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Research Report

Farmers hold diverse and connected values towards crops

Marilou Demongeot[a], Antoine Doncieux[a], Tatiana Cardenas[a], Anna Porcuna-Ferrer[b,c,d], Yildiz Aumeeruddy-Thomas[a], Sophie Caillon[a], Jonathan Locqueville[a], Doyle B. McKey[a], Victoria Reyes-García[d,e,f] and Delphine Renard[a,*]

[a]CEFE, CNRS, EPHE, IRD, Univ Montpellier, Montpellier, France
[b]CIRAD, UMR AGAP Institut, 34398 Montpellier, France
[c]AGAP Institut, CIRAD, INRAE, Institut Agro, University of Montpellier, 34398 Montpellier, France
[d]Institute of Environmental Science and Technology, Universitat Autònoma de Barcelona (ICTA-UAB), 08193 Barcelona, Spain
[e]Institució Catalana de Recerca i Estudis Avançats (ICREA), 08010 Barcelona, Spain
[f]Dept Antropologia Social i Cultural, Universitat Autònoma de Barcelona, 08193 Barcelona, Spain
*To whom correspondence should be addressed: Email: delphine.renard@cefe.cnrs.fr
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Abstract

Considerations of yield and profit often drive decision-making in agriculture, but these are not the only values farmers ascribe to crops. Recognizing the multiple values farmers use to choose crops and their management holds potential as a leverage point for sustainable transformations. To assess the diversity of values attributed by farmers towards individual crops, mixes of crops, and agroecosystems, we conducted a literature review of 125 studies published between 2010 and 2022. We analyzed 1,716 unique reports of value ascribed by farmers to 135 crop species across 67 countries and 20 agroecosystems. Farmers' values towards crops are diverse and connect economic, agronomic, social, cultural, and ecological dimensions of agriculture. While yield and profit are the values most frequently reported by farmers, social and cultural values, such as identity and cultural preferences, are also often considered as vitally important. Although most reviewed studies examined smallholder farmers and values assigned to single crops, results indicate that values vary across farm size and market orientation and across crop types. We also show that external forces, such as markets, policies, and climate change, interact with farmers' values to influence their management of crops. Finally, this review shows that researchers in different disciplines highlight different values, and that the complexity underpinning farmers' decisions about crops can be enlightened by interdisciplinary approaches. The article thus supports and extends the recommendation of IPBES to integrate diverse values linking farmers and crops into research and policy.

Keywords: agroecosystems, crops, human–nature relationships, local knowledge, values

Significance Statement

This research reveals the diverse and connected values guiding decisions of farmers regarding crops. The analysis of over 1,700 reports of values farmers ascribe to crops across 67 countries demonstrates that, while yield and economic profit are important to farmers, multiple economic, agronomic, ecological, and sociocultural values underpin farmer–crop interactions. Demonstrating the key role of socially and culturally grounded values, such as identity and cultural preferences, helps create a more accurate and comprehensive understanding of what matters to farmers. Rooting policymaking in farmers' multiple values holds the potential to support more adequate and effective decisions that can contribute to transforming the way food is produced and the types of food made available to consumers.

Introduction

Connections between societies and nature transcend market values. The concept of Nature's Contributions to People (NCP) highlights the diversity of those connections, emphasizing the importance of social–cultural, spiritual, religious and identity-based significance of the living parts of the biosphere, alongside their role in providing food and medicine and regulating climate (1). The comprehensive synthesis of knowledge on NCPs and values led by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) compels policymakers to mobilize the diversity of ways that nature can be understood and perceived to conserve and sustainably use it (2). Generally, however, efforts to analyze NCPs have focused on wild biodiversity and natural ecosystems, resulting in a gap in the understanding of the contributions and values ascribed to managed ecosystems in general, and crop plants in particular. This article aims to fill this gap.

Understanding the multiple values of crops is important because this component of biodiversity underpins global food security and sovereignty (3) and represents a key asset in addressing the sustainability and resilience challenges posed by current

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global agricultural simplification and homogenization (4–6). Recent research suggests that promoting crop diversity can lead to greater and more stable yields at levels from farms to nations, spreading risk of crop failure caused by diseases or climatic conditions (7). Promoting crop diversity also reduces the need for land clearing and lowers the use of harmful agrochemicals (6). Finding ways to preserve crops and their diversity is particularly urgent given ongoing changes (8), including widespread loss of landraces and crop wild relatives (9). As crops and their diversity are lost, so are the local knowledge and traditions associated with them (10). Although agricultural changes are led by multiple drivers, policies aimed at maximizing yield and minimizing prices to feed a globalized market play a major role (11). Transforming the types of food produced and offered to consumers requires a shift in agricultural policymaking to support goals that embrace diverse crop values—a crucial, yet often overlooked step.

Farmers are the primary decision-makers regarding crops and their management. Yet, current knowledge about the values that guide farmers' decisions about what crops to grow and how to manage them comes from a fragmented, disciplinary literature. People grow crops either as food, nonfood products (i.e. wood, fodder) or for cash, all instrumental values that directly relate to the essence of agriculture. But case studies illustrate that additional values, related to health (12), cultural, and social aspects of life, also play a role in farmers' crop selection (13–16). What we lack is a global picture illustrating the diversity of values guiding farmers' crop selection and the relationship between value diversity and crop diversity. Filling this gap is pivotal to support the mobilization of these multiple values into policy decisions that drive transformative changes in agriculture.

To address this gap and provide a synthesis of knowledge about the values held by farmers regarding the crops they grow, we conducted a literature review (spanning academic articles published between 2010 and 2022). Our work aims to provide a better understanding of (i) the diversity of values expressed by farmers towards individual crops, mixes of crops, and agroecosystems, (ii) how the social, economic, agronomic, and environmental values of crops interact and affect decision-making, and (iii) the academic approaches adopted to identify farmers' values and the potential biases of these approaches.

In line with the IPBES framework, *values* are understood as the diverse principles and meanings that individuals or groups assign to nature, which guide their decisions and actions. IPBES differentiates among three types of values: instrumental values, which reflect the utility of nature for people; intrinsic values, referring to the inherent worth of biodiversity and nature, regardless of human use; and relational values, which arise from the relationship between people and nature (1). Using this typology as a theoretical backdrop, we took a different approach. We developed a hierarchical classification of values based on reports of values ascribed by farmers to crops as found in the scientific literature. Through a review of this literature, we recorded all the expressions—explicitly mentioned by farmers or deduced by academic researchers—of what matters to farmers regarding their crops. Due to the large diversity of approaches of researchers and to the fact that the terms "value" or "valuation" are not systematically used in the literature on crops and farmers' management practices, we established a set of proxies defined collectively by experts, the co-authors of this article. They are ethnoecologists, geographers, agronomists, and ecologists with a common interest in values and complementary approaches to their study. All participated in the identification of documents including the various dimensions that can be associated with values, and in the coding of the results (see Methods). An inductive approach was used to build a classification that encompasses all the values recorded from the literature. To do that, the same group of experts grouped values into sub-domains, themselves grouped into large domains. The classification was discussed and refined based on illustrative narratives extracted from articles. Domains and sub-domains were designated based on our expertise, on the conceptual academic literature on values (17), and on our observations from the reviewed case studies (see Methods for further details). While this work aims to capture the various dimensions of farmer–crop interactions, the interpretations offered reflect the perspectives of the authors and do not claim to represent any specific group or to speak on their behalf.

Results

We evaluated 125 studies reporting farmers' values of crops across 67 countries (Fig. 1A, Supplementary Fig. S1). Studies were primarily conducted in tropical areas, with half of them based in Africa (53% of studies, $n = 14$ in Ethiopia alone). Only six were conducted in Europe and three in North America. Small-scale agricultural systems (holdings < 5 ha, 80% of the 80 studies providing the information) were more represented than medium- (5–50 ha) to large-scale systems (>50 ha, altogether 20%). The literature also gives more attention to subsistence and local market economies (77% of the 92 studies providing the information) compared to systems oriented towards national and global markets (23%). We found values for 20 agroecosystems (e.g. cacao-based agroforestry systems, mixed cereal–cattle agroecosystems) and for 135 crop species, of which 72% were food crops. Values of cereals (16 species) appeared in 42% of the documents reviewed (Fig. 1B), including globally dominant cereals such as rice, but also locally important ones such as teff. For only 32 crop species, values were reported at the varietal level (24% of all species covered), which included landraces and hybrid varieties.

Farmers' values ascribed to crops are diverse

We collected 1,716 distinct reports of farmers' values that we assigned into six broad domains (i.e. *Socio-economic*, *Agroecological traits*, *Social and symbolic meaning*, *Cultural preferences*, *Ecological interactions*, and *Maintenance of options*, Fig. 2).

In the *Socio-economic* domain (43% of all citations), monetary value (27% of the citations in this domain), and specifically cash income, is the most frequently reported reason why farmers value crops. Crops are also frequently valued by farmers for their usages, as food for self-consumption (20% of citations in this domain) and other uses (i.e. energy, fodder, construction, 20%), and for their yield (19%) (18–22). Supporting food self-consumption was often cited for cereal crops. In Ethiopia, for example, teff and maize landraces are valued for their critical roles in filling seasonal periods of food scarcity (23). Other values in the *Socio-economic* domain refer to agricultural work (e.g. labor and working time demands, 9% of values cited in this domain), seed system (3%) and access to land (1%).

Farmers also frequently reported values related to crops' suitability to local conditions (49% of the citations in the domain) and morphological characteristics (29%), two values included in the *Agroecological traits* domain (26% of all citations). Suitability to local conditions was highlighted in studies taking place in challenging and changing environmental conditions [e.g. (24–26)]. For example, farmers in Syria (24) and in Sierra Leone (27) expressed higher preference for crop landraces compared to hybrid varieties,

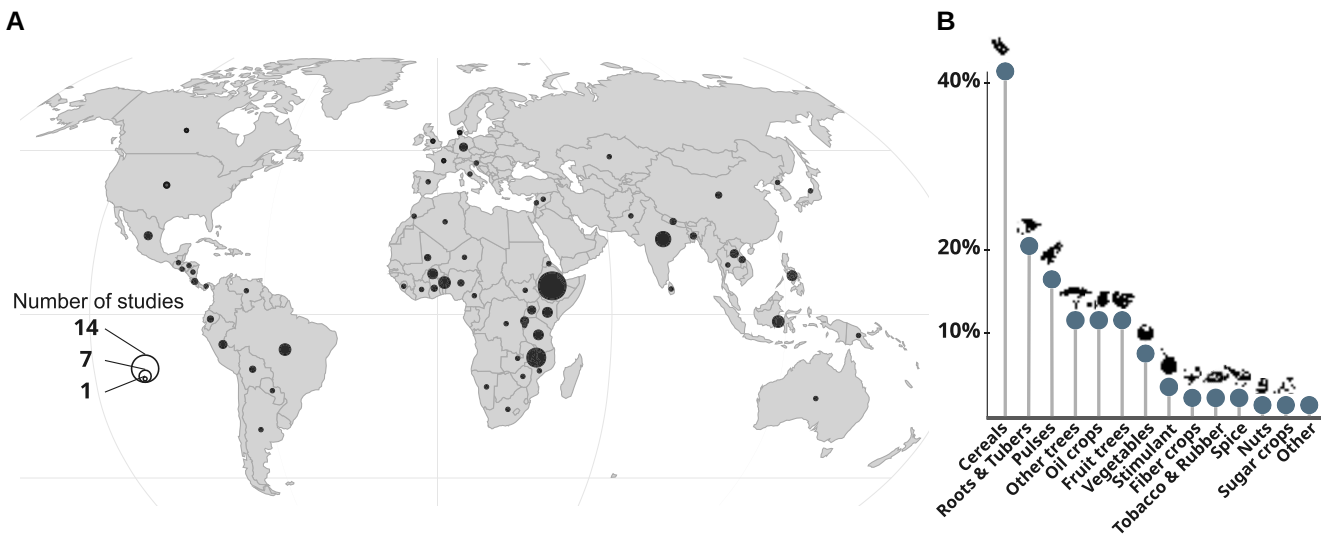

Fig. 1. Representation of countries and crop types in the reviewed literature on values. A) Map of the distribution of the 125 studies. The size of the circles is proportional to the number of case studies per country. B) Proportion of studies considering the different crop types.

as they valued the better performance of some landraces when faced with climatic change, extreme weather events, or pest and disease attacks.

We found that the frequency of citations did not necessarily reflect the importance of values for farmers (the relative importance of values was evaluated in 49% of articles). Income and yield were ranked as top priority or most important about half of the time (in 56% of studies for yield, 51% for monetary value), but several studies suggest that additional dimensions of farmers' activities are also important. For example, Tekken et al. (28) report that elder rice cultivators in Vietnam and the Philippines attached more value to the social dimension of traditional rice varieties, including traditional rice varieties' contributions to identity, shared traditions, and sense of place, than to reducing their workload or increasing their income. We found that although the domain of *Cultural preferences* only received 11% of all the citations, a large

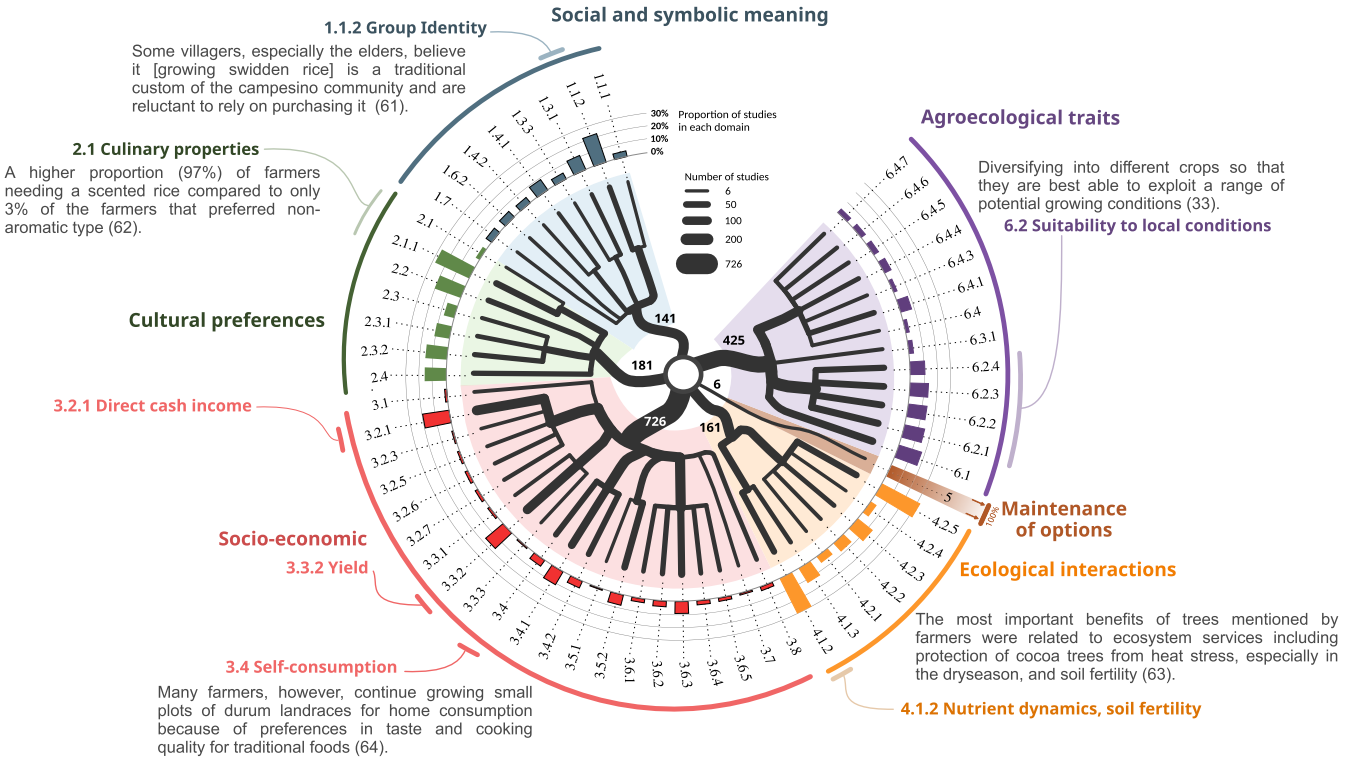

Fig. 2. Diversity of farmers' values. Circular tree of values resulting from our review analysis, with illustrations of frequently cited values. Our classification is divided here into three levels. The largest branches (close to the center of the circle) represent the six domains, which are color-coded. The third level, leaves of the tree, offers a fine level of description of values. Our analyses were conducted at the second, intermediate level. Bar plots show the overall proportion of reports in the literature for each value across domains. Values at level 2 are detailed in Fig. 3, full classification details can be found in the data (see Data Availability).

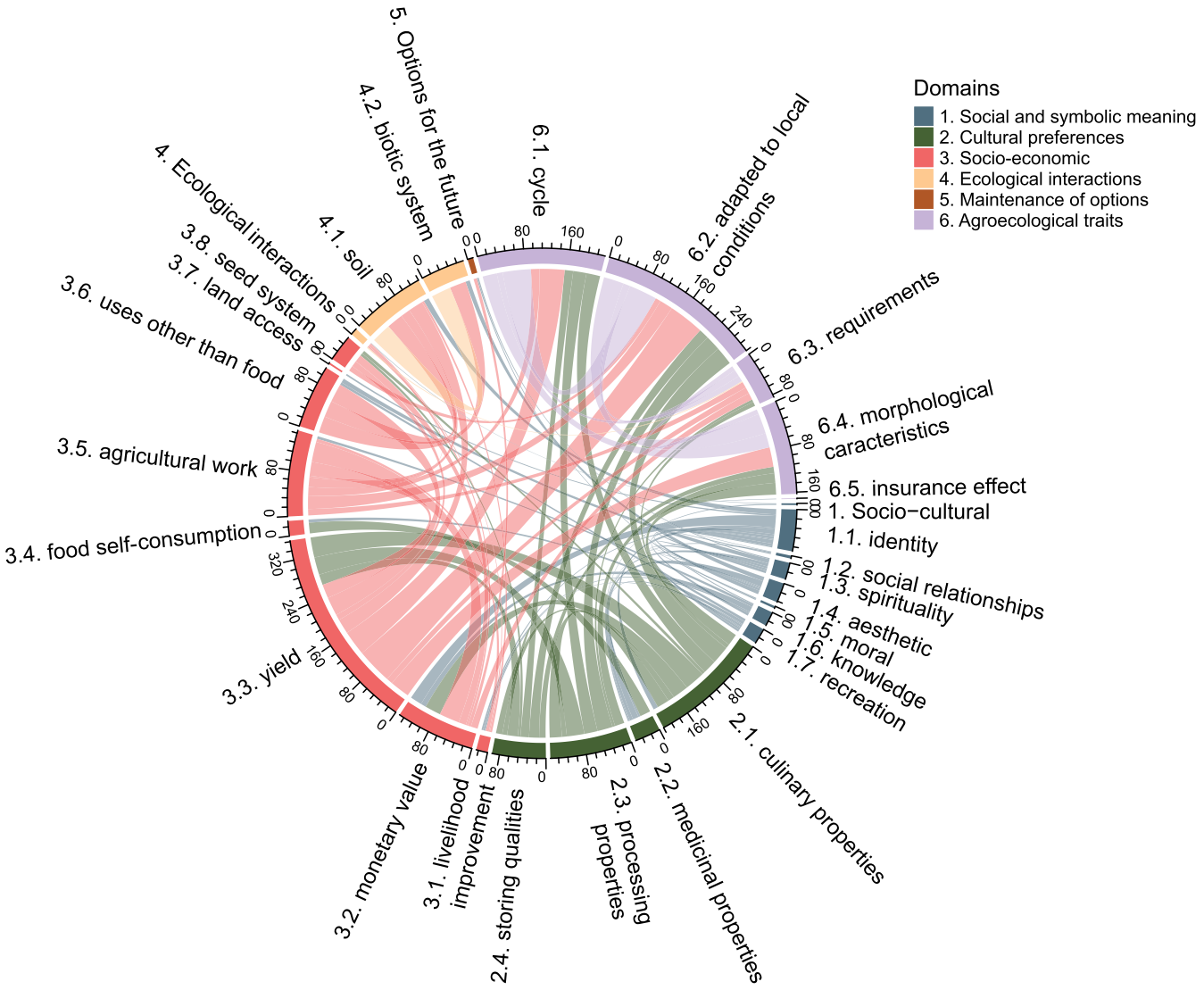

Fig. 3. Values are connected. Chord diagram showing the significant co-occurrence of citations among values (level 2) from the six value domains (n = 1,306 connections in total).

proportion of values from this domain (64%) were ranked as top priority or most important by farmers. This domain groups farmers' values related to crops' culinary, processing and storage properties, as well as their healing capacities.

Although less frequently cited overall, we found many values of rice (*Oryza sativa*) in the *Social and symbolic meaning* domain (10%) that refers to the emotional and ethical bonds between humans and crops. For rice, identity-related values (individual or collective) account for 22% of total value reports for this crop (n = 167). Fujisawa's work (29) illustrates how a community of farmers in Panama identify themselves as "*arroceros*," or "rice cultivators", to express the centrality of this crop in their way of life. Among the least frequently cited values, those related to the interactions among crops, and between crops and other life forms (e.g. pollinators [e.g. (30)] and companion plants [e.g. (31)]), and between crops and the pedoclimatic environment, all captured in the *Ecological interactions* domain (10%). The last domain included values related to *Maintenance of options* (0.3%), which refers to crops' ability to meet farmers' needs and to support production in the face of a changing and often unpredictable environment [e.g. (13)].

Farmers' values ascribed to crops are connected

We found a mean of 14 ± 11 [SD] citations referring to values per article. Our analysis of co-occurrence of values per article revealed different types of connections within and between domains. Within the *Agroecological traits* domain, about a quarter of co-occurrences (24%) involved values within the same domain (Fig. 3). In such cases, studies provide long and detailed lists of farmers' reports related to crops' physiological and morphological characteristics, environmental needs, and resistance traits [e.g. for cassava (25), potato (32), or rice (20)]. However, most articles (90%) reported values for more than one domain. Values from domains of *Socio-economic* and *Agroecological traits* on the one hand, and *Cultural preferences* and *Agroecological traits* on the other hand, were the most frequently cited together in the same article and for the same crop (19 and 17% of all citations, respectively). Values related to identity (value 1.1 in Fig. 3) and yield (value 3.3) had high centrality values, meaning they had the highest number of significant connections with other values (11, respectively). Interestingly, of all values significantly cited along with identity, the most frequent connection was with crop monetary value (value 3.2). No significant connection between identify and

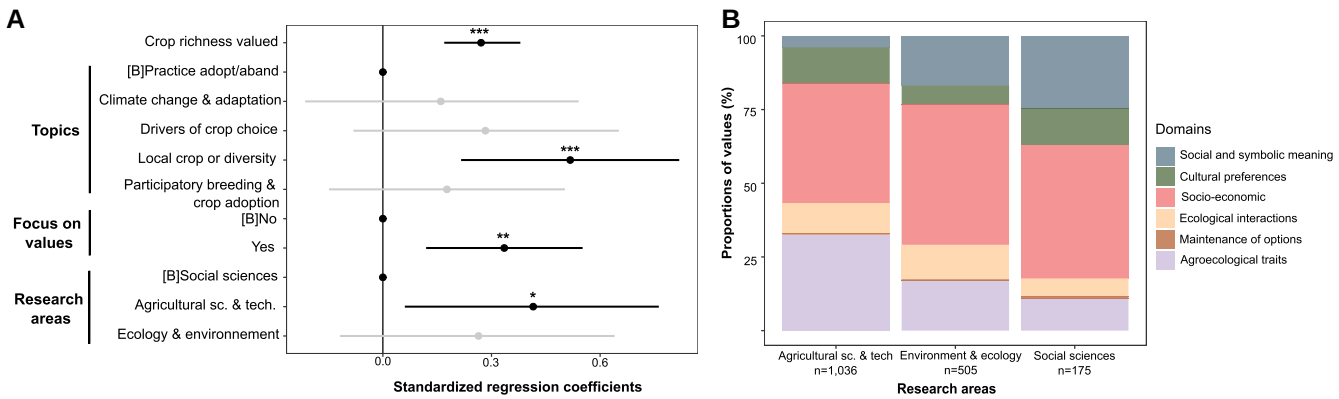

Fig. 4. Relation between research approach and diversity of values. A) Regression coefficients and their 95% CI showing the magnitude of the effects of studies' characteristics on the number of values reported. Article characteristics include the number of crops valued, the study's main topic, the study focus (or lack of) on values, and the journal research area. Effects of categorical variables (e.g. topic) on the number of values are interpreted relative to an omitted category [preceded by (B)]. For example, articles aiming at studying the cultivation of local crops or of crop diversity had a significantly higher number of reported values compared to articles on adoption or abandonment of practices. Black dots and bars indicate a significant effect of the corresponding variable ($^{*}P = <0.05$, $^{**}P = <0.01$, $^{***}P < 0.001$) in contrast to gray dots and bars, which denote nonsignificant effects ($P > 0.05$). B) Proportion of value reports per domain for articles published in the three research areas. Numbers in parentheses indicate the total number of reports of values per research area.

yield was found. Conversely, yield was frequently connected to culinary, processing and storing qualities (values 2.1, 2.3, 2.4, representing 26% of the co-occurrences with yield).

Values vary across farming systems and crop types

On average, studies focusing on market-oriented farms cited fewer values (9 ± 8, 21 articles) compared to studies focusing on farming systems based on subsistence and local markets (14 ± 9, 71 articles). Although crop monetary value was the most frequently reported value in both types of systems (*Socio-economic* account for 46 and 43% of all citations, respectively for subsistence and market-oriented systems). Smallholder farmers also frequently valued crops for their suitability to local conditions (*Agroecological traits* domain, 24% of all citations) and food self-consumption (*Socio-economic* domain, 10%). Farmers oriented towards national/global markets frequently valued crops for their biotic interactions (*Ecological interactions* domain, 19%) and for identity-related values (*Social and symbolic meanings* domain, 15%). Grape growers in South Australia reported that "We have got some vineyards over a hundred years old still; so they are some of the oldest vineyards in the world apparently; so there is a lot of heritage there" [in Ref. (33)].

Across all farming systems, annual (representing 48% of all values reported) and perennial crops (33%) were both valued for their suitability to local conditions (e.g. stress resistance) and source of cash. However, perennials, most represented in agroforestry systems, were also valued for their multiple usages (e.g. source of fodder and energy) while morphological traits were important values reported for annuals (mainly cereals but also tubers). Values of cash and staple crops (27 and 20% of all species, respectively) were mainly related to the *Socio-economic* domain (cash crops: 52%; e.g. monetary value; staple crops: 40%; e.g. food self-consumption) and the *Agroecological traits* domain (cash: 17%, staple: 28%; both mainly for suitability to local conditions). The main differences between cash and staple crops were found for values in the domains of *Cultural preferences* (cash: 4%, staple: 16%).

When the diversity of crops in an agroecosystem was valued as a whole (in only 14% of studies), usages other than food [e.g. fodder, energy, construction (20–22)], monetary value and identity [e.g. (33)] were the values most frequently reported in the *Socio-economic* and *Social and symbolic meanings* domains, respectively. Biotic interactions (in the *Ecological interaction* domain) were also important to farmers, especially in the prevention or mitigation of climate hazards. Farmers in Uganda explain, for example, that the diversity of banana cultivars contributes to "risk avoidance because each cultivar has its own strengths and weaknesses" [(34) p. 126].

Values reported relate to studies' academic field

We found large variations in the number of values reported across the studies analyzed. This variation is explained by the number of crops evaluated in each study ($\chi^2 = 31$, df = 1, $P < 0.001$), the overall topic of the study ($\chi^2 = 12$, $df = 4$, $P < 0.05$), whether or not the assessment of values was the study's primary goal ($\chi^2 = 9$, $df = 1$, $P < 0.01$), and the study's research area ($\chi^2 = 6$, df = 2, $P = 0.06$) ($n = 123$, Fig. 4). While most studies focused on farmers' values of only one crop (56%), the diversity of values increased with the number of crops studied (Fig. 4A). Greater diversity of values was also reported in studies on local crop diversity, from the landrace [i.e. cassava (25)] to the agroecosystem [i.e. coffee agroforests (31)] levels, and published in the area of "Agricultural science and technology." The research area of the publication influenced not only the diversity of values but also the type of values reported (Fisher exact test, $P < 0.001$). Studies from the "Agricultural science and technology" area reported a larger proportion of values from the *Agroecological traits* domain (33%) whereas studies in the "Social and human sciences" area reported a higher proportion of values of the *Social and symbolic meaning* (25%) domain (Fig. 4B). More specifically, identity-related values at both individual and group levels, were illuminated by studies in the "Social and human sciences" area on various crop models [rice (35), barley (36), and oca (37)] using qualitative methods including semistructured interviews.

Values interact with contextual factors in crop choice

Most studies (79%) also report factors that are external to the farming system but that interact with farmers' values to influence crop choice. Economic and political factors, such as market prices and national policies, were the two most frequently cited factors influencing crop choice [in 37 and 28% of studies, respectively

(Supplementary Fig. S2)]. For example, market prices have driven the adoption in tropical agroforests of high-value fruit crops including durian (*Durio zibethinus*), langsat (*Lansium domesticum*), and pineapple (*Ananas comosus*) (38, 39). After economy and policy, ecological factors were the third most cited external factor affecting farmers' crop choices (cited in 24% of studies), reflecting concerns related to adaptation to harsh environmental conditions and climate change.

Discussion

This study presents the first global compilation of farmers' values of crops as reported in the literature. It clearly illustrates the diversity of values farmers ascribe to crops and the intertwining of economic, agronomic, ecological, and sociocultural dimensions of agricultural values. We provide robust evidence that, while economic values are important to farmers across farming systems and directly relate to the primary objectives of agricultural activities, they constitute an overly narrow understanding of how farmers value crops. Our results point to the significance of social and cultural values of crops, which extend beyond agronomic and economic performance. Our review further suggests that the values farmers associate with crops often align, rather than trade-off, and are dynamic, evolving in response to changing contexts.

Before discussing these findings, we acknowledge several limitations that may affect their interpretation. First, our sample of reviewed articles is geographically skewed and disproportionately focused on smallholders, limiting the comparative analysis between smallholder and industrial farmers. This unbalance highlights the unequal research attention given to different farming systems. Nonetheless, our sample is representative of the global farming population, where smallholder farmers comprise approximately 84% of all farmers worldwide (40). Second, current academic approaches lead to biases in the diversity and types of values reported in the literature. A large proportion of reviewed studies were published in the "Agricultural science and technology" research area and primarily report values related to crop morphology, physiology, and uses, often overlooking the intangible sociocultural bonds between farmers and crops. Sociocultural aspects are more frequently documented in studies from the "Social and human sciences," which conversely tend to underestimate the importance of values related to ecological interactions and agroecological traits. While acknowledging that disciplinary biases risk skewing and narrowing the scope of reported values, results from our study importantly point to the need for interdisciplinary approaches drawing on complementary conceptual frameworks and tools. Engaging agronomic research with research in social sciences, for example through biocultural approaches (41, 42), can help us reach a more comprehensive image of farmers' own point of view on crops instead of projecting what is important for scientists according to their discipline (43).

Additional factors may also contribute to the unequal representation of values and their interconnections. For example, some values may remain overlooked: either because they are not spontaneously or explicitly articulated by farmers, or because methodological constraints linked to the diversity of methods used by different disciplines, each with its own focus, may bias farmers' responses or the way responses are transcribed by scientists. Furthermore, the reliance on co-citation patterns as proxies for value alignment or trade-offs inherently limits interpretive depth. Translating locally grounded meanings into broader analytical categories that isolate values from one another is an additional challenge, subject to the risk of overgeneralization, loss of nuance on how farmers prioritize, and simplification of the integrative decision-making process of farmers. Finally, the IPBES framework constituted the basis for our work. Although our classification of values assigned to crops shows numerous overlaps with the instrumental and relational values identified by IPBES, notable differences also emerge, most notably the absence of intrinsic values in our framework. These differences likely reflect the fact that the IPBES classification was originally developed for wild biodiversity and ecosystems. Despite the limitations of our work, we thus argue that developing a classification of values specifically focused on managed biodiversity—such as crops—offers a necessary common framework for understanding farmers' values and fosters dialogue across disciplines and knowledge systems. In the face of urgent agricultural challenges, such holistic frameworks can support more inclusive and context-sensitive approaches.

Despite these limitations, this study represents the most comprehensive effort to date to compile, harmonize, and classify the diverse values farmers attribute to crops across varied contexts. Importantly, this study reveals the importance of social and cultural values of crops. We found that cultural preferences, such as those regarding culinary, storage and processing qualities, are often ranked as highly important by farmers. Previous studies have demonstrated the significant role that social–cultural preferences have played in shaping the evolution and geographical distribution of crops (44) and in preventing the complete wipeout of traditional crop diversity by modern hybrids (9, 45). In line with these findings, our study contributes to show that the importance of the nonmaterial elements extends to the way farmers value crops. The finding is robust across farming systems, despite their unbalanced representation in our review. Although we found that, on average, fewer values were reported in studies focused on industrial systems, we also found that identity-related values were frequently reported on these settings. For example, ethnographic research on winemakers in Australia (33), and more recently in France (46) show the importance of the feelings of attachment and sense of belonging to the region in their cropping decisions. Greater recognition and integration of these values into research and policymaking can not only support farmer-led in situ conservation and/or promotion of crop diversity, but also nurture the intricate ties between societies and their environments and safeguard cultural heritage from global homogenization.

Importantly, our research shows that farmers engage with interconnected values that shape their relationship with crops. Cultural preferences and identity-related values play a central role into this network. The recent emphasis on nonmaterial or relational values (1) has illuminated previously neglected dimensions of human–nature relationships that are crucial for social cohesion, cultural identity, sense of place, and well-being (47). However, because these values were not fully embedded in historically dominant valuation frameworks, they have often been mischaracterized as noninstrumental and nonintrinsic rather than recognized as relational values (48). The analysis of co-citation patterns further provides a glimpse into how some values may align or come into conflict, revealing potential synergies or trade-offs in the way crops are valued. Our results suggest that social and cultural values may align with agronomic and economic performances. But further research should explore how farmers express and articulate values to select crops and crop portfolios that locally balance social, cultural, economic, and agronomic values. This is an important step in identifying pathways for sustainable intensification that respect cultural identity while supporting agronomic performances.

Our results indicate that balance across farmers' values can also be managed at the level of their crop portfolio, through crop diversity. We found a positive relationship between crop

diversity and diversity of farmers' values, a finding that can be interpreted as evidence that farmers assign different and complementary values to different crops. Analysis at both the crop group and agroecosystem levels supports this interpretation. For example, crop diversity is valued because it contributes both to healthy food and to risk management, functions that arise from the complementarity between crops in terms of nutrient contents (49) and biological responses to stresses (50). In this sense, recent case study research further illustrates that maintaining varietal diversity is a key strategy through which farmers manage value complementarity and navigate trade-offs. For example, Bassari farmers in Senegal maintain lower-yielding varieties that have superior organoleptic qualities, symbolic value, or cultural significance (51). Shifting the focus from examining the value of a single crop, the dominant approach in the literature we reviewed, to examining multiple species and intraspecific diversity offers a more comprehensive understanding of how crop diversity underpins value diversity. This shift is critical not only for advancing knowledge of how interconnected values shape farmers' decision-making but also for expanding the scope of agricultural diversification research beyond its current emphasis on ecological and agronomic functions (5, 52).

Our results highlight that farmers' values interact with markets, policies, and climate change to shape crop choice. Further exploring these interactions offers promising research directions. Existing literature highlights that economic and agricultural development is a key driver of agrobiodiversity decline (9, 42), posing risks to productivity, resilience, and adaptive capacity. Agricultural intensification, through landscape simplification and crop diversity loss, is also expected to result in the erosion of farmers' values (53–55). However, Hoelle et al. (55) challenge this assumption and instead frame these shifts as opportunities for reconfiguration and for fostering the emergence of new ways of engaging with nature. In other words, the introduction of new crops and the abandonment of others do not necessarily lead to an erosion of values, but instead can foster new relationships between farmers and their crops, support alternative food practices, and contribute to the revitalization of local identities and cultural practices. More attention should be devoted to evaluate the dynamic process of changes in values that can either drive or result from changes in agrobiodiversity, through loss, gain, or recomposition of farmers' crop portfolios. Up to now, the rate at which economic, agronomic, and sociocultural values are changing, the potential shift in their relative importance to farmers, and how these dynamics intersect with individuals' characteristics (e.g. age, gender, education) are poorly understood. To better assess implications for human well-being and environmental sustainability, greater attention must be directed toward rapidly evolving smallholder farming systems, where agricultural intensification and climate change are increasingly influential in driving change, while also considering simplified, more intensive farms in the Global North—for which we identified a major gap in knowledge.

Conclusions

Our work provides evidence that strengthens the recognition of farmers' stewardship of agricultural systems. It also deepens our understanding of the complexity that underpins farmers' values towards crops, while de-emphasizing the importance of economy and yield in agricultural policymaking (11). This study points to the importance of developing research approaches best suited to encompass the large set of farmers' values, based on both qualitative and quantitative methods. Nevertheless, this literature review contributes to extend our understanding of the interconnected nature of environmental, sociocultural, and economic values beyond natural ecosystems to agricultural contexts. Although agroecosystems are considered less natural than other ecosystems, they are nevertheless characterized by complex relationships between different values. In line with IPBES recommendations, and extending them, this research emphasizes the need to integrate farmers' diverse values towards crops into policymaking. Recognizing the importance of socially and culturally grounded values is essential to draw a more realistic picture of what matters to farmers and thus support more adequate and effective decisions that address the intricate agrobiodiversity and sustainability crises facing modern agriculture. Achieving this will require expanding the range of values, crops and farming systems, employing not only interdisciplinary but also transdisciplinary approaches that actively involve farmers and recognize them as knowledge holders and stewards of their crops and fields. Such approaches are critical for developing solutions that tackle the interconnected challenges of farmers' ill-being, population growth, climate change, and crises of biodiversity, including agrobiodiversity. Despite its limitations, our classification offers a foundation for further work to articulate context-specific values, rooted in local knowledge alongside generalizable insights, for policymakers, addressing both commonalities and differences in conceptualizations of farmer–crop relationships.

Materials and methods

We used the Web of Science (WOS) search engine to select academic articles published in English between 2010 and 2022 and describing farmers' values underpinning the choice of crops and crop diversity in their fields. The set of keywords included various proxies of values such as preferences, importance, motivations, and attachment (list in Supplementary materials).

The initial search resulted in 3,719 documents, of which we retained only research articles, excluding reviews, books, and conference articles. The titles and abstracts of the remaining 3,582 articles were systematically screened by five authors of this work using the Colander online platform (56). We focused on three inclusion criteria: (i) the articles reflect farmers' perspectives, (ii) the articles are based on first-hand data, including qualitative, quantitative, or mixed approaches, and (iii) the articles focus on crops/crop-based agroecosystems (including all crop plants, whether grown for food or for any other use but and excluding domestic animals) managed by farmers at the time of the initial research. We used the same criteria and refined our selection by reading the materials and methods and results sections of the 574 remaining articles. After the screening phases, we obtained a final set of 125 articles that met our inclusion criteria. For each of these articles, we extracted bibliometric information from WOS (e.g. DOI, authors, year of publication, research area; see Supporting information), information on the study including methods used to collect farmers' values, main topic, whether the article focused on values or not, the geographical, social and agricultural context of the study (e.g. geographic coordinates, integration into the market economy, area of lands cultivated by the household, agroecosystem type), the identity and details of the crops studied (e.g. scientific and common name, species or variety level, staple/cash crop, modern/landrace), and the values associated (see Supporting information). A report of value refers to the explicit or implicit expression of what farmers consider important in relation to their crops. We characterized each crop as annual or perennial, and according to crop groups: cereals, oil crops, sugar crops, legumes, roots and tubers, nuts, stimulants, and spices. Research areas defined by WOS cover five categories: Agriculture, Environmental sciences, Agronomy, Anthropology, and Food science and technology. To avoid redundancy, we collapsed

these groups into three: Agricultural science and technology, Environmental sciences and biodiversity, and Social and human sciences. We ordered all values collected from the 125 articles into 94 categories, organized in four hierarchical levels, from the fourth, most detailed level, to the first, i.e. broad domain, level (see Fig. 2, level 3). To do this, we used a mixed deductive-inductive method rooted in the conceptual academic literature on values (57) and completed with reports of values found in the 125 case studies reviewed. Exchanges between the five different coders (among authors: M.D., T.C., Y.A.T., D.R., and A.P.F.) led to refining categories and confronting their views until consensus was found. We agreed on broad categories and four different levels or sub-categories of value. A complete and final revision was done by one coder (DR) to homogenize the classification, based on verbatim transcripts. In addition to this final step, we tested for an effect of coders on the number of values recorded. To do this, we used a linear model that controls for the interaction between the number of crops within each paper and the coder and found no significant effect. A first classification based on a sample of articles ($n = 12$) was approved and used for the IPBES values assessment (58).

We acknowledge that our review approach to identifying values is mediated by our own value system and the value systems and interests of the scientists who conducted the individual case studies included in this literature review. We also acknowledge that other, possibly complementary, values can be found in alternative sources such as Indigenous science and books on various themes. Also, while English is not only the main language for international academic knowledge but also a colonial language, we acknowledge that publications in other languages may hold values that we have missed. However, we also note that the fact that we might not have collected an exhaustive classification of values reflects the conservative nature of our findings on the diverse values of crops, perhaps making our study more robust.

Analyses

Data were analyzed using R v.4.0.4 (59). We calculated the frequency of citation of each value coded from the literature, focusing at the second and first (i.e. broad domain) levels of classification. Frequencies of citation were calculated per type of agroecosystem (i.e. systems based on subsistence and locally oriented market, systems oriented towards national to global market), crop species, and crop types (i.e. staple vs. cash crops, annual vs. perennial crops). To understand the interconnectedness between domains and values level 2, we calculated the probability (i.e. maximum likelihood estimate) of co-occurrence of each pair of values in the same article for a given crop, by using a co-occurrence index (alpha) from the R package Co-occurrence Affinity (60). We retained only pairs of values with a positive and significant affinity index. One indicator of alignment or trade-offs between values—that we could derive from our review—is co-citation and lack of co-citation, respectively. Then, we identified the values that were the most connected to other values using the degree function, an index of network centrality, from the Igraph package (61), on the undirected network. We used a negative binomial generalized linear model to identify variables influencing the number of values cited per article. Variables used in the model were the number of crops studied (species or varieties, quantitative variable), whether the study focused on values or not (binomial variable), the area of research (categorical variable), and the main topic of the study (categorical variable). The model included 123 of the 125 initial studies because the general topics of two articles were classified as "other." This family of model was chosen to avoid the overdispersion associated with poisson glm. We assessed the model's goZodness-of-fit using the R package DHARMa (62). We then used a Type II Anova to assess the significance of each variable in the model. We tested whether values from the six domains were randomly distributed across the three research areas of the 125 publications using a Fisher exact test.

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Supplementary Material

Supplementary material is available at *PNAS Nexus* online.

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Author Contributions

Marilou Demongeot (Conceptualization, Data curation, Formal analysis, Validation, Investigation, Visualization, Methodology, Writing—original draft, Writing—review & editing), Antoine Doncieux (Data curation, Formal analysis, Validation, Investigation, Visualization, Methodology, Writing—original draft, Writing—review & editing), Tatiana Cardenas (Conceptualization, Data curation, Validation, Investigation, Methodology, Writing—original draft), Anna Porcuna-Ferrer (Conceptualization, Data curation, Validation, Investigation, Methodology, Writing—original draft, Writing—review & editing), Yildiz Aumeeruddy-Thomas (Conceptualization, Data curation, Validation, Investigation, Methodology, Writing—original draft, Writing—review & editing), Sophie Caillon (Conceptualization, Validation, Methodology, Writing—original draft), Jonathan Locqueville (Conceptualization, Data curation, Formal analysis), Doyle B. McKey (Conceptualization, Writing—original draft, Writing—review & editing), Victoria Reyes-Garcia (Conceptualization, Funding acquisition, Validation, Investigation, Visualization, Methodology, Project administration, Writing—original draft, Writing—review & editing), and Delphine Renard (Conceptualization, Data curation, Formal analysis, Supervision, Funding acquisition, Validation, Investigation, Visualization, Methodology, Writing—original draft, Project administration, Writing—review & editing)

Data Availability

All the data and R scripts used for analyses are shared here: https://github.com/AntoineDoncieux/crops_values_review.

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