, through this thesis, I evaluate the need for, the process, the impact and the outcomes of a technology mediated citizen science initiative aiming at documenting, sharing, and protecting TAeK as a digital commons: the CONECT-e project (www.conecte.es). The need for this project was evaluated by looking both into the global literature on traditional knowledge conservation and the local reality of TAeK conservation efforts in a case study in Catalonia. The project's process was examined by looking into CONECT-e's platform users' participation and profile data. The impact of the project was evaluated by testing if CONECT-e could enhance valuation and access to TAeK among agricultural technical students in Catalonia. Finally, the project's outcome was examined by looking into the content and visits to CONECT-e's platform and by evaluating the overall platform's contribution to TAeK conservation as a digital commons.

Results from this work show that there is a need for this type of initiatives, since most TAeK conservation projects in the academic world are not participatory and follow a rather top-down approach. The need for this type of projects is also showcased by the multiplicity of locally grounded projects found working in close connection despite their different approaches to TAeK conservation and their different discourses about TAeK loss. Moreover, my results demonstrate that initiatives such as CONECT-e can attract diverse and active participants, partly because of their political nature and their ability to establish tight partnerships with interested actors. Results from this work also highlight that initiatives like CONECT-e can help increase valuation and access to TAeK among young agricultural students in industrialized contexts, thus contributing to halting TAeK's erosion. Finally, my results show that resisting to TAeK erosion

and enclosure is in line with resisting to industrialized food systems, and that the participatory documentation, sharing, and protection of TAeK as a digital commons can contribute to agroecological transitions.

Thus, overall, this work contributes to the literature on TAeK conservation and on political agroecology by highlighting elements that can prevent the erosion and enclosure of TAeK, a key knowledge base to agroecological transitions. Furthermore, findings from this thesis contribute to the literature on participation and post-normal science as they advance our understanding of 1) the complexity inherent to any participatory method and 2) the limitations and opportunities of citizen science as a tool for TAeK conservation.

RESUMEN

En las últimas décadas, el conocimiento agroecológico tradicional (CAeT) ha sufrido un rápido proceso de erosión y privatización, especialmente en contextos industrializados. Numerosas iniciativas de conservación del CAeT han surgido como respuesta a esta situación, incluyendo iniciativas que se dedican a la revitalización local del CAeT (conservación de conocimiento *in situ* o contextualizado) e iniciativas que se dedican a la documentación e inventario global del CAeT (conservación de conocimiento *ex situ* o descontextualizado). A otro nivel, esfuerzos emergentes que provienen de movimientos como la ciencia abierta están tratando de incluir múltiples puntos de vista y epistemologías en la producción de conocimiento, presionando para que se vuelva a reconocer la validez de los saberes locales. Sin embargo, estos enfoques complementarios no siempre se han combinado.

Esta tesis avanza nuestra comprensión sobre el nexo entre la conservación del CAeT, la participación pública en la ciencia y la co-producción y co-gestión del conocimiento en entornos digitales al explorar el potencial de la ciencia ciudadana digital para convertirse en una herramienta participativa para la conservación del conocimiento tradicional. Específicamente, en esta tesis, evalúo la necesidad, el proceso, el impacto y los resultados de una iniciativa digital de ciencia ciudadana cuyo objetivo es documentar, compartir y proteger el CAeT como un bien común digital: el proyecto CONECT-e (www.conecte .es). La necesidad de este proyecto se evaluó analizando la literatura global sobre la conservación de los conocimientos tradicionales y la realidad local de los esfuerzos de conservación del CAeT en un estudio de caso en Cataluña. El proceso del proyecto se evaluó analizando los datos de perfil y participación de los usuarios de la plataforma CONECT-e. El impacto del proyecto se evaluó midiendo cambios en la valoración y el acceso al CAeT entre estudiantes de formación profesional agraria en Cataluña

que usaron la plataforma. Finalmente, el resultado del proyecto se evaluó analizando el contenido y las visitas a la plataforma, y evaluando la contribución general del proyecto a la conservación del CAeT como un bien común digital.

Los resultados de este trabajo demuestran que existe la necesidad de este tipo de iniciativas, ya que la mayoría de los proyectos de conservación del CAeT en el mundo académico no son participativos y siguen un enfoque de arriba hacia abajo. Además, mis resultados demuestran que iniciativas como CONECT-e pueden atraer a participantes diversos y activos, en parte debido a su naturaleza política y su capacidad para establecer asociaciones estrechas con los actores interesados. Los resultados de este trabajo también destacan que iniciativas como CONECT-e pueden ayudar a aumentar la valoración positiva y el acceso al CAeT entre los jóvenes estudiantes de agricultura en contextos industrializados. Finalmente, mis resultados muestran que resistir a la erosión y privatización del CAeT está en línea con resistir a los sistemas alimentarios industrializados, y que la documentación participativa, el intercambio y la protección del CAeT como un bien común digital pueden contribuir a las transiciones agroecológicas.

Por lo tanto, en general, este trabajo contribuye a la literatura sobre la conservación del CAeT y la agroecología política al resaltar algunos elementos que pueden prevenir la erosión y privatización del CAeT, un conocimiento que es clave para las transiciones agroecológicas. Además, los hallazgos de esta tesis contribuyen a la literatura sobre participación y ciencia post-normal dado que mejoran nuestra comprensión sobre 1) la complejidad inherente a cualquier proceso participativo y 2) las limitaciones y oportunidades de la ciencia ciudadana como herramienta de conservación del CAeT.

RESUMEN

En les últimes dècades, el coneixement agroecològic tradicional (CAeT) ha patit un ràpid procés d'erosió i privatització, especialment en contextos industrialitzats. Nombroses iniciatives de conservació del CAeT han sorgit com a resposta a aquesta situació, incloent iniciatives que es dediquen a la revitalització local del CAeT (conservació de coneixement *in situ* o contextualitzat) i iniciatives que es dediquen a la documentació i inventari global del CAET (conservació de coneixement *ex situ* o descontextualitzat). A un altre nivell, esforços emergents que provenen de moviments com la ciència oberta estan tractant d'incloure múltiples punts de vista i epistemologies en la producció de coneixement, pressionant perquè es torni a reconèixer la validesa dels sabers locals. No obstant això, aquests enfocaments complementaris no sempre s'han combinat.

Aquesta tesi avança la nostra comprensió sobre el nexe entre la conservació del CAeT, la participació pública en la ciència i la co-producció i co-gestió del coneixement en entorns digitals en explorar el potencial de la ciència ciutadana digital per convertir-se en una eina participativa per a la conservació del coneixement tradicional. Específicament, en aquesta tesi, avaluo la necessitat, el procés, l'impacte i els resultats d'una iniciativa digital de ciència ciutadana amb l'objectiu de documentar, compartir i protegir el CAeT com un bé comú digital: el projecte CONECT-e (www.conecte .es). La necessitat d'aquest projecte es va avaluar analitzant la literatura global sobre la conservació dels coneixements tradicionals i la realitat local dels esforços de conservació del CAeT en un estudi de cas a Catalunya. El procés del projecte es va avaluar analitzant les dades de perfil i participació dels usuaris de la plataforma CONECT-e. L'impacte del projecte es va avaluar mesurant canvis en la valoració i l'accés al CAeT entre estudiants de formació professional agrària a Catalunya que van usar la plataforma. Finalment, el resultat del projecte es va avaluar analitzant el contingut i les visites a la plataforma, i avaluant la contribució general del projecte a la conservació del CAeT com un bé comú digital.

Els resultats d'aquest treball demostren que hi ha la necessitat d'aquest tipus d'iniciatives, ja que la majoria dels projectes de conservació del CAeT al món acadèmic no són participatius i segueixen un enfocament de dalt a baix. A més, els meus resultats demostren que iniciatives com CONECT-e poden atraure participants diversos i actius, en part a causa de la seva naturalesa política i la seva capacitat per establir associacions estretes amb els actors interessats. Els resultats d'aquest treball també destaquen que iniciatives com CONECT-e poden ajudar a augmentar la valoració positiva i l'accés al CAeT entre els joves estudiants d'agricultura en contextos industrialitzats. Finalment, els meus resultats mostren que resistir a l'erosió i privatització del CAeT està en línia amb resistir als sistemes alimentaris industrialitzats, i que la documentació participativa, l'intercanvi i la protecció del CAeT com un bé comú digital poden contribuir a les transicions agroecològiques.

Per tant, en general, aquest treball contribueix a la literatura sobre la conservació del CAeT i l'agroecologia política en ressaltar alguns elements que poden prevenir l'erosió i privatització del CAeT, un coneixement que és clau per a les transicions agroecològiques. A més, les troballes d'aquesta tesi contribueixen a la literatura sobre participació i ciència post-normal atès que milloren la nostra comprensió sobre 1) la complexitat inherent a qualsevol procés participatiu i 2) les limitacions i oportunitats de la ciència ciutadana com a eina de conservació del CAeT.

ACKNOWLEDGEMENTS

This thesis is the result of four years of ups and downs and would not have been possibly done without the support and efforts of many people.

First, I would like to acknowledge my supervisors Viki and Marta, for believing in my research capacity and for guiding my sometimes crazy ideas with just the right mix of direction and flexibility. You are both an inspiration in many ways, and have guided both my academic and personal evolution during this time, a footprint that will last forever.

I would also like to acknowledge my colleagues from ICTA and specifically from the LASEG and LICCI research groups, which have become more than just co-workers and are also a source of inspiration in research and life. Special thanks go to my Saras and my Mars, you are all so incredibly talented and precious women! It has been such a gift to get to know you and I hope you will continue to be part of my personal and academic life for many more years. Also to the fellow PhD students at ICTA that fight hard to make that place a better one, María, Raúl, Gorka, Alex, Albert, Diana, Fulvia, Sole… it has been great to fight and learn by your side and you have been through times the main reason to come to the office. Same goes for my friends from the UAB precarious researchers' assembly, for all the struggles, defeats and victories we have lived together: Antón, Calvo, Jofre, Maria, Laura… you provided me with hope for a future anticapitalist academia.

This thesis would also have not been possible without CONECT-e and all the people that participated in the project. To the Red de Semillas and its members, for trusting us "academics" and partnering with us. To the fellow researchers that participated in the project: Manuel, Laura A., Laura C., Toni, David, Teresa, Airy, Sara, María, Montse, Daniel, Javier, Joan. It has been a ride to make this weird inter-transdisciplinary project happen, but it did, and it would have not without you. Also to the administrative people and interns at ICTA, those caring partners without which no project would be possible: Cristina, Pere, Montse, Lola, Isa, Marta, Mònica, Anna, Adrià… And most importantly, to all of CONECT-e users and to all the teachers, students, farmers and locals of Osona, for believing in the project even before it was tangible and for their constant effort to maintain traditional agroecological knowledge.

Last but not least, I would like to thank all the incredible people beyond academia that have been around during this time supporting and inspiring me in every step of the way. To my IMRD's for being there at the very start of the journey, to my Cerdanyolians and Tarragonians for making me feel at home from the beginning, to my Pepitas for staying in touch and listening even if they did not understand what I'm doing, to my Australian family for sending inspiration and love across the world to me… And of course, special thanks to some very unique people that have stuck around no matter what. To Laura M. for proposing always crazy plans, I was so lucky to meet you again in the same geographical context and be able to share so many stories. To Laura S., who despite the distance manages to be one of my life's pillars. To Andy, for all the creativity, kindness, laughs and shelter! To Mom and Dad for being such loving, inspirational, and comforting parents, I would not be who I am without you and this thesis is also a product of the hours you spent reading to me at night, taking me to explore the mountains, checking and correcting my English and teaching me R! And of course, to Fran, for being my skype confident, my climbing buddy, my travel companion, my housemate, my intellectual challenger, my cook/cleaner and my lover during all these years.

INTRODUCTION

The idea of a universal, neutral, and objective scientific truth has been widely criticized since the mid-20th century by scholars such as Michel Foucault or Jean Piaget, who also questioned scientific expert legitimacy (Piaget 1967, Foucault 1979). Following a constructivist epistemology, they argued that scientific knowledge is indeed socially constructed by the scientific community and influenced by cultural and ideological biases (Poster 1982, von Glasersfeld 2001, Klein 2015). More recently, the emergence of post-normal science (PNS) gave a specific framework to these lines of thought, insisting in the existence of multiple legitimate perspectives that can contribute to studying complex problems (Funtowicz and Ravetz 2003, Turnpenny et al. 2011). The PNS framework postulates that extended multidisciplinary (more than one discipline) and transdisciplinary (scientific and non-scientific) peer communities need to be created to foster dialogues between multiple perspectives, encouraging a diversity of participants to contribute as equal partners in knowledge co-production. These ideas have recently been advanced by emergent approaches, such as open science and participatory or citizen science (CS), which are increasingly implemented and accepted as valid in the academic and policy arenas, (Dillon et al. 2016, Wildschut 2017).

However, non-scientific forms of knowledge continue to be questioned. For instance, the CS community constantly struggles to prove the validity and legitimacy of knowledge generated with data and ideas contributed by non-scientists (Ottinger 2010, Kosmala et al. 2016). Moreover, positivist approaches are still dominant in most scientific and policy contexts, in which the inclusion of other epistemologies continues to be an issue (Turnhout et al. 2014, Sumberg 2017). The field of Agricultural and Food Sciences is a good example of these trends, as in this field the positivist approach (i.e., "agricultural modernization") has contributed to the abandonment and devaluation of traditional cultivation practices on the assumption that scientific agricultural knowledge is more legitimate than other forms of agricultural knowledge (Naredo 2004, Toledo and Barrera-Bassols 2008). Indeed, research suggests that -together with the generalized industrialization and commoditization of food systems that brought land use changes, rural depopulation, and privatization of common resources (Naredo 1971, Kloppenburg 1988)- agricultural modernization has also contributed to the erosion of traditional agroecological knowledge systems (TAeK), especially in western industrialized countries (Gómez-Baggethun et al. 2010, Hernández-Morcillo et al. 2014). The promotion of agricultural modernization in detriment of other ways of knowing is based on the assumption that objective and neutral agronomic scientific knowledge provides the most valid and legitimate approximation to solve the complex issue of "feeding the world" (Thompson and Scoones 2009, Rivera-Ferre 2012, Rivera-Ferre et al. 2013, Sumberg 2017). However, despite the neutrality claim, positivist scientific agricultural knowledge -from the problematization of the issues to the solutions proposed- is indeed socio-politically constructed and highly influenced by certain values, power imbalances, and hierarchies (Giraldo 2019). Thus, even though transdisciplinary and open science approaches have reached the agricultural sciences (for instance through the emergence of open seed breeding or open agricultural tools; Deibel 2013, Kloppenburg 2014, Cox 2015), there is still a need to promote the creation of extended peer communities in which lay experts participate with scientists in the co-production of agricultural knowledge (Waltner-Toews and Wall 1997, Delgado 2008).

To advance this post-normal science scenario, we need to understand the role of initiatives aiming to document, share and protect traditional knowledge systems and the possible synergies between these initiatives and emergent open science approaches, such as citizen science. Moreover, there is a need to better understand how the extended peer communities promoted under the PNS approach can overcome participation barriers and internal power hierarchies to favor truly equitable and diversified dialogues (Wesselink and Hoppe 2011, Rosendahl et al. 2015). Responding to these needs, this thesis evaluates the potential of citizen science to become a participatory tool for traditional knowledge conservation. I do so by examining a citizen science initiative aiming at documenting, sharing and protecting[1] TAeK as a digital commons: the CONECT-e project (www.conecte.es). The goal of this initiative was to create a wiki-like platform in which anyone could document TAeK from their elders and community. The initiative also opened up the possibility for user interaction through commenting and editing features. The CONECT-e project constitutes an excellent case study for at least three reasons. First, CONECT-e is an innovative project, since the citizen science approach has been rarely used to prevent TAeK erosion and enclosure (see Sieber and Strohmeier 2016 for an exception). Second, CONECT-e was co-created between researchers and activists from a civil society organization, who participated in the design, development and implementation of the whole project. Third, CONECT-e takes place in an industrialized context, where TAeK is being most dramatically eroded but

[1] In this thesis, I use "protection" mostly to refer to defensive protection, or the compilation of traditional knowledge in searchable databases that patent examiners can use as evidence of prior art when assessing patent or breeder rights applications (WIPO 2012). I also use "protection" to refer to TAeK maintenance under a *commons* framework to prevent misappropriation (Calvet-Mir et al. 2018).

also where the digital environment is more accessible (Dimaggio et al. 2004, Gómez-Baggethun et al. 2010, Graham et al. 2014).

1. Theoretical framework

Two main theoretical frameworks are in dialogue in this thesis, political agroecology and post-normal science. Political agroecology is used to frame the notions of TAeK erosion, agroecological resistances, and sustainable food systems. Post-normal science is used to explore the theoretical and practical notions of knowledge co-production and citizen science. This section lays out the main theoretical concepts in which this thesis is based and gives some practical examples of how these ideas dialog and interact.

1.1. Political Agroecology: TAeK for resilient agroecological food systems

Agroecology conceptually intertwines three dimensions: one linked to the techno-scientific advances in ecology and agriculture at the cognitive level, one related to the practical applications of these cognitive advancements, and one linked to their political nature as they support and seed rural social movements (Wezel et al. 2009, Toledo and Barrera-Bassols 2017). This third pillar is at the core of political agroecology, which looks at the socio-ecological relations that take place in agroecosystems (including agroecological knowledge and practices) through the lens of power relations and conflict (Gonzalez De Molina 2013). Indeed, from a political agroecology perspective, agroecology is proposed as an emancipatory tool that feeds into political resistances of peasants and into the construction of alternative food systems (Calle Collado et al. 2013, Toledo and Barrera-Bassols 2017). Moreover, from this perspective the conflicts and power relations inherent to most contemporary food systems, from production of agricultural knowledge to distribution and commercialization of food, are highlighted. In this context, several authors have pointed out the role of traditional knowledge systems as powerful knowledge bases that could sustain the return and maintenance of peasant agroecological farming systems, since the social-ecological rationale of traditional small-scale agriculture is often aligned with the principles of agroecology (Altieri et al. 1987, Altieri and Toledo 2011, Méndez et al. 2013, Calvet-Mir et al. 2018).

Traditional knowledge systems[2] are the holistic set of knowledge, beliefs, practices, institutions, and worldviews that indigenous peoples and rural communities have developed and sustained throughout generations of human-nature interactions (Berkes et al. 2000, Folke 2009). These knowledge systems support community resilience since they include adaptive strategies to deal with everyday life issues while considering the long-term maintenance of the ecological system in which the communities are embedded (Reyes-García 2015, Calvet-Mir et al. 2016). Moreover, some authors suggest that these knowledge systems can be understood as *commons*[3] (Hess and Ostrom 2007, Reyes-García et al. 2018b). This is so for several reasons. First, traditional knowledge systems are immaterial non-rival resources with some level of excludability. This means that, although their use by one user does not prevent their use by others, certain property rights could exclude some users from accessing them (Bauwens et al. 2017). Second, traditional knowledge systems are governed by collectively decided rules. Indeed, several authors have highlighted that local and rural communities often manage their agrobiodiversity-related knowledge collectively, i.e., through collective use and knowledge exchange practices (e.g. Aw-Hassan et al. 2008, Abay et al. 2011, Labeyrie et al. 2016). Third, traditional knowledge systems are developed through the cumulative efforts of generations of community members experimenting, improving, and adapting them. Finally, such systems produce a long-term use value rather than a short-term exchange value, the type of value normally generated when commodities are created and transferred according to market rules (Kostakis and Bauwens 2014). A specific domain of traditional knowledge refers to the knowledge, practices and believes related to agroecosystems, or what can be named as Traditional Agroecological Knowledge[4] (TAeK). TAeK includes, among other

[2] Many terms have been used to describe this concept. Throughout this thesis, the terms "Traditional Knowledge", "Traditional Ecological/Agroecological Knowledge" and "Indigenous and Local Knowledge" will be used, reflecting the diversity of domains and dimensions these knowledge systems include, and also reflecting the multiple terminologies used in the policy arena (specifically in the science-policy platforms related to biodiversity and climate change). The use of the word 'traditional' (rather than 'local' or 'folk') emphasizes the long-term historical continuity of these bodies of knowledge and the importance of social processes in their transmission and maintenance. The word 'traditional' does not imply being archaic or pre-modern, as traditional knowledge systems are highly dynamic and adaptive (Reyes-Garcia et al. 2014).

[3] The concept of *commons* has been alternatively used to refer to resources or goods, social processes, or even to a worldview (Bollier and Helfrich 2014; Kostakis and Bauwens 2014). One of its most standard definitions refers to "the institutional approach that governs the production, use, management and/or preservation of shared resources according to which people manage such resources by negotiating their own rules through social or customary traditions, norms, and practices" (pp. 174, Reyes-García et al. 2018b).

[4] In this thesis, the term "traditional agroecological knowledge" will be used as opposed to "traditional agricultural knowledge" to highlight the holistic nature of this body of knowledge that refers to the whole

elements, traditional water or soil management practices, knowledge about the agronomic and organoleptic characteristics of landraces (i.e., locally adapted cultivated plant varieties), landmark names, or beliefs and worldviews related to agricultural cycles (Calvet-Mir et al. 2018).

Several authors have highlighted the important role of TAeK for agrobiodiversity conservation and management and for providing resilient and locally adapted food systems (Altieri and Merrick 1987, Armitage 2003, Altieri and Toledo 2011). Indeed, some studies have shown that agricultural practices that emerge from traditional knowledge and worldviews contribute to the maintenance of cultivated biodiversity (Altieri and Nicholls 2000) and wild species (Blanckaert et al. 2007). For example, traditional animal husbandry practices, such as transhumance, provide seed dispersal opportunities for several plant species, for which they are considered as useful approaches to plant diversity restoration in fragmented grasslands (Rico et al. 2014, Babai and Molnár 2014). Moreover, a wide diversity of plant and animal species are supported by traditionally managed agroecosystems such as *dehesa* grasslands, an agrosilvopastoral system found in southern and central Spain and Portugal (Peco et al. 2000, Plieninger and Wilbrand 2001). Similarly, traditional homegardens have been highlighted as agrobiodiversity hotspots, contributing to the *in situ* conservation of crop genetic diversity (Perrault-Archambault and Coomes 2008, Calvet-Mir et al. 2011). Indeed, homegardens not only provide food services to the communities, but also cultural services such as the maintenance of cultural identity and social networks (Calvet-Mir et al. 2012b).

Furthermore, TAeK is considered critical for agroecological transitions, understood as the different processes leading to the scaling up and scaling out of agroecology (Calvet-Mir et al. 2018). On the one side, TAeK-based practices can help reduce farm inputs and intensify farm biodiversity, but –on the other side- TAeK also provides answers to some of the political and economic challenges that agroecological transitions face (Gliessman and Rosemeyer 2010, Koohafkan and Altieri 2011, Altieri et al. 2012, Guzmán et al. 2013, Calvet-Mir et al. 2018). For example, several authors have stressed the important role of TAeK in strengthening local communities' identities and shared

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system of interrelated elements that play a role in the agro-ecosystem. The term is also used to emphasize the connection between this knowledge system and agroecological theory and practices (Calvet-Mir et al. 2018).

discourses, and thus its potential to set up an environment favourable to agroecological transitions (Guzmán et al. 2013, Mier y Terán Giménez Cacho et al. 2018).

Despite TAeK's adaptive nature and the fact that farmers might use it in parallel to modern farming knowledge and practices (Reyes-García et al. 2014), there is a great concern regarding TAeK's rapid erosion (e.g., loss of traditional management practices or landrace names) and enclosure (i.e., the establishment of restrictive property rights over agrobiodiversity and associated knowledge). The factors driving these processes of erosion and enclosure are multiple. Several authors have linked the rapid loss of traditional agroecological practices in Europe to the intensification and commoditization of agricultural systems and the strict regulations concerning both food production and protected areas (Gómez-Baggethun et al. 2010; Hernández-Morcillo et al. 2014). Other authors have highlighted the problems related to the private and public management of TAeK (especially landrace knowledge), calling for its protection or maintenance under a "commons" framework (Brush 2007, Srinivas 2012, Reyes-García et al. 2018a, 2018b).

In the light of these threats, several TAeK conservation initiatives have emerged (Benyei et al. 2019). Some initiatives engage in the static documentation or storing of TAeK (an *ex situ* or de-contextualized approach), while others focus on gathering, reproducing, transmitting and revitalizing TAeK among knowledge holders and their communities (an *in situ* or contextualized approach). These initiatives are largely led by scientists, civil society organizations and activists who want to study or access the remaining bodies of TAeK and promote its conservation, use and protection. For instance, in Spain, the different local seed networks (coordinated under the civil society organization "Red de Semillas: Resembrando e Intercambiando") have played a crucial role in inventorying and sharing traditional landrace knowledge to protect farmers' breeding rights (Reyes-García et al. 2018a). This type of TAeK conservation initiatives are the ones that best fit into the political dimension of agroecology, as they can be understood as a form of resistance, defined as individual or collective efforts that oppose, confront, and try to prevent or reverse social, cultural, or economic structural conditions (Hollander and Einwohner 2004; Lee 2017). Indeed, the interests of initiatives resisting TAeK loss could theoretically overlap with the interest of movements resisting industrialized food systems in general and with the agroecology movement in particular (Koohafkan and Altieri 2011; Gliessman 2013; Mier y Terán Giménez Cacho et al. 2018; Bonanno and Wolf 2017).

1.2 Post-normal science: using citizen science to create extended peer communities of knowledge co-production

At the core of post-normal science lies the idea of the need to co-create knowledge using inputs from scientific and non-scientific peers to find solutions to complex and uncertain problems (Funtowicz and Ravetz 2003). This idea is increasingly accepted in fields such as biodiversity conservation or digital knowledge production (Tengö et al. 2014, Klein 2015). Moreover, this idea has materialized in diverse and increasingly present initiatives, such as online creation communities (OCCs), community-based biodiversity monitoring projects (CBM), or hackers and makers spaces (Danielsen et al. 2008, Fuster Morell 2010, Tanenbaum et al. 2013, Turreira-García et al. 2018), which mostly fall under the open or participatory science framework, that also frames citizen science (Friesike and Bartling 2014, Wildschut 2017).

Citizen science (CS) is a rapidly growing approach referring to the participation of non-professional scientists in scientific activities, from research design to data collection (including monitoring) or data analysis (Wiggins and Crowston 2011, Haklay 2013a, Kullenberg and Kasperowski 2016, Eitzel et al. 2017, Schrögel and Kolleck 2019). This approach to knowledge production holds the potential to transform science and generate extended peer communities that foster pluri-epistemological dialogues (Wildschut 2017). However, in the past decade, most CS projects have taken a utilitarian and unidirectional approach to participation, i.e., scientists using citizens to crowdsource data for them while "providing" scientific literacy or expertise in exchange (Strasser et al. 2019). Indeed, some studies have called attention to the fact that most CS projects do not provide spaces for citizen participation beyond data collection (Stepenuck and Green 2015, Turreira-García et al. 2018). For some authors these different levels of engagement in CS are an expression of volunteer interest rather than of power relations (Haklay 2013a). However, using the idea of participatory ladders or a continuum of participant engagement that goes from non-participation to citizen control (Arnstein 1969), other authors argue that data collection is a lower form of participation, since project control typically takes place at the level of project ideation and management (Burke and Heynen 2014, Turreira-García et al. 2018, Strasser et al. 2019). Thus, although originally CS emerged from the critical questioning of expertise and scientific legitimacy and advocated for science *by* and *for* the people (Irwin 1995), many authors in the field of science and technology studies (STS) have distanced themselves from the current concept of CS, and started using other terminologies such as “Do It Yourself” (DYI) science or ‘participatory science’ to stress the difference between their projects and the top-down approach that has become popular in citizen science (Burke and Heynen 2014, Nascimento et al. 2014).

Independently of the terminology used to describe these efforts, understanding participant engagement in them in the framework of empowerment and post-normal science is key to critically examine their potential to emancipate communities and challenge knowledge hierarchies (Florin and Wandersman 1990, Dunn 2007, Burke and Heynen 2014, Dillon et al. 2016, Ruiz-Mallén et al. 2016). Paulo Freire (1970) defined empowerment as the twofold process of being able to (1) ‘‘understand social, political and economic contradictions” and (2) to “act against the oppressing elements of reality’’. Thus, participatory science initiatives that enhance transdisciplinary dialogues and civil society’s scientific literacy, while enhancing social mobilization, collective action, and social transformation could be considered empowering initiatives. However, in order to achieve this transformative potential, these initiatives (and CS in particular) need to take special care in promoting both the ability to understand and the ability to take action. In other words, for these initiatives to be transformative, citizens should not be merely a recipient of knowledge but should be able to actively take part in its production (Bela et al. 2016, Ruiz-Mallén et al. 2016). In the context of CS, and specifically technology-mediated CS, this “ability to act” seems driven by two factors: the participants’ socio-economic and demographic characteristics and the technological infrastructure of the CS project. On the one hand, socio-economic factors (e.g., gender, ethnicity, economic status) prevent the participation of certain groups in science in general and CS in particular, reflecting power imbalances and knowledge hierarchies (Pandya 2012, Dawson 2018, Schrögel et al. 2018). On the other hand, the way technology is designed and the access to the digital infrastructure can be a barrier to the participation of certain geographic and demographic groups, such as the rural or elderly (Dimaggio et al. 2004, Newman et al. 2012, Haklay 2013b, Graham et al. 2014). Indeed, several studies have pointed out that participation in technology mediated CS projects seems to follow a 90-9-1 rule by which 90% of the registered volunteers are mostly spectators, 9% contribute occasionally, and 1% make most of the contributions (Haklay 2016). However, the complexity of these participation trends has led some authors to deconstruct the notion of participation as a single act and introduce the concept of “ecosystemic participation” or the co-dependencies, feedbacks, adaptations and synergies between the different forms and degrees of participation (Fuster Morell 2010). Such processes rely on the project's transparency and decentralization and can lead to an equilibrium between diverse participants that favors the attainment of the common goal.

1.3 From the field to the cloud: Linking TAeK conservation and citizen science

Although not common, efforts to link citizen science and traditional knowledge are not new. Indeed, several examples of initiatives and approaches to the participatory documentation, sharing and protection of traditional knowledge showcase how these two theoretical frameworks are interlinked. In the sphere of participatory traditional knowledge documentation, there has been an emergence of online and offline traditional knowledge databases built with the communities, although mostly under the guidance and control of researchers or administrators (Lakshmi Poorna et al. 2014). In the sphere of participatory traditional knowledge sharing, several school programs have been designed to integrate community elders' knowledge and worldviews in youth formal education (Beeman-Cadwallader et al. 2012). Finally, some initiatives have been developed in the sphere of participatory traditional knowledge protection, including participatory landrace registration efforts and also some documentation efforts that align with the idea of defensive knowledge protection (Kloppenburg 2010, Ansari 2016, Reyes-García et al. 2018a).

Still, most of the documentation initiatives mentioned would fall under the crowdsourcing approach to citizen science, as they encourage community participation only in the phase of knowledge gathering (Benyei et al. 2019). This implies that traditional knowledge is "fitted" into scientific epistemological categories, thus limiting the transdisciplinary nature of these initiatives (Pulsifer et al. 2011). Moreover, some school activities promoting intergenerational exchange could be considered mainly as outreach activities that do not fully engage the students in the knowledge co-production process, but involve them just as "knowledge recipients" (Bela et al. 2016). In that sense, such initiatives are not fully transformative, partially because they are still affected by the politics of knowledge integration that stems from the divide between indigenous/traditional/lay and scientific knowledge (Agrawal 1995, 2002, Nadasdy 1999). Indeed, it has been argued that some of these initiatives struggle to overcome the particular historical and social relations and practices that have shaped the politics of representation of non-scientific knowledge systems and affected their capacity to co-

contribute to knowledge generation because of the underlying power structures (Agrawal 1995, 2002, Nadasdy 1999, Leach and Fairhead 2002). This issue has not yet been resolved, and several authors continue to remind us that there are deep epistemological, ontological, ethical and political issues that prevent transdisciplinary dialogues from been horizontal, thus affecting the transformative potential of citizen science and other participatory or pluriepistemological scientific projects (Fernandez-Gimenez et al. 2006, Ludwig and El-Hani 2019).

Fortunately, there are ways to re-enforce the equal role of lay participants in these experiences, thus making them more transformative and contributing to overcome the epistemological barriers mentioned. For instance, these initiatives could embrace the ideas of *strong objectivity* and *ontological self-determination* (Ludwig 2016). Drawing from feminist standpoint epistemology (i.e., the idea that our social relations actually enable and not determine what we can know), *strong objectivity* refers to the position in which a research project overcomes the idea of neutrality, that can indeed be an obstacle to maximize objectivity (especially when it is driven by distorting interests and values), and embraces the diversity of standpoints as positive for the project (Harding 1995). In a similar line, *ontological self-determination* refers to the right and need for divergent ontologies. In other words, divergence between lay and scientific expertise should not be considered indicator of failure, but rather a reflection of how different practices come with different ontological requirements (Viveiros de Castro 2009, Ludwig 2016). Another way forward towards true transdisciplinarity in citizen science and beyond would be exploring new frameworks in which transdisciplinary dialogues can take place, such as the digital commons. The digital commons refers to the open, decentralized and participatory digital spaces where immaterial commons such as knowledge, information or code are collectively produced and managed (Fuster Morell 2010, 2015, Kuhlen 2014). Examples of transdisciplinarity that exist in this environment include online communities of knowledge co-creation such as Wikipedia (Fuster Morell 2010) or initiatives in which the digitalization of traditional cultural artifacts has fostered transdisciplinary dialogues related to museum or archival collections (Brown and Nicholas 2012). The remaining question would be if traditional agroecological knowledge can be brought to this collaborative environment without losing its ontological self-determination and be documented, shared and protected by an online community of users that participate as equal partners.

2. Case study: The CONECT-e project

CONECT-e was born out of a rather simple idea: using a technology-mediated "citizen ethnoecology" approach to increase participation in the *Spanish Inventory of Biodiversity-related Traditional Knowledge* (IECTB for its Spanish acronym) (Pardo-de-Santayana et al. 2014, Reyes-García et al. 2018a). The IECTB was the result of effort from a large interdisciplinary team of scientists (including botanists, zoologists, agronomists, anthropologists, ethnoecologists, linguists, pharmacologists, and geologists) from 29 research centers and universities who, since 2011, had compiled and classified previously existing research outputs (i.e., articles and books) related to traditional ecological knowledge systems in Spain. The static nature of this compilation (i.e., results were published in books and available online only as a PDF file) drove some of the researchers in the team to explore other options to make this information more available and editable, so that the compilation could dynamically grow and be improved by interested citizens (Reyes-García et al. 2018a). However, CONECT-e's underlying motivation went beyond an interest in documenting traditional knowledge for its academic study, and was also guided by the idea of making it freely available and encouraging its revitalization among the communities where it came from (Calvet-Mir et al. 2018). Thus, departing from a previously well-established scientific protocol for data collection and categorization, CONECT-e aimed to organize the complexity of an holistic knowledge system into manageable knowledge sections that would still be appealing to a non-scientist user base. Moreover, the ultimate aim was to translate this simplified complexity into an online tool, with a user-friendly interface. These tasks were undertaken by a team composed of academics (botanists, anthropologists, environmental scientists, sociologists), computer scientists, and members of a civil society organization that promotes the management of landraces and their associated knowledge as a commons, the Spanish Seed Network "Red de Semillas: Resembrando e Intercambiando" (Red de Semillas 2015a; http://www.redsemillas.info/; Red de Semillas henceforce). The result of this work was the CONECT-e platform (www.conecte.es), a wiki-like platform in which traditional knowledge on plants, landraces and ecosystems were documented, shared, and protected[5].

[5] Note that this thesis focuses on the plant and landraces section of the platform.

2.1 Domains of knowledge included in CONECT-e

The domains of traditional knowledge included in the CONECT-e platform were those already included in the IECTB (Pardo-de-Santayana et al. 2014), although adaptations were made to reduce the complexity of some domains and to adapt the vocabulary (see Table 1). For the different active sections of the platform (i.e., plants, landraces and ecosystems), different domains were established after receiving feedback from early users and project partners. For instance, in the plant section, the platform allowed users to contribute traditional management practices related to plant recollection, cultivation and commercialization; while in the landrace section, users could contribute more detailed information on traditional sowing, soil maintenance, weeding or breeding techniques. Some of these domains are vital for the reproduction of this knowledge in the field and its contextualized maintenance (for instance the knowledge on how to collect medicinal plants or how to water certain landraces, Calvet-Mir et al. 2018), while some other domains are more in line with the preservation or documentation of traditional worldviews (for instance the knowledge on symbolic and ritual uses of plants). Moreover, the platform also allowed users to contribute with images, locations, and references (e.g., books or webpages).

Table 1. Domains of traditional knowledge included in CONECT-e

Section	**Domain**	**Sub-domain**
Plants	Common name	
	Description	How to recognize the plant
		Where and when to find it
	Traditional use	Social, symbolic or ritual use
		Ornamental use
		Environmental use
		Industry and handcrafts
		Construction
		Fuel use
		Toxic and harmful use
		Veterinary use
		Medicinal use
		Animal feed
		Human food and recipes
	Traditional management	Gathering

		Cultivation
		Commercialization
		Other management activities
Landraces	Common name	
	Description	Agroecosystem
		Antiquity
		Why is it valued
		Taste, texture and smell
		Cultivation cycle
		How is the plant and its used parts
	Traditional use	Social, symbolic or ritual use
		Ornamental use
		Environmental use
		Industry and handcrafts
		Construction
		Fuel use
		Toxic and harmful use
		Veterinary use
		Medicinal use
		Animal feed
		Human food and recipes
	Traditional management	Commercialization
		Breeding
		Harvesting and conservation
		Plagues and diseases
		Fertilization and irrigation
		Pruning and plant support
		Sowing or planting
		Soil management and weeding
		Other management activities
	Seeds	Artisan seed producers
		Private seed/tree banks
		Public seed/tree banks
		Community seed/tree banks
Ecosystems	Farming activities	Tillage
		Sowing
		Cultivation

		Harvesting
		Animal breeding
		Animal care
		Animal husbandry and stock moving
		Other
	Forestry activities	Soil preparation
		Planting
		Silviculture
		Timber products
		Other products
	Hunting and fishing	Big wild game hunting
		Small wild game hunting
		Hand fishing or fish gathering
		Spear fishing
		Net fishing
		Thread fishing
		Trap fishing
		Fishing using other animals
		Shellfish gathering
		Other
	Gathering activities	Fruits, leaves and wood
		Eggs and small animals
		Fungi
		Wild medicinal and aromatic plants
		Other
	Water management	Underground waters
		Surface waters
		Other
	Other activities	Geological resources management
		Symbolic and social activities

2.2 Technological infrastructure

The CONECT-e platform was built on a relational database holding user's contributions, profile and activity information. These data could be accessed through a visual interface that allows any registered user to input and retrieve data (although data are not downloadable in bulk through this interface). The first CONECT-e visual interface was designed using mainly PHP programming language and, although it is open source, the source code for the platform was not published in an open repository. However, the team is currently developing more user friendly and fully open source interfaces for a new version of CONECT-e. This new version will incorporate comments from key users and partners, such as the members of Red de Semillas.

CONECT-e's content was protected under a Creative Commons Attribution-ShareAlike 4.0 International License (CC BY-SA 4.0), which requires that any product using original or modified content from the platform is protected under the same license. This type of license guarantees the free exchange and reproduction of knowledge, provided that such exchange and reproduction is done without excluding other users. In other words, the copyleft license in CONECT-e hindered the establishment of copyrights or trademarks over the content, without restricting commercial uses. For example, landrace names registered at CONECT-e were non-eligible for formal trademark registration (Aceituno-Mata et al. 2017, Calvet-Mir et al. 2018). Moreover, since CONECT-e helped prove the previous existence of the landraces, landraces appearing in CONECT-e could not be formally registered as protected varieties (provided for by the Law 3/2000). However, the information on landraces management (and even seed availability) could still be used by farmers and homegardeners as long as they did not impose restrictions on other users.

Users had to register to document traditional knowledge in the platform, and in such a way, their profile data was saved in the platform's database (free prior informed consent was given upon registration). Once registered, users could be allowed either *basic user* or *editor* permissions. Users with both types of permissions could contribute information to CONECT-e, but only the editors (about 10% of total users) were granted editing and validation/elimination permissions. Editor permissions were granted to core team members (scientists and civil society organization members) and to basic users who contributed meaningfully to the project. Although basic users could not officially validate or eliminate entries, they could contribute to improve the overall information quality and to detect wrong information by commenting, 'likeing' or 'agreeing' with information posted in the platform. With this double validation system, CONECT-e tried to overcome the knowledge hierarchy divide by which traditional knowledge should be validated by scientific knowledge and emphasized the complementarity of the two knowledge systems (Tengö et al. 2014).

Finally, users that made their profiles public could see each other's contributions and receive updates on changes made to the pages they had collaborated with, although CONECT-e did not implement any inter-user communication system.

2.3 Platform dissemination and participation incentives

CONECT-e's citizen science approach required active community engagement. In this sense, several strategies were put in place to incentivize, support and/or compensate the participation of key partners. For instance, the project compensated some partners with copies of the IECTB. Also, the Red de Semillas was compensated with a symbolic financial contribution to support the activities of the regional and local seed networks. Although compensating volunteers in CS has been a very debated topic (Mao et al. 2013, Irwin 2018), it is a common practice in community-based monitoring and other environmental justice initiatives that rely on equitable and bottom-up partnerships (Liboiron and Molloy 2017).

Moreover, a school program based on CONECT-e was designed to encourage young participants to serve as a link between the platform and the knowledge holders (in our case mainly rural elders) and -in that way- bridge the technological gap that traditional knowledge holders might face. More specifically, the idea was to recruit technologically literate students with an interest in nature and farming (i.e., agricultural technical students) and to promote their participation in the platform. The CONECT-e school program had both theoretical and hands-on activities that were based on the CONECT-e educational materials (available in the project website). The theoretical activity was an informal 50 minute talk in which the researchers clarified the concept of traditional agroecological knowledge and gave some examples of the importance of this knowledge system, the causes for its loss, and the pathways to its recovery. At the end of the talk, the students were provided with a practical guide that they could use to conduct interviews with elders and document traditional agroeocological knowledge. The practical activity was a 50 minute session in the schools' computer room during which the students would use CONECT-e to document the knowledge they had previously gathered. The school program was implemented mostly in Catalonia due to the proximity to the research team, although some schools in other Spanish regions (Extremadura and Canary Islands) also did some of the activities.

Other dissemination activities included formal and informal talks in several forums of reference in the area of traditional knowledge conservation, including more local non-scientific fora (such as the annual meetings of the Red de Semillas and of a well-known Catalan association for the revitalization of traditional plant uses - https://eixarcolant.cat) and more global policy and scientific forums (such as the biannual conferences of the European and North American Citizen Science Associations, or the Second Symposium on Agroecology at the UN Food and Agriculture Organization). Also, at the beginning of the project, contact was made with members of the Ecomuseo del Blat - Xarxa de Patrimoni Rural (open-air participatory ethnographic museum, Riva 2017) in La Plana de Vic. This initiative was of special interest due to the rapid transformation suffered by the food systems in the area (i.e., the displacement of traditional agri-food systems in favor of industrialized systems) and the emergent resistances facing this transformation. The Ecomuseo is composed by several municipality councils, the region's university (UVic-UCC), and several associations and historical site owners that have established exhibition centers around the region with the objective of organizing inter-generational activities with a TAeK conservation vision and mission (Hernández Fernández 2016). Although CONECT-e was finally not used by the Ecomuseo, the contacts made were very important to analyze the existing set of actors, discourses and practices around TAeK conservation in a specific local context.

2.4 Applications and policy implications

The importance of documenting and maintaining traditional knowledge for wild and cultivated biodiversity conservation has been highlighted and discussed in several global policy forums and documents, such as the 1992 Convention on Biological Diversity (CBD), the 2001 International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), the 2010 Conference of the Parties in Nagoya (COP10), the Intergovernmental Panel for Climate Change (IPCC; Ford et al. 2016), and recently in the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES; Alexander et al. 2004, Vohland et al. 2011, Díaz et al. 2015). More specifically, articles 8j of the CBD and Article 9.2 of the ITPGRFA point out that each signatory country (including Spain) should respect, preserve, and promote the contributions of traditional knowledge to biodiversity conservation and take measures to protect and promote Farmers' Rights including appropriate national legislation. These measures include i) the protection of traditional knowledge relevant to biodiversity conservation, ii) the right to equitably participate in benefits arising from the utilization of plant genetic resources; and iii) the right to participate in national level decision making on matters related to the conservation and sustainable use of plant genetic resources for food and agriculture and biodiversity conservation. In Spain, this strategy is embodied in Law 30/2006, which acknowledges that public efforts should be done i) to protect, preserve, and promote the traditional knowledge relevant to plant genetic resources cultivated in the different regions of Spain, ii) to promote benefit-sharing initiatives, and iii) to facilitate farmers' conservation, use and trade of landraces and traditional seeds in line with the seed and plant nursery legislation.

Moreover, the Convention for the Safeguarding of the Intangible Cultural Heritage of UNESCO (2003) underlines the importance of preserving the intangible cultural heritage, including traditions and oral expressions, knowledge and uses related to nature and the universe, and traditional craft techniques. More specifically, Member States (Spain included) were urged to promote measures aimed at guaranteeing the viability of intangible cultural heritage, including the identification, documentation, research, preservation, protection, promotion, valorization, transmission and revitalization of this heritage in its different aspects (UNESCO 2003). Following these lines, in Spain, Law 10/2015 for the Safeguarding of the Intangible Cultural Heritage establishes that (besides other aspects linked to traditional ecological knowledge that were already included in the UNESCO convention) gastronomy, culinary elaborations and specific uses of natural landscapes are part of the intangible cultural heritage. This law also establishes, as a general principle to all heritage safeguarding actions, the principle of participation, by which the actions should respect, maintain and promote the leading role of local groups, heritage-holding communities, and civil society organizations in the recreation, transmission and dissemination of intangible cultural heritage.

By facilitating that knowledge-holders themselves document and share their traditional knowledge with other citizens and with scientists, and by protecting it in the sense of maintaining the knowledge under a commons framework and proving prior art to avoid that patent examiners grant wrongful patent or breeder rights, CONECT-e contributes to the fulfillment of these global mandates and could serve to enhance local community's rights over their biodiversity and the conservation of the Spanish biocultural heritage.

3. Structure and aims of the thesis

In addition to this umbrella introduction and a general conclusion section, the main body of this thesis consists of a compilation of five scientific articles: two of them already published (Chapters I and V) and three submitted to peer-reviewed journals (Chapters II, III and IV). To maintain the chapters' internal coherence and flow, the original article format has not been modified. As such, the reader will find some repetitions through the chapters (e.g., methodological descriptions), and also similarities with the overarching introduction of the thesis (e.g., literature review).

The main objective of this thesis is to *evaluate the potential of citizen science as a tool for participatory traditional knowledge conservation contributing to halt its erosion and enclosure*. Specifically, the focus of the thesis is on evaluating CONECT-e as a tool with which scientists and non-scientists can document, share and protect traditional ecological and agroecological knowledge in Spain. Considering this overarching goal, the specific research questions and sections of this dissertation respond to the different evaluation approaches present in the literature on project evaluation: needs evaluation, process evaluation, impact evaluation, and outcome evaluation (Alvira-Martín 1996, Nirenberg et al. 2000, Frechtling 2002, Plataforma de ONG de Acción Social 2003).

Thus, the first section of this thesis (Chapters I and II) focuses on needs evaluation, or the evaluation of the meaningfulness of a project before it is developed. In the case of this thesis, the research question guiding this evaluation is: *Is there a need for participatory traditional knowledge conservation tools like CONECT-e?* Chapter I of this thesis addresses this question by looking into the global literature describing existing traditional knowledge conservation initiatives, while Chapter II addresses it by exploring the existing set of actors, discourses and practices around TAeK conservation in a specific local context.

The second section of this thesis (Chapter III) focuses on process evaluation, or the evaluation of the project's development according to whether it is actually operating as planned. The research question guiding this section is: *Is CONECT-e able to attract diverse and engaged participants, and thus enhance equalized participation in traditional knowledge conservation?* To address this question, Chapter III examines user profile characteristics and activity patterns during the first year of implementation of the CONECT-e platform.

The third section of this thesis (Chapter IV) focuses on impact/goal evaluation, or the verification of the project's internal logic and the achievement of its inherent goals. The research question guiding this evaluation is: *Is CONECT-e preventing traditional knowledge erosion?* Chapter IV addresses this question by exploring the impact of CONECT-e's citizen science school program on the students' valuation and access to TAeK.

The fourth section of this thesis (Chapter V) focuses on outcome/results evaluation, or the verification of project deliverables and the evaluation of the services/products provided by the project. The research question guiding this evaluation is: *Has CONECT-e been able to document, share and protect traditional knowledge as a digital commons?* To address this question, Chapter V explores the content and visits to CONECT-e's landrace section and assesses if the platform can document TAeK, share it in a reproducible way, and protect it as a digital commons to contribute to agroecological transitions.

This thesis ends by outlining the main contributions of my work, and by discussing policy and epistemological implications that derive from it.

PART 1. THE NEED

This is a post-peer-review, pre-copyedit version of the article:

Benyei, P., Arreola, G. & Reyes-García, V. *Ambio* (2019).
https://doi.org/10.1007/s13280-019-01153-6

Chapter 1

Storing and sharing: A review of Indigenous and Local Knowledge conservation initiatives

INTRODUCTION

Indigenous and Local Knowledge systems (ILK), understood as the different adaptive knowledge systems cumulated during generations of social-ecological interactions in a localized context (Berkes et al. 2000, Reyes-García 2015), include know-how, practices, skills and innovations related to different aspects of human life (e.g., agriculture, medicine or environmental management)[6]. These knowledge systems conform a fundamental part of the communities' cultural expression and identity and have been usually understood in contrast to scientific knowledge (Agrawal 1995, Reyes-García et al. 2014, Tengö et al. 2014, Tang and Gavin 2016).

Research suggests that ILK contributes to biodiversity conservation and environmental management (Dominguez et al. 2010, Porter-Bolland et al. 2012) as well as to food production and health enhancement, thus increasing knowledge holders' wellbeing (e.g., (McDade et al. 2007, Calvet-Mir et al. 2011). ILK is also important for communities' cultural heritage and identity (UNESCO 2003) and a key element providing resilient livelihoods, especially in contexts of social-environmental change (von Glasenapp and Thornton 2011, Gómez-Baggethun et al. 2012).

Despite its importance and relative adaptive capacity, ILK is rapidly eroding due to factors such as knowledge-holders' integration into market economies (Reyes-Garcia et al. 2005, Godoy et al. 2005), lack of ILK-sensitive biodiversity conservation regulations (Gómez-Baggethun et al. 2010, Hernández-Morcillo et al. 2014), and lack of inter-generational transmission, a process reinforced by transculturation and de-contextualized schooling (McCarter and Gavin 2011, Tang and Gavin 2016). Moreover, the use and transmission of ILK is also threatened by Intellectual Property Rights (IPR) issues, such as the appropriation of plant material and knowledge through private property rights (Kariyawasam 2008, Lakshmi Poorna et al. 2014).

These issues have triggered changes in IPR law and global policies, some of which now aim at promoting the inclusion of ILK and ILK-holders in biological conservation efforts (Alexander et al. 2004). Moreover, Indigenous Peoples and Local Communities

[6] Many terms have been proposed to define this concept, including Traditional Knowledge, Indigenous Knowledge, Folk Knowledge or Local Knowledge. Here, we use the term Indigenous and Local Knowledge (ILK) recently proposed by the Intergovernmental Science−Policy Platform on Biodiversity and Ecosystem Services (https://www.ipbes.net/deliverables/1c-ilk), except when referring to the work of other authors, when we use their own terminology.

(IPLC) have increasingly taken part in global citizen action and used Information Technologies (IT) and social media to push forward their claims, including the respect for and the conservation of their ILK (Benyei et al. 2017). In fact, both internally and externally driven ILK conservation actions have been flourishing in recent years (Tang and Gavin 2016) including initiatives aiming at the static documentation of ILK, or what we call here ‘storing’, as well as initiatives to dynamically reproduce, transmit and revitalize ILK use, or what we call ‘sharing’.

The diversity of ILK conservation initiatives can be interpreted through the lens of the dichotomy *in situ* vs. *ex situ*, a classification well accepted in biodiversity conservation (Altieri and Merrick 1987), but not yet systematically used in the field of ILK conservation (see McCarter and Gavin 2014 as an exception). As part of this dichotomy, on the one hand, some initiatives adopt a rather static vision of ILK that draws on the literature on ILK-loss and that argues that ILK should be preserved in its original form to prevent its loss. Initiatives in this line include national ILK inventories (i.e., databases and related IPR protection mechanisms) and ethnobotanical studies (e.g., Pardo de Santayana et al. 2014). On the other hand, some initiatives acknowledge the dynamic nature of ILK arguing that this body of knowledge should be maintained in ways that allow adaptation to change. Initiatives in this line include community-based and education activities such as contextualized schooling programs (McCarter et al. 2014).

In addition, at least three different classifications of ILK conservation initiatives have been proposed. A first classification focuses on defensive mechanisms (i.e., databases) to protect Traditional Knowledge (TK) (Lakshmi Poorna et al. 2014). This classification includes three categories: 1) preserving codified TK (e.g., the Indian Traditional Knowledge Digital Library, www.tkdl.res.in), 2) preserving non-codified/oral TK (e.g., the Ulwazi project, http://www.ulwaziprogramme.org), and 3) preserving oral and recorded TK through community archives (e.g., the Ara Irititja Project, http://www.irititja.com). A second classification focuses on strategies for the maintenance of Indigenous Ecological Knowledge (IEK), and includes five non-exclusive categories: 1) securing intellectual property, 2) databases, 3) formal education, 4) biocultural conservation, and 5) community-based IEK maintenance (McCarter et al. 2014). Finally, Tang and Gavin (2016) recently proposed a more extensive classification focusing on Traditional Ecological Knowledge (TEK) conservation actions. Their classification includes five overarching categories with several subcategories: 1) Indigenous capacity building (including institutional development, alliance and partnership development and Indigenous financing), 2) community-based TEK conservation activities (including traditional lifeway programs, environmental conservation activities, and TEK commoditization), 3) education and awareness building (including TEK inclusion in formal education, customary education, and Indigenous media/informal learning), 4) policy and legislative support (including global conventions and national or *sui generis* laws) and 5) research and documentation of TEK (including TEK research and TEK databases).

While this work has contributed to the classification of ILK conservation initiatives and the understanding of the different approaches that underlay ILK conservation, a number of issues regarding ILK conservation initiatives remain under-examined. For example, although much has been discussed about the importance of including IPLC in ILK conservation (McCarter et al. 2014, Tang and Gavin 2016), few studies have systematically measured ILK holders' *participation* in ILK conservation initiatives or empirically measured the factors influencing initiatives' *inclusiveness*. Participation in ILK conservation can be analyzed through participation ladders, an approach that originally examined citizen's engagement in social programs to create a spectrum of inclusiveness possibilities (see Arnstein 1969). Non-participation (i.e., when citizens remain as objects over which decisions and programs are imposed) would be at the bottom of the ladder, while citizen control (i.e., when citizens take an active role in several moments of the program) would be at the top of the ladder. These ladders have been used to categorize citizen science (Haklay 2013a) or participatory monitoring initiatives (Danielsen et al. 2008, Turreira-García et al. 2018), but have not yet been used in the field of ILK conservation. Moreover, participation is influenced by a myriad of internal and external factors (Nov et al. 2011, Haklay 2016), which have not been necessarily considered in previous work regarding ILK conservation. For instance, citizens science and participatory mapping scholars have shown that *digitalization*, or the increase in the use of digital or information technology (IT) tools (Brennen and Kreiss 2016), favors true participation by challenging project's power structures (Dunn 2007; Stevens et al. 2014). However, this issue has not been yet addressed in studies exploring ILK conservation initiatives.

ILK conservation initiatives could also be analyzed considering external factors such as their *timing* and *location*. Analyzing the time when ILK conservation efforts occurred could provide insights on how the field has evolved over the past decades; and analyzing their geographical distribution could contribute to understanding which areas have been prioritized in terms of ILK conservation (see Tang 2012 for a similar approach concerning TEK-related studies).

Finally, an updated analysis of the *approaches* underlying ILK conservation initiatives and their issues could contribute to better understanding current trends regarding the choice of ILK conservation actions and its impact on the inclusiveness of these efforts (for previous work in this line see Tang 2012; McCarter et al. 2014; Tang and Gavin 2016).

In this study, we systematically coded 138 ILK conservation initiatives documented in peer-reviewed articles and used quantitative analyses to provide an updated picture of 1) trends in ILK-holders' *participation*, 2) trends in *digitalization, timing, location and approach*, and 3) factors influencing *inclusiveness* of ILK conservation initiatives.

METHODS

Data collection

During March 2017, we searched for ILK conservation initiatives described in the scientific literature. Specifically, we used a web-based search engine for scientific peer-reviewed publications in English (Scopus; https://www.scopus.com/). The search included the simultaneous use of keywords related to three main concepts: i) traditional knowledge, folk knowledge, Indigenous knowledge, or local knowledge; ii) conservation, protection, revitalization, or maintenance, and iii) initiative, project, program, plan, or strategy. The terms were not combined in the search (i.e., we used "traditional" "knowledge" instead of "traditional knowledge") to avoid excluding more specific initiatives (e.g., "traditional ecological knowledge" initiatives). A preliminary search suggested that the keyword "conservation" mostly resulted in entries related to biodiversity, not to knowledge conservation, thus resulting in thousands of documents most of which were not related to ILK conservation initiatives but to broader issues such as the values of ILK or the interlink between ILK and natural habitat or natural resource management. Therefore, we also included a set of restrictions to our search (e.g., excluding “nature conservation”, “protected areas” or “management”). The final keywords used were: TITLE-ABS-KEY ("indigenous" "knowledge" OR "folk" "knowledge" OR "traditional" "knowledge" OR "local" "knowledge" AND "conservation" OR "maintenance" OR "revitalization" OR "protection" AND "initiative" OR "program" OR "project" OR "plan" OR "strategy" AND NOT "management" OR "habitat" OR "protected areas" OR "nature conservation").

The search resulted in 293 documents, out of which 103 presented or mentioned at least one ILK conservation initiative in the title or abstract. We used ILK conservation initiative, defined as an action, program or strategy to document, protect, reproduce, transmit or revitalize ILK, as our sample unit. Some documents reported more than one ILK conservation initiative, in which case we collected information separately for each initiative. Our final sample comprises 138 ILK conservation initiatives. We collected information on the level of ILK-holders’ *participation* and on the initiatives’ *digitalization* (IT tools used), *timing* (when it took place), *location* (where it took place) and *approach* (what ILK conservation strategy was used). To complete information missing from the documents, we consulted other initiative-related documents and web sites. Remaining missing information was coded as ‘no answer’ (NA).

We entered data in a Microsoft Office Access 2007 database designed for this research. The information on each ILK conservation initiative was coded by the two first authors, who used a codebook with consensual definitions and consulted one another in case of doubts. Inter-coder consistency was tested by comparing the coding for the same first 10 articles (ordered by title) and discrepancies in coding were used to refine the codebook.

Variable description

ILK-holders’ *participation* was measured using a set of variables recording which stakeholders (i.e., NGO’s, IPLC/ILK holders, government, researchers, local authorities, private sector, international organizations, multiple, and other) participated in the different phases of the initiative (i.e., ideation, design, financing, ILK contribution, ILK management, and dissemination) (see Méndez-López et al. 2018 or Turreira-García et al. 2018 for a similar approach; Table 1). We also created two dummy variables to capture the initiatives’ *inclusiveness,* one captured high participation levels (1= ILK holders participated in more than one phase of the initiative) and another captured whether the management of the gathered ILK was exclusively in the hands of the ILK holders (=1) or not. To assess the initiatives' *digitalization*, we used a dummy variable recording the use of information technology (IT) tools (1= IT tools used). To capture *timing***,** we classified initiatives by their initiation decade (e.g., "72-92", "93-03", "04-15") and temporal continuity (1=the initiative lasted more than 3 years, 0=otherwise). To capture *location***,** we used variables recording the region and the continent where the initiative took place (following the classification from Encyclopedia Britannica 2006), categorized the initiatives' scale (i.e., local, regional, national, or global), and differentiated between initiatives taking place in western-industrialized regions (i.e., US, Canada, Australia, New Zealand or Europe) and elsewhere and between initiatives targeting indigenous communities or not (1=yes). To assess the initiative's *approach*, we followed Tang and Gavin's 2016 classification of TEK conservation actions (i.e., capacity building, community-based activities, education/awareness, policy/legislation, and research/documentation). We also used a variable recording the ILK domain targeted (i.e., "agricultural" - e.g., landrace knowledge or agroecological practices; "cultural" - e.g., traditional languages, crafts and artistic expressions; "ecosystem" - e.g., knowledge on ecosystem elements and interactions or natural resource management practices, "medicinal" - e.g., medicinal uses of plants, and "multiple" - e.g., initiatives targeting several domains of ILK) and two dummy variables, one recording whether the initiative had a specific IPR protection objective (1=yes) and one recording whether it had specific ILK conservation goals (1=yes). The Access database was imported to RStudio Version 1.0.153 for data processing and analysis.

Table 1. Variables used in the analyses

Group	**Variable**	**Type**	**Definition**
Timing	I_ReferenceYear	Interval	Year when the initiative started
	I_ReferenceDecade*	Factor with 3 levels	Grouped I_ReferenceYear in approximated 10yr periods from first initiation year
	I_Continuity*	Binary	Did the initiative take place for more than 3 years? (1=yes)

Location	L_Region	Factor with 31 levels	In which region did the initiative take place?
	L_Continent	Factor with 8 levels	In which continent did the initiative take place?
	L_Scale*	Factor with 3 levels	What was the scale of the initiative?
	L_Industrialized*#	Binary	Did it take place in the US and Canada, Australia, New Zealand or Europe? (1=yes)
	L_Indigenous	Binary	Did the initiative specifically targeting indigenous communities? (1=yes)
Approach	I_ApproachMain	Factor with 19 levels	Categories based on Tang and Gavin (2016)
	I_ApproachGroup2*#	Factor with 5 levels	Categories based on Tang and Gavin (2016)
	I_TypeILK_2*#	Factor with 5 levels	What type of ILK did the initiative target?
	I_IPRObjective*	Binary	Did the initiative state having a specific IPR protection objective? (1=yes)
	I_ConservationGoal*	Binary	Was knowledge conservation the specific and main goal of the initiative? (1=yes)
Digitalization	M_IT*#	Binary	Did the initiative use any IT tools? (1=yes)
Participation	M_PrivateDataManagement	Binary	Was the ILK gathered exclusively managed by the ILK holders or the community? (1=yes)
	P_Ideation	Factor with 9 levels	Who participated in the ideation of the initiative?
	P_Design	Factor with 9 levels	Who participated in the design of the initiative?
	P_Financing	Factor with 9 levels	Who participated in the financing of the

			initiative?
	P_Datacontribution	Factor with 9 levels	Who contributed with data/traditional knowledge?
	P_DataManagement	Factor with 9 levels	Who participated in the data management of the initiative?
	P_Dissemniation	Factor with 9 levels	Who participated in the dissemination of the initiative results?
	P_Inclusiveness*#	Binary	Did the ILK holders participate in more than one phase of the initiative?
*Included in MCA, # included in LOGIT analyses, the rest were used in the descriptive analyses			

Data analysis

We used descriptive and exploratory analyses to unveil trends in our data. To explore trends in ILK-holders' participation, we analyzed the frequency in which ILK-holders participated in the different phases of the initiative. To explore trends in ILK conservation initiatives' digitalization, timing, location and approach, we conducted a descriptive analysis of our variables and produced summary metrics. Finally, to explore the factors influencing ILK conservation initiatives' inclusiveness we used Multiple Correspondence Analysis (MCA) and generalized linear models (GLM) with a binomial error structure based on a logit link (logistic regression). The MCA was performed to assess potential underlying structures in our dataset and explore potential associations between inclusiveness (P_Inclusiveness) and other variables (i.e., I_ReferenceDecade and I_Continuity for timing, L_Scale and L_Industrialized for location, I_ApproachGroup2, I_TypeILK_2, I_IPRObjective and I_ConservationGoal for approach, and M_IT for digitalization) (Le Roux and Rouanet 2010; see Table 1). The GLM were performed to model the probability of inclusiveness (P_Inclusiveness= 1) as a function of digitalization, approach and location, variables that were selected because they contributed to the same MCA dimension than *inclusiveness*, and thus emerged as potentially affecting ILK holders' participation. The model was built using manual stepwise forward regressions by which each variable was added manually to the model and kept when it significantly increased its explanatory power (Crawley 2007). The significance of each model term was checked using Chi2 tests and we used the Akaike

Information Criterion (AIC) to compare the models and select the parameters included in the final model. The final model was the one that most parsimoniously explained the greatest variation in inclusiveness (AIC= 118.3). This model (expressed by the function: P_Inclusiveness ~ I_ApproachGroup2 + M_IT + I_TypeILK_2 + L_Industrialized) was checked for absence of multicollinearity using the VIF index (no multicollinearity was found) and for absence of auto-correlated errors using the Durbin-Watson test. Post-analysis diagnostic plots (residuals, q-q plots) were used to check other assumptions of the model. We also used the McFadden R^2 to assess the model fit and effect plots to interpret the odds ratio coefficients. All models were developed using the glm function in R (R Development Core Team 2009).

RESULTS

Participation in ILK conservation

The ILK gathered by the initiatives analyzed in this study was exclusively in hands of the ILK holders in only one fifth of the initiatives (21.7%). In fact, ILK holders were not only largely absent from ILK management, but also from other phases of the initiative's development (Figure 1). Indeed, only 34 initiatives (24.6%) included ILK holders in more than one phase. Moreover, even when included in more than one phase, ILK holders were more likely to participate in the initiative's later stages than in its inception (i.e., ILK holders participated in ILK management in 15.2% of the initiatives and in dissemination in 10.2% but only participated in ideation in 5.1% of the initiatives and in design in 2.2%). For instance, some of the most inclusive initiatives (e.g., Traditional Life Skills Project in Namibia (Klein 2011) or Ojibwemodaa! project in the USA (Hermes et al. 2012)) were proposed by researchers or the government. Thus, although ILK holders were fully engaged in most phases of these initiatives, they were still absent from their inception. ILK holders' contribution to financing the initiatives was even rarer, with only one documented initiative (Fundación Sabiduría Indígena and Kothari 1997).

Other trends in ILK conservation

Only 24.64% of the studied initiatives used IT tools. Most (65.2%) started after 1993, with initiation peaks in 2002 and 2010, and almost half of the initiatives (44.9%) lasted more than three years, although several (32.6%) did not state their initiation and/or ending year, for which we could not calculate their duration (Figure 2).

Figure 1. Stakeholders' participation in the different stages of the initiatives. Note that NA/NR stands for no answer-not relevant (did not include that phase).

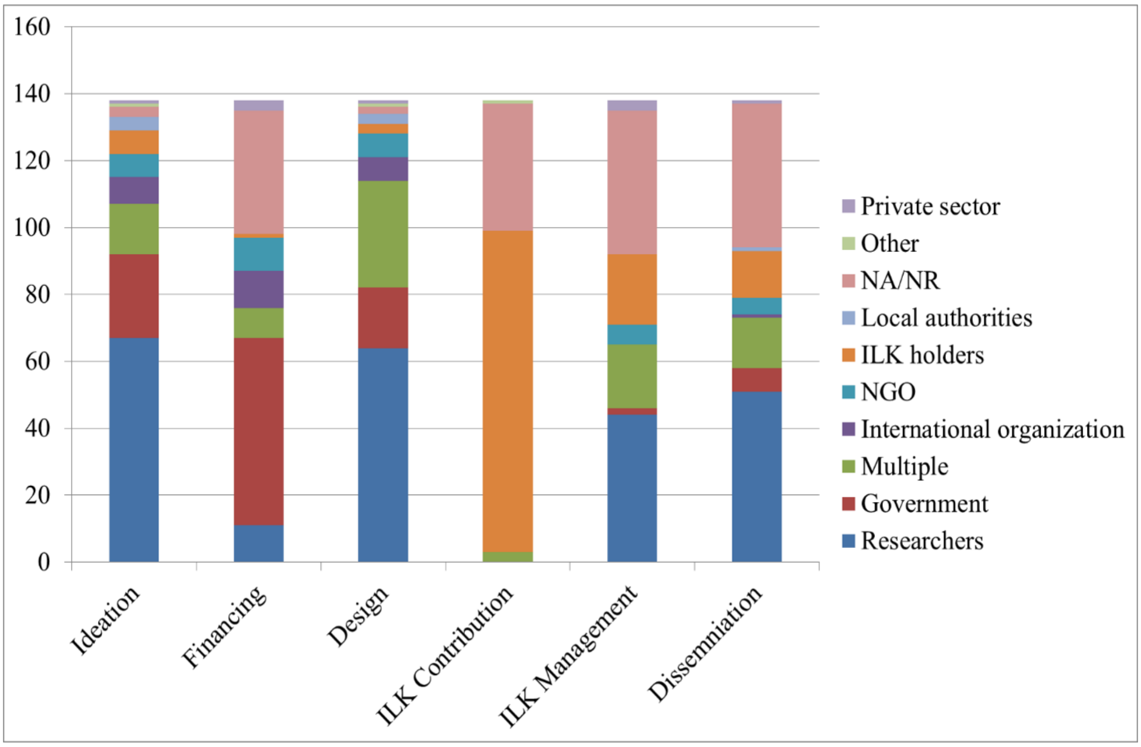


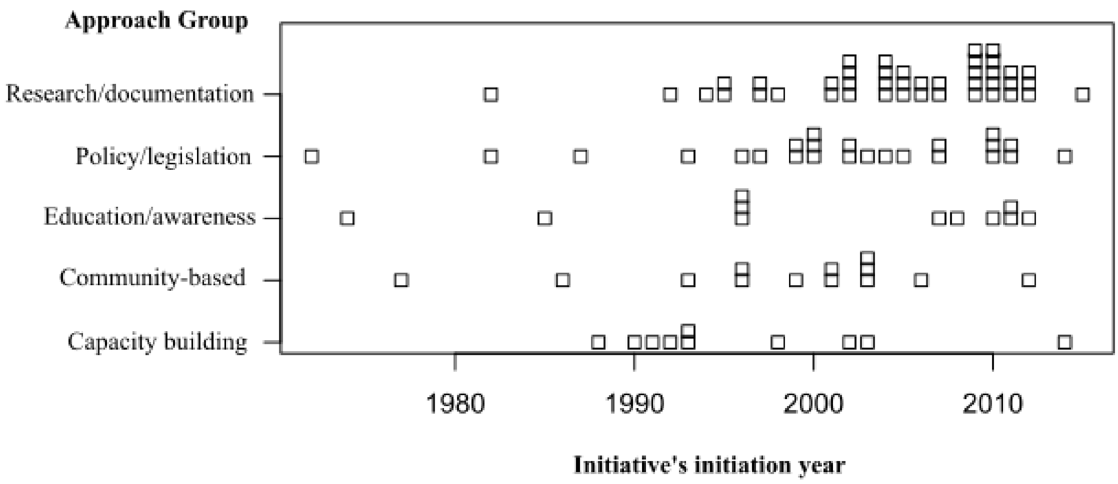
Figure 2. Initiation year for the studied initiatives

The studied initiatives were mainly located in Asia (30.4%) and Oceania (21%), and particularly in South-Central Asia, including India and the Himalayas (15.9%), and Australia (10.2%). Some initiatives (10.9%) took place in multiple regions. We did not find any initiative in Europe, but 5.8% were found in United States and Canada. Most studied initiatives were developed at a local scale (53.6%) and in areas with Indigenous communities (72.5% of the initiatives specified targeting Indigenous communities).

About half (48.6%) of the initiatives had a research/documentation approach, including ethnobotanical research, the most common approach subcategory (15.9%). Policy/law was the second most frequent approach (18.8%), including IPR law approach (5.1%). However, 23.2% of the initiatives had some IPR protection goal even if IPR law was not their main approach. The rest of the initiatives followed either a capacity building (7.2%), a community-based (12.3%), or an education and awareness (9.4%) approach.

Initiatives with a capacity building or a community-based approach were generally initiated in the 1990's, while initiatives with a research/documentation and policy/legislation approach were initiated in the 2000's and onwards (Figure 3).

Figure 3. Initiatives' initiation year by approach group (following Tang and Gavin 2016).



Finally, most of the studied initiatives targeted medicinal (26.8%) or cultural knowledge (18.8%) although only 32.6% of the initiatives specifically targeted ILK conservation. Rather, in most studied initiatives, ILK conservation was a side effect or a means to economic development or environmental conservation. For example, subprojects 138 and 570 of the Pilot Program for the Protection of Brazilian Tropical Forests (Little 2005) focused on creating an alternative source of income for local communities by developing a medicinal garden, which, as a side effect, contributed to traditional medicinal knowledge conservation. Similarly, the PLEO method tested in Cameroon (van der Hoeven et al. 2004), focused on integrating ILK in animal population calculations, tangentially helping revitalize this knowledge.

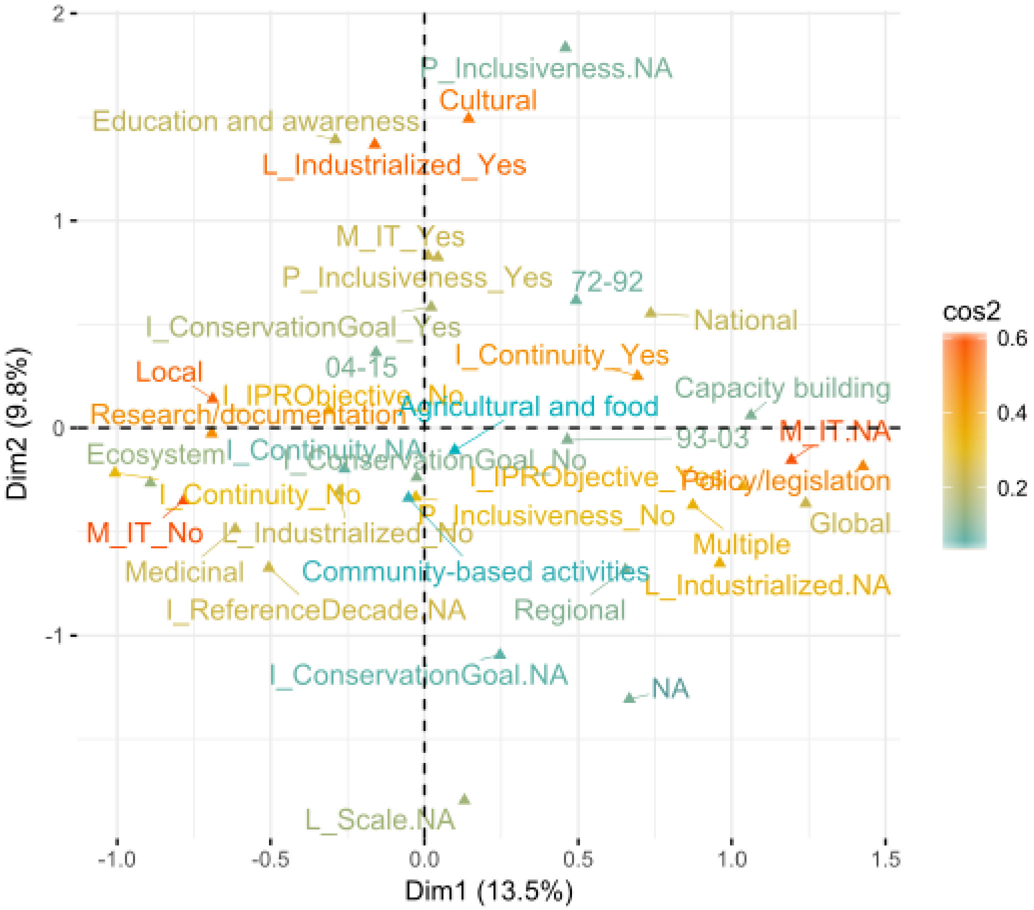
Factors influencing initiatives' inclusiveness

We found no clear underlying structure in our data (i.e., no clear relationship between the previously described trends), as only 23.3% of the variability in our data was explained by the MCA's first two dimensions. However, some of the categories of the variables analyzed seem to meaningfully contribute to the same MCA dimension and have a high Cos2. This means that they might be significantly associated (Husson et al. 2017, see Figure 4 and Table 2).

The first dimension of the MCA seems to capture two groups of initiatives. On the one side (close to the Dim2 axis but to the right of the Dim1 axis), there were initiatives having a policy approach (*Policy/legislation*), taking place globally (*Global*), and lasting more than three years (*I_Continuity_yes*). Examples include global long-term policy measures emerging from the World Intellectual Property Organization (WIPO) or the Council for the Uruguay Round Agreement on Trade Related Aspects of Intellectual Property Rights (e.g., Lettington 2002). On the other side (close to the Dim2 axis but to the left of the Dim1 axis), there were initiatives having a research/documentation approach, taking place locally (*Local*), lasting less than three years (*I_Continuity_No*), and not using IT tools (*M_IT_No*). Examples include researcher-led ethnobotanical studies aiming at documenting ILK in a specific geographic area and over a brief period of time to preserve ILK in scientific publications or books (e.g., Aziz et al. 2016).

The second dimension of the MCA (close to the Dim1 axis) captures initiatives having an education and awareness approach (*Education and awareness*), using IT tools (*M_IT_yes*), focusing on cultural knowledge (*Cultural*), occurring in USA, Canada, Australia or New Zealand (*L_Industrialized_yes*), and including ILK holders in more than one phase of the initiative (*P_Inclusiveness_yes*). Examples include projects documenting North American Indigenous cultural artifacts by building online platforms, initiatives in which the community contributes, manages and learns from the information and artifacts displayed, engaging both young and old community members (e.g., Solomon and Thorpe 2012).

Figure 4. Contribution and Cos2 of variable categories to the MCA's first two dimensions. Note that if a variable category is well represented by two dimensions, the sum of the Cos2 is close to one (Husson et al. 2017).



Thus, these analyses suggest that the initiatives characterized by being more inclusive also tend ***i)*** to have an educational approach, ***ii)*** to use IT tools, ***iii)*** to target cultural ILK, and ***iv)*** to be located in western-industrialized contexts.

Table 2. Contribution (in %) of the main variable categories to the first two MCA dimensions.

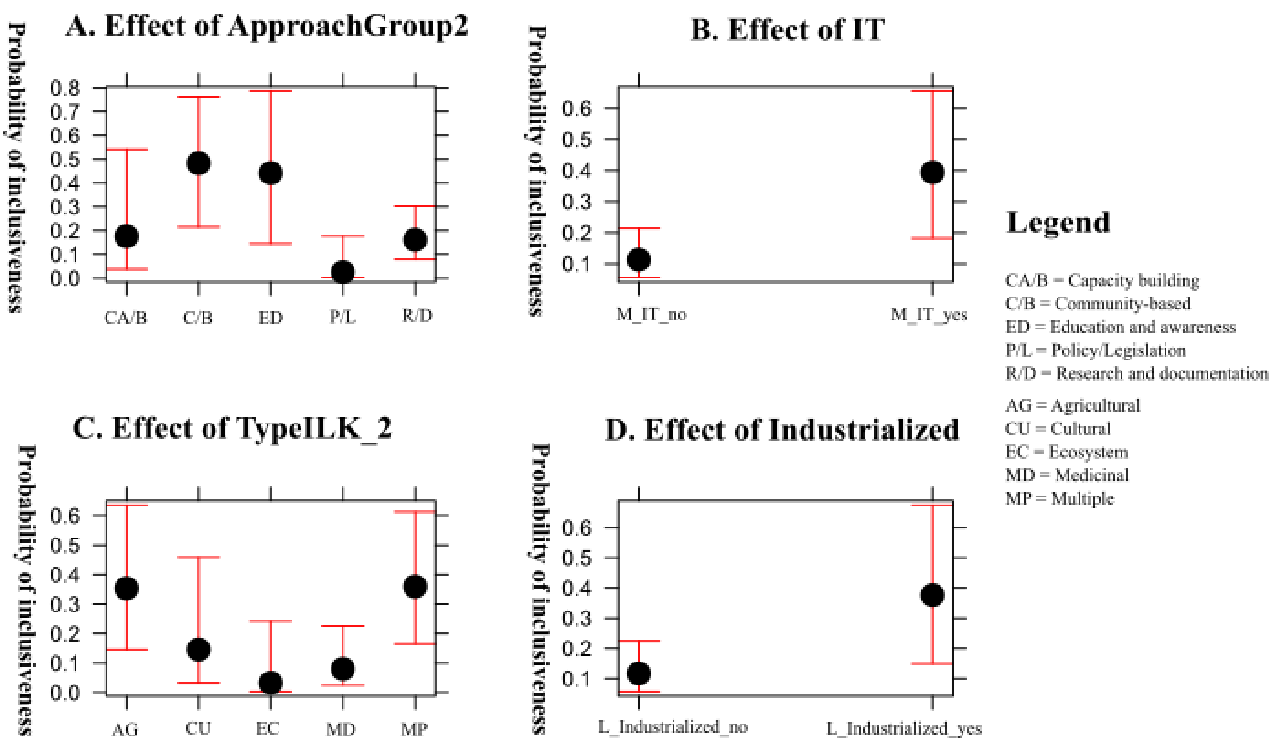
Dimension 1	**%**	**Dimension 2**	**%**
Policy/legislation	10.5	L_Industrialized_Yes	15.9
M_IT_No	7.7	Cultural	15.9
Local	7	Education and awareness	6.9
I_IPRObjective_Yes	6.8	M_IT_Yes	6.4
Research/documentation	6.4	P_Inclusiveness_Yes	6.3
I_Continuity_No	6.3		
I_Continuity_Yes	5.9		
Multiple	5.8		
Global	5.2		

Results from the final logistic regression model support his result in that they point out that initiative's approach, use of IT tools, type of ILK targeted, and location in western-industrialized contexts were in fact significantly associated with the likelihood of an initiative being more inclusive (McFadden $R^{2=}$ 0.37, see Table 3).

Table 3. Results from the analysis of deviance (ANOVA) of our model expressed by the function: P_Inclusiveness ~ I_ApproachGroup2 + M_IT + I_TypeILK_2 + L_Industrialized

P_Inclusiveness	**Df**	**Deviance**	**Resid. Df**	**Residual. Dev**	**Pr (>Chi)**
NULL			126	143.380	
I_ApproachGroup2	4	16.0033	122	127.377	0.003015 **
M_IT	1	15.4093	121	111.967	8.656e-05 ***
I_TypeILK_2	4	11.6648	117	100.302	0.020026 *
L_Industrialized	1	4.0405	116	96.262	0.044419 *
Signif.: 0 '***' 0.001 '**' 0.01 '*' 0.05					

Figure 5. Effects of the variables on the initiative's inclusiveness (P_Inclusiveness)



Initiatives using IT tools and located in an industrialized context had a significantly higher probability of been inclusive (Figure 5B and 5D, p-values 0.013 and 0.051 respectively). Moreover, having a policy/legislation approach decreased significantly the probability of the initiative being inclusive when compared to initiatives with a community-based approach (Figure 5A, p-value 0.009). Finally, initiatives targeting ecosystem or medicinal ILK had significantly lower probabilities of being inclusive than initiatives targeting agricultural (Figure 5C, p-values 0.031 and 0.021 respectively) or multiple domains or types of ILK (Figure 5C, p-values 0.029 and 0.019 respectively).

DISCUSSION

Results from our analysis reveal important gaps and inclusiveness issues in ILK conservation that can meaningfully contribute to the discussions in this field. However, as these results might be biased, we start the discussion presenting potential caveats of our work and discussing how those might affect our results.

Potential caveats of our study

The single most important caveat of this work relates to sampling, thus potentially affecting the overall generalizability of the results presented. Our sample only includes initiatives documented in peer-reviewed articles. This might result in a systematic sampling bias regarding the initiatives' timing (i.e., results may be influenced by trends in journal digitalization and changes in publication culture), approach (i.e., researchers might have documented more documentation/research initiatives than community-based initiatives) and inclusiveness (i.e., scientists tend to document initiatives they have lead, leading to an under-representation of NGO/IPLC-led initiatives). Moreover, our sample also excluded documents in languages other than English, which could affect location results (for example, we only found 9% of initiatives located in South America). Our sample might also be biased through our selection of keywords (i.e., traditional, local, folk), as suggested by the fact that we mostly retrieved initiatives involving Indigenous communities (72.5%), and none located in Europe. We acknowledge that these sampling biases might make our results only generalizable to initiatives developed by or relevant to the academic world (thus excluding a large set of initiatives developed by NGO's and IPLC that would not be reported in the sampled documents).

Another caveat of this study is the use of a single method and analytical approach. Considering the holistic, dynamic and organic nature of ILK (McCarter et al. 2014), we acknowledge that this is a very important issue that might lead us to a reductionist view of ILK conservation.

These caveats affect our interpretation of results and were taken into consideration in the following discussion.

Inclusion and the politics of TK conservation

Our results revealed important inclusiveness issues related to the participation of ILK holders in ILK conservation initiatives reported in the scientific literature. We found that in most initiatives studied, ILK holders did not participate beyond the collection of ILK and that, when they did participate, they did so in the later phases of the initiative. Moreover, in most of the examined initiatives the ideation and design phases were led by researchers. Interpreted through the lens of participatory ladders, our result unveils a tendency towards non-participation or tokenism (following Arnstein's categories, 1969) revealing that the real objective of many initiatives is to "educate" participants rather than to enable their participation. Moreover, even when initiatives "enable participants to hear and to be heard" (in Arnstein's words), ILK holders still lack the power to ensure that their views will be taken into account beyond ILK collection. This result brings attention to the fact that ILK holders continue to be widely absent from initiatives aiming at ILK conservation and that researchers continue to design ILK conservation initiatives in which ILK-holders only contribute their knowledge. These results can be interpreted as a consequence of existing knowledge hierarchies that promote ILK integration into western-scientific knowledge systems (as opposed to other ways of knowledge co-production), a process that has been contested by several authors (Agrawal 1995, Nadasdy 1999, Tengö et al. 2014). However, given the biases in our sample, it is possible that this result do not reflect inclusiveness in initiatives led by the communities.

Our findings also suggest that some types of initiatives are more inclusive than others. For instance, initiatives targeting ecosystem or medicinal ILK seem to be less inclusive than initiatives targeting agricultural or multiple types of ILK, a finding that could just be reflecting the dominance of an "extractivist" approach to ILK documentation among initiatives in our sample. Contrarily, initiatives that used IT tools were more inclusive than the rest, a finding in line with results from other fields such as participatory GIS (Dunn 2007), participatory monitoring (Benyei et al. 2017) or public participation in science in general (Stevens et al. 2014). Indeed, Information and Communication Technologies (ICTs) are considered to be key elements in enabling true participation and in challenging the power structures in participatory projects. It should be noticed, however, that the use of IT tools does not necessarily guarantee full participation, nor does the lack of it compromises the participatory nature of an initiative, as we can see in the cases presented by Lakshmi Poorna and colleagues (2014), which are all IT-based but do not necessarily engage ILK-holders in all the phases of the initiative.

Finally, we found that initiatives with a community-based or an education and awareness approach tended to have higher probability of being inclusive than initiatives with a policy/legislation and research/documentation approaches. In other words, *ex situ* initiatives such as databases and ethnobotanical inventories were less inclusive than *in situ* initiatives such as inter-generational school activities, which have already been described as better serving ILK dynamic maintenance (e.g., McCarter et al. 2014). While not surprising, the result is relevant in that it complements with quantitative results the challenges of *ex situ* (research and policy) approaches and the strengths of *in situ* (education and community-based) approaches previously reported in the literature (McCarter et al. 2014, Tang and Gavin 2016).

Other gaps in ILK conservation

Our results highlight that trends found in previous research regarding the frequency of ILK conservation actions or approaches still prevail. Initiatives that follow research/documentation or policy/legislation approaches, i.e., *ex situ* approaches to ILK conservation, were prevalent among the initiatives reviewed (and more so in recent years). These findings are generally in line with Tang and Gavin's results (most initiatives followed a research/documentation approach, 2016) and with McCarter and colleague's findings (securing IPR was the most widely documented approach, 2014). In contrast, initiatives with an education/awareness or community-based approach, i.e., *in situ* initiatives, were scarce (see the Parque de la Papa project described by Graddy 2013 as an exception), and more frequent in the 1990's than in the 2000's. Moreover, in our sample of peer reviewed articles we rarely found initiatives that tried to combine both paradigms (i.e, *ex situ* and *in situ*), for example through community databases that actively engage school students or other community members (see the Ara Irititja project described by Lakshmi Poorna et al. 2014 for an exception). While it is possible that these findings only reflect sampling biases, they can also be showing that academic ILK conservation is increasingly shifting towards more *ex situ* approaches, a trend that should be revised considering the challenges related with removing ILK from its situated context and from the control of the ILK-holders (Zent 1999, Agrawal 2002, Campbell and Vainio-Mattila 2003, McCarter et al. 2014).

Our results also reveal important trends regarding the focus of ILK conservation initiatives. The initiatives analyzed targeted some types of knowledge more frequently than others and not many initiatives focused on ILK conservation on itself. Many initiatives primarily had biological conservation or economic development goals, ILK conservation being a secondary objective or side effect result. Moreover, agricultural ILK was somewhat less targeted, especially when compared to medicinal ILK (19 versus 37 ILK conservation initiatives). Initiatives targeting other domains or types of ILK, such as climate knowledge or knowledge about traditional tools, were even less frequent (two and one initiatives respectively). These results reveal a possible tendency towards favoring the protection of one type of ILK (medicinal) over others, possibly reflecting a system of values for different types of knowledge that could be influenced by epistemological and power issues such as knowledge hierarchies or knowledge commoditization tendencies (e.g, commoditization of medicinal knowledge). These issues have been previously described by the literature on the scientific-lay knowledge divide and politics of knowledge (Nadasdy 1999, Burke and Heynen 2014). Our findings also reveal a tendency towards favoring the conservation of ILK potentially relevant for biological conservation (for examples see McCarter et al. 2014). However, this approach should be re-examined since its effectiveness is not fully understood and since it limits the potential contributions of ILK to other fields, although in most cases the ILK conservation and biodiversity conservation are not mutually exclusive (McCarter et al. 2014, Reyes-García 2015).

Finally, our findings also contribute to the discussions on ILK legal protection. Although most initiatives emerged after the CBD agreements (which had important sections regarding benefit sharing and rights over ILK), few initiatives had an IPR approach. This might reflect the numerous challenges faced by legislative solutions to ILK protection. For instance, some authors have described that the mismatch between collectively managed knowledge systems and individual-rights based IPR could hinder the protection of ILK via IPR mechanisms (Reyes-Garcia et al. 2003, Lakshmi Poorna et al. 2014, McCarter et al. 2014). While several authors have claimed that intellectual property legislation alone will not be able to address and reverse ILK degradation (Oguamanam 2004, McCarter et al. 2014), our results call for further attention to the issue of IPR, especially considering the problems derived from an inappropriate or absent ILK legal protection (Lakshmi Poorna et al. 2014).

CONCLUSION

Responding to calls for a more comprehensive understanding of ILK conservation initiatives (Tang and Gavin 2016), we conducted a systematic review of 138 ILK conservation initiatives exploring trends in participation/inclusiveness, digitalization, timing, location, and approach. We withdraw two main conclusions from our results. First, despite the existence of a myriad of complementary ILK conservation efforts reported in the academic literature and despite their many challenges (McCarter et al. 2014), *ex situ* strategies (i.e, documentation and policy/legislation efforts) prevail. Second, ILK holders are generally absent from the development of the initiatives reviewed, with IT based and *in situ* (education and community-based) initiatives being generally more inclusive. This type of initiatives, we argue, are the ones that could lead the participatory turn challenging the knowledge hierarchy divide.

Based on our findings, further research on the topic should tackle several issues. One, there has not been yet a systematic study of ILK conservation initiative effectiveness, and this is a gap that must be addressed by creating systematized protocols of initiative evaluation that include aspects related to the initiative's inclusiveness. Two, there is a need for further reviewing the literature and including non-academic documents in different languages in order to overcome our biases. Three, there is a need for qualitatively complementing our results in order to disentangle issues such as motivation or social networks behind ILK conservation. And four, there is a need to re-formulate the way in which *ex situ* conservation is done but also for the support to scientific projects that are community led and include educational activities. Such work is critical in order to inform decision making regarding the funding and promotion of those initiatives that are more inclusive towards ILK-holders and that break the knowledge divide contributing to a more just and locally sensitive ILK conservation.

This is a pre-print version of the article:

Benyei, P., Calvet-Mir L., Reyes-García V., & Rivera-Ferre M. *Agroecology and sustainable food systems* (under revision).

Chapter 2

Resistance to Traditional Agroecological Knowledge loss in industrialized contexts: The case study of la Plana de Vic (Catalonia)

INTRODUCTION

Traditional Agroecological Knowledge (TAeK or TAK) is a term used to define the cumulative body of knowledge, practices, and beliefs about an agroecosystem that has evolved and adapted to the local environmental and cultural contexts after generations of farmer-nature interactions (Rocha 2005, Toledo and Barrera-Bassols 2008, Reyes-García et al. 2013, 2018b). Examples of TAeK can be found in the knowledge farmers have on landraces (i.e., plants of a certain botanical taxon selected by farmers and resulting in local environmentally and culturally adapted crops), practices related to the preparation/transformation of cultivated plants, or beliefs and institutions related to agricultural resource management such as local rules around water management (Calvet-Mir et al. 2018).

TAeK is essential not only for agrobiodiversity conservation and management, but also for providing resilient and locally adapted food systems that contribute to food sovereignty (Altieri and Merrick 1987, Armitage 2003, Altieri and Toledo 2011). Research has shown that traditional agricultural practices contribute to biodiversity maintenance (Altieri and Nicholls 2000), including the maintenance of wild diversity (Blanckaert et al. 2007). For example, traditionally managed agroecosystems, such as *dehesa* grasslands (an agrosilvopastoral system found in southern and central Spain and Portugal), support a wide diversity of plant and animal species (Peco, Oñate, and Requena 2000; Plieninger and Wilbrand 2001). Similarly, traditional animal husbandry practices, such as shepherding, provide dispersal opportunities for multiple plant species and are thus considered useful approaches to plant diversity restoration in fragmented grasslands (Babai and Molnár 2014; Rico, Boehmer, and Wagner 2014). In the same line, traditional home gardens contribute to the *in situ* conservation of crop genetic diversity (Perrault-Archambault and Coomes 2008, Calvet-Mir et al. 2011) and to the provision of other ecosystem services, especially cultural services such as the maintenance of cultural identity and social networks (Calvet-Mir et al. 2012b). Furthermore, TAeK is considered critical for agroecological transitions since this knowledge offers the potential to contribute to the reduction of farm inputs and to the intensification of farm biodiversity, providing answers to some of the environmental, political and economic challenges that agroecological transitions face (Koohafkan and

Altieri 2011; Altieri, Funes-Monzote, and Petersen 2012; Guzmán et al. 2013; Gliessman and Rosemeyer 2010; Calvet-Mir et al. 2018).

Although TAeK has some level of resilience that might allow its co-existence with modern farming knowledge and practices (Reyes-García et al. 2014), there is a great concern regarding TAeK's rapid erosion (e.g., loss of traditional management practices or landrace names) and enclosure (i.e., the establishment of restrictive property rights over agrobiodiversity and associated knowledge). For instance, several authors have noticed the rapid loss of traditional agroecological practices in Europe, a phenomena that has been often linked to the intensification of the agricultural systems and to strict regulations in protected areas (Gómez-Baggethun et al. 2010; Hernández-Morcillo et al. 2014). Other authors have highlighted the problems related to the private and public management of TAeK (especially landrace knowledge), calling for its protection under a "commons" framework (Brush 2007, Srinivas 2012, Reyes-García et al. 2018a, 2018b).

In the light of these threats, several initiatives aiming to promote TAeK conservation have emerged around the world, including initiatives engaged in the static documentation or storing of TAeK (an *ex situ* or de-contextualized approach) and also efforts to gather, reproduce, transmit and revitalize TAeK's use among knowledge holders and their communities (an *in situ* or contextualized approach; Benyei et al. 2019). For instance, after the signature of the Convention on Biological Diversity (1992) that had articles referring to the inclusion of traditional knowledge in biological conserveation efforts (Alexander et al. 2004), there has been an emergence of policy and legislative initiatives to protect traditional knowledge (including TAeK) through databases and inventories (Lakshmi Poorna et al. 2014, Pardo-de-Santayana et al. 2014). In parallel, a diversity of community-based programs have been initiated to encourage *in situ* traditional knowledge maintenance (McCarter et al. 2014; Tang and Gavin 2016). These initiatives include projects aiming at putting TAeK into practice through workshops, the cultivation and exchange of landraces, the use of traditional tools, or the recovery of traditional gastronomy, among others. Some initiatives have also started to focus on traditional knowledge gathering and sharing among an extended online community, as a way both to protect and revitalize these knowledge systems (Calver-Mir et al. 2018). Moreover, civil society organizations have also been promoting TAeK conservation and protection. For instance, in Spain, the different local seed networks (coordinated under the non-governmental organization "*Red de Semillas. Resembrando e Intercambiando*") have played a crucial role in inventorying and sharing traditional landrace knowledge (Reyes-García et al. 2018a).

Recent research shows that initiatives targeting TAeK conservation seem to be more inclusive than initiatives targeting other domains of traditional knowledge (Benyei et al. 2019). This could be due to the specificities of some TAeK conservation actions that rely on community networks, public participation, and collective action (e.g., community seed banks, lifeway museums, or inter-generational TAeK exchange activities). Moreover, TAeK conservation initiatives can be understood through the framework of resistance, defined as individual or collective efforts that oppose, confront, and try to prevent or reverse social, cultural, or economic structural conditions (Hollander and Einwohner 2004; Lee 2017). In that sense, TAeK conservation initiatives could be understood as resistance actions since they represent efforts to halt TAeK loss, which is a result of certain sociopolitical and economic conditions, namely the industrialization of food systems. Moreover, resistance to TAeK loss could be overlapping with the interest of movements resisting industrialized food systems in general and with the agroecology movement in particular (Koohafkan and Altieri 2011; Gliessman 2013; Mier y Terán Giménez Cacho et al. 2018; Bonanno and Wolf 2017).

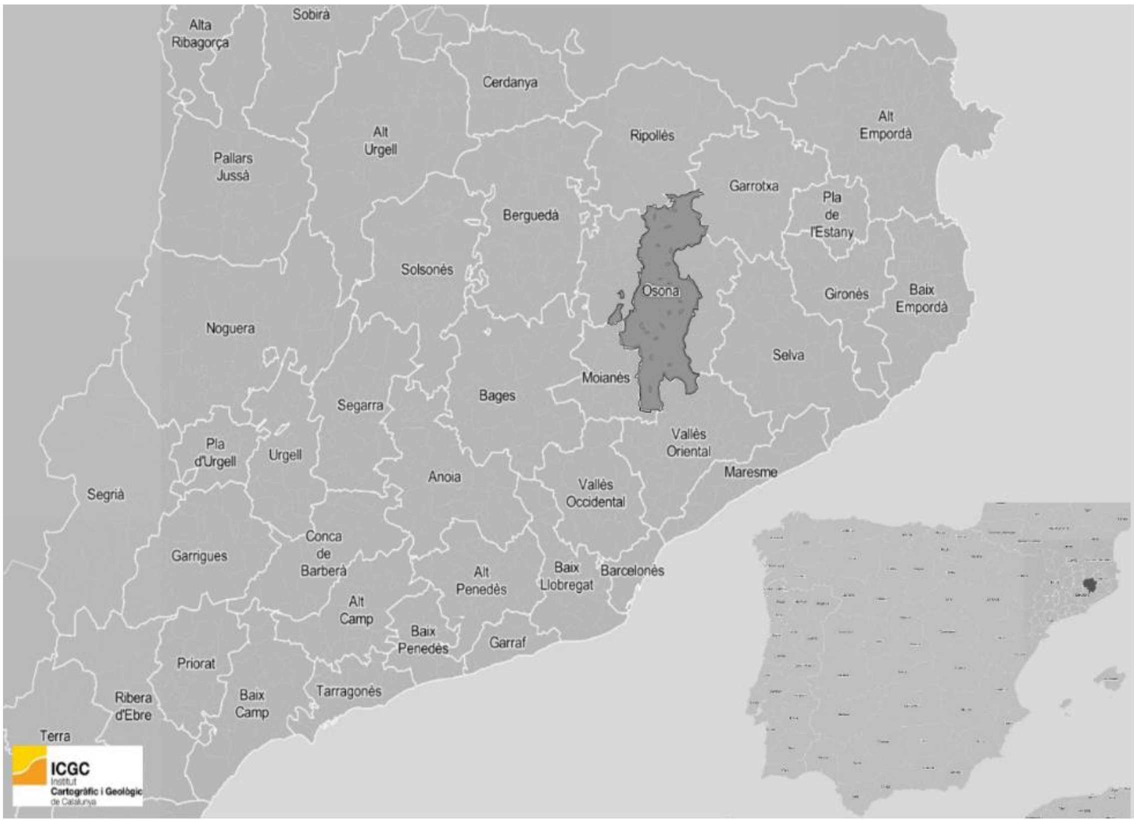
While the resistance movements against industrialized agri-food systems have received more scholarly attention (McMichael 2005), it is still not clear how the different approaches to TAeK conservation align with these movements in industrialized contexts, where the connection between agricultural production and TAeK has been weakened. Moreover, although TAeK conservation has been studied before, previous work has mainly explored conservation efforts related to one physical element in the TAeK systems (e.g., landrace knowledge conservation through seed networks, see for instance Calvet-Mir et al. 2012a or Calvet-Mir and Salpeteur 2016). Thus, we lack a more holistic understandings of how TAeK conservation efforts are conceptually and relationally articulated (i.e. which are the motivations behind TAeK conservation and how do the different TAeK conservation efforts relate to one another; Benyei et al. 2019).

In this work, we shed light on these research gaps by exploring 1) local actors' perceived opportunities and threats to TAeK conservation; 2) local actors' discourses around TAeK conservation; and 3) the local network of TAeK conservation projects in a study area in central Catalonia where an industrialized agri-food system has rapidly been replacing traditional agri-food systems.

STUDY AREA

This study took place in the region of Osona, central Catalonia (north-east Iberian Peninsula). More specifically, we focused on the area called *La Plana de Vic* (Figure 1), the main flatland of the region where industrialized agriculture has taken over drastically, especially since the mid-20th century (Torrents i Buxó 2009, del Val i Torra 2016).

Figure 1. Geographical location of the study area.



La Plana de Vic is an erosion basin, about 30 km long and 10 km wide that includes 31 municipalities, with a population of 142.465 people and a surface of 620km^2 (IDESCAT 2017; Vilamala 2018). Despite the relatively high average population density of the area (230 inh/km^2) some municipalities (8 out of 31) are considered rural and predominantly agricultural, according to municipal indicators of population density and economic activity (Domínguez i Amorós, Monllor i Rico, and Simó i Solsona 2010). However, despite being rural according to their population density, most municipalities (20/31) are predominantly oriented towards services and industry (including the food processing industry). Three municipalities (Manlleu, Torelló and Vic) are considered urban. Moreover, despite the importance of the services sector when compared to the agricultural sector (74.6% of Osona's GDP and 60% of employment versus 1.8% and 3.3% respectively), the food sector (including the meat industry) still has a relatively important weight in the economy of the area (IDESCAT 2017). Considering the whole food chain, from production of raw materials (e.g., seed, fertilizers etc.) to elaboration of food products and food retailing, the food sector in Osona employs 22% of the active population and produces 58% of the region's income (CREACCIÓ 2014; del Val i Torra 2016).

Indeed, these data reflect an important industrialization of the agricultural sector, a process that started in the mid-19th century, with the emergence of the textile and cold meat (sausage) processing industries in the area (Castell i Castells 2001). Although until the mid-20th century, industrial activities coexisted with traditional family farming, this socio-ecological configuration changed drastically from the 1960's onwards, when there was an increasing intensification and mechanization of agriculture, oriented towards intensive pig and cattle production (Torrents i Buxó 2009). Overall, agriculture industrialization lead to the abandonment of traditional farming systems (as it happened in other areas of Spain, Naredo 1971). According to the latest agrarian census, fodder plants are the predominant crop in La Plana de Vic (13% of UAA), which also produces 2% of all the Spanish pork (being Spain the 2nd pork producer in Europe according to EUROSTATS 2016 and INE 2009).

Agricultural intensification had and still has important socio-ecological consequences in the area. For instance, the area has experienced an important rise in land prices driven both by growing urbanization but also by increasing land concentration and the high land demand of the pork industry (which requires land to deposit pig manure). The rise in land prices makes it very hard for small producers to acquire land (Torrents i Buxó 2009). Also, nitrification of soils and aquifers due to integrated pork farming and intensive manure fertilization is one of the biggest ecological concerns in the area (Vitòria et al. 2008, Torrents i Buxó 2009, Menció et al. 2011).

Despite this general situation, several sustainable agriculture experiences have emerged in the area, including both organic and agroecological productive projects. Moreover, some of these projects are starting to organize collectively around the APA-Osona (Osona's Agroecological Farmer's Assembly, for its Catalan acronym). According to the latest agrarian census (INE 2009), 5.5% of the agricultural area in La Plana de Vic is under organic production, being Taradell and Torelló the municipalities leading this tendency. Furthermore, a strong rural cultural identity still exists in the area, and multiple local and regional historical societies have emerged since the 1980's. These societies include cultural associations recording elders' life histories with an emphasis in documenting TAeK related information. Some lifeway museums have also been created, including an Ecomuseum (open-air participatory museums, Riva 2017) in which several municipal councils, the region's university, and several associations and historical site owners have organized exhibition centers that hold inter-generational activities with a TAeK conservation vision and mission (Hernández Fernández 2016).

METHODS

Data collection

We collected data in several municipalities of La Plana de Vic during 2016 and 2017 using qualitative (i.e. in-depth interviews) and quantitative (i.e. survey) methods.

In-depth interviews

To explore the perceived opportunities and threats that TAeK conservation projects face and the discourses around TAeK conservation, in December 2016 we performed 11 semi-structured in-depth interviews with key informants tightly connected to TAeK conservation in the area.

To select informants, we used snowball sampling (Bernard et al. 2017). We started by interviewing individuals contacted in an activity organized by the Ecomuseum in which traditional cereal harvesting tools and practices were exhibited and taught by local elders. These individuals gave us the contact details of other people participating in TAeK initiatives in the area, who were also contacted and interviewed and who, in turn, gave us further contacts. This process was repeated until we reached information saturation. People interviewed were mainly adult men (only 2 of the11 persons interviewed were women) directly engaged in one or several of the studied TAeK conservation projects (only two did not participate in any of the projects). One of the interviews was a group interview to members of the local seed bank (see Table 1).

Before starting the interview, we presented our definition of TAeK to the informants, also providing some examples. This allowed us to have a common basis for discussion. The interview followed a guideline that included questions addressing 1) TAeK loss in the area, 2) threats to TAeK conservation, 3) opportunities for TAeK conservation, and 4) TAeK conservation projects in the area. These interviews were recorded with the interviewees' consent and later transcribed.

Survey

In order to explore the network of TAeK conservation projects in La Plana de Vic, in May 2017 we conducted a survey designed to capture the existence of relations among ongoing TAeK conservation projects in the area.

The sample for the survey was selected through name generation techniques following a respondent-driven sampling design (Bernard et al. 2017). Specifically, we first obtained a list of TAeK conservation projects in the area from our in-depth interviews. The list was then reviewed and completed by participants in a workshop on "The value of TAeK" organized by the research team in the University of Vic. We also included in the survey those projects that were mentioned during the first surveying round. Our final sample was 28 TAeK conservation projects, which, to the best of our knowledge, are all the ones that exist in La Plana de Vic. From the 28 projects approached, 25 responded to the survey (a response rate of 89%). The projects missing were an organic farming project, an educational foundation and a wood products workshop.

The survey was based on a closed-ended questionnaire in which we asked the respondent to grade the relationship between his/her project and each of the other projects in the list in a scale from 0 (non-existing collaboration) to 3 (tight collaboration). We emphasized that the respondent did not have to provide a personal answer, but an answer that reflected the projects' relationships.

Data Analysis

We started by classifying both interviewees and projects according to their main approach to TAeK conservation. These approaches were defined as accumulative, exhibitive, productive, processing, or educative. The accumulative approach focused on collecting TAeK and storing it in archives; the exhibitive approach focused on exhibiting TAeK-related artifacts, documents or practices; the productive approach focused on using TAeK to produce agricultural products; the processing approach focused on using TAeK to transform or process agricultural products; and the educative approach focused on including TAeK in curricula. We then analyzed the data differentiating between our qualitative and quantitative data.

In depth interviews

To explore local actor's perceived opportunities and threats to TAeK conservation, we transformed the in-depth interviews transcriptions into plain text with UTF-8 encoding using LibreOffice. This text was analyzed using RQDA (an R package for qualitative data analysis, Huang 2018) and following a grounded theory approach (Corbin and Strauss 1990) by which segments of text were coded and extracted. The codes were generated following an inductive process by which we looked for patterns in the text and established codes for opportunities and threats to TAeK conservation that were not previously defined (Newing 2011).

To analyze the local actors' discourses around TAeK conservation, we used IRaMuTeQ (Ratinaud and Déjean 2009), an R based interface that uses the ALCESTE algorithm to produce word count based statistics that allow lexicometric analyses (Gavard-Perret et al. 2012; Reinert 1983, 1986). The plain texts from each interview were compiled in a single file that included coded headings expressing each interviewee's attributes. The attributes used were the ID of the interviewee and the TAeK conservation approach to which the interviewee was most strongly associated (i.e., accumulative, exhibitive, productive, processing or educative, see Table 1). Then, the software divided the text into Text Segments (TS) and calculated the frequency of word co-occurrences. Furthermore, the software identified clusters with a Descending Hierarchical classification Analysis (DHA). These TS clusters gathered pieces of text containing similar vocabulary. Thus, each cluster can be considered as a relatively stable cognitive-perceptual framework (Reinert 1983). Finally, using Chi^2 tests, the software calculated if certain words, interviewees, or TAeK conservation approaches were significantly associated to a certain cluster. These analyses allowed establishing the link between interviewees' profile and the words they used, which we interpreted in terms of types of discourses.

Survey

To explore the network of TAeK conservation projects in the study area, we transformed the answers from our survey (i.e., degree of relationship among projects) into an adjacency matrix (a square data matrix showing the relationship/distance between every two projects/nodes). We then coded the nodes according to the municipality where the project took place (color code) and the type of project (shape code). To code the type of project, we followed the classification of TAeK conservation approaches (i.e., accumulative projects - e.g., the historical societies; exhibitive projects - e.g., the museums; productive projects - e.g., farms; processing projects - e.g., basketry enterprise; and educative projects - e.g., technical school, see Table 5 in the results section).

The adjacency matrix was imported to Social Network Visualizer (SocNetV) 2.3 (Kalamaras 2017), an open software used to perform network visualization and social network statistical analyses (SNA). We calculated two network-level measures: (1) size, or number of nodes (projects) in the network, and (2) density, or the ratio of existing edges (connections) to all possible edges (n*(n-1)) between nodes. We also calculated two node-level centrality measures: (1) degree centrality (DC), or the number of weighted edges (connections) a node has to other nodes in the network, and (2) betweenness centrality (BC), or the ratio of edges between pairs of nodes which run through a node. Degree centrality is a measure of node activity (i.e. how active is the project in the network) that takes into account the number of projects a project relates to and the weight of that connection. Betweenness centrality is a measure of brokering capacity that quantifies how much a specific project acts as an intermediary between other projects. To better interpret these measures, we calculated standardized indexes (DC' and BC') ranging from 0 to 1, being 1 the maximum possible DC and BC (i.e., DC'=1 when the node has the maximum possible connections and BC'=1 when the node falls on all edges). These centrality measures are widely acknowledged by the literature as reliable indicators assessing the structural relations of a social network (Knoke and Burt 1983; Wasserman and Faust 1994).

Table 1. Local actors interviewed in the study area

ID	Approach	Description	AgeGroup	Gender	Residence
A1	Exhibitive	Local university professor (anthropology) with a rural background and a passion for agricultural tools (he wrote his dissertation on that topic). He is one of the founders of the Ecomuseum.	>60 y.o	Male	Folgueroles
A2	Processing	Local chef managing a catering/events enterprise that has a specific focus in revitalizing landrace cuisine. He participates in many of the Ecomuseum activities.	40-60 y.o	Male	Manlleu
A3	Accumulative	Retired school teacher that initiated the regional historical society, which has been studying folklore (doing interviews with elderly people) in the region for more than 20 years. He keeps the audio recordings' archive in his house.	>60 y.o	Male	Folgueroles
A4	Exhibitive	President of the regional association for the recovery of the wagon/cart tradition, which organizes a yearly festival in which the carts are exhibited together with other TAeK-related tools and practices (Festa dels Tonis de Taradell). Hi is also one of the founders of the Ecomuseum.	40-60 y.o	Male	Taradell
A5	Productive	Veterinary scientist linked to the university that did her postgraduate thesis related to the revitalization of the agroecological farmer assembly, including a section on their use of traditional agroecological knowledge.	20-40 y.o	Female	Vic
A6	Accumulative	Librarian leading a local research group in Taradell that aims at recording oral history using video to record elderly peoples' accounts. They hold the video and photography archive in the library, which sometimes holds thematic exhibitions and also posts some of the documents on their website.	20-40 y.o	Female	Taradell
A7	Educative	Technical agrarian school teacher that participates with his students in the activities organized by the Ecomuseum, especially those	40-60 y.o	Male	Vic

		related to the recovery of ancient wheat varieties and traditional rotation systems.			
A8	Productive	Agroecological shepherd and cheesemaker associated to the agroecological farmer assembly and with links to the university. He doesn't come from a farmer family but he studied at the shepherd school of Catalonia, an initiative with linkages to the agroecological transition movement that gives emphasis to traditional animal husbandry knowledge.	20-40 y.o	Male	Manlleu
A9	Productive	Agroecological vegetable producer that sells most of his produce in the market and in a local shop, and that also produces some cereal and is working to set up a bakery. He comes from a family of farmers (more than 20 generations) and inherited the family property. Is also part of the agroecological farmer assembly and was educated in the technical school of Manresa, with an important focus on landrace revitalization and agroecology.	20-40 y.o	Male	Taradell
A10	Productive	Historical agroecological farmer in the region, one of the first ones to do the shift from intensive agriculture in the 70's. Comes from a farmer family and has inherited his land, where he cultivates some vegetables for medium-big eco-produce retailers and sells only part of the produce directly in the market.	>60 y.o	Male	Santa Eulàlia
A11	Productive	Landrace seed bank group interview, including 3 men and a women of different ages and backgrounds, some were farmers and some were not, but they all volunteer in the seed bank and organize activities for landrace revitalization.	Multiple	Multiple	Multiple

RESULTS

Opportunities and threats to TAeK conservation

Actors engaged in TAeK conservation in La Plana de Vic reported economic, institutional, and sociocultural opportunities to TAeK conservation (Table 2). The most frequently mentioned opportunities for TAeK conservation were sociocultural opportunities (mentioned 34 times and in ten of the eleven interviews). These opportunities included both strong networks and TAeK cultural and social revalorization (each mentioned in six interviews). For example, A6 reported that "*there are many associations, since the late 70's, and this facilitates the initiation and maintenance of TAeK conservation projects*", thus emphasizing the opportunity that networks offer to the maintenance of TAeK. Regarding the revalorization of TAeK, A2 reported that "*now people are eating products and landraces that were not previously valued because they were considered animal feed*" and A1 added that "*we are starting to re-value the knowledge of these men*[7]*, which use to be considered old and ignorant*". Some other sociocultural opportunities for TAeK conservation mentioned by the interviewees include knowledge transmission activities (mentioned in five interviews) and individual or collective will to maintain TAeK (mentioned in three interviews). For example, A3 mentioned that "*to revert this process* (TAeK erosion), *there is a need for social activities that, from the youngest to the eldest, favor knowledge transmission*".

Economic factors were also often mentioned as opportunities for TAeK conservation (mentioned 17 times and in six of the eleven interviews). The most commonly mentioned economic opportunity was the appraisal of new markets for landraces and products derived from the use of TAeK (mentioned in six interviews). For example, A4 mentioned that "*now we* (consumers) *are looking for artisanal bread. We want to recover what existed before*" and A8 reported that "*we are now living a small boom of artisanal cheese making*". Some other interesting economic opportunities mentioned were failures in the industrial agricultural system and the potential that alternative responses to these failures have, such as organic agriculture and neo-rural settlers (each mentioned in two interviews). For instance, A1 said "*There are still some small farmers, some of these neo-rural people, new generations of organic farmers that are*

[7] Note that the interviewee referred to men when talking about the TAeK holders while several studies have proven that large amounts of TAeK are held by women.

trying to change things… I think that they are the last stronghold, the traditional knowledge "guerilla"".

Finally, institutional factors were also mentioned as opportunities for TAeK conservation (mentioned 15 times in eight of the 11 interviews). The most mentioned institutional opportunities for TAeK conservation were the potential inclusion of TAeK in schools and the institutional support of TAeK conservation activities (each mentioned in five interviews). For example, regarding the inclusion of TAeK in schools, A4 mentioned as an opportunity that "*there is a youth summer camp and we get funding so that the students come to help inventorying the traditional farm tools and learn about traditional agricultural practices*". As for the institutional support of TAeK conservation, A11 mentioned the fact that "*several municipality councils are supporting these initiatives*" as an institutional opportunity.

Table 2. Opportunities to TAeK conservation from the analysis of the in-depth interviews (n=11)

CodeGroup	**Code**	**Occurrence**	
		Total	**In x interviews**
O_Sociocultural	Opportunity_dinamism	1	1
	Opportunity_neorural	3	2
	Opportunity_networks	9	6
	Opportunity_revalue	11	6
	Opportunity_transmission	7	5
	Opportunity_will	3	3
Total		34	10
O_Economic	Opportunity_failsystem	2	2
	Opportunity_newmarkets	12	6
	Opportunity_production	2	1
	Opportunity_smallholder	1	1
Total		17	6
O_Institutional	Opportunity_education	6	5
	Opportunity_instsupport	7	5
	Opportunity_newrules	1	1
	Opportunity_research	1	1
Total		15	8
O_Other	Oportunity_newformats	2	2
	Opportunity_luck	1	1
	Opportunity_organic	2	2
	Opportunity_web	5	3
Total		10	6

In relation to the perceived threats to TAeK conservation in La Plana de Vic, the interviewees reported economic, institutional, sociocultural, and resource access threats (Table 3). The most frequently identified threats for TAeK conservation were economic (mentioned 46 times and in all of the interviews). Economic threats to TAeK conservation included global issues such as industrialization (mentioned in seven interviews), globalization, modernization, and agricultural standardization processes (mentioned in four interviews each); but also, local issues such as the high investments needed by TAeK conservation initiatives and the lack of funding (mentioned in five interviews). For example, in relation to industrialization, A8 mentioned that "*the region's economy is oriented to global models. Industry has invaded the agricultural fields and that is surely facilitating TAeK erosion*". Regarding globalization, A2 said "*my children communicate more easily with someone from Ireland or China than with their grandmother*". Finally, regarding local economic issues, A9 reported that "*my first priority is economic viability, and if on top of that I can recover some landrace, then that's something I gain*".

Sociocultural threats were also frequently mentioned in relation to TAeK conservation (they were mentioned a total of 42 times and in all the interviews). These included aspects such as changes in lifestyle (mentioned in seven interviews), loss of perceived sociocultural TAeK value (six interviews), and inter-generational gaps (four interviews). For example, regarding changes in lifestyle, A10 reported that "*farmers nowadays have no idea* (about TAeK practices) *because they are far away from the plant and the soil, from their vital processes*". Regarding loss of TAeK's perceived value, A7 said that "*the students only see tractors, big machines, big production and money; they don't see the value of TAeK*". Finally, regarding inter-generational gaps, A1 explained that "*there was a time when the grandfather drove a wagon and the son drove a tractor and didn't want anything to do with the wagon*". Another interesting sociocultural threat was personal conflicts between local actors engaged in TAeK conservation (mentioned in three interviews). For instance, A5 and A10 mentioned that personal and ideological conflicts were blocking the functioning of Osona's Agroecological Farmer's Assembly and preventing TAeK productive projects from further collaborating.

The interviewees also perceived institutional threats to TAeK conservation (mentioned 23 times and in eight of the 11 interviews). These threats included strict food production regulations to small scale farmers (mentioned in five interviews), lack of TAeK integration in school curricula or lack of farmer's training (four interviews), lack of institutional support to initiate TAeK conservation initiatives (three interviews), and institutional conflicts that prevent the materialization of TAeK conservation initiatives (two interviews). For example, regarding the strict regulations that are imposed on small or traditional farmers, A8 said that "*our parents still remember watching the cheesemaker come down from the mountains or buying milk directly from the farm, but nowadays these practices are hindered by European regulations*", and A10 added that "*they* (regulators) *are controlling the amount of manure you can put in the soil, but if you fertilize with chemical fertilizers, then there is no problem*". Regarding the lack of integration of TAeK in school curricula, A2 mentioned that "*students know about machinery and how to maintain it, but don't know anything about the ancient cereals and how to grow them*". In relation to the lack of institutional support, A8 and A9 perceived as a threat the fact that there was little institutional financial support, especially when compared to other countries such as France or even other areas in Spain such as Andalusia. Lastly, in relation to the institutional conflicts, A1, A4 and A6 mentioned some frictions between TAeK conservation projects and local institutions or other administrative units that hindered their activity.

Finally, the interviewees also mentioned threats to TAeK conservation related to access to resources (mentioned 21 times and in eight of the 11 interviews). The most frequently mentioned were access to land (mentioned in five interviews) and access to landrace seeds and seedlings (three interviews). For example, A5 mentioned that "*land ownership is a threat; a lot of people who want to do these projects* (agroecological production, including landrace cultivation) *do not own the land, and land owners prefer leasing to someone with intensive pork production that will pay more money*". Regarding access to seeds, A10 said that "*what we generally see is that although farmers keep one or two landraces, they mostly go and buy seedlings, which are normally hybrid varieties*".

Table 3. Threats to TAeK conservation that emerged from the analysis of the in-depth interviews (n=11)

CodeGroup	**Code**	**Occurrence**	
		Total	**In x interviews**
T_Economic	Threat_globalization	7	4
	Threat_industrialization	14	7
	Threat_modernization	5	4
	Threat_money/production	9	5
	Threat_specialization	5	4
	Threat_standarization	3	3
	Threat_supermarketization	3	3
Total		46	11
T_Sociocultural	Threat_conflicts_personal	3	3
	Threat_disperssion	6	4
	Threat_generationgap	5	4
	Threat_interestloss	2	2
	Threat_lifestyle	11	7
	Threat_lostvalue	11	6
	Threat_notime	2	1
	Threat_private	2	1
Total		42	11
T_Institutional	Threat_conflicts_intitutional	3	2
	Threat_education	9	4
	Threat_institsupport_lack	4	3
	Threat_regulations	7	5
Total		23	8
T_Access	Threat_access_land	7	5
	Threat_initiation	1	1
	Threat_largeholders	6	4
	Threat_seedbreeding	7	3
Total		21	8
T_Other	Threat_complicated/hard	15	6
	Threat_forget	8	4
	Threat_missuse	1	1
	Threat_rigid	2	2
Total		26	8

Discourses around TAeK conservation

From our lexicometric analysis, we found 383 text segments (TS) and five clusters with significantly associated words and attributes that retained 74.41% of the information (see Table 4). We interpret these clusters in terms of different discourses.

The first cluster, capturing 26.32% of the information, was associated to the technical agrarian school teacher (A7) and, to lower extent, to the members of the local seed bank (A11). The cluster was also associated to the educative approach to TAeK conservation, and to the words "big", "hybrid", "family" and "organic". This cluster represents a discourse that highlights the substitution of family farms by big farms and the replacement of landraces by hybrid varieties as threats to TAeK and organic farming.

The second cluster (which captured 20.70% of the information) was strongly associated to the librarian from the local historical society in Taradell (A6) and to the president of the cart recovery association and co-founder of the Ecomuseum (A4). This cluster was also strongly associated to the accumulative approach and to a lower extent to the exhibitive approach. The words significantly associated to this cluster were "to document", "school", "fair (i.e., exhibition)", "network," and "mill". Thus, this cluster represents a discourse that highlights the importance of documentation, fairs, school activities and networks for TAeK conservation.

The third cluster, capturing 13.33% of the information, was strongly associated to the initiator of the regional historical society (A3) and to a lower extent to the president of the cart recovery association (A4). It was also associated (although not very strongly) to both the accumulative and exhibitive approaches. A very diverse group of words including "work", "serve" (i.e., to be useful), "bread", "song", "horse", "legend", "economic", "mills", "potato", "remedy", "historic" and "lose" were associated to this cluster. This cluster represents a discourse that highlights the idea that TAeK can be better preserved by its use. It also highlights the diversity of elements within TAeK, as it includes varied elements such as horse carts, legends, bread making, songs, medicinal remedies or cultivated plants.

Table 4. Results from the lexicometry cluster analysis of our interviews. For each cluster, the total word count (n) and the Chi² value.

P	Cluster 1	n	Chi²	Cluster 2	n	Chi²	Cluster 3	n	Chi²	Cluster 4	n	Chi²	Cluster 5	n	Chi²
Words <0.0001	Big	21	20.73	To document	8	27.49	Work	17	27.02	Producer	18	30.19	Manure	11	25.77
	Hybrid	8	17.16	School	8	18.48	Serve (use)	5	26.37	France	6	27.88	To plant	12	19.19
	Family	7	15.89	Fair (Exhibit)	7	18.48	Bread	5	26.37	Tradition	7	27.15	Flock (sheep)	7	19.19
	Organic	13	15.4	Network	5	15.54	Song	4	26.37	To worry	4	22.22	Humidity	8	19.19
				Mill	4	15.54	Horse	6	25.99	Industrialize	4	22.22	Throw	12	17,58
							Legend	5	19.71	Region	18	22.17	To need	5	15.93
							Economic	4	19.71	Catalonia	8	17.23	Sheep	5	15.93
							Mills	3	19.71	Market	19	15.76	Organic matter	6	15.93
							Potato	11	19.71						
							Remedy	5	19.71						
							Historic	5	19.57						
							Lose	45	19.39						
Attributes <0.05	*id_A7		10.06	*id_A6		33.65	*id_A3		27.02	*id_A8		19.22	*id_A10		47.25
	*id_A11		5.65	*id_A4		23.85	*id_A4		4.57	*id_A5		9.48	*appr_prod		35.86
	*appr_educ		10.06	*appr_accu		30.1	*appr_accu		8.22	*id_A11		6.9			
				*appr _exh		5.13	*appr _exh		7.06	*id_A2		4.79			
										*appr_proc		4.79			

The fourth cluster (which captured 15.44% of the information) was strongly associated to the agroecological shepherd and cheese maker (A8), but also to the veterinarian (linked to the APA-Osona, A5), the members of the local seed bank (A11), and the local chef that is revitalizing landrace-based cuisine (A2). It was also associated, although not very strongly, to the processing approach. The words "producer", "France", "tradition", "to worry", "industrialize", "region", "Catalonia", and "market" were associated to this cluster. This cluster represents a discourse that highlights the differences between countries and regions regarding industrialization and market regulations for traditional producers, which are threatening the revitalization of TAeK.

Finally, the fifth cluster (which captured 24.21% of the information) was strongly associated to the historical agroecological farmer (A10) and the productive approach. The words associated to this cluster included "manure", "humidity", "sheep", "throw", and "organic matter". This cluster represents a discourse highlighting TAeK's productive dimension, focusing on issues of manure regulations (very relevant in the area due to the pork industry manure legislation) and how they can threaten traditional soil maintenance practices.

The TAeK conservation network

Results from the social network analysis suggest that in La Plana de Vic there is a network of TAeK conservation projects composed by 28 nodes (projects) and 152 edges (connections).

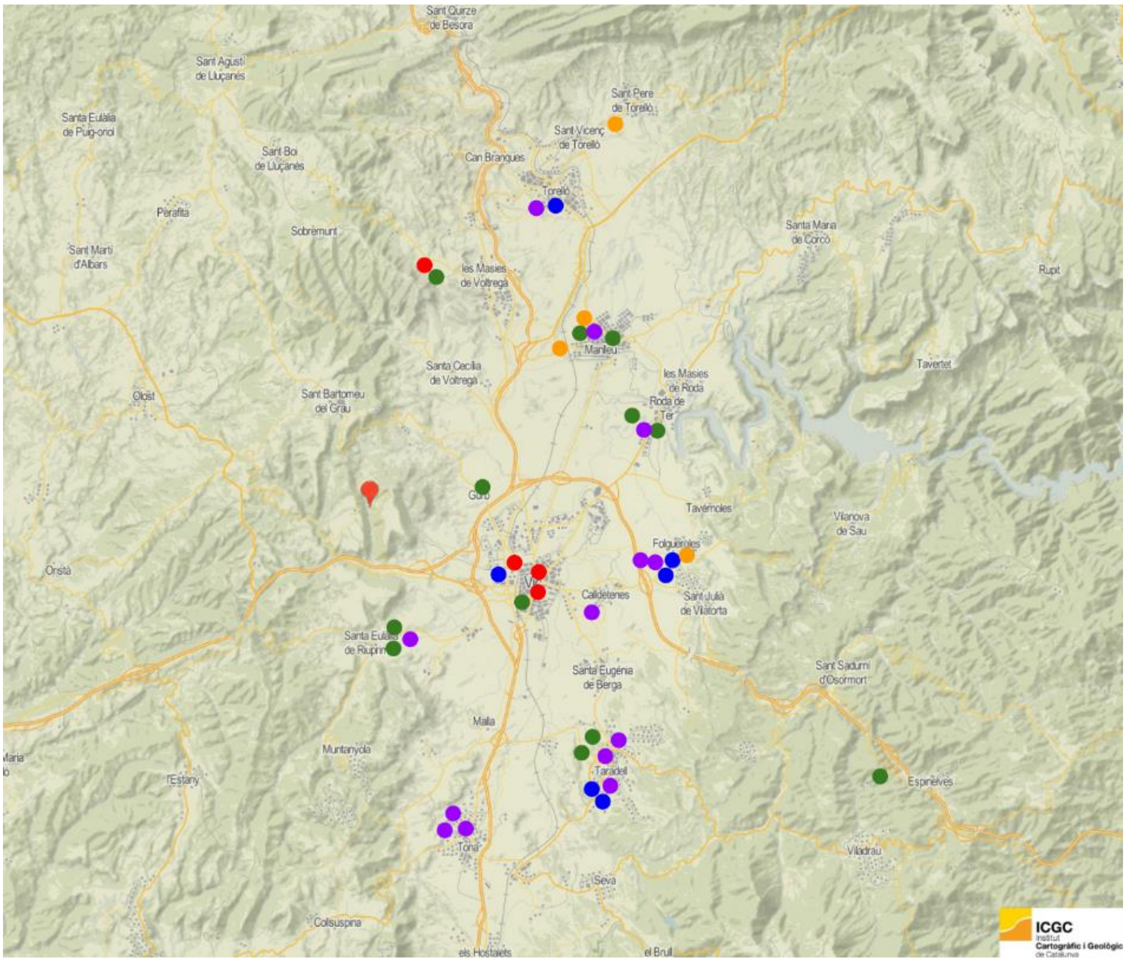
Table 5. TAeK conservation projects in the study area

ID	Description	Type	Location
P1	Basketry museum	Exhibitive	Tona
P2	Mill museum	Exhibitive	Calldetenes
P3	Bakery museum	Exhibitive	Tona
P4	Traditional lifeway museum	Exhibitive	Folgueroles
P5	Cart/wagon museum	Exhibitive	Taradell
P6	Cart festival association	Exhibitive	Taradell
P7	Sowing festival association	Exhibitive	Santa Eulàlia de Riuprimer

P8	Regional historical society	Accumulative	Folgueroles
P9	Local historical society	Accumulative	Taradell
P10	Local historical society	Accumulative	Torelló
P11	Natural history museum	Exhibitive	Manlleu
P12	Archaeological museum	Exhibitive	Tona
P13	University	Educative	Vic
P14	Technical agricultural school	Educative	Masies de Voltregà
P15	Landrace catering enterprise	Processing	Manlleu
P16	Basketry enterprise	Processing	Folgueroles
P17	Landrace seed bank	Productive	Roda de Ter
P18	Agroecological farm	Productive	Manlleu
P19	Agroecological farm	Productive	Taradell
P20	Agroecological farm	Productive	Santa Eulàlia de Riuprimer
P21	Agroecological farm	Productive	Espinelves
P22	Agroecological farm	Productive	Masies de Voltregà
P23	Textile museum	Exhibitive	Torelló
P24	Archaeological museum	Exhibitive	Roda de Ter
P25	Regional research group	Accumulative	Vic
P26	Agroecological farm	Productive	Gurb
P27	Education foundation	Educative	Vic
P28	Wood products enterprise	Processing	Sant Pere de Torelló

The TAeK conservation projects identified were evenly distributed throughout the study area (see Table 5 and Figure 2). Some projects had overlapping objectives and approaches (e.g., most museums that had primarily an exhibitive approach to TAeK conservation had also some educative goals). However, when examining their main approach, we found that many projects (10/28) were primarily exhibitive, as they collected TAeK-related artifacts, documents or practices for their exhibition. These projects were mainly museums (including several exhibition centers associated by means of the Ecomuseum consortium). One fourth of the projects (7/28) were productive projects, as they cultivated landraces and/or used some type of TAeK in their farm. These projects were mainly agroecological farms connected through the APA-Osona. Some projects (5/28) were accumulative, as they collected TAeK-related documents (including oral, photographic and written documents) and stored them in archives. These projects were mainly local historical societies or associations led or co-led by local volunteers. Few projects (3/28) were processing projects which used TAeK in the transformation of food (e.g., cheese) or other agricultural products (e.g., basketry). Finally, we also found few educative projects (3/28), or projects that included some aspects of TAeK in their courses and curricula.

Figure 2. Detailed map of the study area. The colored dots are the TAeK conservation projects and interviewed stakeholders according to their approach (blue for accumulative, purple for exhibitive, green for productive, orange for processing, and red for educative).

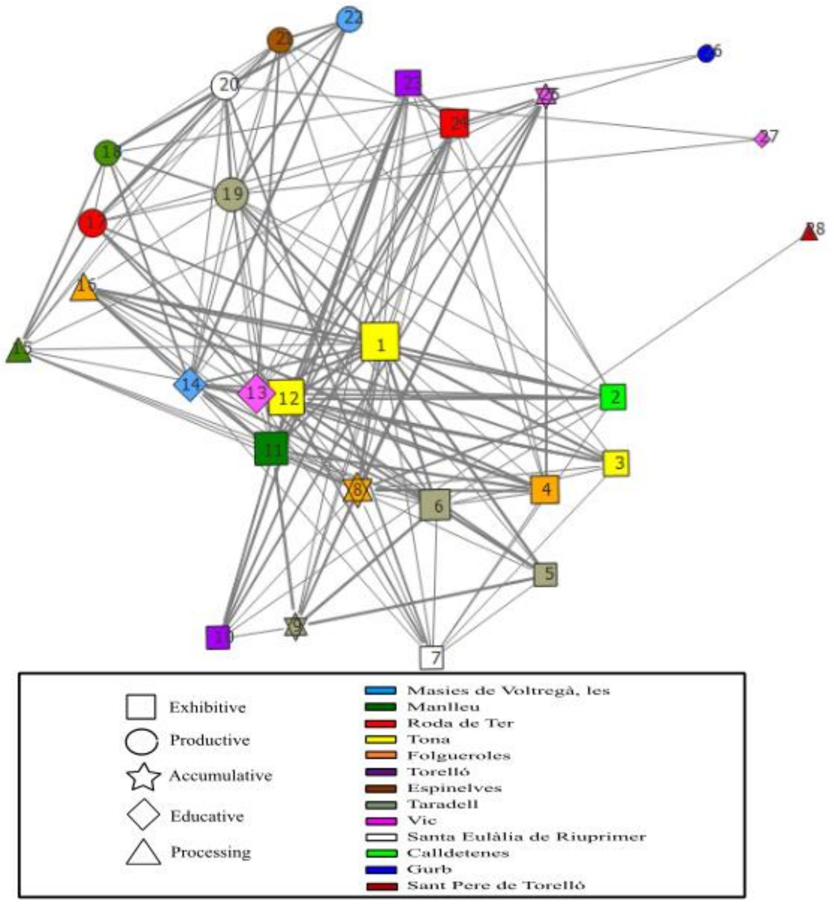


The network of TAeK conservation projects in La Plana de Vic has a relatively high density (Density = 0.40212), which means that there are many connections between the different projects. The visual analysis suggests that exhibitive and educative projects are at the center of the network, accumulating more and stronger connections, while productive, processing and accumulative projects are at the periphery, having less and weaker connections in the network (see Figure 3).

Table 6. Results from the social network analysis. Degree and betweenness centrality of the projects in the study areas' TAeK conservation network

Node/Project	**%DC'**	**%BC'**
1	**7.540**	**84.630**
2	3.571	5.223
3	3.175	0.000
4	3.968	3.466
5	2.976	**27.350**
6	4.960	14.019
7	2.579	0.153
8	**5.556**	17.349
9	3.175	**25.252**
10	2.579	5.081
11	5.754	**28.373**
12	**6.548**	11.845
13	**6.151**	10.084
14	5.159	5.722
15	2.381	2.968
16	3.373	1.833
17	3.175	3.742
18	2.778	4.907
19	**4.762**	**12.909**
20	3.175	1.854
21	2.778	0.095
22	2.579	0.522
23	3.571	0.095
24	3.968	0.594
25	2.778	0.641
26	0.397	0.000
27	0.397	0.000
28	0.198	0.000

Figure 3. Network of TAeK conservation projects in the study area. Node size represents degree centrality.



The degree centrality measure does not vary much among projects and is relatively low (maximum DC' of any node is 0.075, in a 0-1 scale, see Table 6), meaning that no single project has substantially more or stronger connections than the other projects. The projects with higher degree centrality, or higher and stronger direct contact with other projects, were the basketry museum (DC'= 0.075), the archaeological museum in Tona (DC'= 0.065), and the University of Vic (DC'= 0.062). Differently, the betweeness centrality measure varies greatly between projects (from 0.000 to 0.846 in a 0-1 scale), meaning that there are projects with substantially higher brokering capacity than others. The project with highest betweenness centrality was the basketry museum (BC'=0.846). Other projects with relatively high betweenness centrality were the natural history museum (BC'=0.284) and the cart/wagon museum (BC'=0.274).

Exhibitive and accumulative projects were among those with higher degree and higher betweeness centrality. For example, the regional historical society in Folgueroles had relatively high degree centrality (DC'=0.058, BC'=0.173), and the local historical society in Taradell had relatively high betweenness centrality (DC'=0.032, BC'=0.253). Differently, the productive and processing projects had generally very low degree and betweenness centrality, except for the agroecological farm in Taradell (DC'= 0.048, BC'=0.129).

DISCUSSION

The diversity of discourses local actors' had around TAeK conservation and the connectedness of TAeK conservation projects in the study area can contribute to understand 1) who engages in TAeK conservation and what motivates/hinders this engagement, and 2) how the different approaches to TAeK conservation align with resistance movements against industrialized agri-food systems.

Who and why participates in TAeK conservation

From our lexicometric and social network analyses we found that there are differentiated discourses around TAeK conservation, which reflect diverse motivations to participate in these efforts. However, we also found that these differences do not prevent the existence of a relatively tight network of TAeK conservation projects in La Plana de Vic.

Actors and projects following exhibitive and accumulative approaches to TAeK conservation were linked to a discourse that emphasized the importance of documenting TAeK and exhibiting it through school activities and fairs. These type of projects were also central in the network and had high brokering capacity (with information mainly flowing through them). Differently, actors and projects following productive and processing approaches to TAeK conservation, that were less central in the network, were linked to a discourse centered on the economic and institutional threats to TAeK. These actors and projects emphasized the importance of increasing market opportunities for TAeK-based products, re-thinking food and environmental regulations and increasing institutional support.

Despite these different approaches and discourses, most projects seem to have collaborated one with another, although with a varying degree of frequency. Also, there seems to be a consensus among local actors about the importance of local networks as an opportunity for TAeK conservation. The level of connection between projects suggests that, overall, the TAeK conservation network of the area is strong. Moreover, the many connections between the projects guarantee access to information and the establishment of trust relations between projects, with potential positive implications for TAeK conservation (Calvet-Mir et al. 2015). Our results contrast with results from studies focusing on networks of individuals exchanging seed and TAeK, that have shown a more fragmented and less dense network (Calvet-Mir et al. 2012a, Reyes-García et al. 2013), arguably because the establishment of trust relations and the collaboration between projects is easier than between individual actors and because having a common final goal (protect, maintain and revitalize TAeK), enhances inter-project connections and collaboration (Calvet-Mir et al. 2015).

Our results also highlight three main issues in relation to TAeK conservation. First, they bring into attention that TAeK conservation is approached in many different ways, with initiatives that can range from documenting and exhibiting TAeK (often out of its original context), to those that aim at the reproduction of TAeK based practices in the field. The range of actions for TAeK conservation found in our study site are in line with the diversity of actions described by other authors in the field of indigenous and local knowledge (ILK) conservation (McCarter et al. 2014; Tang and Gavin 2016). For example, these authors have reported many examples of community-based programs that focus on reproducing traditional medicinal knowledge by building community medicinal plant gardens. These programs resemble efforts by the seed bank in La Plana de Vic, which aims to reproduce TAeK by building community gardens and selecting some gardeners as "seed guardians". In the same line, other authors such as Lakshmi Poorna and colleagues (2014) have reported documentation initiatives comparable to the ones initiated by the museums and historical societies in La Plana de Vic. Indeed, we argue that the diversity of projects probably responds to the diversity of factors challenging traditional knowledge maintenance, which require diversified responses suitable for each context and moment (Benyei et al. 2019).

Second, given that *ex situ* or accumulative-exhibitive projects (and especially the basketry museum in Tona) have a higher brokering capacity in the studied network than other types of projects, and considering that previous research has demonstrated that these types of initiatives tend to be less inclusive than *in situ* initiatives (Benyei et al. 2019), the results presented here raise concerns regarding the possible exclusion of the views of the productive and processing approaches when planning TAeK conservation actions in the area. Thus, even though the density of the TAeK conservation network is high, the differences in betweenness centrality among projects needs to be addressed so that the views of all the actors are adequately included in the development of collective actions. One possible line of work would be to try to address the personal and institutional conflicts that were mentioned by the interviewees as threats to TAeK conservation. This is especially relevant considering that the productive projects are normally unipersonal projects with little or no institutional support, and thus depend on the capacity of an individual to stay connected with the rest of projects in the area. Another line of work would be to promote online communities of TAeK conservation agents in which they can interact and support each other while contributing to preserving TAeK as a digital commons (Calvet-Mir et al. 2018).

Finally, our results highlight that some actors and projects have a vision of TAeK as an element with a strong political and economic dimensions and with an impact in their livelihoods, whereas other actors confine it to the anecdotic or folkloric-cultural domains. In this line we also found that, while most actors mentioned economic threats to TAeK conservation (such as agricultural industrialization), not so many mentioned economic opportunities. Thus, most actors focused on how sociocultural changes could enhance TAeK conservation rather than on how transforming the mainstream economic and political model could enhance TAeK conservation. Interpreted through the lens of agroecological transitions (Méndez et al. 2013), for which TAeK is a key transformative element that is mobilized in response to mainstream farming models, our findings suggest that some TAeK conservation projects and actors are not politicized around TAeK conservation. This could mean that their motivations towards engaging in TAeK conservation do not necessarily overlap with those of resistance movements (i.e., to prevent or reverse social, cultural, or economic structural conditions through collective action) and could determine whether they do or do not align with resistances to the industrialized food system (Bonanno and Wolf 2017).

Resistances to TAeK erosion for an agroecological transition

Results from the grounded theory analysis suggest that many actors in La Plana de Vic referred to the agricultural industrialization and globalization processes as key threats to TAeK conservation. Most of the actors holding this position were related to processing or productive agroecological projects, but some of them were also linked to accumulative, educative or exhibitive projects. This result might suggest that many of the actors engaging with TAeK conservation in our study area have become aware of the threats that the agro-industrial system in general and the pork farming intensification in particular represent not only to traditional farming systems but also to the overall maintenance of environmentally and socioeconomically sustainable territories. Thus, even TAeK conservation initiatives that do not politicize around TAeK conservation, that are not working in the direction of an agroecological transition, and that are not even linked to the agroecology movement can potentially become aligned with the resistance movement confronting industrialized food systems. This result is similar to what has been observed in the context of urban farming in Barcelona (Calvet-Mir and March 2017) and is a result of the actors' awareness regarding the multidimensional threats the industrialized food system poses to their activity (Bonanno and Wolf 2017). In that sense, since revitalizing TAeK can secure a knowledge base that gives answers to the environmental, economic and sociocultural challenges that the agroecological transition faces (Mier y Terán Giménez Cacho et al. 2018), and since the threats that TAeK conservation faces are tightly connected to those challenging an agroecological food system (Wezel et al. 2009, Altieri and Toledo 2011, Koohafkan and Altieri 2011, Altieri et al. 2012, Gliessman 2013, Guzmán et al. 2013), the agroecology movement could very likely find an ally in the strong resistance movement to TAeK erosion in La Plana de Vic, which could lead to the generation of synergies and to common collective action. However, this potential alliances are hindered by the previously mentioned marginality of TAeK conservation projects that are more closely linked to the resistance movement against industrialized food systems in the study area.

CONCLUSION

In this work we have explored the social network and discourses around TAeK conservation in an area in which TAeK has suffered a process of rapid erosion, partially due to the increasing predominance of an industrialized food system. We withdraw two main conclusions from our results that might me replicable to other contexts. Fist, that despite the contrasting discourses about TAeK conservation and the diversity of TAeK conservation projects, TAeK conservation initiatives and approaches are tightly connected. This highlights their complementarity, which altogether suggests a strong potential to generate alliances. Second, that independently of their approach, most actors engaging in TAeK conservation are aware of the multiple threats that industrialized farming poses on both the conservation of TAeK and the sustainability of their territory. This suggests parallelisms between resistances to TAeK erosion and resistances to industrial agri-food systems, which leads us to conclude that there is a potential ground for resistance and collective action that could be mobilized to counterweight the loss of TAeK, a key element in agroecological transitions that oppose the predominant industrial food system.

PART 2. THE PROCESS

This is a pre-print version of the article:

Benyei, P., Pardo-de-Santayana M., Aceituno-Mata L., Calvet-Mir L., Rivera-Ferre M., Perdomo-Molina A., Carrascosa-García M., & Reyes-García V. *Science, Technology and Human Values* (under revision).

Chapter 3

What's in it for you? Participant diversity and engagement in politically motivated citizen science projects.

INTRODUCTION

Citizen science (CS), also known as participatory science or community-based science, is a rapidly growing transdisciplinary research approach that promotes the participation of both lay and scientific experts in the co-production of knowledge during its different phases, from research design to data collection (including monitoring) or data analysis (Wiggins and Crowston 2011, Haklay 2013a, Kullenberg and Kasperowski 2016, Eitzel et al. 2017, Schrögel and Kolleck 2019). Although the participation of non-scientists in scientific activities is documented at least since the 19th century, the concept of CS was born in the 1990's following the critical questioning of expertise and scientific legitimacy and the advocacy for science *by* and *for* the people (Irwin 1995, Nascimento et al. 2014). Since then, a thriving community has pushed these ideas forward by designing politically motivated CS projects such as environmental justice oriented monitoring or mapping projects (Dunn 2007). The underlying mission of these initiatives was to work towards creating transdisciplinary dialogues between lay and scientific experts with an empowering goal in mind (Funtowicz and Ravetz 2003, Wildschut 2017). However, in the past decade, many CS projects have adopted a utilitarian and unidirectional approach to participation, which has driven those more political projects to distance themselves from the concept of CS. Under this approach, scientists engage with citizens in a top-down manner, asking them to crowd source data in exchange for "scientific literacy" or "expertise", very often not providing spaces for citizen participation beyond data collection (Turreira-García et al. 2018, Strasser et al. 2019).

One of the most pressing issues for CS (and specifically for contributory or crowd-sourcing CS) is unequal participant engagement (i.e., participation inequality), since it potentially biases the projects' results and hinders their transformative potential (Burke and Heynen 2014, Graham et al. 2014). Indeed, most CS projects struggle to maintain diverse and equitable participation for several reasons (Pandya 2012). For instance, some studies suggest that socio-economic and demographic factors including gender, age, ethnicity, income, rurality, or education prevent the participation of certain minority groups in science in general, and in CS in particular (Jolly 2015, Dawson 2018, Schrögel et al. 2018). Additionally, previous work points out that differentiated access to and use of Information and Communication Technologies (ICT) could be hindering the participation of certain people (e.g., the elder, the rural) in technology-mediated CS projects (Newman et al. 2012, Graham et al. 2014). Moreover, some studies highlight that participation in technology mediated CS projects seems to follow a 90-9-1 rule by which 90% of the registered participants are mostly spectators, 9% contribute occasionally, and 1% make most of the contributions (Haklay 2016). However, the complexity of these participation trends highlights the need to deconstruct the notion of participation as a single act and introduce the concept of ecosystemic participation (Fuster Morell 2010). This concept describes the existence of co-dependencies, feedbacks, adaptations and synergies between the different forms and degrees of participation, that rely on the transparency and decentralization of the project and that can lead to an equilibrium between participants that favors the attainment of the common goal.

In the field of Citizen Science Studies (i.e., a line of work mainly exploring motivations and participation in CS), these different levels of engagement are generally considered as an expression of volunteer interest (Haklay 2013a). Indeed, several authors in this field have concluded that participation in CS seems mediated by individual incentives and motivations, which in turn result in unequal volunteer engagement (Forte and Bruckman 2008). For instance, affiliation to a team inside or closely related to a CS project has been described as enhancing participation in it (Nov et al. 2010). Moreover, based on Batson's classification of motivations for community engagement (Batson et al. 2004), Rotman and colleagues (2012) concluded that volunteers participating in online CS projects have dynamic motivations (i.e. motivations that can change over the life-time of the project) that include collectivistic (i.e., benefiting the group of participants), altruistic (i.e., benefiting the scientists or the public in general), principalistic (i.e., making scientific knowledge accessible to everyone), and egoistic motivations (i.e., participants' own benefit through the interaction with the scientists and the project). The importance of each factor driving participation depends on the project type and phase, so does the relationship between these drivers and the actual participation. For instance, Nov and colleagues (2011) found that, in projects requiring a high individual investment to make a contribution, the association between collectivistic motivations and participation intention was significantly higher than in projects with lower investment required. Moreover, the same authors also concluded that, although attributing importance to the project's objectives can incentivize people to join the project in the first place, aligning with project's objectives is not necessarily linked to participation intentions nor to contribution levels once the user becomes an active contributor.

However, under the perspective of participatory ladders (i.e., a continuum of participant engagement that goes from non-participation to citizen control, Arnstein 1969), these different levels of engagement can be interpreted as an expression of power imbalances and knowledge hierarchies. Indeed, restricting participation to data collection can be considered as a mere symbolic effort to be inclusive (i.e., tokenism in Arnstein's words), since project control lies at the level of project ideation and management. Consequently, crowdsourcing projects (i.e., those focused only on citizen massive data collection) do not really facilitate participant's ability to take action, a basic element of empowerment (Freire 1970, Burke and Heynen 2014, Strasser et al. 2019). Moreover, the choice for a lower level of engagement can be a result of participant's perceived self-legitimacy, which is influenced by knowledge hierarchies (i.e., scientific expert knowledge being perceived as more legitimate than lay expertises) and socio-economic and demographic factors (Strasser et al. 2019; Schrögel et al. 2018).

Several authors have called for the need to go back to the original concept of CS, partially in response to the challenges for maintaining and diversifying participation (Dunn 2007, Burke and Heynen 2014, Dillon et al. 2016). The idea underlying this call is that politically motivated CS projects could be potentially more successful in creating extended peer communities in which lay and scientific experts participate as equal partners in the co-production of knowledge, thus attracting more diverse and active participants and restoring the transformative and empowering potential of CS (Burke and Heynen 2014, Dillon et al. 2016, Wildschut 2017, Strasser et al. 2019). However, few studies have examined participation or motivational patterns in politically motivated projects that depart from a more critical approach to CS (see Fuster Morell 2010 as an exception). In that sense, there is a need to further study who participates in projects that engage with communities from the beginning and with an empowerment objective in mind, and what are the motivations behind this participation.

In order to understand if politically motivated CS projects can indeed attract more diverse participants and which factors drive participants to this type of projects, in this work we examine participants and participation in CONECT-e, a politically motivated

CS project. Specifically, we examine: (1) users' profile characteristics (including socio-demographic and motivational variables), (2) users' activity patterns (including quantity and diversity of actions) and (3) the association between user's profile and activity.

CASE STUDY

CONECT-e is an initiative that aims at documenting, sharing and protecting traditional ecological knowledge (TEK) in Spain by mobilizing ICT and a network of participants that document, validate and explore TEK on plants, landraces and ecosystems in an online wiki-like platform (www.conecte.es). CONECT-e can be considered a politically motivated project for two main reasons. First, because it targets a body of knowledge (TEK) that is key for local communities' resilience but endangered by misappropriation processes. Second, because it has been co-designed with a civil society organization in a way that allows long-term peer knowledge co-production and management (under the digital commons framework) with an empowering objective in mind.

Traditional ecological knowledge

TEK, understood as the dynamic and adaptive knowledge, practices and beliefs about the use and management of ecosystem elements such as plants and animals (Berkes et al. 2000), has been reported to be key for sustainable resource management and community's resilience to environmental and socio-economic changes, as well as a basic element of the world's biocultural heritage (Reyes-García 2015). However, TEK systems are threatened by processes of erosion and enclosure. On the one hand TEK is being widely despised and abandoned due to socio-cultural and economic changes, including industrialization, land-use change, lack of intergenerational communication, and certain biodiversity conservation and food policies (Gómez-Baggethun et al. 2013, Hernández-Morcillo et al. 2014). On the other hand, the establishment of private property rights over TEK (e.g., patents over medicinal plant properties or breeder rights over landraces) has contributed to its privatization, limiting the capacity of communities to use and manage this knowledge (Calvet-Mir et al. 2018, Reyes-García et al. 2018b). In response to these trends, many initiatives have tried to study, preserve and protect TEK by maintaining it in its localized context (e.g., through contextualize schooling programs or community gardens) and by documenting it in external databases, although not so many have engaged in both efforts simultaneously (Benyei et al. 2019). In CONECT-e, participants were encouraged to interview their elders and document and share their TEK online, thus enhancing public participation in TEK's conservation and contributing to halt TEK's erosion and enclosure. It is important to notice that these efforts rely on transdisciplinarity and need to be participatory and inclusive to avoid a simplistic approach by which TEK is "integrated" into scientific accounts of reality without considering the epistemological and power implications of doing so (Nadasdy 1999, Agrawal 2002).

Project design

CONECT-e's design was guided by the original CS approach to public participation in science, by which an extended and diverse peer community of lay and scientific experts participate as equal partners in the co-production of knowledge. CONECT-e was co-designed between a multidisdiplinary research team from six research institutions and the Spanish seed network (*Red de Semillas "Resembrando e Intercambiando"*, Red de Semillas hereinafter), a decentralized civil society organization defending farmers' rights and promoting community based and dynamic management of cultivated biodiversity (Red de Semillas 2015a, Calvet-Mir et al. 2018). Red de Semillas participated in the project's design, development and dissemination. This participation was channeled through two members of the organization although project design and initial results were also discussed in two general assemblies, where suggestions for future development were also given (Red de Semillas 2015a, Calvet-Mir et al. 2018). To sustain the engagement of the Red de Semillas, CONECT-e established a symbolic financial compensation that contributed to support the activities of the regional and local seed networks. To further incentivize participation, CONECT-e had a dissemination plan that included a school program in several partner agricultural schools and several talks in academic and non-academic contexts (for instance in local seed fairs or in academic conferences and university programs).

In order to facilitate true knowledge co-production, and try to overcome the knowledge hierarchy divide by which traditional knowledge should be validated by scientific knowledge (Tengö et al. 2014), CONECT-e developed a double validation system. Editor permissions (i.e., the right to edit other participants' content) were granted to any user that contributed meaningfully to the project (as well as to scientific and civil society members of the design team), meaning that not only the scientists were able to validate or eliminate content. Furthermore, although basic users (i.e., those without editor permissions) could not officially validate or eliminate entries, they could contribute to improve the overall information quality and detect wrong information by commenting, 'likeing' or 'agreeing' with information posted in the platform.

Finally, CONECT-e also had in place a strategy to prevent TEK's misappropriation and assure its long-term management. For instance, the content of the platform was managed as a digital commons in which all users abide to a common set of management rules assuring the long-term use value of the information (Calvet-Mir et al. 2018, Reyes-García et al. 2018a, 2018b). More specifically, all users had to abide to the terms of the copyleft creative commons license (CC BY-SA 4.0) that protected the content of the platform. This type of licenses require that any product using original or modified content from the platform is protected under the same license, guaranteeing the free exchange and reproduction of knowledge provided that such exchange and reproduction is done without excluding other users. In this sense, CONECT-e could be considered an online creation community (OCC) because, to some extent, it is a "collective action performed by individuals that communicate, interact, and cooperate in several forms and degrees via an Internet-based platform and with the common goal of knowledge-making and sharing, resulting in a digital common" (Fuster Morell 2010, pp.271; Calvet-Mir et al. 2018).

Thus, the interest behind the inception of the platform went beyond an ethnobotanical interest in documenting TEK for its academic study, and was rather guided by the idea of making TEK freely available under common norms and encourage its revitalization among the communities where it came from (Calvet-Mir et al. 2018). This is especially true for CONECT-e's landrace section documenting Traditional Agroecological Knowledge (TAeK), or the knowledge, practices and beliefs about the use and management of cultivated biodiversity (including landraces, Reyes-García et al. 2018b). This is so because documenting and sharing landrace names, characteristics, and management under a digital commons framework potentially allows the communities safeguarding cultivated biodiversity to support their claims against this knowledge's misappropriation, although this strategy depends on having mechanisms and resources to monitor and denounce misappropriation process and fight them legally in court (Reyes-García et al. 2018a).

However, at least two characteristics of CONECT-e challenge our departing assumption regarding the co-created and bottom-up nature of the project. First, although the Red de Semillas' decision to participate was taken by the organizations' assembly and all the members were able to evaluate the project results and suggest future improvements, only two members of the organization, who are also professional researchers, were constantly active in the design of the project. Second, despite being attributed to the authors and protected with open licenses, the content of the platform is not downloadable by users. This feature reduces the users' possibility to participate in data analysis and interpretations, since they have to ask the core team (researchers and Red de Semillas) for the data base.

METHODS

We used a quantitative approach to assess participation patterns in CONECT-e and to understand what factors were associated to this participation. We did so by quantitatively describing user's profile characteristics and activity patterns and by statistically examining the association between user's profile and activity.

Data collection and processing

Data were collected through the CONECT-e project's online platform. As users had to register to document TEK in the platform, their profile and activity data were saved in the platform's database (free prior informed consent was given upon registration). User's actions included data entry, commenting, and grading. Additionally, about 10% of the users were granted editing and validation/elimination permissions. Users could also contribute different type of contents (e.g., text content describing traditional landraces' characteristics, medicinal plant use locations, or pictures of plants and landraces) related to different domains of knowledge (from traditional plant uses such as medicinal, ornamental or symbolic uses; to traditional management practices such as collecting, seed production or commercialization). Content was structured in three sections (plant, landraces and ecosystems) that contained pages for each species/landrace. The information about traditional use and management of the species/landrace was structured using the categories of the Spanish Inventory of Traditional Knowledge related to Biodiversity (see Pardo-de-Santayana et al. 2014). In the analyses conducted here we only examine aggregated user's actions for the plants and landrace sections (see Calvet-Mir et al. 2018 for in-depth content results).

We downloaded the CONECT-e database a year after the platform was launched (i.e., data analyzed includes data collected from 14/02/2017 to 16/03/2018). Specifically, we downloaded the data sets with the user's profile and activity information. We then transformed the data to create a unique data set in which each row was a user and the columns were variables capturing socio-demographic or participation information (see Table 1).

The user's profile data set was used to create socio-demographic variables. For each registered user we collected the following information: registration date, age (in years), gender (three level categorical variable; male, female, other), education level (five level categorical variable; 1=no formal education, 5= university education), use of ICT (four level categorical variable; 1=never use ICT, 4=use ICT daily), experience with CS (binary variable; 1=has previous experience with CS), town of residence, work sector (eight level categorical variable; Administration, Agriculture, Animal husbandry, Education, Forestry, Industry, Tourism, Other), primary motivation for participation (seven level categorical variable; participate in collective action, curiosity, gain knowledge, obtaining a good school grade, share knowledge, prevent knowledge loss, other), affiliation to the project (five level categorical variable; partner school, core team, Red de Semillas, other, none), and association membership (binary; 1=is member of at least one association).

The town of residence variable was transformed into a three level categorical variable (rurality of residence) according to Eurostat's DEGURBA classification of the town into urban, intermediate and rural (European Commission 2014). The work sector variable was transformed into a four level categorical variable that grouped work sectors into primary (i.e., agriculture, animal husbandry and forestry), services (i.e., administration, education and tourism), industry and other. The motivation for participation was transformed into a three level categorical variable; i.e., collectivistic motivation (i.e., "participate in collective action", "share knowledge" and "prevent knowledge loss”), individualistic motivation (i.e., “curiosity”, “gain knowledge” and “obtaining a good school grade”), and other motivation. Finally, affiliation to the project was re-coded into a three level categorical variable; i.e., none (no affiliation to the project), project (affiliation to project core groups, i.e., partner school, core scientific team, or Red de Semillas) and other (affiliation to other parts of the project, i.e., university students attending university activities).

The user’s activity data set was used to calculate the participation variables. Specifically, for each user, we calculated the number of total actions (num_total_actions), the diversity of action types (num_total_action_types), and the diversity of platform sections in which these actions occurred (num_total_sections). Number of total actions was a continuous numeric variable. Diversity of action types was measured in as scale of zero to three (from not participating to participating in all types of actions). Diversity of platform sections was measured in a scale from zero to two (from not participating to participating only in the landrace or the plant sections to participating in both sections). Using the number of total actions to create a binary variable capturing whether a user was active or not (use_binary), where 1=user had some activity (i.e., number of total actions different than zero). We also created a three level categorical variable recording the level of activity (activity_level), in a scale from zero to two, where 0=doing zero actions, 1= doing less than 50 actions, and 2= doing more than 50 actions. Data transformations were done using the *tydiverse* R package (Wickham 2017).

*Table 1. Variables used in the analyses (*bivariate analyses, ^ cluster analyses)*

Variables	Code	Type	Attributes
Registration date	registration_date	numerical	yyyy-mm-dd
Age*^	user_age	numerical	years old
Gender*^	user_gender	categorical	“male” “female” “other”
Education level*	user_education	categorical	1= no formal education 2= basic schooling 3= high school level 4= technical higher education 5= university education
Use of Information and Communication Technologies (ICT)*	user_ict	categorical	1=never uses ICT 2=uses ICT once per month 3=uses ICT once per week 4=uses ICT daily

Experience with CS*	user_experience	dummy	1=has previous experience
Town of residence	user_residence	numerical	town numeric code
Rurality of residence*	rurality_residence	categorical	1=urban 2=intermediate 3=rural
Work sector	user_sector	categorical	“Administration” “Agriculture” “Animal husbandry” “Education” “Forestry” “Industry” “Tourism” “Other”
Recoded work sector*^	user_sector_rcd	categorical	“primary” “services” “industry” “other”
Motivation for participation	user_motivation	categorical	“participate in collective action” “curiosity” “gain knowledge” “obtaining a good school grade” “share knowledge” “prevent knowledge loss” “other”
Recoded motivation*^	user_motivation_rcd	categorical	“individualistic” “collectivistic” “other”
Affiliation to the project *^	user_type	categorical	“partner school” “core team” “Red de Semillas” “other” “none”
Association membership	user_association	dummy	1=is member of at least one association
Number of total actions*	num_total_actions	numerical	number of actions
Diversity of action types	num_total_action_types	categorical	0= not participating 1= only participating in one action type 2= participating in two action types 3=participating in all action types
Diversity of sections	num_total_sections	categorical	0=not participating 1=participating only one section 2=participating in both sections
Activity binary *	use_binary	dummy	1=use/activity
Activity level^	activity_level	categorical	0=non-active 1=activity<50 actions, 2=activity>50 actions

Data analysis

To analyze the user's profile characteristics and activity patterns, we performed descriptive analyses of our socio-demographic and participation variables using the *ggplot2* R package for visualization and the *base* R package for basic descriptive statistics (Wickham 2016, R Core Team 2018).

To analyze the association between user's profile and activity, we performed bivariate and cluster analyses. More specifically, with the binary participation variable (use_binary), we run a Wilcoxon rank sum test against age (numeric variable), and Pearson Chi-Square tests against gender, education level, use of ICT, experience with CS, rurality of residence, work sector, motivation for participation, type of affiliation to the project, and association membership (categorical variables). We also performed Kruskal Wallis rank sum tests with Tukey non-parametric pairwise comparisons to analyze the differences in mean number of total actions (num_total_actions) between different user motivation, affiliation, and association groups. Finally, with the three-level participation variable (activity_level) and some socio-demographic variables (i.e., age, work sector, rurality of residence, motivation and affiliation), we performed a partitioning k-medoids clustering analysis (specifically the Partitioning Around Medoids algorithm) to cluster users in four groups based on their Gower distance dissimilarity metric. Seven users were excluded from the cluster analysis because their user profile was incomplete. The number of clusters (groups) was set a priori based on the silhouette coefficient, a measure of how similar an object is to its own cluster compared to other clusters (Foss et al. 2018).

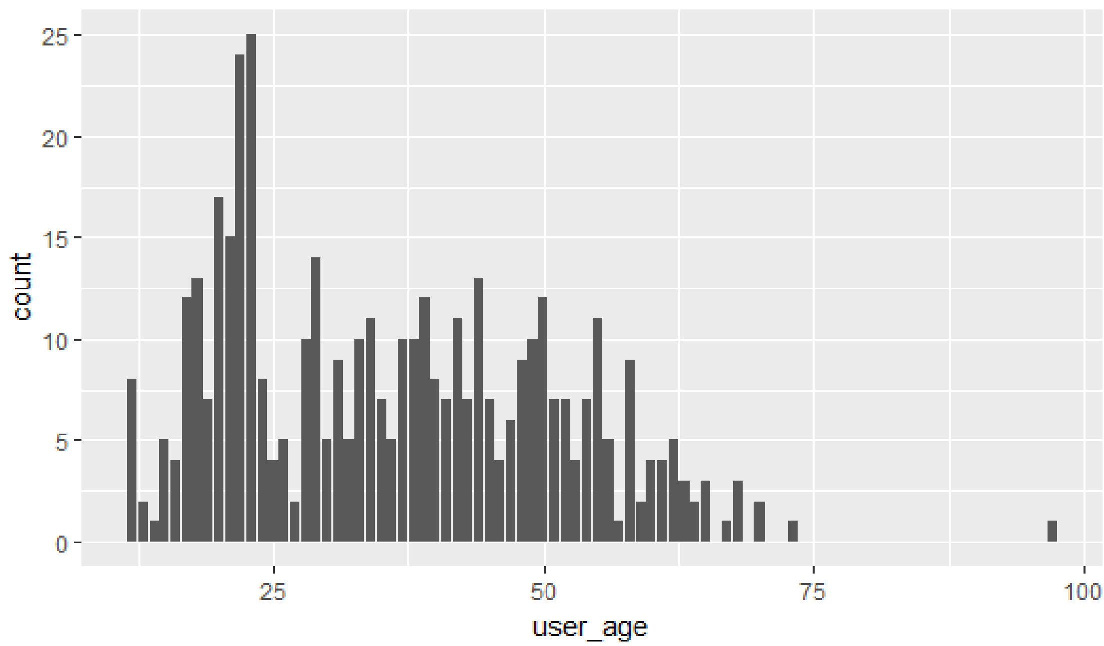
We did the bivariate analyses using the wilcox.test, chisq.test and kruskal.test functions from R *stats* package (R Core Team 2018) and *nparcomp* package (Konietschke 2015). We did the clustering analyses using the daisy and pam functions from R *cluster* package (Maechler et al. 2018). We did all the analyses and data transformations using RStudio Version 1.1.456.

RESULTS

User profiles

During the period analyzed, 467 users registered in CONECT-e. Most of them did so in the early months of the project with a peak in registration around March 2017, when the platform was publicly announced and several dissemination activities, including the school program, took place.

Figure 1. Distribution of user age

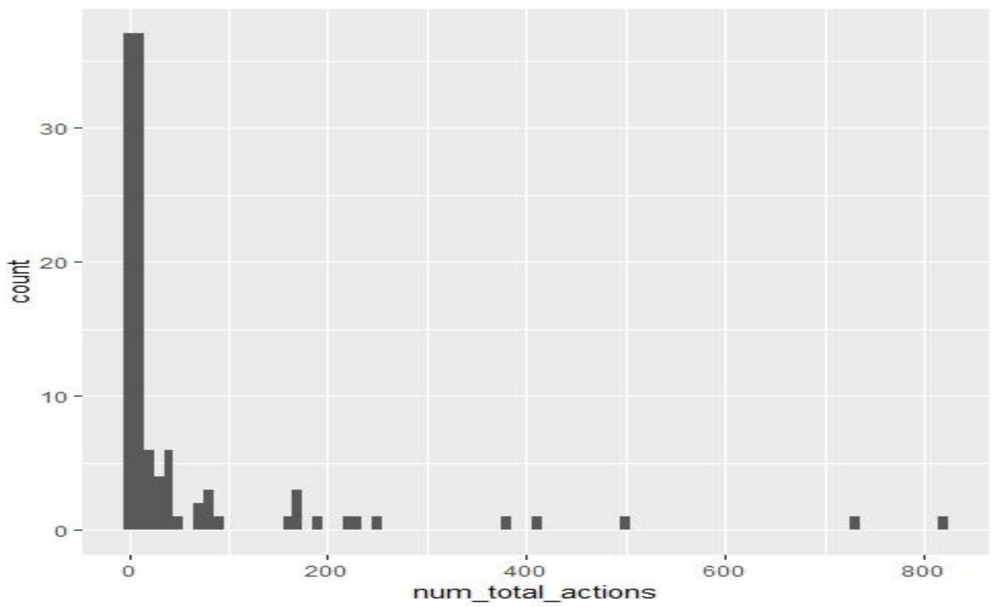


CONECT-e's users were highly educated (65.5% of them had a university degree), young (median age was 35 years old, see Figure 1), active ICT users (85.2% of them stated using ICT tools daily), and new to CS (only 5.6% had ever participated in a CS program before participating in CONECT-e). CONECT-e's users were also relatively rural (50.3% lived in a rural or intermediate-rural town) and more than one third of them were linked to the primary sector (22.1% to agriculture, 5.6% to animal husbandry, and 10.1% to forestry). Gender was relatively balanced, with 43.9% female and 50.5% male users; some users did not define themselves as either. Motivation was also balanced, with 41.1% of the users having an individualistic motivation ("gain knowledge", "curiosity" or "school grade") and 40.5% of them having a collectivistic motivation ("prevent knowledge loss", "engage in collective action" or "share knowledge"). The most frequent motivations were to gain knowledge (33.6%) and to prevent knowledge loss (22.7%). Around one third of users (34.1%) stated they belonged to at least one association and most users (47.5%) had no affiliation to the project, but some were affiliated to it by being members of a partner school (21.8%), the Red de Semillas (8.6%), or the core scientific team (4.7%).

Activity patterns

About one quarter (24%) of the registered users were active users (i.e., did at least one action in the platform, mostly data entry, but also commenting, grading, modification, or validation/elimination). The percentage of active users was proportionally higher when looking at users affiliated to the Red de Semillas (n=40), from which 40% were active users. Out of the subset of active users, 63.6% only participated in the plants section, 17.3% only participated in the landraces section, and 19.1% participated in both.

Figure 2. Distribution of user actions for the active users of CONECT-e



The active users of the platform did 5821 actions. The number of actions per active user varied from one to 818. However, most active users did very few actions (mean=52.9, median=7.5, see Figure 2). In fact, we found three distinctive groups of users: some users did not participate at all (76%), some did between 1 and 50 actions (19.5% of active users), and a few did more than 50 actions (4.5% of active users).

Although 40% of the active users had editing and validation permissions, most of them did actions of just one type, normally content creation actions (42.7% of active users). For instance, in the landrace section, 68.9% of actions were content creations. However, some users also modified content and did some brokering (verified or eliminated content). In fact, about one quarter of the active users did the three types of actions (21.8% of active users created, modified and verified/eliminated content).

Factors influencing participation

Participation patterns found in CONECT-e were associated to the user's profile in different ways.

Table 2. Table with association test results (contingency table with Chi-Square test results for categorical variables and Wilcoxon rank sum test for numeric variables). Note that the percentages do not include missing values.

Characteristic		**No activity n=355 (100%)**	**Some activity n=112 (100%)**	**Test value (p-value)**
Age		Mean=38.16	Mean=29.30	23202 (<0.01)
Residence	Urban	n=154 (43%)	n=58 (52%)	8.9427 (<0.05)
	Intermediate	n=72 (20%)	n=31 (28%)	
	Rural	n=112 (31%)	n=20 (18%)	
Sector	Services	n=128 (36%)	n=28 (26%)	12.89 (<0.01)
	Primary	n=120 (34%)	n=56 (51%)	
	Industry	n=11 (3%)	n=0 (0%)	
	Other	n=90 (25%)	n=25 (23%)	
Motivation	Collectivist	n=151 (42%)	n=38 (35%)	49.216 (<0.01)
	Individualist	n=163 (46%)	n=29 (26%)	
	Other	n=20 (6%)	n=31 (28%)	
Affiliation	None	n=208 (58%)	n=14 (13%)	97.451 (<0.01)
	Other	n=58 (16%)	n=17 (15%)	
	Red de Semillas	n=24 (6%)	n=16 (15%)	
	Schools	n=54 (15%)	n=48 (44%)	
	Team	n=7 (2%)	n=15 (14%)	

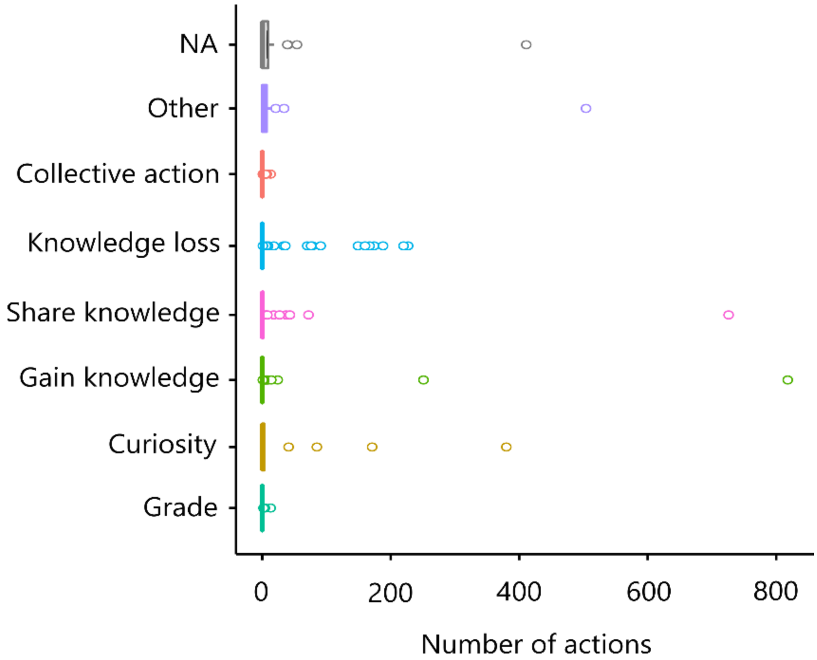
Bivariate analyses of the variable capturing whether the person had some activity or not (use_binary) show that active users were significantly younger than non-active ones (W= 23202, p-value = $1.173e^{-07}$). Active users were also significantly different from non-active users in that they more frequently had an affiliation to the project's core groups (partner schools, core team or Red de Semillas; X^2= 97.451, df = 4, p-value = $2.2e^{-16}$). Additionally, if compared to non-active users, the proportion of active users reporting individualistic motivations was significantly lower (X^2= 49.216, df = 2, p-value = $2.055e^{-11}$), and the proportion of active users reporting other motivations than collectivistic or individualistic was significantly higher (X^2= 49.216, df = 2, p-value = $2.055e^{-11}$). Finally, if compared to non-active users, the proportion of active users working in the primary sector was higher (X^2= 12.89, df = 3, p-value = 0.004881), although the proportion of active users living in a rural areas was lower (X^2= 8.9427, df = 2, p-value = 0.01143). Being active or not in CONECT-e was not significantly associated to any of the other socio-demographic variables (i.e., gender, education level, use of ICT, experience with CS, and association membership; see Table 2).

When analyzing the continuous variable capturing number of user actions (num_total_actions), we found significant differences in mean number of total actions depending on user's motivations (Kruskal-Wallis chi-squared = 41.943, p-value < 0.01, see Table 3). Users with individualistic motivations did less actions (mean number of actions= 9.8) than those with collectivistic motivations (14.5). Indeed, when looking at the disaggregated motivations (Kruskal-Wallis chi-squared = 52.848, p-value < 0.01, see Figure 3), we found that users motivated by preventing knowledge loss (mean number of actions= 16.6) and sharing knowledge (23.6) did significantly more actions than those motivated by knowledge gain (7.5), and obtaining a good school grade (1.4). However, those reporting curiosity as a motivation (which was coded as individualistic) did on average more actions than the rest (mean number of actions= 32.7).

Table 3. Results from the Kruskal Wallis rank sum tests with Tukey non-parametric pairwise comparisons.

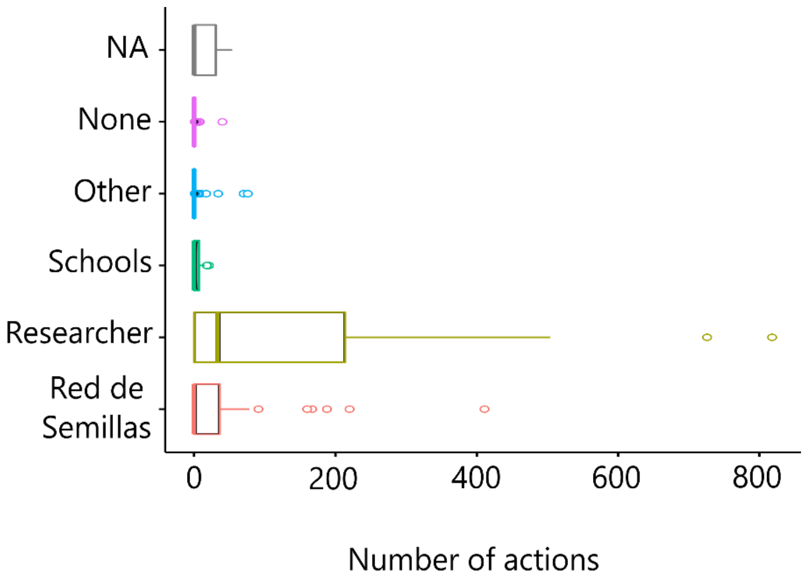
Comparison	Estimator	Lower	Upper	Statistic	p.Value
p(Collectivist-Individualist)	0.471	0.425	0.516	-1.496364	2.875212e-01***
p(Collectivist-Other)	0.675	0.583	0.755	4.305275	3.391016e-05***
p(Individualist-Other)	0.723	0.629	0.801	5.157210	4.937854e-07***

Figure 3. Number of actions by user motivations



We also found significant differences in mean number of total actions when comparing user's affiliations (Kruskal-Wallis chi-squared = 110.24, p-value < 0.01, see Figure 4). The core scientific team (i.e., researchers) did significantly more actions than other groups of users (mean number of actions=162.8). Similarly, the users affiliated to the Red de Semillas did significantly more actions (40.4) than users affiliated to the partner schools (3.5) and more than users not linked to the project at all (0.4). We did not find significant differences in mean number of actions based on association membership.

Figure 4. Number of actions by user affiliations



The results from our cluster analysis, point in the same direction than the findings from bivariate analyses. Based on activity level and some socio-demographic characteristics (i.e., age, work sector, rurality of residence, motivation and affiliation), we found five user clusters (see Table 4 and Figure 5).

Figure 5. Projection of users in a two-dimensional space according to their responses to the variables included in the PAM analysis and colored by assigned cluster.

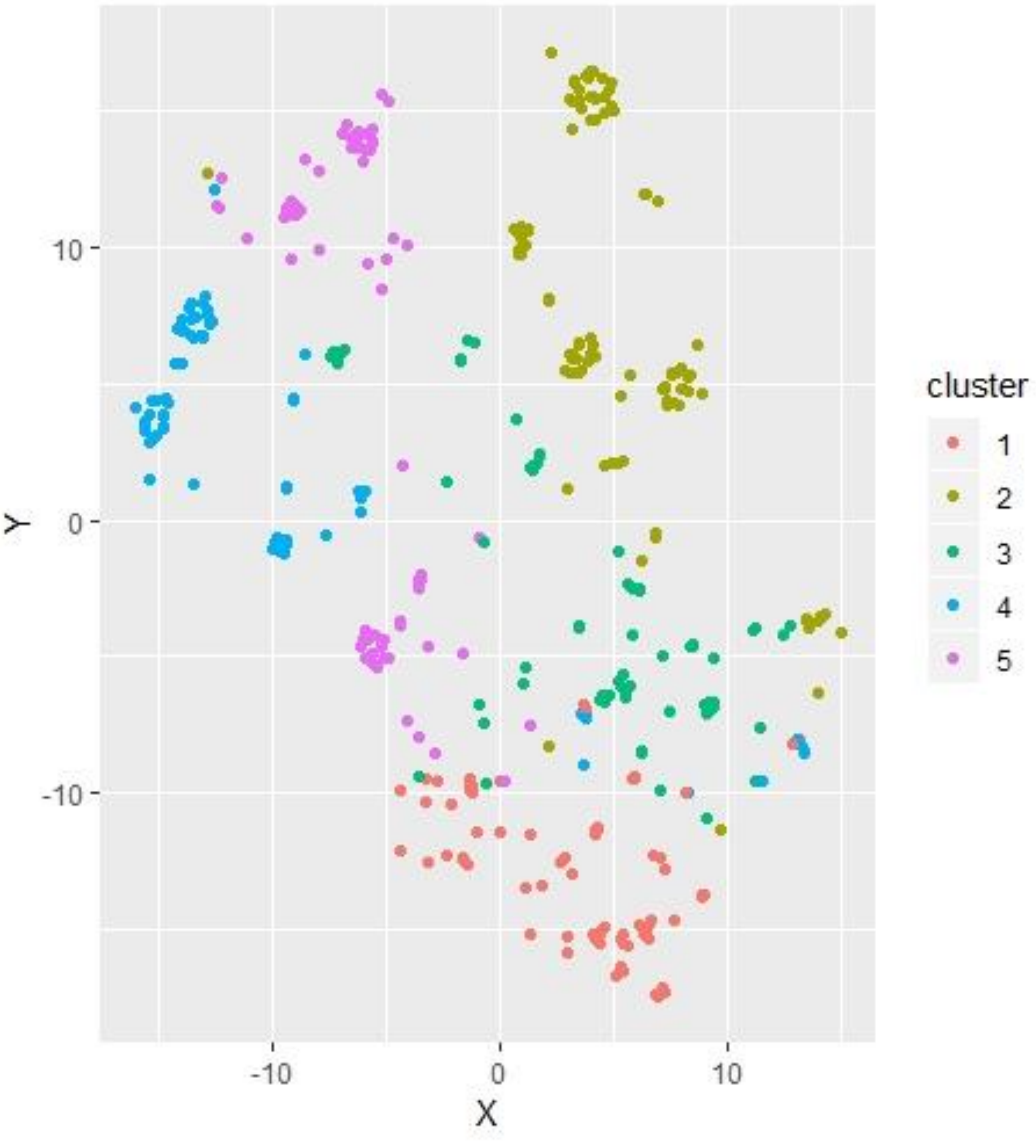


Table 4. Results from PAM clustering analysis

Cluster	user_age		user_sector_rcd		user_motivation_rcd		user_type		rurality_residence		activity_level	
1	Min.	12.00	Industry	0	Collectivist	28	None	5	**Urban**	**49**	Non-active	4
	Median	**22.00**	Other	15	Individualist	20	Other	13	Intermediate	24	**Activity<50 actions**	**76**
	Mean:	26.99	**Primary**	**56**	Other	29	RdS	12	Rural	13	**Activity>50 actions**	**6**
	Max.	67.00	Services	15	NA's	9	**Schools**	**51**	NA's	0		
	NA's	4	NA's	0			Team	5				
2	Min.	12.0	Industry	3	Collectivist	31	**None**	**82**	**Urban**	**56**	**Non-active**	**105**
	Median	**40.0**	Other	0	**Individualist**	**74**	Other	11	Intermediate	20	Activity<50 actions	4
	Mean	39.24	Primary	0	Other	4	RdS	2	Rural	31	Activity>50 actions	3
	Max.	70.0	**Services**	**109**	NA's	3	Schools	12	NA's	0		
	NA's	5	NA's	0			Team	5				
3	Min.	12.00	Industry	2	**Collectivist**	**71**	None	2	**Urban**	**38**	**Non-active**	**77**
	Median	**31.00**	Other	15	Individualist	3	**Other**	**29**	Intermediate	21	Activity<50 actions	3
	Mean	33.88	**Primary**	**37**	Other	6	**RdS**	**20**	Rural	26	**Activity>50 actions**	**7**
	Max.	68.00	**Services**	**32**	NA's	7	**Schools**	**32**	NA's	2		
	NA's	7	NA's	1			Team	6				
4	Min.	16.00	Industry	1	Collectivist	28	**None**	**63**	Urban	26	**Non-active**	**82**
	Median	**39.00**	Other	0	**Individualist**	**49**	Other	7	**Intermediate**	**23**	Activity<50 actions	0
	Mean	39.56	**Primary**	**83**	Other	2	RdS	6	**Rural**	**33**	Activity>50 actions	2
	Max.	73.00	Services	0	NA's	5	Schools	7	NA's	2		
	NA's	3	NA's	0			Team	1				
5	Min.	12.00	Industry	5	Collectivist	31	**None**	**71**	**Urban**	**43**	**Non-active**	**83**
	Median	**38.50**	**Other**	**85**	**Individualist**	**45**	Other	15	Intermediate	15	Activity<50 actions	6
	Mean	39.62	Primary	0	Other	10	RdS	0	Rural	29	Activity>50 actions	2
	Max.	97.00	Services	0	NA's	5	Schools	0	NA's	4		
	NA's	5	NA's	1			Team	5				

The first cluster was the most differentiated, grouping predominantly younger users working in the primary sector, living in urban or intermediate areas and affiliated to the project core groups (especially to the partner schools). This cluster also grouped the most active users, which also had very diverse motivations. The second cluster grouped predominantly middle-aged urban users working in the service sector, not affiliated to the project and with an individualistic motivation. This cluster also grouped mostly non-active users. The third cluster grouped predominantly relatively young urban users affiliated to the project core groups and with a collectivistic motivation. This cluster grouped both non-active and active users, but those that were active showed predominantly high levels of activity. The fourth cluster grouped predominantly middle aged rural users working in the primary sector, not affiliated to the project and with an individualistic motivation. This cluster was also characterized by grouping non-active users. Finally, although not very well differentiated (see Figure 5), the fifth cluster grouped predominantly middle aged urban users working in other sectors than primary or services and not affiliated to the project. This cluster also grouped predominantly non-active individualist users.

DISCUSSION

Results from this work shed light into the capacity of politically motivated CS to attract participants with diversified socio-demographic backgrounds and to challenge participation inequalities. Our findings also contribute to explain the factors influencing participation in these type of projects. However, before discussing these issues we would like to highlight some caveats that might affect the empirical results presented here.

Caveats

Three main issues related to our research methods and to the overall design of the CONECT-e project might have influenced our results.

First, the data analyzed correspond to data collected during CONECT-e platform's first year of existence. Thus, our results could be biased by the dynamics of starting projects in terms of the boost that these types of initiatives usually have in the beginning, but which are hard to maintain (Nov et al. 2011). For instance, although funding was obtained for three years, most dissemination activities concentrated in the first 12 months after launching the platform, corresponding to the data period analyzed here. Indeed, the future development of the platform is uncertain and will depend on the maintenance of the community of users that created it.

Second, although here we generally speak of users as individuals, some users (circa 1%) represented a group (i.e., seed network, community). This is so not only representing the nature of our dissemination activities but also the collective nature of TEK. While our analyses focus on individual profile characteristics, we must acknowledge that the participation of these individuals stands on the shoulders of the collective efforts of generations of biocultural diversity guardians. Thus, our results regarding the low participation of certain users (i.e., rural or non-educated) might be inaccurate since many times it is their knowledge that was contributed, even if they did not directly post it online. The existence and recognition of entries' collective authorship should be acknowledged when examining our results and when designing future platform implementations.

Finally, asking informants to report their motivation through selecting options from a questionnaire upon registration had several limitations as a way to grasp the diversity and complexity of the motivational drivers for participation. Although we drew on previous research to select the motivation categories (Nov et al. 2010, Rotman et al. 2012), a relatively big proportion of users stated having "other" motivations (10% of total users, 28% of active users). Since we did not ask the question in an open-ended way, we are not able to discern if those "other" motivations can be grouped into collectivistic or individualistic. The issue is particularly important because the level of engagement of users with "other" motivations was significantly higher. Moreover, aggregating motivations in very broad categories such as "collectivistic" or "individualistic" leaded to contradictory results. For instance, we found that users with individualistic motivations were less active than those with collectivistic motivations, but when examining disaggregated motivations, users with motivations such as "curiosity" (which were classified as individualistic) were highly active. These limitations should be taken into account when trying to extract broader conclusions about the relationship between motivations and participation in politically motivated projects.

Challenging participation inequalities

Our results suggest that CONECT-e challenged participation inequalities in two main ways: by including the voices of some groups normally under-represented in CS and by breaking the 90-9-1 rule regarding participation in technology-mediated knowledge co-production projects. Although CONECT-e was not able to overcome the education and technology skills gaps (i.e., CONECT-e's users were highly educated and active ICT users), the project managed to attract female and rural users who are normally not so active in CS projects (Raddick et al. 2013, Stephens 2013). Moreover, despite having a long-tailed distribution of user actions, with most users not contributing to the project and very few users doing many contributions, the proportion of active users (24%) was higher than what has been reported in similar projects (Fuster Morell 2010, Nov et al. 2011, Haklay 2016).

While these results seem to suggest that CONECT-e has more equalized patterns of participation than those previously reported in the literature for CS projects, two issues deserve further discussion. First, attracting more diverse participants to a project in terms of registered users does not necessarily mean that participation will be diversified. For instance, in CONECT-e, even though the project managed to attract a more rural pool of users, the engagement of users residing in rural areas was significantly lower than expected if activity and residence were independent. In other words, even if people in rural areas joined CONECT-e, they did not actively participate in it. Although this finding could be simply the expression of the rural ICT gap that exists in many countries (Graham et al. 2014), it could also be signaling the complexity of bridging scientific and lay knowledge systems in a situation where knowledge hierarchies still exist (Nadasdy 1999, Agrawal 2002). In industrialized contexts such as the one in our case study takes place, TEK has been widely despised and its value has been undermined (Naredo 2004, Reyes-García et al. 2015). This devaluation of TEK could potentially have led some users to feel that their knowledge and expertise was not sufficiently legitimate to contribute to a project hosted at a university (Forte and Bruckman 2008; Strasser et al. 2019; Dawson 2018). Moreover, the structure of the platform followed the logic of the scientists documenting TEK into categories, which may not be familiar or relevant to the people using that knowledge. Thus, although the project tried to create an extended peer community of lay and scientific actors with diverse epistemologies (e.g., ethnobotanists, farmers, activists, students), it did not manage to completely overcome the lay/scientific knowledge divide (Funtowicz and Ravetz 2003, Tengö et al. 2014). Indeed, in the final evaluation with the Red de Semillas, the platform structure was perceived by some users as too complex, potentially hindering many users' contribution to the initiative and therefore hindering knowledge co-production. In that sense, more efforts should be done in order to make users feel valuable contributors and actively engage in the platform. This is vital specifically in projects like CONECT-e, which try to reach the few remaining TEK pockets in rural Spain.

Second, it might be interesting to discuss our findings in the framework of ecosystemic participation (see introduction). In this sense participation patterns and user clusters in CONECT-e can be understood as elements of an ecosystem of participation, thus deconstructing the notion of participation as single independent acts. For instance, since the goal of CONECT-e is the generation of a knowledge commons that revitalizes TEK in Spain by documenting, sharing, and protecting it (Calvet-Mir et al. 2018), users that are only looking at the content or doing very few actions are still main contributors to the ultimate goal, since they can be learning TEK-based gardening practices for instance, and applying them in the field. In that sense, applying the ecosystemic participation lens to our results would lead to a view of participation as interdependent layers of a pyramid, as opposed to participation level interpretations (Fuster Morell 2010).

Factors influencing participation in politically motivated projects

Our results highlight that the main factors driving active participation in CONECT-e were being young, working in the primary sector, being affiliated to the project core groups (i.e., Red de Semillas, schools or core scientific team), and having a motivation aligned with the project objectives (i.e., prevent TEK loss and share TEK). We also found that elder and rural users were not participating as actively as the other users. In the light of these results, several issues can be discussed.

First, results from this work seem to confirm that overcoming the age and rurality participation barriers (Graham et al. 2014, Schrögel et al. 2018) is challenging in technology-mediated citizen science, even for topics which are familiar to these populations (i.e., elder and rural). As it has been argued, overcoming such barriers will require adapting the technologies and increasing intergenerational communication (Newman et al. 2012).

Second, we found that, contrary to our expectations, individualistic motivations were not necessarily associated to lower activity in the project. While counterintuitive, this result aligns with results from other studies, that concluded that, at least in the short term, it is a dynamic configuration of hedonistic and altruistic motivations and incentives that defines participation in CS (Nov et al. 2011, Rotman et al. 2012).

Finally, our results also suggest the importance of partnering with key actors and organizations with a long-term engagement in the topics that the project targets (such as the Red de Semillas in our case), not only to sustain participation, but most importantly to make the project meaningful for the participants. As reported in similar studies (Nov et al. 2010), belonging to a project group or the CONECT-e team was associated with making more contributions to the platform. This might be related to the amount of dissemination and support efforts dedicated to these specific groups, but is also a reflection of the conceptual and practical alignment these groups have with the project (e.g., having common purposes and methods) and the relationships of trust and transparency the project has built with some groups of participants. More so, it is important to highlight the relevance of compensating these groups for their engagement in the way they feel they need it, be it economically or with other type of support/compensation strategies. For instance, in CONECT-e the Red de Semillas was compensated economically (a compensation that was collectively and internally managed), and the schools received books on traditional ecological knowledge for their libraries. Although compensating participants in CS is a very debated topic (Irwin 2018), it is a common practice in community-based monitoring and other environmental justice initiatives that rely on equitable and bottom-up partnerships (Liboiron and Molloy 2017).

CONCLUSION

Three main conclusions can be withdrawn from our results. First, politically motivated projects, such as CONECT-e, have more equalized patterns of participation than those previously reported in the literature in terms of (a) the proportion of groups that are usually under-represented in CS initiatives (specifically women, young people and people from rural communities) and (b) the proportion of active participants. Second, active participation in politically motivated CS projects is associated to dynamic motivations and incentives including users' alliance with the project's objectives and partners. In the case of CONECT-e, the active participation of Red de Semillas was key to include under-represented groups, since this civil society organization is mainly composed of young women from rural areas, and they were motivated to participate because they were already engaged with the organizations' activities. Finally, participation in web-based CS projects is better understood under the ecosystemic participation, since both active (entering information) and passive (consulting information) participation can have transformative potential in the sense of knowledge spreading and co-creation.

PART 3. THE IMPACT

This is a pre-print version of the article:

Benyei P., Aceituno-Mata L., Calvet-Mir L., Tardío J., Pardo-de-Santayana M., García-del-Amo D., Rivera-Ferre M., Molina-Simón M., Gras-Mas A., Perdomo-Molina A., Guadilla-Sáez S., & Reyes-García V. *Ecology and Society* (under revisión)

Chapter 4

Seeds of change: Reversing Traditional Agroecological Knowledge's erosion through a citizen science school program in Catalonia.

INTRODUCTION

Traditional Agroecological Knowledge (TAeK) systems, understood as the set of knowledge, practices and believes related to the use and management of the elements in an agroecosystem, are basic components of the world's biocultural heritage (Berkes et al. 2000, Calvet-Mir et al. 2018). Maintaining traditional knowledge systems has been an emerging priority because of their multiple social, ecological, and economic values and their potential relevance for agroecological transitions (Reyes-García 2015, Calvet-Mir et al. 2018). However, and despite TAeK's dynamic and adaptive nature that allows its co-existence with other types of knowledge systems, there is a growing consensus among scientists and policy makers regarding its rapid erosion (Reyes-García et al. 2010, 2014, Shukla et al. 2017). Two main factors significantly contribute to traditional knowledge erosion in industrialized societies: its devaluation and lack of transmission to younger generations (Gómez-Baggethun et al. 2010, Oteros-Rozas et al. 2013, Hernández-Morcillo et al. 2014, Iniesta-Arandia et al. 2014).

First, traditional agroecological practices in Europe have been widely abandoned partly due to a negative valuation of TAeK systems. This valuation can be understood as the result of a set of socio-cultural, political, and economic factors that influence people's preferences and value perceptions. For instance, agriculture modernization paradigms have resulted in non-industrial agricultural systems based on TAeK being considered to be outdated, inefficient, and unworthy (Naredo 2004, Gómez-Baggethun et al. 2010, Hernández-Morcillo et al. 2014). Also, the stigmatization of wild plant consumption, considered a sign of poverty in some contexts, has resulted in the erosion of wild edible plant knowledge (Cruz García 2006, Reyes-García et al. 2015). Finally, acculturation through decontextualized schooling might have also negatively affected TAeK valuation (Castagno and McKinley Jones Brayboy 2008, McCarter et al. 2014). All these issues are framed by asymmetrical power relations that go back to colonial ideas about the underdevelopment of indigenous and local communities and that favor "expert" upon "lay" knowledge (Agrawal 1995, Nadasdy 1999, Burke and Heynen 2014, Benyei et al. 2017).

Second, the lack of traditional knowledge transmission can lead both to knowledge loss and to a decline in local communities' capacities to manage natural resources

(Fernández-Llamazares et al. 2015, Ianni et al. 2015, Ramet et al. 2018). Traditional knowledge is accessed through a combination of different pathways that include knowledge transmission from peers (horizontal), parents (vertical), and other adults (oblique transmission) (Cavalli-Sforza and Feldman 1981, Calvet-Mir et al. 2016). The relevance of these different pathways depends not only on the cultural group, but also on the age and characteristics of the learner (Reyes-García et al. 2016). In this sense, contextualized and intergenerational school activities could result both in horizontal knowledge transmission through fellow students and in vertical/oblique knowledge transmission through the interactions with elders. More so, these activities can increase access to TAeK and help prevent the "biocultural amnesia" (in Toledo and Barrera-Bassols words, 2008) of the younger generations (McCarter and Gavin 2014, Tang and Gavin 2016).

The general decline in TAeK has called the attention of researchers and policy makers who have started to investigate and promote initiatives to stop TAeK's devaluation and enhance its transmission (Tang and Gavin 2016, Benyei et al. 2019). An innovative experience in this line has been the development of citizen science school programs focused on documenting TAeK through student-led interviews, which enhance access to TAeK and contribute to counteracting social stigma and re-valuing the community's biocultural patrimony (Sieber and Strohmeier 2016, Calvet-Mir et al. 2018). Normally explored in the context of STEM (Science, Technology, Engineering, and Math) or environmental education, citizen science school programs increase participants' knowledge base as well as their valuation of certain ecosystem services or natural elements (Ruiz-Mallén et al. 2016). Previously evaluated citizen science school programs focus on natural science issues, such as biodiversity conservation or environmental monitoring, and not on biocultural issues, such as TAeK conservation (Bela et al. 2016), for which it is unclear how these programs can affect issues such as students' valuation and access to TAeK. Indeed, although some research has investigated socio-cultural valuation of ecosystem services provided by TAeK-based practices (Calvet-Mir et al. 2012b, Oteros-Rozas et al. 2014) and TAeK intergenerational transmission in industrialized contexts (Calvet-Mir et al. 2016, Gómez-Baggethun et al. 2010), most research in these fields has focused on adults from indigenous populations who have a relatively low exposure to other sources of TAeK, such as the internet, or who have more connection to nature than the younger populations living in industrialized countries. Thus, there is a need to investigate the factors behind and the degree to which the young generations in industrialized countries value and access traditional knowledge systems. More so, there is a need to evaluate the potential of citizen science school programs for TAeK conservation.

In this study, we analyze results from a citizen science school program implemented in Catalan schools teaching agricultural technical studies. The program aimed at engaging the public in the documentation of TAeK through a wiki-like platform (www.conecte.es). In our study, we explore students' (1) TAeK valuation and (2) access to TAeK, and (3) the impact of the citizen science program on (1) and (2). We end by discussing the implications of our results in terms of halting TAeK's erosion and promoting its maintenance.

METHODS

To answer our research questions, we used a quasi-experimental design that captured student's valuation and access to TAeK with a survey before and after an intervention consisting on exposing students to a citizen science school program.

Intervention and sampling

Our intervention was designed based on the CONECT-e school program (see educational materials in the project's website) and had two activities. The first activity was a 50-minute talk in which a researcher explained the concept of TAeK and gave some examples of its importance, drivers of erosion, and potential recovery pathways. At the end of the talk, the students were provided with a practical guide to document TAeK through interviews with elders. The second activity was a 50-minute practical session in the schools' computer room during which the students would enter the traditional knowledge they had previously gathered in an online wiki platform (www.conecte.es). Both sessions were separated by at least one month, so that the students would have time to interview elders. The students and their teachers had to sign a free prior informed consent sheet to be able to participate.

Since students in a class can be considered a captive population, our sampling strategy was voluntary sampling at the classroom level (i.e., sampling interested teachers that would volunteer to participate with their classes). Specifically, we invited teachers from all the schools teaching agrarian technical studies to participate in our study via personal contacts, social media, email and telephone. Eleven teachers from nine schools volunteered to participate with their classes in our study (15 classes in total). We did a systematic assignation of the classes to control (N=4) and treatment (N=11) groups (Tuckman and Harper 2012). Group assignation was done so that both groups were relatively equivalent in terms of the number of students (i.e. some of the treatment classes had as few as four students), the geographical diversity, and the study programs offered. To avoid potential interferences due to students sharing information, we assigned classes from the same school to the same group. Some of the teachers and students were lost to follow-up (i.e., only attended the first intervention activity and/or were not available to respond the post intervention survey even though they were all approached both physically and by email). This left us with two treatment groups, one with students who only attended the talk (n= 59) and one with students who attended the talk and did the practical activity (n= 88), and a control group (n= 26) with students who answered both surveys without doing any activity (total sample size= 173, see Figure 1 and Table 1).

Figure 1. Geographical location of the schools teaching agricultural technical studies.

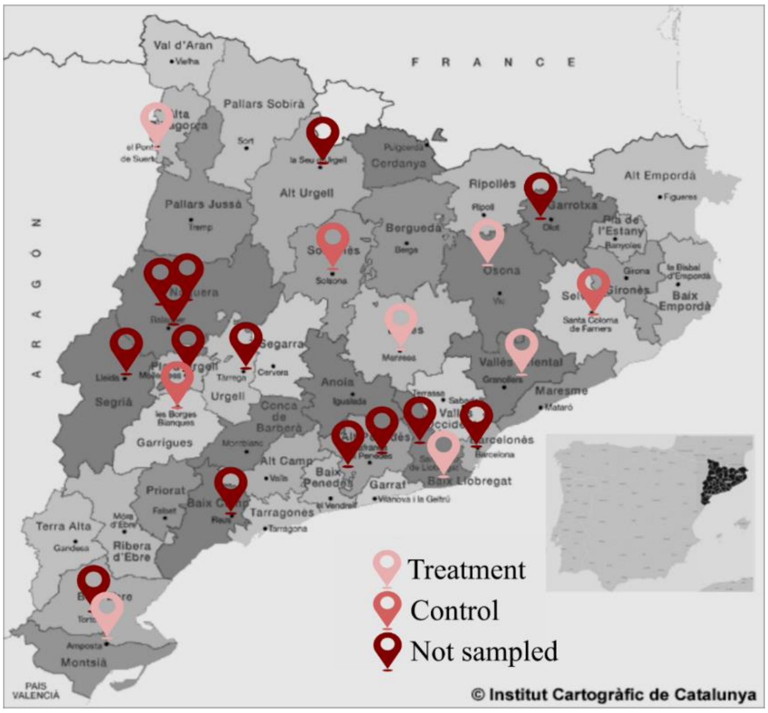


Table 1. Sampled students by school, class, and treatment group

School	Class (level and program)	Group	N
EA Borges Blanques	Basic. Conventional agriculture	Control	13
EA Solsonès	High. Forest management	Control	1
	High. Agriculture and landscape	Control	3
EA Santa Coloma de Farners	High. Forest management	Control	9
Sub-total			26
INS Pont de Suert	High. Forest management	Talk	24
	Basic. Natural resources management	Talk	6
INS Ribera Baixa II	Basic. Agroecology	Talk	11
	High. Agriculture and landscape	Talk	7
EA Manresa	Basic. Agroecology	Talk	11
Sub-total			59
EFA Quintanes	High. Agriculture and landscape	Talk + Platform	19
	High. Conventional animal health	Talk + Platform	23
EA Amposta	High. Forest management	Talk + Platform	16
	High. Agriculture and landscape	Talk + Platform	16
	Basic. Gardening	Talk + Platform	11
INS Giola	Basic. Agroecology	Talk + Platform	3
Sub-total			88
TOTAL			173

Pre and post intervention survey

During the academic year 2016-2017, we conducted the same survey in two moments: one right before the first activity of the intervention (but after clarifying the concept of TAeK) and one at the end of the school year, at least a month after we did the second intervention activity. Participants who dropped out and only did the first activity were also approached to complete the post-intervention survey at the end of the school year.

Our survey was based on a questionnaire that had three sections. The first section recorded students' valuation of TAeK with a Likert scale (Croasmun and Ostrom 2011). Based on literature exploring the values of TEK (Reyes-García 2015), we proposed sentences to which the students could agree or disagree in a five-point scale (1= completely disagree, 5= completely agree). Each sentence tried to capture the perceived value of TAeK regarding TAeK's contribution to V1) biodiversity enhancement, V2) farm productivity, V3) identity promotion, and V4) farm sustainable management; and TAeK's validity as V5) an updated knowledge base, V6) equally relevant as scientific knowledge, and V7) something that should be taught in schools. To discourage automatic responding, some sentences were inverted (e.g., "TAeK does NOT contribute to …").

The second section of the questionnaire gathered data regarding the frequency with which the students talked about TAeK (0= never, 1= rarely, 2= frequently). This frequency was a proxy to measure access to TAeK. We included four potential ways of accessing TAeK: A1) elders (including parents and grandparents), A2) friends, A3) classroom, and A4) digital or physical sources.

The third section of the questionnaire gathered data on the students' sociodemographic characteristics including year of birth, sex, actual residence (town name), study program (i.e., conventional agriculture, agroecology, natural resources management, gardening, agriculture and landscape, conventional animal health and forest management), and desired work sector (i.e., organic agriculture, conventional agriculture, environmental/forestry, gardening or other). It also captured information related to the student's rurality, measured through family ties to the primary sector (1= yes), current employment in a natural resources related job (1= yes), maintenance of a leisure homegarden (1= yes), and stated intention to live in a rural area in the future (1= yes).

Variables

To construct a TAeK valuation index ($TAeK\_v_{sum}$), we first checked the internal correlation of the seven valuation scores using Pearson correlation tests (*cor.test* function, R Core Team 2018). As we found internal consistency, we added the value of the seven individual topic scores ($\sum TAeK\_v_i$). The TAeK valuation index is expressed as:

$$TAeK\_v_{sum} = TAeK\_v_1 + TAeK\_v_2 + TAeK\_v_3 + TAeK\_v_4 + TAeK\_v_5 + TAeK\_v_6 + TAeK\_v_7$$

This index could range from 7 (a student that strongly disagreed with all the topics) to 35 (a student that strongly agreed with them).

To build a TAeK access index ($TAeK\_a_{sum}$), we added the scores for each of the four ways of accessing TAeK ($\sum TAeK\_a_i$) after checking for absence of internal association using Pearson Chi-squared tests (*chisq.test* function, R Core Team 2018). The TAeK access index is expressed as:

$$TAeK\_a_{sum} = TAeK\_a_1 + TAeK\_a_2 + TAeK\_a_3 + TAeK\_a_4$$

This index could range from 0 (a student who never talked about TAeK, i.e., never accessed TAeK) to 8 (a student who frequently accessed TAeK through multiple ways).

We also re-coded some of the socio-demographic variables (Table 2). The actual residence variable was re-coded into a three level categorical variable according to the classification of the town of residency as (1) urban, (2) intermediate, or (3) rural (Domínguez i Amorós et al. 2010). After examining the content and approach of the courses, the study program variable was re-coded into a program theme categorical variable with three categories: (1) alternative farming (grouping “agroecology” and “landscape and agriculture” programs), (2) conventional farming (grouping “conventional agriculture” and “conventional animal health”), and (3) environmental management (grouping “gardening”, “natural resources management” and “forest management”).

Data analysis

To explore students’ valuation and access to TAeK, we conducted descriptive analyses and linear mixed-effects models (LMMs) with the pre-intervention survey data.

Specifically, we tested the association between individual covariates or fixed effects (i.e., age, gender, actual residence, program theme, desired work sector and rurality variables) and the TAeK valuation and access indexes, while controlling for the inter classroom variation (random effects).

To measure the impact of the citizen science initiative in both students' valuation and access to TAeK, we conducted descriptive analyses on the post-intervention survey data and Wilcoxon signed-rank tests and LMMs using data from both surveys. Specifically, we used non-parametric paired t-tests to compare our indexes' mean scores before and after the intervention ($Pre\_TAeK\_v_{sum}$ vs. $Post\_TAeK\_v_{sum}$, and $Pre\_TAeK\_a_{sum}$ vs. $Post\_TAeK\_a_{sum}$) and LMMs to test the effect of the treatment on the TAeK valuation and access indexes after the intervention ($Post\_TAeK\_v_{sum}$ and $Post\_TAeK\_a_{sum}$), while controlling for 1) the baseline values ($Pre\_TAeK\_v_{sum}$ and $Pre\_TAeK\_a_{sum}$, 2) individual covariates, and 3) inter classroom variation (random effects).

The LMMs were performed separately for each index. These models were built using manual stepwise backwards regressions by which we departed from all the explanatory variables in our dataset and progressively discarded those that were not significantly affecting our outcome variable. Variables were only discarded if the model without them was not significantly different from the model with them (Crawley 2007). The final models were the ones that most parsimoniously explained the greatest variation in valuation and access indexes, for which variables included in each model are different. The assumptions of the final models were checked by looking into the residual graphics.

The final models were expressed by the following formula:

$Pre\_TAeK\_v_{sum}$ ~ 1 + age + leisure_garden + (1 | class)

$Pre\_TAeK\_a_{sum}$ ~ 1 + program_theme + desired_work + work_rural_nature + leisure_garden + (1 | class)

$Post\_TAeK\_v_{sum}$ ~ 1 + $Pre\_TAeK\_v_{sum}$ + treatment + sex + desired_work + (1 | class).

$Post\_TAeK\_a_{sum}$ ~ 1 + $Pre\_TAeK\_a_{sum}$ + treatment + desired_residence + (1 | class).

For statistical analyses we used RStudio Version 1.0.153. To perform the Wilcoxon signed-rank tests we used the *wilcox.test* function (R Core Team 2018). To conduct the mixed-effects models we used the lmerTest and lme4 packages (Bates et al. 2014). Mixed-effects models have been proven to be an effective way to account for school intervention effects in studies that include both categorical and continuous variables and that need to account for unbalanced datasets and random effects that arise during sampling, for instance the selection of a classroom (Wyman et al. 2010, Cunnings 2012). They are also described as been robust against violations of sphericity, homoscedasticity and missing data (Quené and Van Den Bergh 2004, Kelder et al. 2005, Quené and van den Bergh 2008).

Table 2. Description of variables used in the analyses

Variables	Code	Type	Attributes
TAeK's perceived contribution to biodiversity enhancement	$TAeK\_v_1$	Interval	Scale 1-5
TAeK's perceived contribution to farm productivity	$TAeK\_v_2$	Interval	Scale 1-5
TAeK's perceived contribution to identity promotion	$TAeK\_v_3$	Interval	Scale 1-5
TAeK's perceived contribution to farm sustainable management	$TAeK\_v_4$	Interval	Scale 1-5
TAeK's perceived validity as an updated knowledge base	$TAeK\_v_5$	Interval	Scale 1-5
TAeK's perceived validity as equally relevant as scientific knowledge	$TAeK\_v_6$	Interval	Scale 1-5
TAeK's perceived validity as something that should be taught in schools	$TAeK\_v_7$	Interval	Scale 1-5
TAeK valuation index	$TAeK\_v_{sum}$	Continuous	$\sum TAeK\_v_i$
How frequently the students talked about TAeK with elders	$TAeK\_a_1$	Interval	Scale 0-2
How frequently the students talked about TAeK with friends	$TAeK\_a_2$	Interval	Scale 0-2
How frequently the students talked about TAeK in the classroom	$TAeK\_a_3$	Interval	Scale 0-2
How frequently the students consulted TAeK in digital or physical sources	$TAeK\_a_4$	Interval	Scale 0-2
TAeK access index	$TAeK\_a_{sum}$	Continuous	$\sum TAeK\_a_i$
Age	age	Continuous	Converted year of birth
Sex	sex	Dummy	1=female
Actual residence	residence	Categorical	1=urban 2=intermediate 3=rural
Program theme	program_theme	Categorical	1= alternative

			farming 2= conventional farming 3= environmental management
Desired work sector	desired_work	Categorical	1= organic agriculture 2= conventional agriculture 3= environmental/forestry 4= gardening 5= other
Family ties to the primary sector	family_primary	Dummy	1=yes
Current employment in a natural resources related job	work_rural_nature	Dummy	1=yes
Maintenance of a leisure homegarden	leisure_garden	Dummy	1=yes
Intention to live in a rural area in the future	desired_residence	Dummy	1=yes
Treatment	treatment	Categorical	0= control 1= only talk 2= talk and practical activity

RESULTS

Participants' description

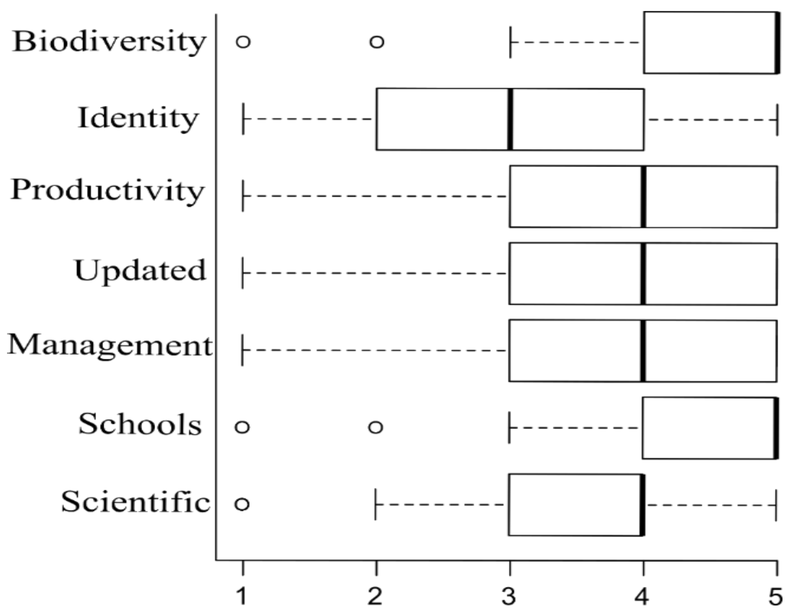
Participants were mainly young men between 19 and 23 years old (83% male participants), although some were older. Two thirds of the participants (63.2%) were studying a high level program and one third (31.8%) was studying a basic level program. Programs were related to gardening, natural resource management, and forest management (39.9% of participants) as well as to alternative (37.6%) and conventional farming (22.5%).

One quarter of the participants (25%) wanted to work in organic farming while 18.6% wanted to work in conventional farming. The remaining participants wanted to work in sectors other than agriculture, including environmental management/forestry (32.5%) and ornamental gardening (9.9%). Participants came from different areas in Catalonia, with 66.5% of them living in a rural or intermediate-rural town and 33.5% in an urban town. However, 73.8% of participants stated their intention to live in a rural area in the future. Half (50.3%) of the participants came from a family with ties to the primary sector (farming, fishing or forestry) and about the same proportion (49.4%) were or had been employed in a natural resources related job (e.g., in family farms or in fire prevention squads). Two-thirds of participants (64.5%) maintained a leisure homegarden.

TAeK's valuation and access before the intervention

Results from the pre-intervention survey suggest that participants highly valued TAeK before our intervention (Figure 2). On average, most participants showed a relatively strong agreement with sentences that stated TAeK's contribution to improving farm biodiversity (mean= 4.34 in a scale of one to five), productivity (mean= 3.82), and sustainable management (mean= 3.80). They also agreed with sentences stating that TAeK was updated (mean= 3.68) and equally relevant than scientific knowledge (mean= 3.61). The statement with which they most strongly agreed was the one stating that TAeK should be taught in schools (mean= 4.53), while the one they less strongly agreed with was the one stating that TAeK contributed to their identity (mean= 3.22).

Figure 2. Participant's valuation scores for the different TAeK's value statements before the intervention.



Moreover, results from the LMMs show that the TAeK valuation index ($Pre\_TAeK\_v_{sum}$, mean= 26.99, SD= 3.49; note that maximum possible score was 35) bears a positive and statistically significant association with the participant's age (F= 8.6647, $p<0.01$) and maintenance of a leisure homegarden (F=3.9348, $p<0.05$, as shown in Figure 3 and Table 3).

On the contrary, most participants rarely talked about TAeK with people around them, or in other words: they rarely accessed TAeK (Figure 4). Those with whom they most often talked about TAeK were their elders (38.7% of the participants stated talking frequently about TAeK with their elders), whereas those with whom they least often talked about TAeK were their classmates (only 9.8% of the participants stated talking frequently about TAeK in the classroom). Also, only 30.6% of the participants stated talking frequently about TAeK with friends and only 23.9% frequently consulted TAeK in digital or physical sources.

Figure 3. Pre-intervention TAeK valuation index against age and colored by maintenance of a leisure homegarden

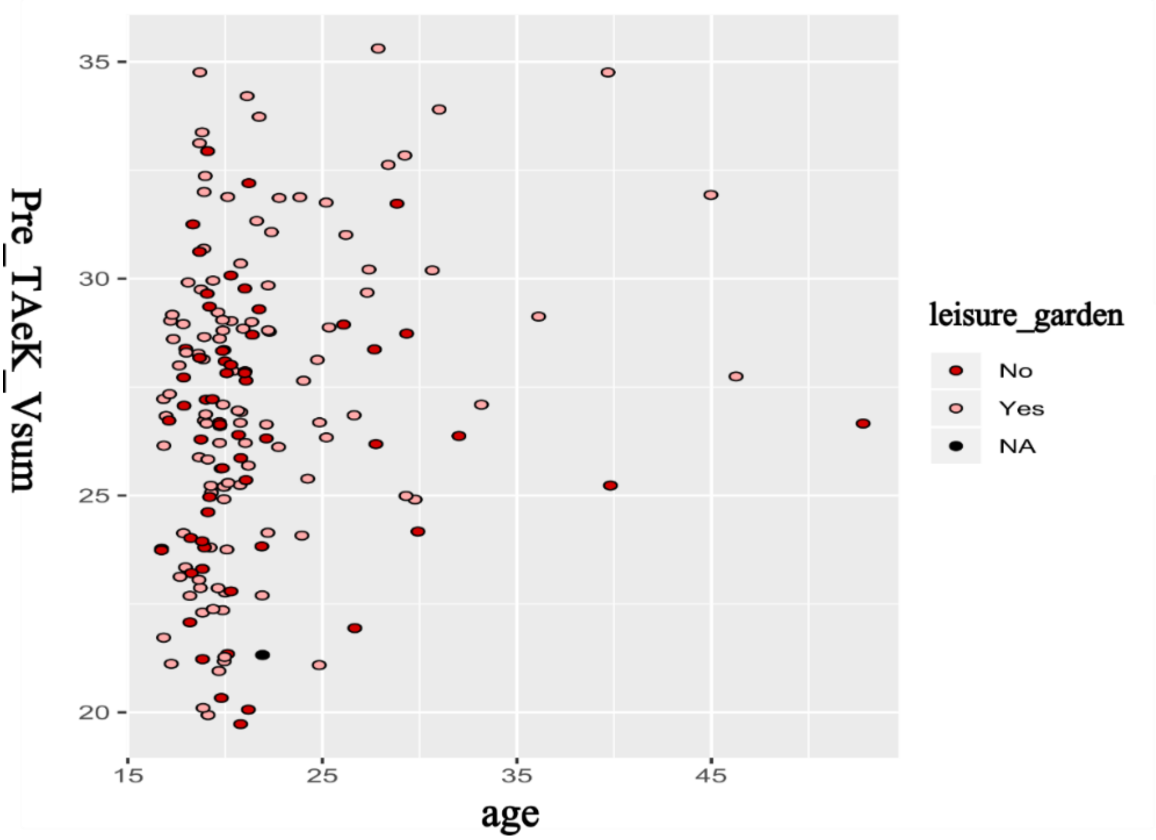
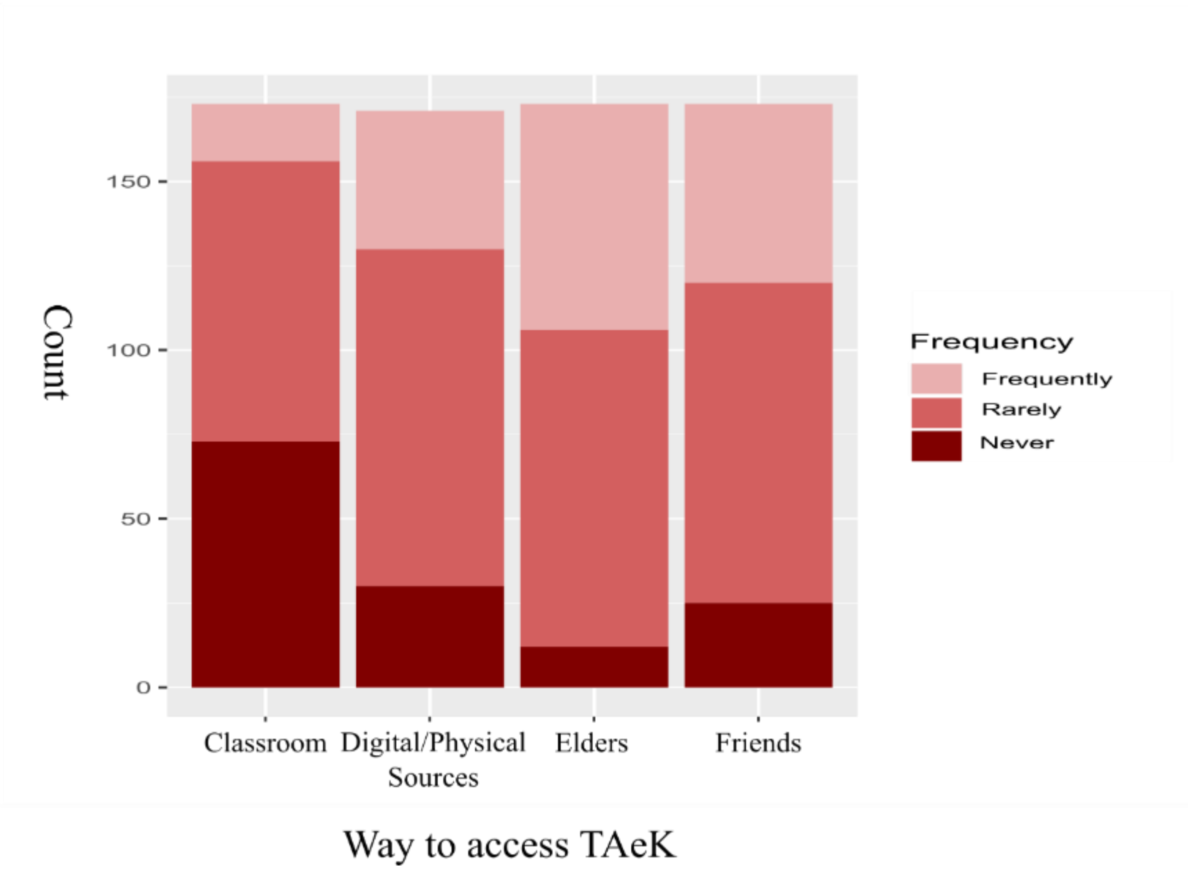


Table 3. Most parsimonious linear mixed model fit by REML. t-tests use Satterthwaite approximations to degrees of freedom lmerMod. Formula: Pre_TAeK_$_{Vsum}$ ~ 1 + age + leisure_garden + (1 | class). REML criterion at convergence: 899.4. Number of obs: 171, groups: class, 15

Fixed effects	Estimate	Std.Error	df	tvalue	Pr(>|t|)
(Intercept)	23.17114	1.10926	168. 0e+02	20.89	<2e-16***
age	0.14263	0.04723	168. 0e+02	3.02	0.00292**
leisure_garden_yes	1.14675	0.53340	168. 0e+02	2.15	0.03299*
Signif.codes:'***'0.001 '**'0.01 '*'0.05 '.'0.1					

Figure 4. Pre-intervention frequency of access to TAeK for the different access pathways.



Results from the LMMs show that the TAeK access index (Pre_TAeK_a_{sum}, mean= 4.21, SD= 1.83; maximum possible score was 8) is associated to the participants' program theme ($F=12.0204$, $p<0.001$), desired work sector ($F=2.9547$, $p<0.05$), employment in a natural resources related job ($F=9.3896$, $p<0.01$), and maintenance of a leisure homegarden ($F=13.6958$, $p<0.001$, Figure 5 and Table 4). Indeed, participants studying conventional farming and environmental management programs accessed TAeK significantly less often than participants in alternative farming programs. Also, participants who wanted to work in the conventional agriculture, environmental/forestry, gardening and other sectors accessed TAeK significantly less often than those who wanted to work in the organic agriculture sector. Finally, participants employed in a natural resources related job and/or maintaining a leisure homegarden accessed TAeK significantly more often than their peers.

Figure 5. Distribution of the pre-intervention TAeK access index for those variables statistically significantly associated to it.

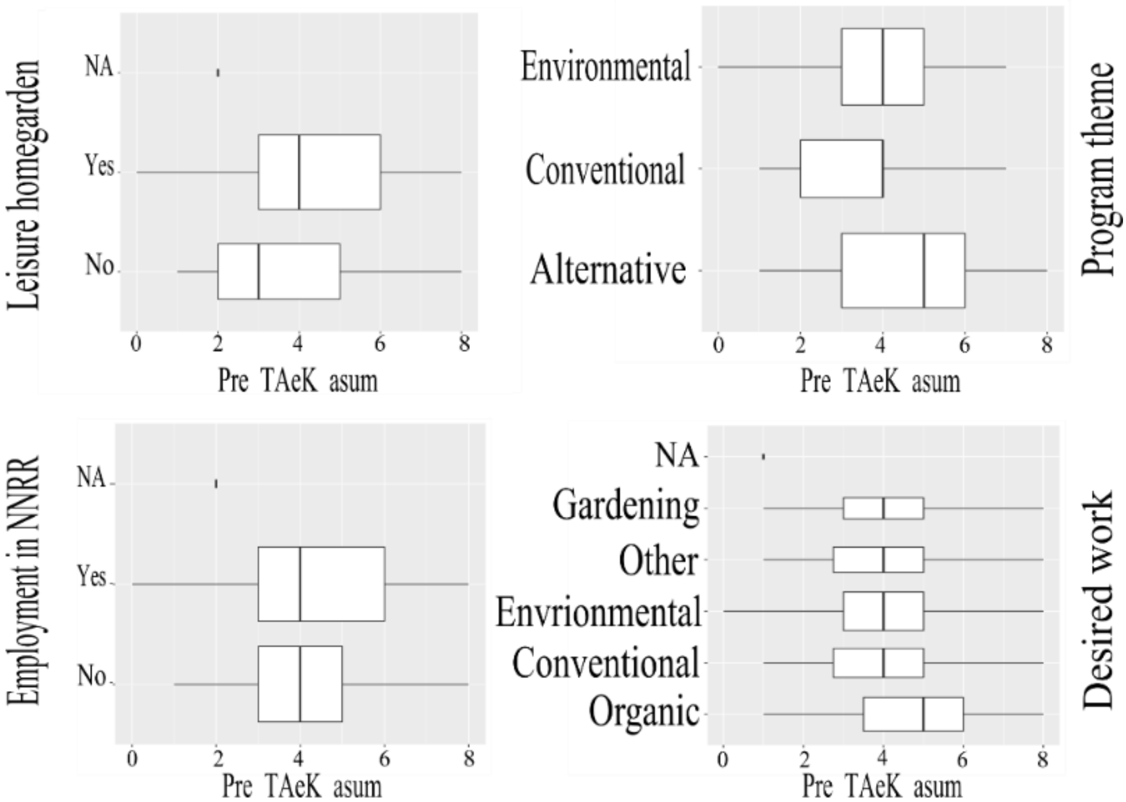


Table 4. Most parsimonious linear mixed model fit by REML. t-tests use Satterthwaite's method lmerModLmerTest Formula: Pre_TAeK_$_{Asum}$ ~ 1 + program_theme + desired_work + work_rural_nature + leisure_garden + (1 | class). REML criterion at convergence: 638.2. Number of obs: 171, groups: class, 15

Fixed effects	**Estimate**	**Std. Error**	**df**	**t value**	**Pr (>|t|)**
(Intercept)	4.6797	0.3650	162.0000	12.819	<2e-16***
program_theme conventional farming	-1.8879	0.3887	162.0000	-4.857	2.79e-06***
program_theme environmental management	-0.7877	0.3216	162.0000	-2.449	0.015397*
desired_work conventional agriculture	-0.7932	0.3916	162.0000	-2.025	0.044475*
desired_work environmental/forestry	-0.9946	0.3658	162.0000	-2.719	0.007264**
desired_work other	-0.9092	0.4121	162.0000	-2.206	0.028776*
desired_work gardening	-1.2757	0.4936	162.0000	-2.584	0.010639*
work_rural_nature_yes	0.7757	0.2532	162.0000	3.064	0.002557**
leisure_garden_yes	0.9894	0.2673	162.0000	3.701	0.000294***
Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1					

Intervention impact on TAeK valuation and access

The mean TAeK valuation index score was not significantly higher after the intervention (Post_TAeK_v$_{sum}$, mean= 26.86, SD= 3.56, p-value = 0.5516, see Figure 6). However, there seems to be some variations in TAeK valuation when looking at specific questions, particularly TAeK's perceived contribution to identity promotion (with an increase in mean score from 3.22 to 3.31 in a scale of one to five), TAeK's perceived validity as an updated knowledge base (from 3.68 to 3.71), and TAeK's perceived validity as equally relevant as scientific knowledge (from 3.61 to 3.76).

Figure 6. Distribution of the pre-intervention (a) and post-intervention (b) TAeK valuation index.

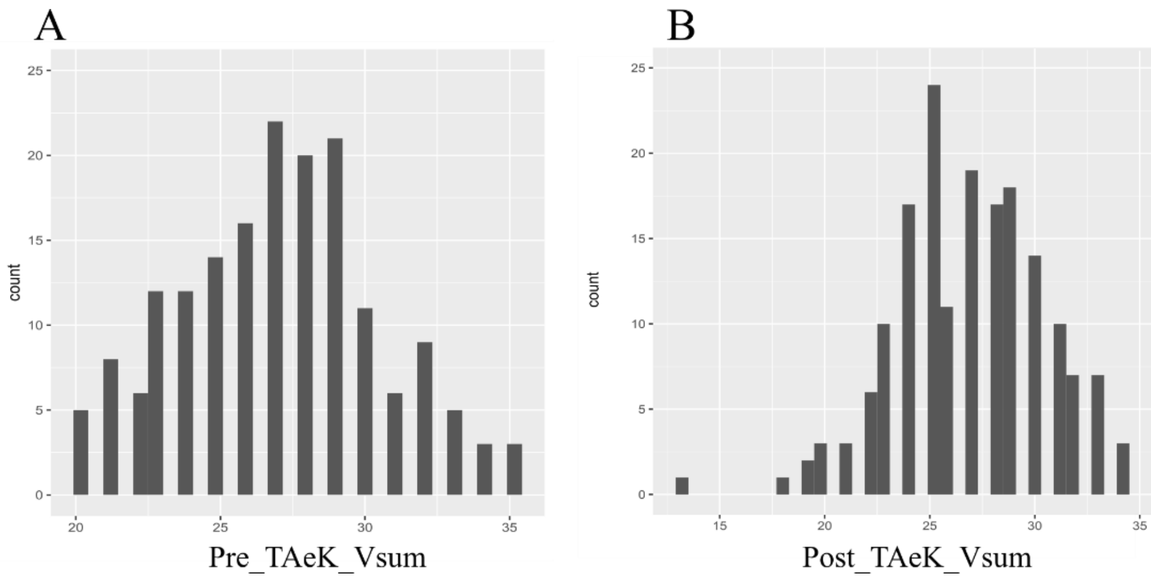
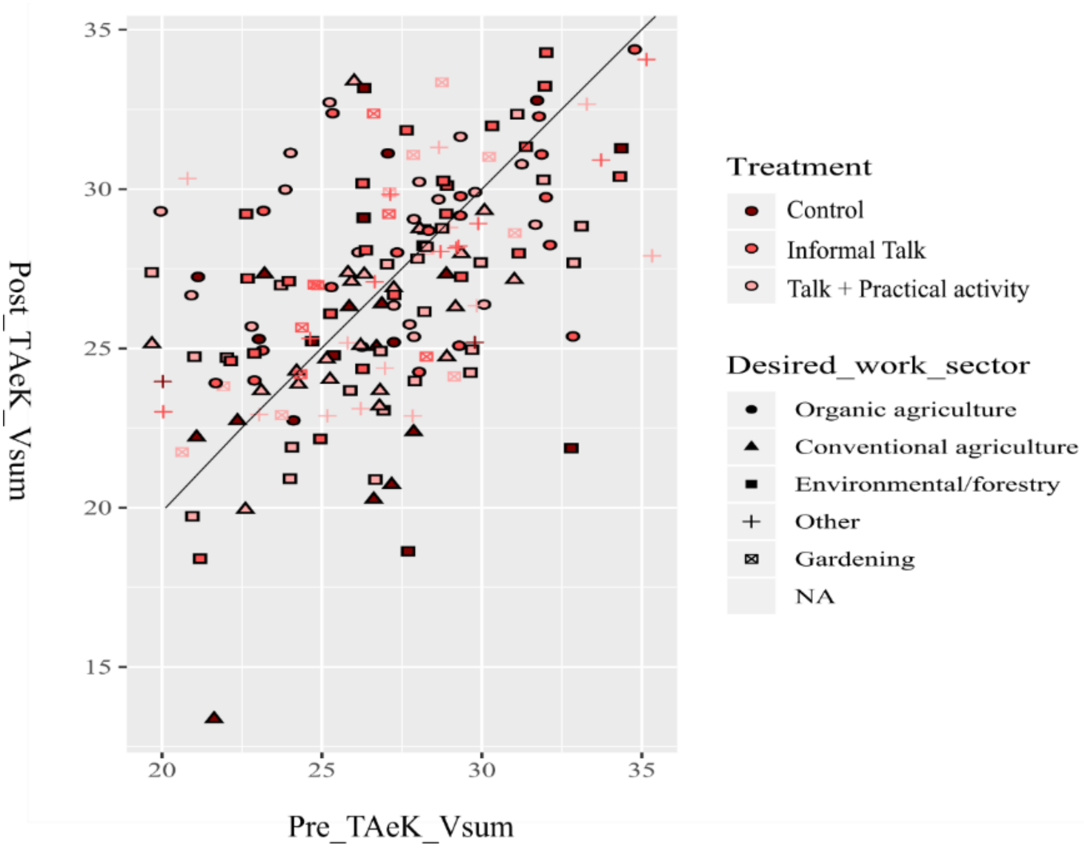


Figure 7. Plot of the post-intervention TAeK valuation index against the pre-intervention TAeK valuation index, coloured by treatment and shaped by desired work sector. Note that those data points falling above the diagonal of the graph respond to participants that valued TAeK higher after than before the intervention.



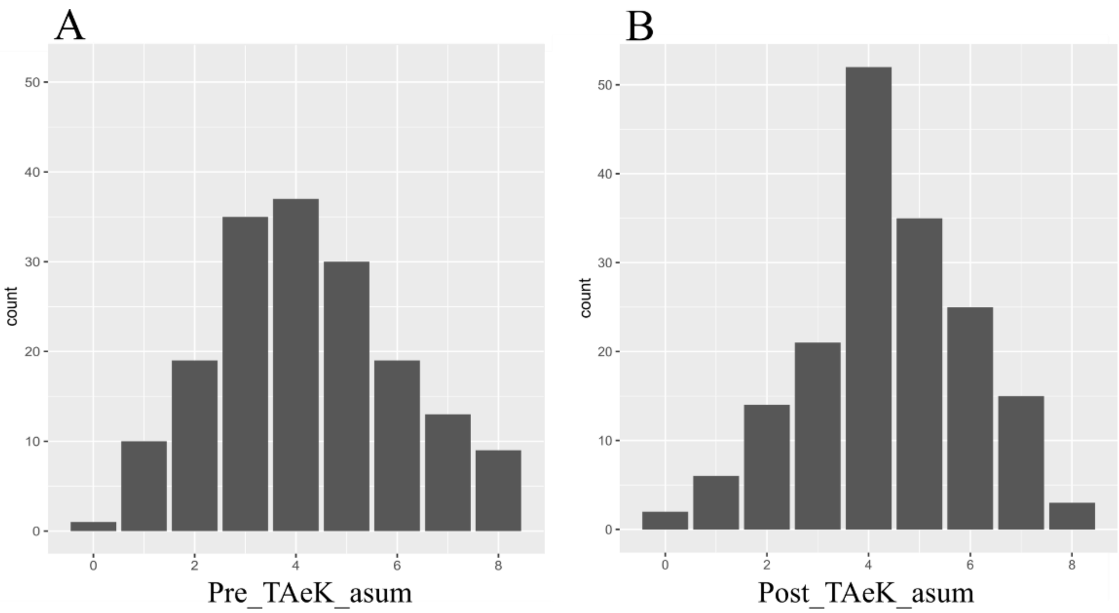
Results from the LMM suggest that these variations in TAeK valuation might be associated to our intervention (F=2.2583, p-value=0.15463) but also to other factors. Controlling for participants' TAeK valuation before the intervention, the participation in the first intervention activity (the talk, T1) had a significant direct and positive effect on the participants' valuation of TAeK. Participation in both intervention activities (talk and practical activity, T2) was also directly and positively associated to participants' TAeK valuation, although the association was not statistically significant. Participants' gender (F=5.4467, p<0.05) and desired work sector (F=3.4442, p<0.05) were also associated to TAeK valuation after the intervention: women valued TAeK significantly less than men, as did participants willing to work in the conventional agriculture, environmental/forestry and other sectors when compared to those willing to work in the organic agriculture sector (see Figure 7 and Table 5).

Table 5. Most parsimonious linear mixed model fit by REML. t-tests use Satterthwaite's method lmerModLmerTest Formula: Post_TAeK_$_{Vsum}$ ~ 1 + Pre_TAeK_$_{Vsum}$ + treatment + sex + desired_work + (1 | class). REML criterion at convergence: 843.6. Number of obs: 172, groups: class, 15

Fixed effects	Estimate	Std. Error	df	t value	Pr (>|t|)
(Intercept)	15.02391	1.88501	147.57539	7.970	3.97e-13***
Pre_TAeK_$_{Vsum}$	0.44823	0.06416	157.32076	6.987	7.51e-11***
treatment_talk	1.87197	0.87023	14.53101	2.151	0.04873*
treatment_talk+practical	1.33078	0.79913	11.38433	1.665	0.12311
gender_female	-1.40591	0.61017	162.66098	-2.304	0.02248*
desired_work conventional agriculture	-2.32367	0.73306	148.06599	-3.170	0.00185**
desired_work environmental/forestry	-1.74521	0.63195	105.78336	-2.762	0.00678**
desired_work other	-1.70314	0.74548	162.04090	-2.285	0.02363*
desired_work gardening	-0.65308	0.86116	142.09345	-0.758	0.44948
Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1					

The impact of the intervention was more evident when looking at the access to TAeK. Indeed, although results were not statistically significant, participants seem to have accessed TAeK more often after than before the intervention (Post_TAeK_a_{sum}, mean= 4.39, SD= 1.63, p-value= 0.1701, see Figure 8). Specifically, compared with the answers before the intervention, participants talked more frequently about TAeK with friends and in the classroom, and also consulted TAeK more frequently in digital and physical sources after the intervention. In fact, the proportion of students that never talked about TAeK with friends or in the classroom went down 6.4% and 19.1 % respectively.

Figure 8. Distribution of the pre-intervention (a) and post-intervention (b) TAeK access index



The LMMs showed that, controlling for the pre-intervention answers, both treatments had a significant direct and positive effect on the post-intervention TAeK access index (F=4.2503, p<0.05). In other words, attending the talk and using CONECT-e's platform significantly increased the frequency with which participants talked about TAeK. Access to TAeK after the intervention was also positively associated to the participant's desire to live in a rural area in the future (F=8.2162, p<0.01, see Figure 9 and Table 6).

Figure 9. Plot of the post-intervention TAeK access index against the pre-intervention TAeK access index coloured by treatment and shaped by rurality of desired future residence. Note that those data points falling above the diagonal of the graph respond to participants that accessed TAeK more frequently after than before the intervention.

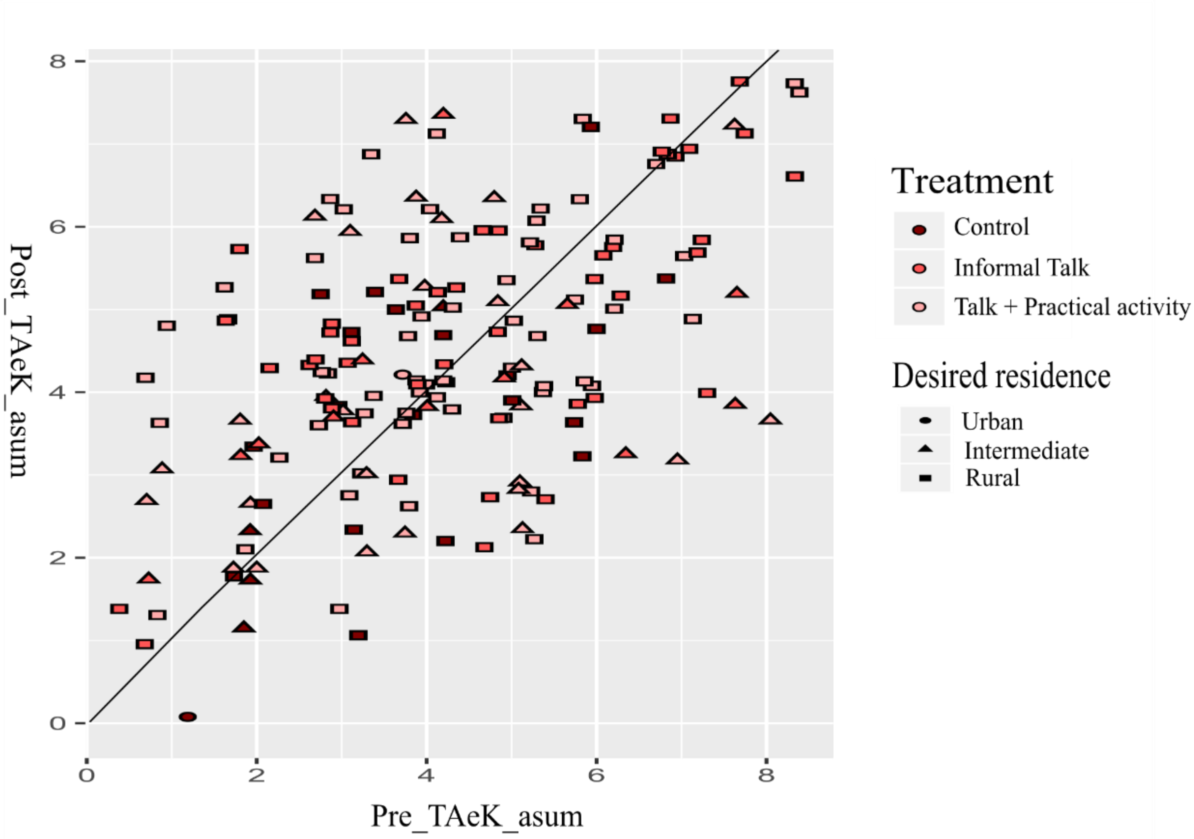


Table 6. Most parsimonious linear mixed model fit by REML. t-tests use Satterthwaite's method 'lmerModLmerTest' Formula: $Post\_TAeK\_a_{sum}$ ~ 1 + $Pre\_TAeK\_a_{sum}$ + Treatment + desired_residence + (1 | class). REML criterion at convergence: 583.6. Number of obs: 172, groups: class, 15

Fixed effects	Estimate	Std. Error	df	t value	Pr (>|t|)
(Intercept)	1.39638	0.36485	167.00000	3.827	0.000183 ***
$Pre\_TAeK\_a_{sum}$	0.43624	0.05608	167.00000	7.778	7.23e-13 ***
treatment_talk	0.75799	0.31202	167.00000	2.429	0.016187 *
treatment_talk+practical	0.84278	0.29317	167.00000	2.875	0.004571 **
desired_residence_yes	0.65787	0.22951	167.00000	2.866	0.004687 **
Signif.codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1					

DISCUSSION

Results from this study contribute to understanding valuation and access to TAeK among young rural populations of industrialized countries. Moreover, our results also shed light on the potential of citizen science school programs in terms of increasing valuation and access to TAeK. Before discussing these results, we address some of the caveats that might have potentially affected them.

Caveats

The first caveat of this study relates to potential sampling biases. Schools selected for this study mainly focused on agricultural/environmental education and most of them were located in rural areas where TAeK-holders live. Although this sampling strategy makes sense in the context of our study, it also reduces result's external validity as study participants do not represent the average youth in industrialized countries, but a subsample with previous interest in agricultural/environmental topics and easy access to the traditional knowledge holders. Moreover, our study faces self-selection biases for two reasons. First, teachers voluntarily enrolled their students in the activity, which might result in a self-selection of students with previously interested teachers that could in turn be influencing their students. Second, students were able to abandon the study by not answering the post-intervention survey (in fact 19.5% did so), which might have biased our sample towards students who are more willing to participate in our activities.

Second, the survey design might have affected participants' responses. On the one hand, the use of a five point Likert scale (1 to 5) limited the valuation score's range. This meant that if a participant valued TAeK very highly before the intervention (5), he/she will not be able to increase this value after the intervention. In this case, the null (or negative) valuation change probably relates more to the measurement instrument than to a real valuation change. On the other hand, the fact that the surveys were done with the teacher and researcher in the classroom could lead to social desirability response bias (van de Mortel 2008), meaning that the students might have reported high valuation and access to TAeK just because they thought they were expected to do so.

The third caveat of this study relates to the selection of variables. In this study, we focused on two of the variables (valuation and access) that the literature has highlighted as key to the maintenance of TAeK (Gómez-Baggethun et al. 2010, Hernández-Morcillo et al. 2014). However, there could be unmeasured confounding variables, for which we cannot assume that students who highly value highly and talk a lot about TAeK would be more likely to use TAeK in the future.

A final caveat of this study relates to the lack of more baseline and longitudinal measures. Although the access to TAeK could be indicative of TAeK transmission in the sense that there is a chance for transmission if a person talks frequently about TAeK, we cannot prove that the transmission was effective in the long term unless we measure (1) the baseline knowledge, and (2) if the student actually retained the information after some time.

To value or not to value

Findings from this work contribute to better understand 1) the degree to which devaluation of TAeK is happening in industrialized contexts and 2) the factors behind this devaluation.

First, our results point out that students who enroll in agricultural technical studies in Catalonia value TAeK quite highly. In fact, they strongly agree with statements related to the importance of including TAeK in school curricula and to the equal value of TAeK and scientific knowledge. Although these results may be only representative of our sample, they show a tendency towards overcoming the previously reported devaluation of traditional knowledge systems in favor of “expert” knowledge systems (Agrawal 1995, Nadasdy 1999, Naredo 2004, Gómez-Baggethun et al. 2010, Burke and Heynen 2014, Hernández-Morcillo et al. 2014). Indeed, our results might be indicative of a revalorization of TAeK by young generations of future alternative farmers, a trend that could break with the abandonment of TAeK reported in Spain, and Europe in general (Naredo 2004, Hernández-Morcillo et al. 2014).

Second, our results highlight that the most important factors affecting the valuation of TAeK among agricultural technical students in Catalonia are age, maintaining a leisure homegarden, and willing to work in the organic farming sector. Older students, students who spend leisure time working in a homegarden, and students who would like to work in the organic sector in the future value TAeK more than their peers. Considering that TAeK is experience-based, learner-centered, and acquired through contextualized interaction with community members (Lancy 1996, Hunn 2002, Reyes-García et al. 2010, McCarter and Gavin 2011), it seems logical that older students, who have been able to spend more time with elders and in nature, and who are willing to do so in the future, also value TAeK more. Most importantly, our results could be understood as a call for including hands-on gardening activities in the school curricula of the younger students in order to promote TAeK's revalorization.

Accessing TAeK

TAeK was most frequently accessed by talking with elders and rarely accessed by talking about TAeK in class. Talking about TAeK with friends and consulting digital sources occurred more frequently than talking about TAeK in class but was still not very frequent. Assuming that talking about TAeK can mean opening the possibility to TAeK transmission, and considering the different transmission pathways described in the introduction, our results suggest that in our case study oblique and vertical transmission pathways (talking with elders) were more frequent than horizontal pathways (talking in class and with friends). Moreover, the overall use of these pathways was positively associated to studying an alternative farming program, working in a natural resources related job, willing to work in the organic farming sector, willing to live in a rural area in the future, and maintaining a leisure homegarden. These results are not surprising, since previous research shows that the main pockets of TAeK in Spain are held by elderly rural populations and that schools rarely include TAeK in their curricula (Reyes-García et al. 2014, Ramet et al. 2018), for which students need to access TAeK through pathways outside the classroom. The finding, however, has some potential implications for TAeK maintenance.

First, when analyzing the use of different transmission pathways, several authors have highlighted the importance of "scaffolding", or learning from a more knowledgeable person (normally an elder), particularly for the acquisition of complex skills (Reiser and Tabak 2014, Reyes-García et al. 2016). This applies to the transmission of TAeK, which requires the intervention of a more knowledgeable person who explains and guides the learner through the complexity of the TAeK-based practices. Thus, in the context of traditional knowledge systems, the literature reports oblique and vertical transmission as key transmission pathways (see for instance Lozada et al. 2006). lHowever, the literature also highlights that horizontal transmission is very relevant for TAeK maintenance because age-peers will be able to track changes, becoming the best source of updated information (Reyes-García et al. 2016). Thus, considering our results, more emphasis should be made in promoting horizontal TAeK transmission to improve the TAeK-based skills of future farmers and contribute to TAeK maintenance.

Second, independently of the transmission pathway used, and in order to halt TAeK erosion, our results call for reinforcing those factors favoring the access to TAeK. For instance, since access to TAeK was positively associated to studying, working and spending leisure time in alternative faming, supporting these activities and habilitating hands-on experiences related to TAeK might be key to encourage TAeK transmission, a crucial step in TAeK maintenance (Abioye et al. 2014, Eugenio and Aragón 2017, Llerena del Castillo and Espinet 2017).

CONECT-e: Seeds of change

A main finding of this work is that including explanations and technology-mediated exercises related to TAeK documentation in school activities had a positive impact both on the valuation and access to this knowledge system. Moreover, the resources needed to achieve some results are relatively modest (i.e., two 50-minutes sessions in our case). This result helps us unveil the potential of citizen science school programs as tools for TAeK conservation. Previous literature on the field of environmental education in general and citizen science in particular had reported positive impacts of contextualized school programs in the valuation and acquisition of indigenous ecological knowledge (Ruiz-Mallen et al. 2009, Shukla et al. 2017). Still, to our knowledge, this is the first time a citizen science school program developed in an industrialized context is found to have a positive impact on the valuation and access to TAeK. However, two issues must be highlighted in relation to the limits of this tool to halt TAeK erosion.

First, we must be careful when interpreting our results, as the differences in mean valuation and access scores before and after the intervention were not statistically significant. Moreover, the impact of the citizen science program was lower on students' valuation than on students' access to TAeK. This could be a result of our measurement methods (as explained in the caveats section) but it could also signal limitations of citizen science approaches when trying to improve TAeK valuation. Still, even if the intervention's impact was not so high, our results highlight that these types of programs encourage students to talk more about TAeK, a key aspect for its revitalization.

Longitudinal studies are needed to assess whether the impact of this type of programs increase over time.

Second, we must consider that the intervention had effect even without the use of the citizen science platform. Just attending the talk was positively associated to the students' valuation and access to TAeK. This result highlights that the initial approach of the CONECT-e project (using an online platform to promote TAeK sharing through intergenerational activities) might not be the only way to halt TAeK devaluation and lack of transmission among younger generations in industrialized contexts. Indeed, it is possible that simpler efforts, such as including TAeK in school curricula though informal talks, might be already a good enough tool to increase TAeK's perceived value and transmission, as it had already been reported in the literature (McCarter and Gavin 2014, Tang and Gavin 2016).

CONCLUSION

This study contributes to the understanding of how to halt TAeK erosion by exploring the factors behind valuation and access to TAeK and by evaluating the impact of a citizen science school program on both. Four main conclusions can be drawn from this research. First, the study population, i.e., youth studying agricultural technical programs in Catalonia, values TAeK highly and talks relatively frequently about it with elders. Second, encouraging hands-on activities such as homegardening and reinforcing student's interest on alternative farming may increase student's valuation and access to TAeK. Third, relatively simple school programs can have a positive effect on how much and how often the young generations of future farmers in industrialized contexts value and access TAeK. Finally, the promotion of these types of initiatives could be critical for agroecological transitions since they require young farmers to value and access TAeK. Longitudinal studies are required to test whether and why students who engaged in a citizen science school program focusing on TAeK documentation actually put this knowledge to practice in their future life, which is the only way for this knowledge to be kept alive.

PART 4. THE OUTCOME

This is a post-peer-review, pre-copyedit version of the article:

Calvet-Mir, L., Benyei P., Aceituno-Mata L., Pardo-de-Santayana M., López-García, D., Carrascosa-García M., Perdomo-Molina A., & Reyes-García V. *Sustainability* (2018) 10(9):3214.[8]

Chapter 5

The contribution of Traditional Agroecological Knowledge as a digital commons to agroecological transitions: The case of the CONECT-e platform

[8] The first author of this article authorized its inclusion in this Doctoral Thesis. L.C.-M. with the help of L.A.-M. and P.B. conceptualized the article; L.C.-M., D.L.-G., P.B., and V.R.-G. articulated the theoretical framework; L.C.-M., P.B., L.A.-M., M.P.-d.-S., and V.R.-G. were involved in the methodology design; L.C.-M., P.B., L.A.-M., M.P.-d.-S., M.C.-G., and A.P.-M. contributed to data collection; data analysis was performed by P.B. with the help of L.C.-M. and M.P.-d.-S.; L.C.-M. did the writing—original draft preparation and lead the writing of the paper; all authors contributed to the writing—review and editing of the manuscript.

INTRODUCTION

Traditional Agroecological Knowledge (TAeK) refers to the cumulative and evolving body of knowledge, practices, beliefs, institutions, and worldviews about the relationships between a society or cultural group and their agroecosystems (adapted from Berkes et al. 2000). Examples of TAeK include practices and beliefs related to agroecosystem management (Galluzzi et al. 2010, Calvet-Mir et al. 2016), knowledge about landraces (Negri 2003, Riu-Bosoms et al. 2014), or cosmovisions and institutions regulating the management of resources used in agriculture such as water (Perreault 2008). TAeK is culturally transmitted from generation to generation, and it evolves and adapts to the local environment and the cultural contexts (Toledo 2002, Rocha 2005, Reyes-García et al. 2013, 2018b). TAeK systems encompass information about how to recognize and efficiently manage agricultural landscapes and elements of the agroecosystem in environmentally and culturally adapted ways (Vandermeer and Perfecto 2013, Reyes-García et al. 2018b). While TAeK draws from historical and intergenerational continuity in resource use management, it should not be considered static nor in isolation from other knowledge systems (Reyes-García et al. 2014). Rather TAeK is in constant change and has shown capacity to adapt and co-exist with other farming systems, including industrial agriculture, in a dynamic process that encompasses a complex mix of knowledge replication, loss, addition, and transformation (Reyes-García et al. 2014). Recent work suggests that, as other types of knowledge (Boyle 2003, Hess and Ostrom 2007, Bollier and Helfrich 2012), TAeK has been traditionally managed as a common resource. A resource governed by a group of people who have self-developed rules to handle the social dilemmas derived from its collective use, i.e., situations in which there is a conflict between immediate individual self-interest and long-term collective interest (Reyes-García et al. 2018b).

Researchers have highlighted that knowledge embedded in traditional agricultural systems is relevant for social-ecological sustainability (Koohafkan and Altieri 2011), particularly in situations of change or when uncertainty is high (Reyes-García et al. 2014). For example, researchers have argued that considering current demographic, economic, and cultural changes, the conservation of diversified agroecosystems (e.g., dehesas, home gardens) requires the maintenance and application of TAeK (Naredo 2004, Gómez-Baggethun et al. 2010, Reyes-García et al. 2014). TAeK has also been reported to be very relevant for agroecological transitions, or the processes of scaling-up and -out agroecology. Indeed, different bodies of research have documented the relevance of TAeK for the ecological, cultural, economic, social, spiritual, and political dimensions of agroecological transitions (Francis et al. 2003, Méndez et al. 2013, Levidow et al. 2014, López-García et al. 2018, Mier y Terán Giménez Cacho et al. 2018, Rivera-Ferre 2018). A particular domain of TAeK that can be very relevant to agroecological transitions is TAeK on landraces (Reyes-García et al. 2018a). We define landraces as a group of plants of a particular botanical taxon selected by farmers from among domesticated or wild species resulting in crops that are adapted to the local environmental conditions and the local agrarian culture (Aceituno-Mata 2010, Calvet-Mir et al. 2011, 2012a, Tardío et al. 2018). TAeK on landraces includes information regarding landraces' morphologic, agronomic and sensorial characteristics that guide the local evaluation and selection criteria. It also comprises landrace management practices (e.g., sowing, planting, and harvesting calendar, type of manure, rotations, storing) and uses (e.g., culinary, fodder, medicinal) (Calvet-Mir et al. 2010).

TAeK on landraces can contribute to the different dimensions of agroecological transitions. Being dynamic populations adapted to changing local environmental conditions and requirements (Altieri et al. 1987, Negri and Tiranti 2010), landraces have a low dependence on external inputs like pesticides or fertilizers (Prescott-Allen and Prescott-Allen 1982, Altieri and Merrick 1987). In that sense, TAeK on landraces includes pest and soil control management practices that build on the interaction between the natural elements of the agroecosystem and thus offers an alternative to the use of chemical pesticides and fertilizers. TAeK on landraces also allows landraces maintenance and thus fosters cultivated biodiversity and promotes agroecosystem redesign using a biodiversity intensive strategy (Gliessman 2010). These characteristics make landraces and their associated knowledge very relevant to the ecologic and economic dimensions of agroecological transitions. Furthermore, landraces and their associated knowledge are part of the contemporary's natural and cultural heritage (Halewood 2013), deeply rooted in the socio-cultural identity of agrarian communities (Calvet-Mir et al. 2011) and part of the biocultural memory, or the current expression of a long historical legacy of interrelationships between human beings and nature (Nazarea 1998, Toledo and Barrera-Bassols 2008), including the circulation of crop species and biological innovations (Harwood 2018). This relation makes landraces and their associated knowledge very relevant to the social and cultural dimensions of agroecological transitions. Additionally, some landraces and their associated knowledge allow farmers to reduce production costs and to achieve premium prices able to economically sustain alternative or traditional -non-industrial- farming practices (Riu-Bosoms et al. 2014), for which they can contribute to the economic dimension of agroecological transitions. Lastly, peasant communities understand and fight for the need to have access to landraces and the associated TAeK, so that they can use them as an alternative to genetically modified organisms (GMOs) and commercial seeds controlled by corporations (Balázs et al. 2016, Mier y Terán Giménez Cacho et al. 2018). This concern makes landraces and their associated knowledge very relevant to the social and political dimensions of agroecological transitions.

Different voices have underlined the threats that TAeK systems face due to their erosion and enclosure (Altieri and Toledo 2011, Hernández-Morcillo et al. 2014, Reyes-García et al. 2018a). TAeK on landraces is rapidly eroding due to factors such as loss of inter-generational communication (Calvet-Mir et al. 2016) or the industrialization of the agricultural system (Gómez-Baggethun et al. 2010). Moreover, enclosure issues, such as misappropriation of names or the establishment of landrace's patents granted to breeders or companies, are of great concern to farmers, NGO's and scientists who have raised voices demanding the protection of landraces and their associated knowledge under a "commons" framework (Brush 2007, Reyes-García et al. 2018a, 2018b).

Because of the role of TAeK on landraces in facilitating agroecological transitions, its erosion or misappropriation might have potentially negative implications for these processes (Guzmán et al. 2013). Several approaches have been proposed to prevent the erosion and misappropriation of TAeK on landraces including the application of Intellectual Property Rights to compensate farmers (Brush 2007) or the management of landraces as public goods (Shiva 2004). Here, we analyze an approach that tries to include TAeK on landraces under the digital commons framework, where knowledge is possessed and shared collectively and remains openly available (Fuster Morell 2012). Specifically, we analyze the potential of the CONECT-e platform, an initiative for digitally storing, sharing and protecting traditional knowledge in a participatory way, trying to make TAeK widely available as a way to prevent TAeK on landraces erosion and to contest its enclosure (Reyes-García et al. 2018b). We analyze how CONECT-e can contribute to 1) document TAeK on landraces, 2) share this knowledge in a reproducible format, and 3) protect it from enclosure. We argue how achieving these goals can contribute to agroecological transitions and the limitations this approach may face.

METHODS

The CONECT-e platform

CONECT-e (www.conecte.es) is a citizen science initiative funded by Spanish public institutions aiming to obtain civil society collaboration in the documentation and sharing of traditional ecological knowledge and practices. CONECT-e was born out of the need to encourage citizen's participation in the Spanish Inventory of Traditional Ecological Knowledge (a static bibliographic compilation of ethnobotanical referenced knowledge (Pardo-de-Santayana et al. 2014, 2018). The current version of the platform, launched publicly in February 2017, includes sections focusing on traditional knowledge regarding plants, landraces, and ecosystems. A Creative Commons Attribution-ShareAlike 4.0 International License (CC BY-SA 4.0) protects all the content of CONECT-e platform. This license requires that any product using original or modified content from CONECT-e is protected under the same copyleft license, thus impeding the establishment of copyrights or trademarks over it. The need to create a dynamic inventory of landraces and associated knowledge to contest enclosure issues motivated the creation of the section on landraces. This section mainly documents information on landraces names, uses, and management. The structure of CONECT-e's landrace section has been co-created by scientists from Spanish universities and research centers (UAB, UB, UAM, UOC, ICTA, IBB, IMIDRA) working on the Spanish Inventory of Traditional Ecological Knowledge and members of the civil society organization that promotes the commons management of landraces and farmer´s varieties in the agri-food system, the Spanish Seed Network: *Red de Semillas "Resembrando e Intercambiando"* (RdS; http://www.redsemillas.info/).

Data collection and analysis

We used different data collection and data analysis methods to achieve the three objectives of this work. First, to assess whether CONECT-e contributes to the documentation of TAeK on landraces, we explored the information users entered in the CONECT-e platform. We considered an entry as a creation of content of any kind. The CONECT-e platform is linked to a database with tables collecting information on users' profile, users' activity, and content provided by users. Here we analyze the content introduced by users in the landrace section between February 2017 and March 2018. This dataset includes information required to identify the landrace, including landraces' name, species, and location. It also includes eight different sections: 1) vernacular name; 2) description; 3) traditional use; 4) traditional management; 5) images; 6) map; 7) references; and 8) seed providers. Each section has different fields. For example, the section on vernacular names has five different fields: 1) Spanish name, 2) Catalan name, 3) Basque name, 4) Galician name, and 5) other names. In total, there are 41 fields in the eight sections. We used descriptive statistics to analyze these variables and assess the level of landraces documentation in the platform.

Second, to assess whether CONECT-e has contributed to the sharing of TAeK on landraces, we analyzed the quality and reproducibility of the information in the platform and the number of visits to the landrace' pages. Regarding the content quality, CONECT-e uses several filters embedded in the platform to assure information accuracy. Specifically, users are encouraged to provide photographs of the landraces (see Figure 1), to locate the municipalities where the landrace is cultivated and used, and to report the different names that a landrace might receive in each location (see Figure 2). Locating the landraces not only provides a visual representation of the geographical distribution of the landrace, but it can also help in identifying synonymies. Moreover, a team of editors validates all the information entered in CONECT-e before it is made publically available. All these tools help to verify and validate the information, contributing to the accuracy of the information displayed on the platform. To analyze the quality and the reproducibility of TAeK on landraces documented in CONECT-e we used content analysis. Specifically, we selected the content text from the "description," "traditional management," and "seed providers" sections, since information in these sections would allow a user to replicate in the field the knowledge entered in the platform. We obtained 528 text pieces, with an average content length of 125 characters, some content being as short as six characters. We conducted a systematic reading of these data looking for the presence of meaningful patterns potentially indicating its accuracy and reproducibility. We analyzed if the content gave enough details and was sufficiently well written so to allow for an external reader to put it in practice. We then selected textual quotes extracted from these text pieces to exemplify the quality and reproducibility of TAeK on landraces documented by CONECT-e. We also analyzed the number of visits to CONECT-e's pages. For this, we used Google Analytics, a software that uses tracking codes and cookies to acquire information on a website's user (Clifton 2012), and produced summary metrics regarding the number of visits to the landrace page and its different sections.

Finally, to assess whether CONECT-e can protect TAeK on landraces from enclosure, we used literature review, desktop research, and informal conversations (face-to-face and via mail) with members of RdS to identify which landraces documented in CONECT-e suffered from enclosure issues. The three authors that are members of RdS reviewed all the landraces documented and noted those that could have experienced enclosure. We then gathered information through informal conversations with members of RdS and grey literature (i.e., press release, reports and articles) to catalog the landraces threatened and characterized the enclosure's processes.

All the analysis was fed by our involvement in the Spanish Inventory of Traditional Knowledge on Agricultural Biodiversity since five of the authors of the present article are part of the project, and our active participation in RdS, where three of the authors are lively members of the organization. Both cooperations grant us a deep understanding of the dynamics of TAeK on landraces in Spain.

Figure 1: Landraces photographs at CONECT-e's front-page

Figure 2: Municipalities where the landrace mongeta del ganxet (Phaseolus vulgaris) is cultivated.

RESULTS

One year after its launch, the CONECT-e platform had more than 150,000 visits, 467 users registered and over 19,000 entries. From all the visits to the platform, 27,057 (18.04%) corresponded to visits to the landraces pages. From the users registered, 40 (8.6%) created or modified content on landraces, producing a total of 1892 entries (or 10% of the total entries in the platform).

Landraces documented in CONECT-e

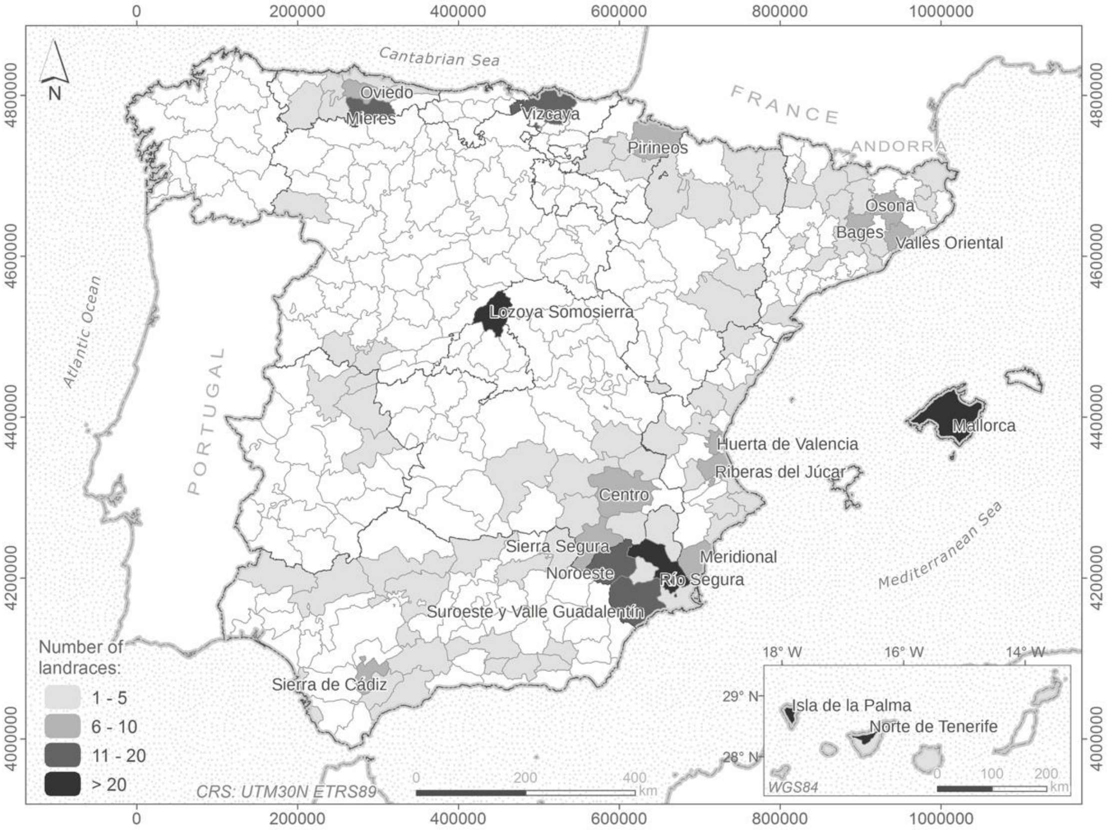
CONECT-e users documented 452 geographically distinct landraces from 81 different species and 86 taxa. The crop species with more landraces were tomato (Solanum lycopersicum) with 68 landraces (or 15.04% of the total); bean (Phaseolus vulgaris) with 45 landraces; and pepper (Capsicum annuum) with 34 different landraces documented (Table 1).

Table 1: Crop species with more than five landraces documented in CONECT-e

Scientific name	English common name	Number (%) of landraces
Solanum lycopersicum	Tomato	68 (15.04)
Phaseolus vulgaris	Bean	45 (9.96)
Capsicum annuum	Pepper	34 (7.52)
Prunus dulcis	Almond	21 (4.65)
Brassica oleracea	Cabbage, broccoli, cauliflower among others	19 (4.20)
Solanum melongena	Eggplant	17 (3.76)
Pyrus communis	Pear	16 (3.54)
Solanum tuberosum	Potato	16 (3.54)
Malus domestica	Apple	15 (3.32)
Lactuca sativa	Lettuce	14 (3.10)
Allium cepa	Onion	13 (2.88)
Zea mays	Corn	9 (1.99)
Citrus sinensis	Orange	8 (1.77)
Cucumis melo	Melon	8 (1.77)
Ficus carica	Fig	8 (1.77)
Vitis vinifera	Grape	8 (1.77)
Pisum sativum	Pea	7 (1.55)
Vicia faba	Broad bean	7 (1.55)
Cucurbita maxima	Pumpkin	6 (1.33)

The CONECT-e platform documented landraces located in 96 (29.4%) of the 327 Spanish regions (comarcas in Spanish) and 14 of its 17 autonomous communities (Figure 3). The regions with more landraces documented were Isla de La Palma (38 landraces) and Norte de Tenerife (35 landraces), both in the Canary Islands. Other regions with a high number of landraces documented were Lozoya-Somosierra (Madrid) with 34 landraces and Mallorca (Balearic Islands) with 32 landraces. The unequal geographic distribution was not necessarily due to the highest number of landraces in these regions since CONECT-e does not register all the landraces of one region but just the landraces that the users entered.

Figure 3: Geographical distribution of landraces documented in CONECT-e.



Users contributed information in 39 of the 41 possible fields. The fields for which participants contributed more data were "images," with 521 photos uploaded, and "traditional uses and management," with 434 entries on the location of landraces' traditional uses and management. These were followed by the fields "plant description and part used", with 116 entries, "Spanish vernacular names", with 115 names recorded, "references and links" with 83 entries documenting references on specific landraces, "taste, flavor and texture", with 63 entries, and "crop cycle", with 55 entries indicating the adequate time for sowing, planting or harvesting. Some fields, such as "Galician vernacular name" (one of the official languages in the Spanish state) or "medicinal," "fuel," and "construction uses," had no entries.

TAeK on landraces shared in CONECT-e

About one-fourth of the total number of entries on landraces (528 entries or 27.91%) corresponded to information entered in one of the three sections that would allow applying the knowledge documented (i.e., description, traditional management, and seed providers). Moreover, 127 landraces (28%) had at least one entry in one of these three sections, and 54 (12%) had four or more information entries in one or more of the fields from these sections. The landraces with more information on these sections were “mongeta del ganxet” (Phaseolus vulgaris, bean), “patata fina” (Solanum tuberosum, potato), with information from 16 fields out of 19 possible, and “judía plancheta” (Phaseolus vulgaris, bean) with 13 fields completed.

The content analysis of these entries showed that the information gathered is well-structured, clear, and reliable. The information registered might allow the replication of the knowledge reported. For instance, the field on “crop cycle” in the “description” section allowed including TAeK on the sowing, planting and harvesting periods of each specific landrace. Users added this detailed information for some landraces, such as in the case of “guindilla de Zalla” (Capsicum annuum, pepper). Data includes the specific months when this landrace is sowed in the seedbed, transplanted, and harvested. Similarly, the field on "pest and diseases" on the "traditional management” section allowed entering accurate descriptions of the most prominent pest and diseases of each landrace and evaluations of the landrace’s adaptation to the agroecosystem. In the case of “nabo de Morcín” (Brassica napus var. rapifera, rutabaga), users entered information acknowledging that this is a rustic, very resistant landrace, although it can suffer the attack of crucifer flea beetle (Phyllotreta cruciferae) when growing at high temperatures. Finally, in the section on “seed providers” users entered the name of specific landrace’s suppliers. In the case of “lechuga moruna” (Lactuca sativa, lettuce), “La Troje” association (www.latroje.org) can provide both seeds and seedlings.

Regarding the dissemination of this content, we found that the most visited sections in the landraces’ pages were “description” and “vernacular names” (3,303 and 2,129 visits each), while the least visited sections were “seed providers” (920), “map” (809), and “documents” (462). Considering the information gathered and the number of visits, the most “popular” landraces are “mongeta del ganxet” (Phaseolus vulgaris, bean) with 181 entries and 319 visits, “boniato saucero” (Ipomoea batatas, sweet potato) with 37 information entries and 751 visits, and “bubango” (Cucurbita pepo, zucchini) with 42 entries and 727 visits. Other highly popular landraces are “patata fina” (Solanum tuberosum, potato) with 38 entries and 164 visits, “nabo de Morcín” (Brassica napus var. rapifera, rutabaga) with 33 entries and 526 visits, “pero de Aragón” (Malus domestica, apple) with 24 entries and 400 visits, and “tomaca quarentena” (Solanum lycopersicum, tomato) with 19 entries and 162 visits. These seven most popular landraces came from seven different regions of Spain and six different autonomous communities.

Threatened landraces documented in CONECT-e

Three of the landraces documented in CONECT-e suffer or have suffered from enclosure: “tomàtiga de ramellet” (Solanum lycopersicum, tomato), “bubango” (Cucurbita pepo, zucchini), and “mongeta del ganxet” (Phaseolus vulgaris, bean). The three landraces resemble one another in that they are very popular in their territories and are much in demand by local consumers. Moreover, their vernacular names are attached to a significant cultural richness around their use and management and represent a sign of cultural identity for their growing regions. Interestingly, these landraces were among the best described in the platform; our informants attributed this fact to the interest of the different local seed networks to document thoroughly these landraces in their efforts to protect them.

In the cases of "tomàtiga de ramellet" and "bubango," companies tried to appropriate the name of these landraces to market their commercial varieties under these names, thus benefiting from the popularity of the landraces. “Tomàtiga de ramellet” is a landrace from Mallorca Island very rooted in the traditional gastronomy, as it is the only tomato that can be preserved throughout the winter. The landrace is also used for the preparation of one of the most typical dishes of the island: bread with tomato and oil. In 2010, two seed companies proposed to create a Protected Geographical Indication (PGI) under the name "tomàtiga de ramellet." This PGI, however, would include a hybrid variety which had neither the landrace capacity for conservation nor its smell or taste. To avoid the misappropriation of the name, in 2012 the "Associació de Varietats Locals de les Illes Balears" (Association of landraces from Balearic Islands, part of RdS) registered the "tomàtiga del ramellet" as a conservation variety in the Commercial Variety Register of the Spanish Ministry of Agriculture (MAPAMA) (Red de Semillas 2012). However, hybrid varieties are nowadays sold under the name of "tomàtiga d´enfilar" (where “enfilar” refers to the traditional management practice of tying the “tomàtiga del ramellet” with a thread to keep them during the winter in a cool and dry place) (Associació de Varietats Locals de les Illes Balears 2015). Our informants from RdS stated that given that registration as a conservation variety could help protect landraces and landrace names from misappropriation, RdS promotes the active registration of landraces, especially of those under risk of misappropriation. However, registration requires a high level of homogeneity in the landrace to be registered, a characteristic not found in many landraces, for which only a small percentage of landraces can be registered under this legal category.

A second variety that faced misappropriation issues is "bubango," a landrace from Tenerife (Canary Islands) of which historical references are going back to 1770 (Hernández Hernández 2003). This landrace has recognized quality and prestige as part of the traditional Canarian gastronomy. In recent decades, commercial varieties of round zucchinis are being sold under the name of "bubangos." These varieties have different quality and type of management than the original bubango (Panizo Casado and Perdomo Molina 2017a), but the use of the name allows companies to set a higher selling price (Panizo Casado and Perdomo Molina 2017b). The "Red Canaria de Semillas" (Canary Seed Network, part of RdS) has worked on the cultivation, multiplication, and description of the landrace to proceed to its registration in the registry of conservation varieties of the Spanish Ministry of Agriculture. Moreover, they have engaged in documentation, communication, and denunciation campaign to halt the misappropriation of its name (http://www.redsemillas.info/operacion-bubango/).

The case of “mongeta del ganxet” is slightly different as in this case the appropriation of the landrace name implies a monopoly that could limit farmers’ rights over the landrace. “Mongeta del ganxet” is a landrace cultivated in different regions of Catalonia, where it is very appreciated for its organoleptic features. The creation of a Protected Designation of Origin (PDO) in 2006 limited to a few regions the area where the landrace could be cultivated, thus limiting farmer's rights to produce and trade their landrace outside the PDO. Some experts argued that this limitation might lead to the genetic erosion of "mongeta del ganxet" since, to be part of the PDO, the landrace must have particular morphologic features, excluding the large variability within the landrace population managed by farmers (Red de Semillas 2015b). The documentation of this landrace in 138 municipalities in CONECT-e (Figure 2) evidence that the cultivation of “mongeta del ganxet” extends beyond the limits of the PDO.

DISCUSSION

In this article, we analyze the potential of an online platform to contribute to the documentation, sharing and protection of TAeK on landraces, a body of knowledge that plays a vital role in agroecological transitions. In this section we elaborate on the findings presented above to help answer a fundamental question raised from agroecological scholars: "In what ways can we recapture the knowledge developed over centuries of traditional agricultural production experience" (Francis et al. 2003; p. 101) so that it contributes to agroecological transitions? (Guzmán et al. 2013).

Results presented here suggest that participatory online projects, such as CONECT-e, hold the potential to document a considerable amount of TAeK on landraces, mostly by compiling scattered information in a shared online space. Indeed, the collaborative collection of TAeK on landraces can contribute to creating synergies among data obtained through standard ethnobotanical methods (e.g., inventories, semi-structured interviews) (Vogl et al. 2004). For example, using the same definition of landrace used in CONECT-e, previous ethnobotanical studies in Spain have gathered information on 133 (Aceituno-Mata 2010), 39 (Calvet-Mir et al. 2011) or 10 landraces (Riu-Bosoms et al. 2014). Meanwhile, CONECT-e documented 452 geographically distinct landraces. While ethnobotanical studies are a primary input for the platform, the compilation of dispersed landrace knowledge offers a higher potential to overcome the TAeK erosion than the partial documentation of this knowledge (Koohafkan and Altieri 2011). Altieri and colleagues (Altieri et al. 2012) stated that, for scaling-up and -out agroecology, it is very important to preserve and rescue traditional agroecosystems' cultural and ecological foundations, including the accumulated knowledge and experience related to the management and use of agrobiodiversity. This preservation and rescue of TAeK need of competent tools to document the knowledge, and we argue that a tool like CONECT-e offers vast potential in this sense. Notwithstanding, achieving widespread documentation of landraces largely depends on civil society participation, for which the continuous dynamization of CONECT-e seems to be a requirement for success. Only a constant exchange between researchers, farmers, consumers, and civil society organizations will allow the development of CONECT-e's potential. Of particular importance is the participation of strong citizen organizations such as RdS, since the effort to document landraces depends on their collective work of monitoring landraces and reacting to misappropriation threats.

We also found that TAeK on landraces was introduced in CONECT-e in a well-structured and clear way, making it potentially reproducible. In a context of a worldwide increase of small farmers (Pérez-Vitoria 2018), it is necessary to provide tools that allow farmers to gain increased access to TAeK. This need is more so in European territories, where there has been a higher and longer lasting agricultural intensification process than in other parts of the world, and where farmers do not always inherit TAeK from their close kin and kith, as it was done in the past (van der Ploeg 2008, Hernández-Morcillo et al. 2014). In such a context, a tool like CONECT-e might ease the sharing of TAeK on landraces, information that might be critical for those newly engaging in agroecological transitions (Altieri and Toledo 2011). Furthermore, by sharing TAeK on landraces, CONECT-e could enhance the conversion of industrialized agroecosystems to more diverse agroecosystems, a fundamental step in agroecological transitions (Gliessman 2010). TAeK on landraces could also provide security to farmers against diseases, pest, droughts, and other stresses avoiding the use of agrochemicals, and also might allow farmers to exploit the full range of agroecosystems existing in each region (Perfecto et al. 2009, Altieri et al. 2012). It should be noted, however, that despite the potential contribution of tools like CONECT-e to agroecological transitions, these transitions largely depend on the massive adoption of a diversity of agroecological alternatives (Altieri and Toledo 2011). In that sense, although CONECT-e can be a tool for sharing landrace knowledge, farmers might continue facing difficulties in cultivating the landraces due to the European and Spanish regulations on plant material reproduction. These regulations are a paramount obstacle mainly to artisanal seed producers and organic farmers (Aceituno-Mata et al. 2017). Artisanal seed producers face two main problems to legalize their activity: 1) the regulations in force demand from them the same requirements as for large seed companies, both regarding the quantity of seed produced and infrastructures; and 2) they usually work with unregistered landraces. Organic farmers also face problems to cultivate landraces due to the organic farming regulations (DOUE 2007) that require the use of organically certified seed, which excludes non-registered landraces.

Finally, CONECT-e has the potential to help protect TAeK on landraces by applying a commons governance system, a move that goes in the direction of fostering an emancipatory movement aiming to increase the power and control of farmers over their own resources and production, a critical foundation for scaling agroecological transitions (Mier y Terán Giménez Cacho et al. 2018). In this line, CONECT-e aligns with other initiatives that seek the scaling-up and -out of agroecology (Rosset and Altieri 2017) through the digital commons movement (Fuster Morell 2012). These initiatives include open software platforms such as Katuma that promote agroecological production and consumption under the framework of the social and solidarity economy using a local version of the Open Food Network tool (https://openfoodnetwork.org/; Tresserra 2018). Other that aim at empowering citizens in the development of innovative and sustainable solutions that try to re-establish the ties between food production and consumption and educate about agroecology, such as P2P Food Lab's (Hanappe et al. 2016). There also exist initiatives such as the Farm Hack seeking to document, share and improve farm tools and associated knowledge with the conviction that transforming agricultural technology into a commons would result in a more adaptive, open and resilient food system (Cox 2015).

By making TAeK largely accessible to a community of users who should follow certain management rules, CONECT-e promotes the digital documentation, sharing and protection of TAeK under the digital commons framework. In this framework, information and knowledge resources are created and possessed collectively or shared between a community that tends to be non-exclusive, that is, making knowledge available (usually free of charge) for third parties. Moreover, the community of people who share this knowledge favors its free use and reuse, instead of exchanging it as a commodity (Fuster Morell 2012). The digital commons approach then contests the enclosure of the knowledge commons and deconstructs the idea of intellectual property rights (Boyle 2003).

In the real world, the commons approach to knowledge has legal implications. For example, some authors argue that the mere existence of databases could already protect the knowledge in case of misappropriation (Lakshmi Poorna et al. 2014). However, others say that is necessary to implement a licensing that follows a copyleft approach (such as the General Public Licensing, used commonly to secure copyleft over open source software) to safeguard TAeK and its commons nature (see for example the ideas on Open Variety Rights; Deibel 2013). Since landrace knowledge in CONECT-e is protected under the Creative Commons Attribution-ShareAlike 4.0 International

License, CONECT-e may offer a powerful tool to counteract against TAeK on landraces commons enclosure. Moreover, this type of registration can be used to account for the ‘notorious previous existence' of a landrace and associated knowledge (as it provides an openly available inventory of existing landrace knowledge). Then being documented in CONECT-e makes varieties non-eligible for formal registration as a protected variety (provided for by the Law 3/2000 of the Spanish Ministry of Agriculture; https://www.boe.es/buscar/doc.php?id=BOE-A-2000-414; Reyes-García et al. 2018a). Notwithstanding, CONECT-e cannot prevent misappropriation on its own; instead, it is just a tool to be used by civil society organizations to fight against privatization processes. To counteract the enclosure of TAeK on landraces it would be necessary 1) to have mechanisms in place for cross-checking that varieties submitted for registration in national registers are not already included in CONECT-e (or similar tools); 2) to guarantee a network of monitors who could detect misappropriation processes; and 3) to have the resources to engage in legal proceedings when misappropriation is observed (Reyes-García et al. 2018a).

CONECT-e has started the on-line compilation of TAeK on landraces in Spain, capturing the attention of potential users. The project now depends on public funding, which has been secured to guaranty CONECT-e’s continuity in the nearby future. However, the project will not be successful unless CONECT-e becomes relevant for farmers, consumers, and agrobiodiversity-related organizations so they are motivated to participate in it. The challenge is not trivial, given that CONECT-e targets traditional knowledge holders who, in the Spanish context, typically are people with strong linkages to the rural world and/or elderly people with limited skills in the use of information and communication technologies. Further dynamization of the platform and increasing collaboration with a large number of stakeholders is required to develop strategies for enlarging CONECT-e’s impact. The effort, however, also needs to be sustained in the long term and spread through the Spanish territory, for which continuous funding for the coordinating team need to be secured in the long term. To become a digital common, CONECT-e also faces the challenge to improve user’s participation, not only in information sharing but also in decision making.

CONCLUSIONS

Digitally documenting and sharing TAeK can make widely accessible a body of knowledge developed over centuries in traditional small-scale agroecosystems, potentially contributing to agroecological transitions. Digitally documenting and sharing TAeK might also contribute to efforts to its protection and contest knowledge commons enclosure, thus helping farmers and social movements to thwart misappropriation processes. This article is relevant for an international audience as it documents and discusses an innovative initiative that digitally documents shares and protects TAeK on landraces under the digital commons framework and presents the potential contributions of this tool to scale-up and -out agroecology. However, although CONECT-e, and alike tools, can contribute to agroecological transitions, these tools alone are not sufficient to deal with the dominant economic and institutional interests promoting research and development under the conventional agroindustrial approach. As other authors emphasize (e.g., Altieri and Toledo 2011), to embrace agroecological alternatives it is necessary to make broad reforms in policies, institutions, and research and development agendas. These reforms should include the cultivation of organic landraces, the open and widespread use of the knowledge generated in research institutions, and the establishment of different regulations for profit-oriented seed companies and for farmers or artisanal seed producers. Finally, we argue that institutional support to local agriculture and groups that carry out the community management of landraces as a political strategy for food security and sovereignty, such as RdS, are necessary to prevent TAeK on landraces erosion and reach social-ecological sustainability of agri-food systems for the long term.

CONCLUSIONS

In this last section, I elaborate on several general conclusions that can be withdrawn from the results presented in this thesis. Specifically, I highlight the most relevant contributions of my work and discuss its policy implications. I end up the section reflecting on some epistemological considerations and potential future research lines.

1. Main contributions

Results from this thesis contribute to a better understanding of the pathways towards traditional agroecological knowledge (TAeK) conservation through digital participatory methods advance, thus contributing to both the field of citizen science (CS) and the field of political agroecology. At the applied level, this might have impacts on improving transitions to agroecological food production.

The use of CS, as a participatory method and approach, is becoming increasingly common in several research fields such as biodiversity monitoring, earth observation, epidemiology, or computer science (Wiggins and Crowston 2011, Dickinson et al. 2012, Turreira-García et al. 2018). However, to date, researchers had not thoroughly addressed the limitations of this methodological and epistemological approach, particularly in terms of participants' engagement and diversity (Wesselink and Hoppe 2011, Rosendahl et al. 2015). Similarly, there was scant research exploring the potential of extending this approach to other fields and topics, in particular to the conservation and maintenance of traditional knowledge systems. Thus, while a growing body of literature had explored traditional ecological knowledge conservation actions (McCarter et al. 2014, Tang and Gavin 2016), this work had not addressed the participatory nature of these actions, and the potential of digital tools and post-normal approaches as tools that could contribute to traditional knowledge conservation. Moreover, although over the last decades a thriving community of practitioners and researchers has been working to advance the understanding and use of participatory methods in agroecology under a post-normal science approach (Cuéllar-Padilla and Calle-Collado 2011), they have done so focusing on the reproduction of TAeK based practices (rather than in their documentation or protection) and mainly via participatory action research (PAR) or rural appraisal methods. In other words, without engaging with the digital world (see Tisselli 2014 as an exception). Thus, there was a need to explore whether methods based on digital infrastructures could contribute to bring multiple standpoints and perspectives to the co-production of agroecological knowledge.

In this work, I used the CONECT-e project (i.e., a politically motivated co-designed CS project based on a wiki-like platform that documented traditional ecological knowledge in Spain) to address these research gaps. Particularly, I explored the need for participatory TAeK conservation tools (Chapter I and II) and used CONECT-e as a case study to analyze, a) the ability of initiatives such as CONECT-e to attract diverse and engaged participants, and thus to equalize participation in TAeK conservation (Chapter III), b) the capacity of tools like CONECT-e to prevent TAeK erosion (Chapter IV), and c) the potential of initiatives such as CONECT-e to document, share and protect TAeK as a digital commons (Chapter V). Two main contributions derive from the results presented in these chapters.

The first main contribution of this thesis relates to the literature on participation and post-normal science, advancing our understanding of the complexity inherent to any participatory method and process, and of the limitations and opportunities of CS in the context of TAeK conservation in a digital environment.

On the one hand, results from the work presented here suggest that digital tools based on a CS approach can be very relevant for participatory TAeK conservation, at least in industrialized contexts. This is so for three main reasons. First, because TAeK conservation initiatives coming from the academic world are generally not participatory and follow a rather decontextualized or *ex-situ* approach, with traditional knowledge-holders being generally absent from the initial design and ideation of such initiatives. There is, therefore, a need for projects like CONECT-e that encourage digital participation from the bottom up (see Chapter I). Second, because CONECT-e, and potentially other politically motivated digital CS projects, attracts more diverse and active participants in terms of the percentage of participants with a continuous engagement and the percentage of participants from socio-economic groups that other CS projects have failed to attract (e.g., rural women, Pandya 2012). Thus, initiatives such as CONECT-e can contribute to the construction of transdisciplinary and diverse extended peer communities that can advance TAeK conservation under a post-normal science approach and challenge participation inequalities (see Chapter III; Haklay 2016). Finally, because CONECT-e, and potentially other digital CS platforms and school programs can contribute to enhance the perceived value and access to TAeK, particularly among the young (see Chapter IV), and to document, share and protect TAeK as a digital commons (see Chapter V). Therefore, projects like CONECT-e can very well contribute, together with other actions, to halt TAeK's erosion and enclosure, thus overall contributing to TAeK's conservation (Gómez-Baggethun et al. 2013, Hernández-Morcillo et al. 2014, Reyes-García et al. 2018a, 2018b).

On the other hand, results from this work also contribute to understanding the limitations of digital tools in the context of TAeK conservation and corroborate other researchers' call for deconstructing the notion of participation as if it was a single act, emphasizing the idea that both active (e.g., in the case of CONECT-e entering information) and passive participation (e.g., consulting information posted by other users) in online initiatives can have a transformative potential (Fuster Morell 2010). In the case of CONECT-e, this transformative potential relates to TAeK sharing and reproduction (see Chapter III). For instance, results from my work add to a growing number of studies highlighting the difficulties of attracting certain groups of users (e.g., elders) to digital CS projects (Dimaggio et al. 2004, Stephens 2013, Dawson 2018, Schrögel and Kolleck 2019). I found that this is true even when the project focused on a topic (TAeK conservation) that might be relevant for such populations. Moreover, results discussed in this work highlight the existing challenges of maintaining active long-term participation even in politically motivated CS projects. As discussed in this and other works, challenges for participant retention could be due to several reasons, including issues related to participants' perceived self-legitimacy or issues related to the restrictive time frames with which CS projects develop (Strasser et al. 2019). Thus, results from my work also highlight the challenges faced by digital projects aiming to create transdisciplinary extended peer communities in tight partnership with civil society stakeholders and with an empowering objective in mind (Burke and Heynen 2014, Nascimento et al. 2014, Dillon et al. 2016, Wildschut 2017) and also are in dialogue with theories on participation in online creation communities (OCC; Fuster Morell 2010). Indeed, my results

The second main contribution of this thesis relates to the literature on TAeK conservation and political agroecology, advancing our understanding of some elements in place that can prevent traditional agroecological knowledge's (TAeK) erosion and enclosure, which are processes affected by power hierarchies and that can hinder agroecological transitions (López-García and Guzmán-Casado 2013, Méndez et al. 2013, Calvet-Mir et al. 2018).

My work highlights four main issues in this field of research. First, my results show that TAeK might be experiencing a revalorization trend in some contexts. Indeed, I found that young students in Catalonia (an industrialized context) receiving training to join the agricultural sector seem to value TAeK highly and they talk relatively frequently about it with their elders (see Chapter IV). While acknowledging that these results might be specific of our study population, the finding contrasts with findings describing generalized TAeK devaluation trends that took place in the past decades, a trend that in Spain has been linked to the industrialization process, but that has also been described in non-industrialized contexts such as the Latin-American one (Naredo 2004, Toledo and Barrera-Bassols 2008). However, it can be argued that the finding mirrors current traditional foods' and peasant agriculture's revalorization trends reported for the past decades in Europe (van der Ploeg 2008, Reyes-García et al. 2015). Second, results from this work also contribute to advance knowledge on which factors can promote this TAeK revalorization trend (see Chapter IV). In this line, I found that, for the studied population, encouraging hands-on activities such as homegardening and reinforcing student's interest on alternative farming may be enough to prevent TAeK erosion. This finding dovetails with previous research results that participating in hands-on activities in nature or including agroecology in formal university curricula can increase both the participants' interest for and actions towards biodiversity conservation and agroecological practices (Shwartz et al. 2012, Ianni et al. 2015, López-García et al. 2018). Third, I unveil the contrasting but complementary and tightly connected discourses and approaches that different actors and projects participating in TAeK conservation have (see Chapter II). This diversity resonates with findings related to the diversity of traditional ecological knowledge conservation actions, a diversity that results as a response to multiple threats (McCarter et al. 2014, Tang and Gavin 2016). Finally, results from my work also contribute to highlighting several processes and factors that can potentially enhance or prevent the development of TAeK conservation communities, which seem to be emerging and resisting in industrialized agricultural contexts, such as rural Spain. The study of these TAeK conservation communities also highlights the potential alliances that could be generated between TAeK conservation projects and agroecological productive projects and the parallelisms between resistances to TAeK erosion and resistances to industrial agri-food systems, an issue that was already highlighted in previous studies on urban gardening (Calvet-Mir and March 2017).

3. Policy implications

In addition to its theoretical significance, two general and two particular (i.e., relative to the case study) policy implications derive from this work. The first general policy implication refers to the importance (on paper mainly but also on budget allocation) that has been given to protecting biocultural diversity in recent decades and in different policy fora (e.g., 1992 Convention on Biological Diversity, 2001 International Treaty on Plant Genetic Resources for Food and Agriculture, 2003 Convention for the Safeguarding of the Intangible Cultural Heritage, 2010 Conference of the Parties in Nagoya). Results from this thesis can contribute to inform decision making regarding funding allocation to TAeK conservation projects. This is so because this thesis highlights which initiatives and methods are more inclusive towards traditional knowledge-holders and can therefore potentially break the knowledge divide, contributing to a more just and locally sensitive traditional knowledge conservation. In this sense, results from this dissertation call for policy support to community based initiatives that seem to be more inclusive, such as participatory plant breeding or co-designed school programs that include contents related to traditional knowledge. Moreover, results from this thesis highlight the need for further accountability of funded efforts in terms of their capacity to include local stakeholders in horizontal and equitable ways.

The second general policy implication of this work refers to the promotion of open science initiatives. This implication is particularly significant in the context of recent developments regarding open science and responsible research and innovation frameworks in Europe and around the world (e.g., 2016 European Charter for Access to Research Infrastructures or 2017 European Open Science Cloud Declaration). Particularly, results from this thesis contribute to highlight important issues that need to be taken into account when designing and promoting open science initiatives (particularly, citizen science initiatives). For instance, this thesis highlights the importance of returning to the original concept of citizen or participatory science, as one that is derived by a critical political standpoint regarding scientific expert legitimacy and that is based on the creation of transdisciplinary peer communities following principles of postnomal science. Indeed, transdisciplinary communities can better foster diversity and equitable participation of non-scientific partners in the co-production of knowledge and definition of research objectives, a key element in agroecological research. Thus, results from this thesis can contribute to better establishing a set of good practices in the field of citizen science that are related to the horizontality and bottom-up nature of these projects, and should be taken into account when designing funding schemes that support open science projects.

Results from this thesis also highlight two issues that directly call on specific policy actions in relation to the case study presented. First, results from this work suggest that, even if citizen science projects targeting traditional agroecological knowledge can contribute to agroecological transitions, these tools alone are not sufficient to deal with the dominant economic and institutional interests promoting research and development under the conventional agro-industrial approach. As other authors have emphasized (e.g., Altieri and Toledo 2011), to embrace agroecological alternatives it is necessary to make broad reforms in policies, institutions, and research and development agendas. These reforms should go beyond TAeK conservation and include a wider set of actions such as the promotion of organic landrace breeding, the encouragement of open and widespread use of the knowledge generated in research institutions, or the establishment of different seed regulations benefitting small-scale farmers and artisanal seed producers (Aceituno-Mata et al. 2017). Second, results presented in this thesis highlight the need for local, regional and national government support to local productive, educative or exhibitive projects as well as to groups that carry out the community management of landraces and their associated knowledge as needed strategies to prevent knowledge erosion and promote food security and sovereignty (see Chapter II). Indeed, this work demonstrates that partnering with local seed networks and seed rights focused civil society organizations is vital for initiatives like CONECT-e to exist (Reyes-García et al. 2018a). In this sense, supporting these organizations is necessary to prevent the erosion of TAeK on landraces and promote sustainable agri-food systems in the long term.

4. Epistemological considerations

Results presented here might be affected by two transversal and overarching epistemological issues.

The first issue relates to my dual position in the CONECT-e project. On the one hand, I was hired by the project and participated in its development, dissemination and management since the beginning. On the other hand, I was evaluating the project in order to answer the research questions that forms the basis of this thesis. Although complete objectivity is very much questioned in research (Harding 1995), it is still a basic principle for project evaluation (Frechtling 2002), and in this dissertation, this principle was not fully attained. Knowing so deeply the project has helped me in the interpretation of the results, however, I should acknowledge that my participation in the design and implementation of results might have introduce some biases which I am unable to quantify.

The second issue relates to the use of positivistic methods to study transdisciplinarity. Most of my analytical line of thought followed a hypothesis testing rationale, by which I used a scientific method to understand the reality of transdisciplinary projects like CONECT-e. Indeed, although CONECT-e itself, as a project, departed from a transdisciplinary standpoint and tried to bridge lay and scientific expertises and despite the fact that some members of the Red de Semillas have participated in the writing of most articles, this thesis studied the CONECT-e experience using mainly a scientific methodological and epistemological standpoint. Thus, there is still a need to incorporate transdisciplinarity in this type of meta-analytical work. For instance, this thesis' process could have been designed together with the actors of CONECT-e, trying to include further their reflection on the project development and their questions regarding traditional knowledge conservation.

5. Future research

In line with the main findings of this work, several future research lines can be developed.

First, in order to overcome the epistemological issues mentioned above, and considering that there has not yet been a systematic and transdisciplinary evaluation of traditional knowledge conservation initiatives, future lines of work could try to co-create systematized protocols of initiative evaluation with the communities, which could include aspects related to the initiative's inclusiveness. Indeed, it would be important to advance the study of transdisciplinarity through transdisciplinary methods in general (i.e., include lay participants in the analysis of extended peer communities of knowledge co-production). For instance, it would be interesting to engage with more participatory evaluation methods and to have lay experts co-design the questions that lead this line of research. Further examining citizen science projects through a transdisciplinarity lens could contribute to co-develop recommendations and good practices' guidelines that make sense also for the lay experts involved in these processes, thus making this type of evaluation more meaningful.

Second, considering that this thesis focuses on a single case study, which might not be representative of mainstream citizen science, results from this work might lack of external validity. In this sense, it would be interesting to complement this work by studying other CS projects dealing with issues related to TAeK, such as local climate observations based on indigenous and local knowledge. Indeed, there is a need for examining more case studies from more diverse contexts in which the original approach to citizen science is used as a method to create transdisciplinary peer communities of lay and scientific experts that work as partners in the co-creation of knowledge.

Third, the limited time during which CONECT-e was examined can lead to results that might not be comprehensive. Consequently, more baseline and longitudinal measures could be included in future case study evaluations. More specifically, this thesis' results regarding CONECT-e's positive effect on access to TAeK would be greatly complemented by the longitudinal study of TAeK transmission, evaluating the baseline knowledge of the participants and the knowledge retention over longer time spans. In the same line, future research could engage in project evaluations taking into account the life cycle of projects, i.e., evaluate projects that are in different phases in order to be able to ascertain which characteristics are actually derived from the project itself and which are a product of the specific timing when the evaluation took place.

Finally, considering that most chapters in this thesis measure individual discourses, perceptions and actions despite the collective nature of traditional knowledge, including more collective measures and interpretations would be a very relevant future line of research. For instance, as explained in Chapter III, although my analyses focus on individual profile characteristics and activity patterns, participation stands on the shoulders of the collective efforts of generations of biocultural diversity guardians, for which a measure of why some groups participate and others do not, might be highly relevant. Also, as explained in chapter IV, valuation of traditional knowledge depends on collective perceptions influenced by socio-cultural, political, and economic factors. Thus, by exploring these issues at the individual level, our results might be misguiding. Indeed, future evaluation guidelines could have a focus on collective perceptions and assessments, and also include more qualitative methods, thus complementing the results found in my work.

These future research lines might contribute to further extend the contributions of this work towards understanding and practicing participatory and transdisciplinary traditional knowledge conservation.

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ANNEX I

Besides producing the content of this dissertation, during my PhD I have contributed/participated in the following scientific and non-scientific publications/activities:

1. Scientific conferences

Benyei, P., M. Pardo de Santayana, J. Vallès, E. Lakovik, and V. Reyes-García. 2016. *Using a citizen science platform for in situ and ex situ traditional ecological knowledge conservation.* Poster presentation at the First ECSA Conference. Citizen Science – Innovation in Open Science, Society and Policy. Berlin (Germany) 19–21 May.

Benyei P., L. Calvet-Mir, L. Aceituno-Mata, and V. Reyes-García. 2017. *CONECT-e: una nueva herramienta para fomentar el control y acceso de los campesinos al conocimiento agroecológico tradicional*. Workshop at the ICAS Colloquium: El Futuro de la Alimentacion y Retos de la Agricultura para el Siglo XXI. Vitoria (Spain) 24-26 April.

Calvet-Mir L., P. **Benyei**, and V. Reyes-García. 2017. *CONECT-e: Compartiendo el conocimiento ecológico tradicional.* Poster presentation at II Encuentro de la Red de Universidades Cultivadas. Barcelona (Spain) 26-29 Abril

Reyes-García V., P. **Benyei,** and M. Pardo-de-Santayana. 2017. *CONECT-e: The Wikipedia of Spanish Traditional Ecological Knowledge.* Workshop at the 59th Annual Meeting of the Society for Economic Botany. Bragança (Portugal) 4-9 June.

Herrera A., P. **Benyei**, M. Pardo de Santayana, and V. Reyes-García. 2017. *CONECT-e: ciencia ciudadana y conocimiento ecológico tradicional.* Oral presentation at the VIII Congreso de Biología de la Conservación de Plantas. Madrid (Spain) 4-7 July.

Benyei P. *Knowledge as commons and CONECT-e*. 2017. Informal presentation at the European Community Exchange on Seed Diversity and Sovereignty. Global Diversity Foundation. Barcelona (Spain) 23- 27 September

Benyei P. *CONECT-e. Citizen Science serving biocultural diversity conservation*. 2017. Oral presentation at XIV Jornada d'Avenços en Ecologia. Societat Catalana de Biologia, CEAB i GECA. Blanes (Spain) 6 October

Benyei P., L. Aceituno-Mata, M. Carrascosa, V. Reyes-García. 2018. *CONECT-e: Sharing Traditional Ecological Knowledge.* Poster presentation at Innovations for agroecology. 2nd International Symposium on Agroecology. FAO. Rome (Italy) 3-5 April

Benyei, P. 2019. *CONECT-e and LICCI projects: case studies to understand how can we create new research topics and research approaches based on cooperation between civil society and researchers*. European Citizen Science Association workshop "Empowering Civil Society through Participatory Investigation?" Paris (France) 1-2 February

Benyei, P., M. Pardo-de-Santayana, L. Aceituno-Mata, L. Calvet-Mir, and V. Reyes-García. 2019. *What's in it for you? Participation inequality in citizen science might be challenged in politically motivated projects*. Oral presentation at the Citizen Science Association Conference CitSci2019. Raleigh (USA) 13-17 March

Benyei, P., L. Aceituno-Mata, L. Calvet-Mir, J. Tardío, M. Pardo-de-Santayana, D. García-del-Amo, M. Rivera-Ferre, M. Molina-Simón, A. Gras-Mas, A. Perdomo-Molina, S. Guadilla-Sáez, and V. Reyes-García. 2019. *The potential of citizen science school programs to reverse Traditional Agroecological Knowledge's erosion: a case study in Catalonia.* Poster presentation at the Second ICTA Spring Symposium. Barcelona (Spain) 16-17 May

2. Scientific publications

Benyei, P. Turreira-Garcia, N. Orta-Martínez, M. and Cartró-Sabaté, M. 2017. Chapter 13. Globalized Conflicts, Globalized Responses. Changing Manners of Contestation Among Indigenous Communities. In Victoria Reyes-García and Aili Pyhälä (Eds.) *Hunter-Gatherers in a Fast Changing World*. Springer

Reyes-García, V. and **Benyei**, P. 2018. Exploring Pathways to Link Agrobiodiversity and Human Health. In *Agrobiodiversity: Integrating Knowledge for a Sustainable Future. Strüngmann Forum Reports*. Ernst Struengmann Forum October 2–7, 2016, Frankfurt, Germany

Aceituno-Mata, L., Tardío, J., Pardo de Santayana, M., **Benyei**, P., Calvet-Mir, L., and Reyes-García, V. 2017. La biodiversidad agrícola como bien comunal: problemáticas y estrategias. Conference proceeding in *ICAS Colloquium: El Futuro de la Alimentacion y Retos de la Agricultura para el Siglo XXI.* Vitoria 24-26 April.

Reyes-García, V., **Benyei**, P. and Calvet-Mir, L. 2018. Traditional Agricultural Knowledge as a commons, in J.L. Vivero Pol, T. Ferrando, O. De Schutter and U. Mattei (eds) *Routledge Handbook of Food as a Commons*, Routledge.

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Ramet, A., **Benyei**, P., Parada, M., Aceituno-Mata, L., García-Del-Amo, D., and Reyes-García, V. 2018. Grandparents’ proximity and children’s traditional medicinal plant knowledge: Insights from two schools in intermediate-rural Spain. *Journal of Ethnobiology* 38:2

Aceituno-Mata, L., **Benyei**, P., Calvet-Mir, L., Pardo de Santayana, M., López-García, D., Carrascosa-García, M., Perdomo-Molina, A., and Reyes-García, V. 2018. *CONECT-e: Documentando, Compartiendo y Protegiendo el Conocimiento Agroecológico Tradicional*. Actas del XIII Congreso de SEAE: "Sistemas Alimentarios Agroecológicos y Cambio Climático". Logroño, La Rioja. pp: 398-402

Reyes-García, V., D. García-del-Amo, P. **Benyei,** Á. Fernández-Llamazares, K. Gravani, A. B. Junqueira, V. Labeyrie, X. Li, D. M. Matias, A. McAlvay, P. G. Mortyn, A. Porcuna-Ferrer, A. Schlingmann, and R. Soleymani-Fard. 2019. A collaborative approach to bring insights from local observations of climate change impacts into global climate change research.

Reyes-García V and **Benyei** P. 2019. Indigenous knowledge for conservation. *Nature Sustainability* In press: doi: 10.1038/s41893-019-0341-z

3. Scientific seminars

Benyei P. *Citizen Science.* LASEG Thursday Seminars. ICTA-UAB. 19th October 2016

Benyei P. *Citizen ethnobotany. A more inclusive method?* Annual seminars of the Doctoral program in Anthropology. UAB. Barcelona. 1st June 2017

Benyei P. *Keeping and sharing. Exploring traditional agroecological knowledge conservation in Spain.* Ecological economics, ethnoecology and Integrated Assesment seminars. ICTA-UAB. Barcelona 14th June 2017

Benyei P. *CONECT-e. Who is in for digitalizing traditional ecological knowledge in Spain*. BIDS Summer Lunch Series. UC Berkeley. California (USA) 14th June 2018

4. International research exchanges

01/05/2018 to 31/07/2018 Visiting researcher at the Berkeley Institute for Data Science. University of California Berkeley. USA.

5. Teaching

12/12/2016 *The overlap between biological and cultural diversity*. Master Class in the Biocultural diversity course. Master's Degree in Interdisciplinary Studies in Environmental, Economic and Social Sustainability . ICTA-UAB

14/09/2016 Evaluation committee of Ebrima Dem. Master's Degree in Interdisciplinary Studies in Environmental, Economic and Social Sustainability . ICTA-UAB

15/09/2016 to 15/01/2017 Supervision of Mònica Junyent. Envirnonmental Science undergraduate intern working for the project CSO2014-59704-P

15/02/2017 to 15/06/2017 Supervision of Guadalupe Arreola. Envirnonmental Science undergraduate intern working for the project CSO2014-59704-P

15/03/2017 to 15/08/2017 Supervision of Anaïs Ramet. Master Thesis Supervision. Master IEGB, Ingénerie en Ecologie et en Gestion de la Biodiversité. Université de Montpellier

12/02/2018 to 21/06/2018 supervision of Ana María Ceballos. Anthropology undergraduate intern working for the project CSO2014-59704-P

1/10/2018 to 15/02/2019 Supervision of Adrià Carrasquer Poveda. Political sciences and law undergraduate intern working for the project CSO2014-59704-P

4/12/2017-29/01/2018 Biocultural diversity course. 2 ECTS. Master's Degree in Interdisciplinary Studies in Environmental, Economic and Social Sustainability. ICTA-UAB

13/09/2018-20/12/2018 Human Ecology course. 1 ECTS. Undergraduate degree in Anthropology. Faculty of Humanities. UAB

3/12/2018-23/01/2019 Biocultural diversity course. 2 ECTS. Master's Degree in Interdisciplinary Studies in Environmental, Economic and Social Sustainability. ICTA-UAB

6. Outreach activities

CONECT-e Una plataforma web para la recuperación participativa de conocimiento agroecológico tradicional. Presentation at XVII Feria Estatal de la Biodiversidad Agrícola, Estella, 8-9 October 2016.

Conservar el Coneixement Agroecològic Tradicional (CAeT). Workshop in Jornades del Pla Anual de Transferència Tecnològica de la DARP, Vic, 20 February 2017

CONECTe. Plataforma web per a la recuperació participativa de coneixements sobre varietats tradicionals. Presentation at II Fira de la Llavor de Roda de Ter, Roda de Ter, 2 April 2017.

CONECTe. Una plataforma web para la recuperación participativa de conocimiento ecológico tradicional. Presentation at II Jornades Gastronòmiques de les Plantes Oblidades, Igualada, 25 March 2017.

CONECT-e al Vallès. Voluntary program with the volunteers from Fundació Autònoma Solidària, UAB, Spring 2018

CONECT-e dos años después. Workshop at XIX Feria Estatal de la Biodiversidad Agrícola, Ciaño-Langreo , 6-7 October 2018.

7. Outreach publications

Benyei et al. 2017 *"Guia Educativa CONECT-e".* Educational materials for CONECT-e school program

Benyei P., López D., and Reyes-García V. 2017. CONECTe para proteger el conocimiento agroecológico tradicional. *La Fertilidad de la Tierra: Revista de agricultura ecológica*, nº69.

Reyes-García V., **Benyei** P., Guadilla-Sáez S., and López-García D. 2017. CONECT-e: La Wikipedia del conocimiento ecológico tradicional. *Ecologista: La revista de Ecologistas en Acción*, nº93