Immutable mobiles: Assessing and Contesting Sustainability in European Quinoa Farming

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Abstract

Sustainability assessment methodologies such as Life Cycle Assessment (LCA) are becoming increasingly prevalent in the evaluation of agri-food value chains. Proponents of such assessment methodologies argue that they offer a factual and robust measure of the sustainability impacts of food production. Yet, assessment methodologies have attracted criticism for portraying a partial representation of the phenomenon. For example, existing LCA models tend to operationalize simplified and generalizable ideals of sustainability. These operationalizations mobilize understandings of sustainability that may clash with the grounded, experientially based understandings of local actors such as farmers. Using a theory of translation and the concept of immutable mobiles, we consider how LCA seeks to stabilize a definition of sustainability by delineating what aspects of agriculture may be considered relevant for sustainability and what is irrelevant, what is made visible in sustainability discourse, and what can be ignored. We then apply our analysis to a case study of quinoa farming in Europe. We compare what quinoa farmers identify as central to sustainability to what is included in dominant LCA methodologies to highlight what is excluded from LCAs: bodies, place, and qualitative aspects of the farm. In describing what is excluded, the farmers pinpoint the limitations of LCA and open the discussion about its possible improvement. Additionally, we consider how farmers are disempowered through definitions of sustainability evolved through new assessment tools and how these elements of the farm become a moot point for sustainable assessment and instead are central to political contestation. Finally, the paper argues for the transformation of power relations in the sustainability sector, which tend to isolate farmers, through the construction of new relationships between farmers and the research sector, as well as the valorization of farmers' knowledge in the definition of sustainable agriculture being advanced in policy.

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DECLARATIONS

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INTRODUCTION

Food production is a sector with a significant impact on biodiversity, climate change, and environmental resources such as soil, water, and air. It also has considerable influence on societal well-being, including that of farmers and workers, as well as consumer health (Czyżewski et al., 2018; Janker et al., 2019). To attempt to mitigate the negative impacts of food production, scientists, policymakers, and private actors have created increasingly complex worlds of compliance, composed of standards, grades, metrics, and benchmarks that assess the impact of food production on the environment and society (Rosin et al., 2017). Over time, sustainability indicators have grown in importance and international recognition as fundamental tools for policymaking, as they provide data on national and corporate performance in the environmental field. Several distinct science-based standardized environmental assessment methodologies have been elaborated and applied to operationalize the sustainability assessment of food production (Singh et al., 2012). One such example is Life Cycle Assessment (LCA), an internationally recognized analysis tool used to calculate the potential impacts on the environment of a product or a service throughout its life cycle (Koroneos et al., 2013). The relevance of LCA goes beyond the research sector into the political one, where LCA has been integrated into public policy and regulatory frameworks (Sala et al., 2021; Jegen, 2024). Additionally, the methodology is becoming the main assessment tool of market-based ecolabels (Iraldo et al., 2020; Roesch et al., 2025).

In recent years, there has been growing interest in applying LCA to quinoa (Chenopodium quinoa) production, motivated in part to assess its bona fides as a 'sustainable crop' or 'superfood'. Quinoa is indeed a highly debated crop (McDonell, 2015). Quinoa is an ancient grain that was initially domesticated in the Andean regions of Bolivia and Peru around 3,000 to 4,000 years ago. Its nutritional characteristics, wide adaptability, and multiple uses explain the increased worldwide interest in growing and consuming this crop over the last decades. The grain is now cultivated in 95 different countries (Bazile, 2015; Jacobsen, 2003). In the last decade, quinoa production has steadily increased in Europe, driven by a loose consortium of plant scientists and breeders, farmers, alternative protein companies and investors, and sustainability proponents (e.g., Jacobsen, 2017; Jaramillo Roman et al., 2020). There is now considerable production of quinoa in Spain, Italy, and France, supporting the livelihoods of a significant number of farmers.

Studies concerning quinoa production in its original countries, Peru and Bolivia, highlight its relationship with local culture and economy (Ehlers, 2021). Yet, researchers also shed light on the negative consequences of the grain's globalization, such as the unsustainable rise of the price for local communities (McDonell, 2015), appropriation of communal lands, increase of intensive agricultural practices with consequent damage to the local ecosystem, and biodiversity loss. These studies concerning the environmental and socioeconomic impact of the boom in quinoa production stimulated a vivid debate about the sustainability of this crop's value chain in the Andean countries (Angeli et al., 2020).

A number of LCAs have been implemented to assess quinoa production in the Andean region, where the crop was originally cultivated. These assessments have demonstrated the sustainability of smallholder quinoa production in the Andes in relation to global warming (Gamboa et al., 2020), food security (Cancino-Espinoza et al., 2018), energy flows (Lotfalian Dehkordi and Forootan, 2020), and communitarian systems (Ramirez-Cando et al., 2022). Conversely, a serious knowledge gap concerns quinoa production in Europe. Particularly, there has been no reflection concerning what quinoa sustainability means in the European context, how it is located in European culture, and how it relates to existing farming systems and is perceived by farmers. Moreover, LCA has not yet been applied to the European production of quinoa, although the use of LCA in policy and for assessing agriculture has increased. Some European quinoa farmers, such as those interviewed for this paper, oppose the assessment of their production as it would entail a comparison with the Andean one. This article aims to start filling this knowledge gap and to better understand the experiences of European quinoa farmers responding to the specter of LCA in its increased implementation.

We utilize a case study of quinoa farming in France and Italy to highlight the competing perceptions and definitions of sustainability between quinoa farmers and LCA scientists. We explore how LCA and corresponding understandings of sustainability are being mobilized. We argue that LCA is constructed as an 'immutable mobile' (Latour, 1987), motivated by a desire to create a unified and standard meaning of sustainability that can be universal. In the case of quinoa, this means allowing the sustainability of quinoa produced in Europe to be compared with quinoa produced in other parts of the world. By detailing the ontological underpinnings inherent in the construction and mobilization of the LCA by researchers and comparing these to the understandings of sustainability expressed by quinoa farmers, we illustrate what is missed and marginalized by the LCA and consider the consequences of this marginalization. We highlight how quinoa is described by farmers as a way to, for example, contribute to sustainability through support for food communities and connections between producers and consumers within Europe, diversify production crops, and enhance culturally valued aesthetic qualities of an agricultural landscape.

By considering how these locally embedded understandings of sustainability compare with the research aims of those implementing LCA, we contribute to a long debate about the definition of sustainability and the political effects of particular sustainability assessment efforts. Sustainability entails a multiplicity of values and interests, and its definition and implementation are inevitably socially and politically constructed, reflecting the perspectives of those involved (Scoones, 2016). This makes sustainability not only highly contested but also its interpretation dependent on local culture and language, as it involves people's relations with nature, the environment, and place. Moreover, as Ratner (2004: 54) argues, sustainability represents a 'dialogue of values', where even meaningful attempts to construct multidimensional understandings that integrate economic, social, and ecological dimensions "easily yield conflicting interpretations". These contestations are important when considering sustainability assessments, as 'whose knowledge counts' will define what is measured, and hence what is valued, in assessments (Fritz and Meinherz, 2020; Hale et al., 2019). These processes of contestation take place within expert and scientific communities, let alone between different actor groups with disparate levels of social power (Fritz and Binder, 2020; de Olde et al., 2017). Applying these reflections to the agricultural sector, recent research has underlined the marginalized position of food producers in debates on sustainability and assessment. Farmers are central actors in any transition towards a more sustainable food system. Therefore, considering their motives and the values behind their on-farm decisions, as well as their own perceptions of sustainability, will be fundamental to realizing just sustainability transitions (Groetenhuis & Schoon, 2000). Despite this central role, farmers are frequently excluded from or inhabit positions of less power in both scientific and political worlds within the sustainability debate (Fleming and Vanclay, 2010; Webster, 1999).

This paper contributes to this ongoing debate by arguing that efforts to render LCA an immutable mobile—a set of quantitative measures that can unify diverse meanings of sustainability—excludes valid meanings of sustainability held by farmers and their situated concerns. We argue that what quinoa farmers identify as central to farming sustainably is excluded from LCAs: bodies, place, and qualitative aspects of the farm. Moreover, this form of assessment, in its immutability and mobility, renders the environmental impacts of quinoa in one area commensurate with the environmental impacts of quinoa in another area, enhancing the degree to which quinoa can be treated as a commodity within an international marketplace. Thus, the LCA methodology can influence policymakers and society at large through this representation and quantification of sustainability, while the views and knowledge of other actors are marginalized. This situation demonstrates the performativity of scientific tools, namely their effectiveness in influencing the representation of a certain phenomenon as well as the political decisions taken about it (Hale et al., 2019; Turnhout, 2018; Waterton, 2002).

In the following section, we review the concept of sustainability and its application to agriculture before a brief discussion of the evolution of sustainability assessment methodologies, focusing on LCA. We then introduce translation theory and the concept of immutable mobiles. The second half of the paper turns to

our case study of quinoa farming in France and Italy, where we use our conceptual framework to tease apart the different interpretations of sustainability between LCA researchers and quinoa farmers and consider the implications of LCA for fixing a particular mobilization of sustainability at the expense of other visions.

CONTESTED CONCEPTS

Sustainability in Agricultural Systems

Sustainability has been a contested concept ever since its coining and diffusion in policy and development discourse in the 1980s (Frank, 2017). Within global and environmental development discourse, the concept is typically expressed as 'sustainable development'. This term was popularized in the Brundtland Commission's report Our Common Future (WCED, 1987: 15), where it was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Today, in mainstream academic, policy, and business discourse, including the UN's Sustainable Development Goals, the term sustainability is dominantly portrayed as consisting of three interconnected 'pillars' that encompass economic, social, and environmental dimensions (Purvis et al., 2019).

Despite these dominant definitions, sociologists highlight that all individuals encounter sustainability in their personal daily lives in different ways, elaborating on their own ideas about what the concept means based on their cultural context and values (Swyngedouw, 2010). Horlings (2015) argues that culture plays a pivotal role in the understanding of sustainability, including how human communities give sense and attribute value to their place and environment. They stress the importance of values in the comprehension of human behavior, conceptualized as the result of people's principles, priorities, and sense-making. Moreover, sustainability has been conceptualized as a social construct, whose definition relies on the standpoint of the observer (Webster, 1999). When these social constructs are shaped by public discourse as groups of concepts and metaphors, sustainability can be studied as a narrative. Narratives shape a framework for categories of actors, creating a certain understanding of the world and transporting values and norms in sight of desirable future developments. They also have the power of justifying and legitimizing social practices and political actions (Guske et al., 2019).

In the life sciences, sustainability in agriculture has dominantly been interpreted as a technical process or outcome. Social scientists, on the other hand, have pointed out that agricultural production should also be regarded as a human and social activity. Beyond biological processes, agriculture involves economics, trade, politics, international relations, and social connections. This makes agriculture as much social as agronomic and ecological (Altieri et al., 2017; Karami and Keshavarz, 2010). Considering the social aspects of sustainability is therefore central to achieving any transition to sustainable agriculture and food systems (Karami and Keshavarz, 2010). Social research underlines that to understand farmers' choices, both internal and external factors must be taken into consideration, including economic constraints, policy, social and natural relations, but also values, conscience, worldview, and experience (Groetenhuis and Schoon, 2000).

Farmers are central actors in the practice and realization of sustainable agriculture, given their role in decision-making over agricultural systems (Aare et al., 2021; Baccar et al., 2020; Fleming and Vanclay, 2010; Groetenhuis and Schoon, 2000). A sustainable agricultural system relies on farmers' knowledge and expectations, their awareness concerning the risk associated with different agricultural practices, as well as their motivation and beliefs (Gebska et al., 2020). Webster (1999) stresses that including farmers in defining and setting the parameters of what sustainability means is crucial to realizing successful sustainability transitions in agriculture. Farmers operate at the coalface of agricultural production systems, facing real-world constraints in their practices and decision-making. Understanding farmer perceptions of sustainability and how these may differ or complement those of experts and policymakers is crucial (Baccar et al., 2020).

Sustainability Assessment Methodologies

Since the growth of attention and interest in sustainability and sustainable development from the 1980s onwards, methods and tools for sustainability assessment have proliferated, including for agriculture (Becker, 1997). Sustainability assessment can be defined as "any process that directs decision-making towards sustainability" (Bond et al., 2012: 53). Sustainability assessment tools measure and assess the outcomes of policy decisions and practices. They are now viewed as crucial to facilitating the transition towards a more sustainable agricultural sector (Alrøe et al., 2017). As Olde et al. (2016: 391) argue, "sustainability assessment tools vary widely in their scope (geographical and sector), target group (e.g., farmers or policymakers), selection of indicators, aggregation and weighing method, and time requirement for execution". Responding to the critique of sustainability being as much a social process as an environmental process, assessment tools have begun to integrate economic and social indicators with environmental parameters, although environmental themes tend to still dominate (De Olde et al., 2016).

With the proliferation of sustainability assessment methodologies, an important critique has emerged that problematizes the typically positivist framing of sustainability assessment. This critique speaks to longer-standing epistemological and ontological debates regarding the philosophy of science and the nature of reality that impinge directly on the sustainability debate (Bond and Morrison-Saunders, 2012). The 'cultural turn' in various disciplines, including sociology in the second half of the 20th century, shifted emphasis away from a positivist epistemology focused on uncovering facts to a sociology concerned with meaning and values (Nash, 2001). This critique underlines how values influence scientific research, as researchers influence the understanding of natural phenomena through their perceptions, personal beliefs, and cultural background (Gorski, 2013). On the other hand, facts also exercise a certain influence on values, as values have an experiential basis, meaning that the life experiences of people can influence their vision of the world (Williams, 1985). Because of this reason, new facts can generate new values, as well as scientific discoveries that convey new social beliefs (Gorski, 2013).

Applied to sustainability assessment, this critique problematizes the representation of assessment tools as value-free and apolitical. For example, supporters of deep ecology thinking argue that sustainability assessment promotes an anthropocentric view of the world in which humans are portrayed as dominating nature (Bond and Morrison-Saunders, 2013). Other authors underline how assessment procedures contain several implicit elements that reinforce positivist thinking but which are in fact based on specific values and assumptions of researchers and scientists who develop these tools. Assessment procedures can therefore be understood as systematized value judgments, where both implicit and explicit values coexist. Biases can come from previous scientific education, cultural values, and personal visions, challenging the principles of objectivity and universality (Bosshard, 2000; Desmond, 2007). Moreover, sustainability assessment has been described as a social process composed of multiple actors who influence the formulation, application, and interpretation of the results (Bond and Morrison-Saunders, 2009). Consequently, considering the relation between knowledge and values is central to the issue of how to implement sustainability assessments to realize sustainability transformations in social-ecological systems (Alrøe et al., 2017).

Sustainability assessment tools are not only particularly complex and therefore often only comprehensible by experts: they also tend to erase context and difference in their attempts to produce generalizable truths and solutions. Local voices and understanding are therefore often marginalized or ignored (Bosshard, 2000). Hale et al. (2019) highlight how sustainability indicators are performative, in that by representing a concept, they shape the discursive world in which it exists and its enactment. In this way, not only do sustainability indicators build a partial representation of a phenomenon, but they can also influence people's understanding of that phenomenon, how decisions are made, and the perceptions of reality that inform actions, making indicator development a political act (Hale et al., 2019). In the context of LCA and agriculture, and particularly the adoption of LCA by large retailers, the development of LCA also relates to the distribution of power

along supply chains. It can be seen as part of a long history of standardization and supply chain management that serves to increase the profits and power of large retailers over global agri-food governance (see Busch 2007, 2011; Burch and Lawrence 2007).

Life Cycle Assessment

One of the most popular sustainability assessment tools developed over the last decades is Life Cycle Assessment. LCA is a system-oriented methodology that addresses the environmental impact of a certain product or service, typically understood as the amount of pollutant emissions (notably carbon, but also others) to water, air, and soil of a product (Jolliet et al., 2015). It is defined by the international standards ISO 14040 and 14044, which focus on the environmental pillar of sustainability (Jouini et al., 2019; Klöpffer, 2014). LCA is a quantitative technique, based on a functional unit and indicators (Hauschild et al., 2018). Moreover, it takes a life-cycle perspective: namely, it considers the whole life cycle of a certain product (Klöpffer, 2014). In this way, the methodology aims to aid in the determination of priority actions and interventions in the life-cycle of a product to optimize the production process and reduce emission impacts (Jolliet et al., 2015). LCA has become a dominant tool for business, including in the agro-food sector, to both integrate sustainability into innovation, design, and evaluation of products or services, and to represent the sustainability of a product to end or intermediary markets (Zamagni et al., 2013).

While the use of LCA has substantially grown, largely to serve increasing interest in corporate responsibility and to provide data for policymakers (Freidberg, 2013, 2015), the science underpinning the development of LCA tools remains highly contested. The work of Freidberg (2013, 2015) highlights the ways that the large diversity in the conditions under which goods are produced makes it difficult for researchers to develop consistent and coherent forms of measurement. Freidberg further illustrates how LCA assessments are linked to corporate interest in supply chain dynamism and management as a source of profit or supply chain capitalism (a term Freidberg borrows from Anna Tsing). 'Governance by numbers' and 'governance by standards' enable quantitative forms of control typical of commodity production and exchange, extending the political logics of free market exchange while generating revenues through audits and labels (Friedberg, 2013; see also Campbell, 2005).

Relatedly, in recent years LCA has also been subject to critique for its narrow view of environmental sustainability. For instance, Pelletier & Tyedmers (2011) argue that LCA assessments typically rely on simplistic market signals when evaluating the economic dimensions of environmental sustainability. They instead advocate for the inclusion of more holistic ecological-economic factors that can assess the environmental dimensions of meeting human needs, broadly defined. Gutowski (2018) highlights that LCA ignores human behavior when making claims about future outcomes or scenarios. The author, therefore, argues for greater inclusion of social science in the methodology to bring people to the core of the discussion. An example of such an approach is provided by Jouini et al. (2019) who combine LCA with a participatory approach to overcome the complexity of reading the results for non-specialists and to involve the values and interests of different stakeholders. Recently, a broader methodology has been suggested, namely Life Cycle Sustainability Assessment (LCSA), which should combine LCA with Life Cycle Costing (LCC), representing economic sustainability, and Social LCA (SLCA), representing social sustainability (Guinée, 2015). However, this combined methodology remains in its infancy, and there are few examples of its application to agriculture. Moreover, research that has applied LCA to organic and conventional systems has found that there is bias in favor of conventional systems due to modelling grounded in ecological processes typical of conventional systems, as well as higher yields associated with conventional production (Meier et al., 2015; see also Tricase et al., 2018). In this paper, we contribute to this discussion by focusing on the primary producers who operate at the beginning of the supply chain and are increasingly subject to LCA and its efforts at total, quantitative, holistic assessment (see Notarnicola et al., 2017; Cucurachi et al., 2019; Garnett, 2014). We use tools from science and technology studies, as described below, to further our understanding of the knowledge politics associated with the advancement of LCA.

Immutable Mobiles

Actor Network Theory suggests that science is culturally produced through efforts to give stable definitions to phenomena of our world by carefully designing and managing environments in which phenomena express themselves (Callon, 1986; Latour, 1996, 2007; Law, 2008). The 'network' of actor-network theory refers to the constellation of tools and conditions that are organized to generate stability in the phenomenon: this acts to produce knowledge, or a translation. In this way, science is always a cultural product embedded in society—a continuum of carefully crafted translations. As a result, science is a material practice with a social politics, as choices are made about what to translate and what, or who, to include in the translation process. It is important for the social scientist to understand the relationships in which science is situated, those which are reproduced by science, and those that are foreclosed within processes of translation. Thus, ANT aims to analyze the daily practices of technology and science in the making, considering both human and nonhuman elements. Science is examined not only as a source of information about the world but as a specific type of intervention in the world (Benton and Craib, 2001). The scientific translation of sustainable agriculture into a concept with a stable meaning is an intervention in the world that also depends on, and reshapes our understanding of, soil, water, weeds, chemicals, as well as a range of human actors, their practices, and their power.

Just as the translation of scallops into science influenced power distributions at St Brieuc Bay, in Callon's (1986) famous study, so too does the translation of sustainability into a scientific framework have a politics. Latour's (1999) work on the transformation of the material world into items of scientific knowledge provides a useful framing of how power is exercised in the arena of sustainability discourse. He suggests investigating the relationship between politics and science by considering them as inextricably connected, as translation transforms "political questions into questions of technique and vice versa" (Latour, 1999: 98). These translation processes result in situations in which certain entities construct the agency of others, engendering power relations. Power is therefore the result of associations of entities in networks, thus the possibility of having others act on or for oneself (Kien, 2009).

Of central relevance to the translation of sustainability is the concept of immutable mobiles, which describes the processes through which knowledge, which is diverse and socially embedded in practice, becomes crystallized into a fact or piece of technology that can move through space and organize human and non-human relationships across distances (Latour, 1987). For example, the test, as a particular kind of education assessment methodology, requires a range of stable practical conditions in the classroom and broader educational environment which then allows a score to be meaningful (Fenwick, 2010). Similarly, academic performance indicators are immutable mobiles that include and exclude particular forms of work (Stöckelová, 2012). Within these areas, Fenwick (2010) and Stöckelová (2012) have illustrated that immutable mobiles influence the agency of people through the validation or invalidation of the network elements in which they are situated. Within agriculture, Carolan (2006) has described the ways that conventional production relies on immutable mobiles which can be considered 'management in a can' and noting that academics engaged with alternative agriculture see these as inherently incompatible with the local expertise necessary for sustainable production (see also Higgins and Kitto, 2004). We use the concept of immutable mobiles to consider what human and non-human aspects of agriculture are stabilized and made visible through the translation of sustainability in the LCA, and what is excluded. In doing so, we can consider what political questions are translated into technical activities in the LCA, and which are made non-technical, political, and external to the questions of sustainable production.

METHODS

France and Italy were selected as focus countries for this study because of their significant role in the European quinoa sector. French commercial production of quinoa started around 2009 and is organized in cooperatives. Production is centered around the historic Anjou area in what is now the administrative region

of Pays de la Loire. Commercial cultivation is smaller in scale in Italy, beginning in earnest in the last 10 years. Production in Italy is mainly carried out by independent farmers in dispersed locations across the peninsula.

Participant observation and exploratory interviews were conducted by the first author with quinoa farmers in the case study areas, as well as with researchers engaged with LCA research and development at a preeminent European agricultural research organization. Quinoa farmers knew of LCA and attempts to increase its use in agriculture. Not all the LCA researchers that participated in the study were necessarily quinoa experts nor actively implementing LCA in the French and Italian quinoa sector. Instead, this part of the fieldwork aimed to build up an in-depth understanding of how LCA researchers, as an example of actors shaping a sustainability assessment tool, conceptualize, define, and operationalize sustainability. The sustainability discourse produced by LCA researchers was then compared to the perceptions of sustainability communicated by quinoa farmers. In this way, the study is not representative of the views of all LCA research nor all quinoa farmers, but rather provides a situated account of contestations over sustainability. Twenty-one interviews were conducted for the study: nine with LCA researchers and scientists (comprising two quinoa experts and seven LCA specialists), and twelve quinoa farmers (six in Italy, six in France). These were small-scale family farmers, owning around 100-200 hectares of land, cultivated following the principles of crop rotation and diversification using a combination of traditional and alternative crops, either in organic or conventional agriculture. In the Italian case, the six interviewees represent almost all the groups producing quinoa in the country, while the six French farmers belong to one of the two main cooperatives involved in quinoa production in France. In the next section, we outline the context and value-dependent ways in which actors from each group construct their own definition and ideas about sustainability.

CONTRASTING DEFINITIONS

Researchers' Perception of Sustainability

The research scientists who participated in this study expressed a vision of sustainability that corresponded with how the concept is represented in the LCA methodology. These results from the LCA researchers demonstrate how the LCA is constructed and deployed as an immutable mobile. All the researcher interviewees agreed on the need to study and collect data concerning all three aspects of sustainability—environmental, economic, and social—to produce a complete sustainability assessment. However, researchers, who were often involved in environmental assessment, noted that this aim is not always accomplished.

> *Every time I intervene, it's usually on the environmental aspects. On the social aspects, there's this little comment of 'Be careful, we are not considering everything. We should also take into account the social aspects', but in practice, they are not dealt with. (Researcher 6)*

This emphasis on environmental assessment, which conceptually excludes human culture and influence, was further emphasized through a commitment to 'strong sustainability'. In other words, in the LCA methodology, a product with an environmentally sustainable life cycle is defined as one that preserves the integrity of all associated ecological systems and every human intervention contributes to unsustainability (Dietz and Neumayer, 2007).

> *Under strong sustainability no damage is acceptable. In LCA every action is considered as a damage, as a negative impact, as something to be avoided. (Researcher 5)*

Damage and integrity within the LCA is determined through quantification, and research participants stressed the importance of measurement in the LCA. Notably, the subjective experience of loss or degradation would be, in theory, represented by these measurements, but also muted by it. Quantification is considered one of the core characteristics of the methodology, because:

> *If you cannot quantify, then you cannot really improve practices. (Researcher 3)*

For the researchers, quantification is proof of the objectivity of research. Quantification and thus the determination of sustainability could be achieved through a network involving human activities, particular ecological elements, measurement tools, modelling programs, and highly technical knowledge held by scientific experts. This is explicitly oriented to the generation of universality, objectivity, and general applicability. The LCA here can be seen as a direct attempt to solidify a network that can define sustainability through a limited set of technical indicators:

> *So it's really a rather mechanistic vision. We start from a modelling framework to model human activities in the form of quantifiable flows, whether it's quantities of products or services, to be able to make the link between that and pressures on the environment, whether it's resources consumed or emissions of polluting substances, to be able to aggregate that into environmental impact indicators. So the LCA framework is based on this mechanistic and biophysical vision of the interactions between what we call the technosphere and the ecosphere. (Researcher 4)*

These indicators have implications for how different kinds of food systems would be evaluated, and what kinds of values would be considered internal or external to questions of sustainability. Researchers confirmed the applicability of LCA to all contexts, implying that the same definition of sustainability can work in all situations and places and can help compare practices using a single method of accounting. Researchers noted that concerns about the transportation of a product, outside of its direct environmental impact, would be excluded from the meaning of sustainability through the implementation of the LCA:

> *You can buy a product, either produced in the village next to where you live in Europe or imported from New Zealand from the other side of the world, and it's possible that the imported product, including all the transportation, has in total lower impacts per unit of product than the one produced next door, so nothing is obvious. Everything needs to be carefully checked, and LCA has the capability of capturing these nuances. (Researcher 5)*

People tend to believe that the more local a product is, the more environmentally sustainable. LCA can challenge these assumptions empirically, demonstrating that the transportation stage is the least impacting on the environment and, therefore, if we define sustainability through a strictly ecological perspective, it does not contribute much to the sustainability assessment of the product. Any remaining social, cultural, or economic concerns people may have about transportation is moot. On the other hand, some suggested the importance of the indicators should be weighted in relation to local challenges. For example, in a context of water scarcity, the indicator evaluating water consumption should have priority over others to develop a more sustainable system, adapted to the situation. Yet these remained comments related to quantifiable ecological integrity and better attuning the math to the local balance.

Finally, some researchers situated the development of the LCA explicitly within the task of defining sustainability; giving stability, and a certain kind of immutable mobility, to a politically hot but unstable concept. As the quote illustrates below, sustainability measurement is recognized as the transformation of a political problem into a technical one:

> *Sustainability is a buzzword. Sustainability is what you call sustainable, and therefore very much dependent on the sustainability criteria that you use. (Researcher 7)*

As we illustrate in the following section, the definition of sustainability advanced by LCA researchers that hinged on ecological measurement, quantification, and universality, contrasted those described by quinoa farmers. By contrasting these definitions, we can consider how the construction of the LCA as an immutable mobile, defining and assessing sustainability in the context of food production across vast spaces, excludes other ways of understanding sustainability.

Farmers' Perception of Sustainability

The interviews with quinoa farmers showed that perceptions of sustainability are strongly multidimensional, touching on economic, social, and environmental aspects. Most notably, farmers in the study connected the idea of sustainability to their daily lived experience, associating the concept with agricultural practices and direct experiential observation. This contrasted an emphasis on measurement advanced by the LCA, and the idea that without measurement, farmers would fail to reflect on the impact of their practices.

> *We love to see pollinating insects in our fields because they take the pollen and so on, so we have to let them do it and that's it, so we know, we observe. (Farmer 10)*

Further, some farmers identified sustainability with alternative practices, or 'doing things differently' from what they have done in the past. This fits well with their foray into quinoa production, a new crop in Europe. As the quotes below illustrate, practices of sustainability are considered to be embedded in local histories and efforts to confront conventional and normative practices and transform landscapes of production. For example, farmers associated sustainability with organic agriculture, conservation agriculture, and intercropping:

> *Sustainability means cultivating the soil differently, working differently, green manure, rotations, things like that. (Farmer 2)*

> *You see, the production system I use is what I consider to be sustainable, namely putting agronomy back at the heart of the production system, lengthening the rotation. [...] A diversity of crops, soil cover, that's all. Sustainability goes with that. (Farmer 9)*

Specific post-harvest techniques were also suggested as synonymous with sustainability, such as using sustainable packaging and recycling waste to produce by-products, demonstrating that farmers do apply a life-cycle vision of production:

> *Everything is designed for sustainability. We are even studying how to use the small part of quinoa that we decorticate to transform this waste into polymers that can be used as cosmetics or as a superfood. (Farmer 3)*

On the one hand, farmers understand sustainability as reducing their impact on nature; on the other hand, through their practices, they also try to contribute to realizing sustainable outcomes at a societal and environmental level. For example, the quinoa farmers in the case study sought to enrich the land, limit erosion, and provide sinks for carbon dioxide. Moreover, through the crops that they select, they can create a beautiful landscape, improving the quality of life of the people living in the surroundings:

> *A quinoa plant, some people will find it pretty, so it makes a beautiful landscape and people are content. (Farmer 12)*

Furthermore, the interviewed farmers strongly valorized the idea of a place-based food system as inherently more sustainable. Reduced environmental impact through short supply chains, closer proximity to consumers, and the creation of a sense of pride and identity were important among the farmers, and illustrate the ways that cultural aspects of proximity and distance may also be viewed as important for sustainability. This attachment to place also means generating relationships with people, both in the sense of solidarity and reciprocal help among farmers, and to the local community (for example, farmers perceived they should have a role in educating consumers about agricultural and sustainable topics). This line of thinking affirms for farmers that it is important to look at the local context and to reflect on local problems in order to adopt suitable solutions. According to the interviewees, proximity brings several benefits:

> *The proximity to the consumer should be taken into consideration because it's not easily reflected in the assessment tools. The fact that I know that this food comes from not too far away, that I could go and meet the producer. I trust that the government structures are in order, they do everything for my health. That closeness, that familiarity, it has a point. I think there's something we would lose quickly if everything came from far away. Beyond just counting the emissions of carbon." (Farmer 8)*

The quantification of the environmental impacts of transportation through mechanisms like the LCA excludes experiences of distance from institutionally valorized definitions of sustainability. Some farmers directly argued against the need of science to quantify and classify every aspect of sustainability. They brought examples such as the pride they have in creating the first national supply-chain of quinoa in their countries, the satisfaction of local communities to have a beautiful landscape that generates experiences of contentedness, the value of contact with nature, human connection, and the built sense of community. Among the societal factors that cannot be quantified, farmers underline the importance of considering the ethical side of sustainability concerning human rights and transparency to the case of quinoa production in its countries of origin, Peru and Bolivia.

> *We know that, especially in Peru and Bolivia, the people of the Andes who used to rely on quinoa as their main source of food until 10 years ago, are now in difficulty because the price of quinoa has risen so much, because the large multinationals are growing quinoa for export to Europe. So if we talk about the sustainability of quinoa in particular, one aspect that should be taken into account, globally speaking, is that of ethical sustainability, namely the non-monetary cost, but the social cost, that people are paying, especially in Bolivia, in the Andes, precisely because quinoa is now used mainly for export, while for the domestic market they no longer have it. But sustainability is also ethical and social sustainability, understood as the exploitation of labour, transparency and a series of aspects that must allow the consumer to know that they are consuming something that has not harmed others." (Interview 12)*

All interviewees were keen to emphasize that quinoa is an ideal crop to interconnect all the above points. Quinoa farmers value place-based production through the creation of shorter value chains, which enable them to create relationships with consumers, while fostering farmers' pride and creating a local identity. In the view of farmers, this type of production supports the local economy, ensures a fair revenue to farmers, guarantees transparency and health standards, and avoids human exploitation—all outcomes that farmers would consider as representing sustainability. Despite their perceptions of quinoa as a sustainable crop, certain farmers doubted whether measurement tools such as LCA could capture the diversity of sustainable outcomes that they regarded as important:

> *We have to assume there will be farming in France; so does the introduction of quinoa in the crop rotation make French agriculture, on the whole, more or less sustainable compared to French agriculture without quinoa? The answer is pretty obvious: diversification is a key element of sustainable agriculture, with positive effects on the whole farm. For example, a lot of beneficial insects develop in quinoa and are there to help with other crops. The effects are impossible to measure, but the problems of lack of diversification and short rotations are clear in this region, in terms of pests, weeds, fertility and declining yields. (Farmer 7)*

Three Points of Divergence: Bodies, Place, and Quantification

The researchers and quinoa farmers in our study share some common ideas about sustainability, but also many differences, which explain the reluctance of quinoa farmers toward the LCA methodology. In the following sections, we identify three elements of sustainability described by farmers that would challenge scientific efforts to make the definition of sustainability stable, mobile, and immutable through LCA. These are identified by farmers as central to sustainability but excluded from LCA: bodies; place; and qualitative aspects of the farm. We aim to underline how the farmers' vision can answer to the weaknesses of the LCA methodology and show the relevance of this marginalized actor in the conversation over sustainability assessment.

Bodies

The findings presented above illustrate that practical, experiential, and embodied definitions of sustainability are not part of the construction of LCA. Observation, aesthetic appreciation, and experiences of familiarity and closeness feature into the farmers' discussions of sustainability. In fact, we could see the body as intentionally excluded from the sustainability actor-network, or immutable mobile, constructed through the LCA, through the emphasis on abstract measurement and modelling systems as the foundation of valid observation. This has implications for the ways that knowledge is valued in sustainability. Our daily practices and experiences as individuals are strongly linked to knowledge construction. Research by Stuiver et al. (2004), for example,

underlines how farmers' way of constructing knowledge is strongly linked to daily experiences and practices working on the farm. Similarly, Feindt Oels (2005) argue that the interconnectedness of knowledge with everyday practices influences how actors articulate or reject particular discourses around environmental problems.

In the present case, farmers' vision of sustainability is influenced by their daily embodied work, illustrated by comments about biodiversity, whereas researchers are conditioned by their specific discipline's methodological and ideological assumptions, reflected in their area of expertise and professional training (Baginetas, 2008). Consequently, farmers identify sustainability with the agricultural practices they use every day, basing their knowledge of what is best or most sustainable on their experience and intuition, as well as on personal choices and values. Conversely, LCA researchers offer a more idealized and abstract idea of sustainability, which originates from years of studying the scientific (ecological, biological, chemical, etc.) impacts of human activities on the environment. This difference can be observed as well in the terminology used by the two kinds of actors, on the one hand, the experiential one of the farmers referring to the observation of nature, the conditions of the soil, the agricultural practices; and, on the other hand, the abstract language of the researchers citing indicators, measures, and scientific processes.

This contact with environment and practices is particularly evident when farmers discuss the positive impact of their work on climate change. The farmers mention the possibility of enriching the land, limiting erosion, and stocking carbon in the soil when applying certain agricultural practices. LCA, instead, reflects the perspective of the concept of strong sustainability, considering any activity impacting the environment as potentially damaging (Pelenc et al., 2015) and expressing this through a carbon footprint logic (Pertsova, 2007). This vision demonstrates attention to positively contributing to the local context, which goes beyond the simple limitation of the damages portrayed by LCA. Farmers impact the environment with their work whatever they do, yet agriculture is necessary for human survival. Therefore, they consider the adoption of those practices in order to foster positive impact, in society and nature. The farmers considered their choice of producing quinoa as a service for those consumers who want to consume healthy local food. The production of quinoa is regarded as a service to the European environment also because it answers to the increasing European problems caused by climate change, such as desertification, soil degradation, salinization, and biodiversity loss. Consequently, simply considering the negative impact on the environment caused by quinoa production compared to another crop or the same crop in another context would not portray a complete representation of the role of quinoa in Europe.

Place

Quinoa farmers' and researchers' discourse about sustainability differs regarding the relevance of place. Farmers in the case study demonstrate a strong attachment to place, manifested as a concern for local context and local solutions, and also place sustainability within a narrative of spatialized production history. For farmers, symbolic and emotional facets of the relation with place coexist next to the more material aspects, demonstrating the relevance of both material practices and values in the conceptualization of sustainability (Grenni et al., 2020). This vision collides with the position of LCA researchers and practitioners, as assessment methodologies tend not to be place-based, but instead are applied generically across different places. Natural sciences are based on a principle of universality, namely on the assumption that scientific knowledge is independent of any context and that certain general rules are always true (Mccomas et al., 1998).

Recently, place-based approaches have challenged the overly abstract-theoretical and non-spatial approach of sustainability science (Grenni et al., 2020). Sustainability is increasingly conceptualized as a place-based phenomenon, recognizing the principle of the uniqueness of each place and rejecting the employment of undifferentiated solutions that neglect local peculiarities (Calvo De Rosa, 2017; O'toole et al., 2006). Furthermore, sustainable place-shaping is a process that works in two directions, as meanings and values connected to a certain place can be shaped through more sustainable practices, while at the same time,

practices should be consistent with local values and meanings of place (Jones Evans, 2012). This 'spatial turn' in sustainability science poses challenges for assessment methodologies like LCA. Farmers' reflections could contribute to reconceptualizing sustainability assessment methodologies to consider this place-based dimension. Reflecting on why a certain crop is produced in a certain area and with certain techniques would be fundamental to a place-based approach to sustainability assessment. Moreover, paying attention to the local context means relativizing and weighing the importance of different indicators considering local challenges and culture. The involvement of farmers in discussions about sustainability assessment would make this discussion inevitable and contribute to the transformation of LCA from an immutable mobile to a mutable and adaptive tool.

Qualitative Aspects of the Farm

The findings from the case study highlight different positions concerning the quantifiability of the concept of sustainability. All researchers agreed on the importance of quantifying the impact of human activities on the environment, indicating that this was necessary to evaluating the impact of practices and the recognition of improvement, while farmers criticized the need for science to quantify all aspects of sustainability. In the case of quinoa, if LCA aims to compare the European and Andean productions, social conditions cannot be ignored. As previously mentioned, the global demand for quinoa is producing nefarious consequences on Andean communities, such as the unsustainable rise of the price for locals, appropriation of communal lands, and increase of intensive agricultural practices (McDonell, 2015).

Previous studies already discussed the non-quantifiable nature of some aspects of sustainability, while reflecting on how to still incorporate measures into a more reflexive program (Hale et al., 2019). When certain aspects are neglected by sustainable assessment only because they are not quantifiable, measurability and validity are not in sync anymore. In other words, according to Katzner (1978: 127), "there is no excuse for setting aside important issues because it is difficult to see how the variables involved might reasonably be measured". Moreover, as reporters of knowledge, researchers play a pivotal role in the symbolic representation of the world through metrics and indicators, which represent the foundations of scientific processes (Hale et al., 2019). Yet, representation has a performative power, meaning that portraying a phenomenon in a certain way can have repercussions on how it is understood and translated into decisions and actions, such as the production of ecolabels based on LCA (Alrøe et al., 2017).

For these reasons, more effort should be made to consider social aspects of sustainability over assessment processes. Tools should be made flexible and adaptable to the priorities of different cultural contexts, taking into consideration local social conditions. The result would be less standardized, but more comprehensive, context-based, and meaningful for understanding sustainability.

POWER AND THE LCA

The LCA, like numerous other tools developed to concretize and stabilize definitions of sustainability in agriculture, creates a boundary around what elements of agriculture are considered components of sustainability—what needs to be networked together to generate a claim about the degree of sustainability. The definition of sustainability is constructed for the purpose of becoming an immutable mobile: something that can travel to different places, and through time, to generate consistent interpretations of the world. What is included and excluded as part of the network that needs to be stabilized for consistency influences the distribution of power. Not only does it shape who can claim that the food they produce is sustainable or not sustainable, but it also influences who can be part of the conversation and how. As a result, the practices, experiences, and observations that are culturally and ecologically valuable to farmers may be branded as irrelevant to questions of sustainability, even while these factors may have been central to crop selection in the first place. The contribution of a crop to a local production mix, given a particular industrial history, is rendered less important than the comparable environmental impact of products as they meet each other in the

marketplace. This knowledge held by farmers is excluded through this tool in particular, but also delegitimized generally as sustainability discourses become increasingly narrowed and crystallized in international policies.

Embodied practices, places, and qualitative assessment—these are things that farmers uniquely manage and enact in farming systems, and their exclusion from sustainability assessment demonstrates a politics to sustainability science that is important to consider, particularly given that the LCA methodology and the vision of sustainability embedded within it have become increasingly influential in policymaking and regulatory processes both in Europe and elsewhere (Guinée, 2015). Indeed, the construction of the LCA can be seen as part of a more extensive attempt to translate and stabilize sustainability assessment through five steps as described by Latour (1999): mobilization, autonomization, alliances, public representation, and the knot. The first of Latour's elements is the mobilization of the world around a certain topic. In the present case, this is reflected in how sustainability assessment tools such as LCA have been created and spread around the world through certain instruments and equipment, as well as sites such as research institutions and international organizations (Frank, 2017). The second element is what Latour calls 'autonomization', where a scientific discipline is professionalized through the formation of its own criteria and expertise. In the realm of sustainability, we see this process in the growing amount of universities around the world offering degrees about sustainability issues as well as offering courses about LCA (Lozano, 2006). Thirdly, Latour underlines the importance of alliances between scientists and other groups in society, government, industry, etc. that act in support of a particular research field. In the case of LCA, the relationship of researchers with political institutions, as well as with big food companies, is evidence of this process of legitimation. As the interviewed researchers confirmed, policymakers are one of the main commissioners for sustainability assessments. European and national institutions often finance sustainability evaluation projects that incorporate methodologies such as LCA. In other cases, agribusiness firms themselves hire LCA practitioners to evaluate their chains of production. Latour's fourth element is public representation, where scientific knowledge is communicated to the outside world to convince the public of its merits. Here, assessment scientists engage in public representation in order to foster a certain understanding of sustainability in people's everyday practices and systems of beliefs. The influence of assessment methodologies can be seen in, for example, the European Citizen's Initiative which proposes an 'EcoScore' sustainability labelling system for food products that would be based on the LCA methodology. Latour's fifth element is what he calls the knot, which unifies the above processes into the scientific concept itself. Here, the translation of sustainability and its assessment tools from scientific terms to social ones and vice versa happens in a complex and heterogeneous network of human and non-human actants (Latour, 1999).

Conversely, quinoa farmers are excluded from this network of alliances, unable to exercise any influence concerning the accepted definition of sustainability. Yet, if LCA becomes the standard methodology to assess the impact of food production, they will be directly touched by the political regulations which will decide the "ecological" score of their quinoa production.

In the interviews, farmers depicted a situation of isolation from other actors in the food production sector. They are constrained by politics through rules and legislations but they also face barriers when trying to influence, for example, agricultural standards. Further, we found little evidence of any sustained relationships between quinoa farmers and LCA experts. From the researchers' point of view, farmers represent resources to collect data for LCA assessments. Researchers employ farmers' knowledge to collect the data required by the tools, not to question the validity and comprehensiveness of the tools themselves. These power imbalances represent a serious obstacle to the possibility of including farmers and their vision in a more holistic sustainability assessment. Researchers themselves confirmed that there was no aim to include farmers in the development of assessment methodologies, as these are considered sophisticated tools based on science, and therefore best managed by scientists. These dynamics support the Latourian idea that the strongest and most influential network is the one with more associations, being therefore able to dominate over other actants. That is how the voices of the actants excluded by the network are lost in the crowd, if not purposely silenced.

Even if every alliance is negotiable, the struggle to reverse the actual system is asymmetrical, delineating clear winners and losers (Kien, 2009). Consequently, the paradox becomes clear: the indicators and metrics prescribed in assessment methodologies such as LCA invariably reproduce a dominant and simplified version of sustainability, yet one that is laden with complexity, politics, and power relationships. At the same time, these assessment methodologies render these contestations invisible through their institutionalization in sustainability policies.

CONCLUSION

This paper has analyzed the ways that the LCA defines sustainability through the construction of an immutable mobile, and it compared these definitions to quinoa farmers' conceptualizations to highlight what is excluded. The concept of immutable mobile helps us to consider how sustainability is constructed by the LCA with the intention of stabilizing the definition so it may travel and be applied in multiple environments. We highlighted what aspects of agriculture are interpolated into this definition of sustainability, and what is excluded. We have argued that embodied practice, place, and qualitative elements of the farm expressed by quinoa farmers are excluded from the LCA definition of sustainability, and, as a result, knowledge held primarily by farmers is made external to assessments and politicized. Through their definition of sustainability, farmers were able to pinpoint the already mentioned limitations of LCA, such as standardization, quantification, and place-dependency, but even to explore new issues such as the possibility to produce a positive impact on the environment with their agricultural choices. Our findings further emphasize the importance of reflexivity among sustainability researchers and scientists, who typically come from a natural sciences background. This means reflecting on the limitations of methodologies like LCA and their political and social consequences. The LCA scientists demonstrate to be aware of the limits of the methodology and interested in possible improvements. Yet, we aim to underline the importance of considering that what researchers choose to measure and how they represent a certain phenomenon matters and has concrete consequences in policymaking (Waterton, 2002). Through this article, we attempt to show 1. the interest in involving farmers in discussions over sustainability assessment as they can pinpoint the limitations of assessment tools thanks to their empirical knowledge and 2. The relevance of doing it considering the political influence of assessment tools such as LCA. Future research should focus on ways to bring disparate actors like farmers and scientists together to co-produce knowledge about sustainability and agriculture. Central to this must be an analysis of the obstacles that prevent cooperation and co-production including the pivotal role of power relations in deciding whose version of sustainability counts, and whose doesn't.

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