Aligning research with policy and practice for sustainable agricultural land systems in Europe

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Agriculture is widely recognized as critical to achieving the Sustainable Development Goals (SDGs), but researchers, policymakers, and practitioners have multiple, often conflicting yet poorly documented priorities on how agriculture could or should support achieving the SDGs. Here, we assess consensus and divergence in priorities for agricultural systems among research, policy, and practice perspectives and discuss the implications for research on trade-offs among competing goals. We analyzed the priorities given to 239 environmental and social drivers, management choices, and outcomes of agricultural systems from 69 research articles, the SDGs and four EU policies, and seven agricultural sustainability assessment tools aimed at farmers. We found all three perspectives recognize 32 variables as key to agricultural systems, providing a shared area of focus for agriculture's contribution to the SDGs. However, 207 variables appear in only one or two perspectives, implying that potential trade-offs may be overlooked if evaluated from only one perspective. We identified four approaches to agricultural land systems research in Europe that omit most of the variables considered important from policy and practice perspectives. We posit that the four approaches reflect prevailing paradigms of research design and data analysis and suggest future research design should consider including the 32 shared variables as a starting point for more policy- and practice-relevant research. Our identification of shared priorities from different perspectives and attention to environmental and social domains and the functional role of system components provide a concrete basis to encourage codesigned and systems-based research approaches to guide agriculture's contribution to the SDGs.

farming systems | trade-offs | codesigned research | communication | science policy

Agriculture is essential to achieving the United Nations' Sustainable Development Goals (SDGs) because of the important nutritional, economic, social, and cultural benefits it provides to people (1–3). However, agriculture also has substantial negative impacts on land (4), biodiversity (5), water (6), and the global climate (7)—for example, agriculture contributes between 15% and 25% of global greenhouse gas emissions (7) and consumes ∼70% of global freshwater withdrawals (8). Researchers and policymakers increasingly recognize that actions to achieve one SDG might constrain achievement of other SDGs (9), which is especially true for competing demands between agriculture and other land uses (10, 11). For example, food production (SDG 2), along with biodiversity (SDG 15) and freshwater resources (SDG 6), may be threatened by using land for climate mitigation (SDG 13) (12). Evaluating such trade-offs is necessary to make prudent, evidence-based policy decisions.

In contrast to the democratic development of the SDGs across stakeholder groups, evaluation of their trade-offs has so far been primarily an academic exercise in which teams of researchers qualitatively and/or hypothetically assess interactions among goals (e.g., 9, 13) without including perspectives of other stakeholders (14). Implementation of the SDGs requires governments, the private sector, and civil society to act together and put innovations into practice (15), guided by transdisciplinary research that cocreates and widely shares knowledge with stakeholders (16, 17). We argue that to comprehensively evaluate relevant sustainability trade-offs in agriculture, research must acknowledge the perspectives of not only the policymakers who set goals and incentives to reach them, but also the practitioners who actually manage the land—both of whom have different priorities for agriculture (18, 19).

Integrating different perspectives and priorities in agriculture, as well as balancing competing land uses and evaluating trade-offs, requires systems approaches to agricultural research (20, 21). Agricultural land systems are complex social-ecological systems in which many components from the environmental and social domains interact with each other across a range of spatial and temporal scales (3, 21, 22). These components (observed as variables) of agricultural systems could take one of three broad functional roles (Fig. 1): (*i*) drivers, such as precipitation or subsidies that directly or indirectly affect agricultural land use; (*ii*) management choices that farmers implement on the ground, such as tillage or irrigation; and (*iii*) outcomes, which may be positive (e.g., income) or negative (e.g., soil erosion) and may have trade-offs or synergies with other outcomes (14).

In this study, we conduct a quantitative analysis of the domain (environmental or social) and functional role (driver, management choice, or outcome) of agricultural system variables (Fig. 1) from the three perspectives: research, policy, and practice (farmers and extension services). We use the European Union (EU) as a case study because of its commitment to be a global leader in achieving the SDGs (24). For the research perspective, we analyze 69 peer-reviewed articles (22) from agricultural land systems research because of its integrated, interdisciplinary, and stakeholder-oriented agenda (21), which is well-positioned to

Significance

Research, policy, and practice should be integrated to understand, guide, and implement the changes necessary to achieve the Sustainable Development Goals (SDGs). However, from an analysis of research literature, policy indicators, and assessment tools for agriculture in Europe, we find that more than half of the 239 variables identified are currently used by only one of these perspectives. We identify a limited set of 32 variables that all three perspectives share and suggest these can be a starting point for designing future research to more comprehensively analyze trade-offs and identify opportunities for achieving the SDGs. Our method for assessing differences among perspectives in research, policy, and practice is a way to balance and implement sustainability goals for sectors and regions.

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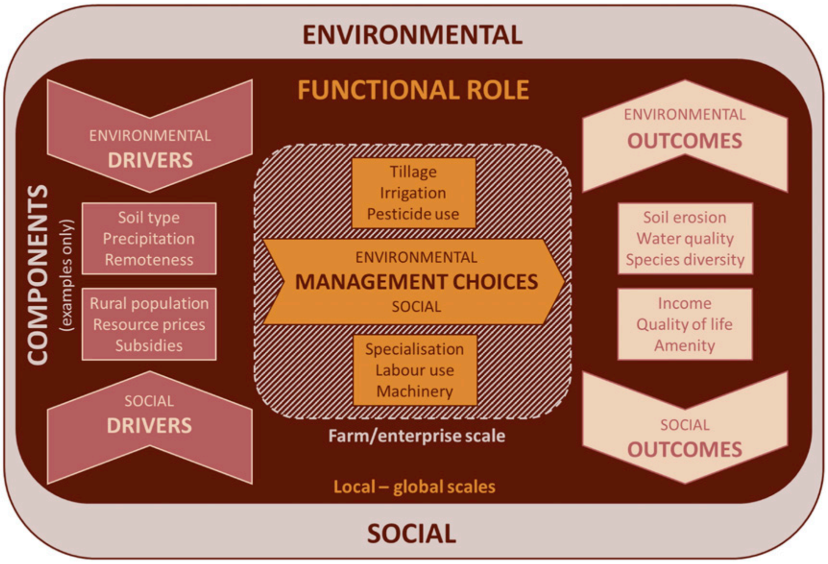

Fig. 1. Conceptual model of agricultural land systems for holistic research supporting the SDGs. System components (parts of the system that interact with other parts) can be observed as variables (something that can vary in space and/or time) in agricultural systems, with examples of variables shown here in boxes (see Dataset S1 for full list). Studies may operationalize variables into qualitative or quantitative indicators (e.g., mean annual precipitation). We classify components of agricultural systems as belonging to either the environmental or social (including economic) domain based on the classification in ref. 22. Including components from both environmental and social domains and across functional system roles (drivers, management choices, or outcomes) enables holistic research to analyze system processes and trade-offs. (Adapted with permission from ref. 23).

lead research on agricultural systems for the SDGs. For the policy perspective, we analyze five policies: the global SDGs, the EU's implementation of SDG indicators, the EU's Sustainable Development Strategy, the EU's Common Agricultural Policy, and the latter's associated agri-environmental indicators. Lastly, we gauge the practice perspective based on a review of seven agricultural sustainability assessment tools that seek to inform the practices of farmers and their extension services (e.g., the Sustainability Assessment of Food and Agriculture systems, www.fao.org/nr/sustainability/sustainability-assessments-safa/en/; see list of tools in *SI Appendix*, Table S1). We use agricultural land systems research as an illustration of how one research field important for contributing the SDGs currently aligns with agricultural policy and practice perspectives; other fields may have different foci.

We identify 32 variables across the environmental and social domains of agricultural systems that are shared by research, policy, and practice. An additional 207 variables, however, are considered from only one or two perspectives, indicating that taking an individual (e.g., research-only) perspective on trade-offs in agricultural systems limits the possibility to understand, incentivize, and achieve the SDGs. We statistically analyze current agricultural land systems research in Europe, identifying four dominant approaches, none of which fully encompasses the 32 variables of shared importance. We argue that the prevailing data and methodological paradigms, as well as the limited adoption of systems approaches, prevent current European agricultural land system research from more fully meeting the needs of policy and practice. We identify opportunities for research to integrate perspectives from policy and practice, particularly through systems approaches, codesign of research, and communication with policymakers and practitioners. Such integration will support research that better evaluates trade-offs and guides agriculture's contribution to the SDGs.

Results

Components of Agricultural Systems from Research, Policy, and Practice. From cataloging all indicators measured or listed in a research, policy, or assessment tool (practice) document, we identified more than 800 specific indicators. We aggregated these to a final list of 239 more-general variables of environmental and social drivers, management choices, and outcomes (Dataset S1). The variables were relatively evenly distributed between the environmental and social domains (Fig. 2*A*), reflecting the balanced importance given to the environment and society in agricultural systems.

In terms of system function, social drivers comprised the largest number of variables, followed by environmental drivers and management choices (Fig. 2*A*). Policies can influence many of the economic and political drivers in the social domain of agricultural systems, whereas environmental drivers may be more difficult to adjust, depending on the temporal and spatial scales being considered. This is perhaps why policies and assessment tools contained so few environmental drivers (e.g., soils, topography, climate) compared with the research reviewed (Fig. 2*B*). The large number of environmental management choices compared with social ones (Fig. 2*A*) reflects the importance from all three perspectives of managing the land on which agriculture relies (Fig. 2*B* compared with Fig. 2*C*). Simultaneously, this finding may indicate that the importance of managing social aspects of agricultural systems has, to date, been underrecognized in Europe. Alternatively, there may simply be fewer social components that can be managed and manipulated in agricultural systems. Social outcomes of agricultural systems also appear to be underresearched (from a land systems perspective, *sensu* ref. 22), relative to the importance of social outcomes emphasized in policy and practice (Fig. 2*C*).

We found a small core set of 32 variables shared among research, policy, and practice, comprising less than 13% of all variables. This suggests a limited consensus among the three perspectives regarding what is considered important for agricultural systems. Consensus among the three perspectives was greatest in environmental management choices, followed by social drivers and environmental outcomes (Fig. 3). The majority (56%) of environmental variables shared by the three perspectives related to soil and biodiversity (which are additional categories described in ref. 22 used to classify agricultural land system components; *SI Appendix*, Figs. S1 and S2), including variables such as tillage, fertilizer use, soil erosion, and pesticides (Fig. 3). Six of the 14 shared social variables related to political drivers, including policies on climate, environment, and agriculture, as well as subsidies and land ownership (Fig. 3). Despite the relatively large emphasis on social outcomes in policies and assessment tools (Fig. 2*C*), only four variables in this category were also shared by research: income, yield, labor productivity, and un/employment rates (Fig. 3). Social outcomes of agricultural systems appear to be underresearched in European land systems research (22), and evaluation of trade-offs among outcomes from a research-only perspective may overlook many variables important to policy and practice.

We use the term "consensus" to indicate the 32 variables included from all three perspectives, but this does not imply that they are equally or similarly prioritized from each perspective. The 32 consensus variables are not a complete list of all potentially important variables for agriculture and the SDGs, but they represent a set of currently shared priorities in research, policy, and practice that could be expanded. For example, water quality is an important environmental outcome of agricultural systems

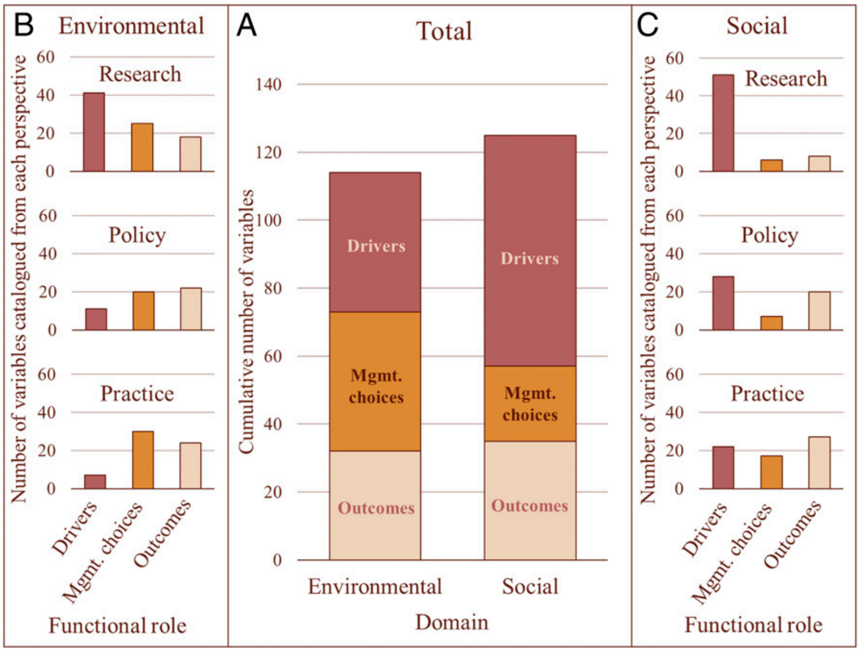

Fig. 2. The focus of research (69 peer-reviewed articles), policy (5 policies), and practice (7 agricultural sustainability assessment tools) on different agricultural system variables in Europe. (*A*) Total number of environmental and social variables of agricultural systems classified by their functional role as drivers, management choices, or outcomes. (*B*) Emphasis of the three perspectives on functional roles of variables in the environmental domain. (*C*) Emphasis of the three perspectives on functional roles of variables in the social domain.

(e.g., ref. 6) and is not in this list of 32 variables (Fig. 3). Water quality was found in policy and practice, but not in research, although it has received attention in scientific disciplines other than agricultural land systems research (22).

Divergence among research, policies, and assessment tools was far greater than consensus, with 53% of variables ($n = 126$) found in only one of the three perspectives. Research explored many environmental and social drivers that were not the subject of policy or practice (Fig. 4 *A* and *D*). Almost 80% of the variables unique to research were categorized as drivers that describe topography, climate, landscape configuration, demographics, workforce, and cultural aspects (see specific variables in Dataset S1). The absence of these drivers from the reviewed policies and assessment tools may reflect the difficulty of influencing them; alternatively, in a circular way, these drivers may be hard to adjust because of the lack of conducive policies. If research finds such drivers to be important for agricultural systems, their effects may need to be more explicitly considered in policy and practice. Research paid little attention to the environmental management choices and outcomes (e.g., relating to livestock and pollution) that were highlighted in policy and practice (Fig. 4 *B* and *C* and Dataset S1).

Policies contained 19 variables not covered by the two other perspectives, most of which related to physical health drivers and outcomes, as well as technology and innovation drivers, showing a gap in research and practice (Fig. 4 *D* and *F* and Dataset S1). Assessment tools from practice covered 11 unique variables in both the social management and social outcomes (Fig. 4 *E* and *F*). Management choices unique to practice included income diversification and community engagement, among others, indicating the importance from this perspective of managing the social domain of agricultural systems as well as the environment. Policy and practice both focused on social outcomes such as food quality (e.g., calories, nutrition), equality, and inclusion that were not covered by the reviewed research (Fig. 4*F*).

Relevance of Land Systems Research to Agricultural Policy and Practice in Europe. We analyzed the frequency of variables used in research and their functional roles to distinguish four prevailing approaches that currently dominate European agricultural land systems research: environmental determinism, production management, sociopolitical, and quasi-systematic (Box 1; *SI Appendix*, *Supplementary Results* and Fig. S12). These approaches focus on different components of agricultural systems (22) (*SI Appendix*, Figs. S1 and S12, Panels 1–3), as well as on different functional roles of drivers, management choices, and outcomes of agricultural systems (*SI Appendix*, Fig. S12, Panels 4–7). We interpret these approaches to reflect the four prevailing paradigms of agricultural land systems research design and variable choice in Europe.

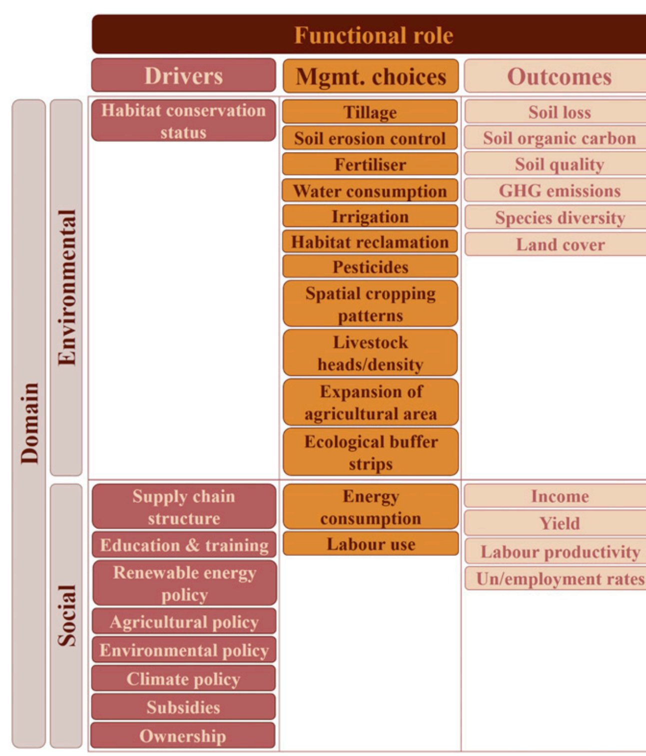

Fig. 3. The 32 agricultural system variables shared across research, policy, and practice in Europe. Variables were identified from an initial set of >800 indicators and condensed to 239 unique variables across perspectives. Each variable was then classified according to environmental or social domain (gray boxes, *Left*) and their functional role in the system as a driver, management choice, or outcome (*Top*).

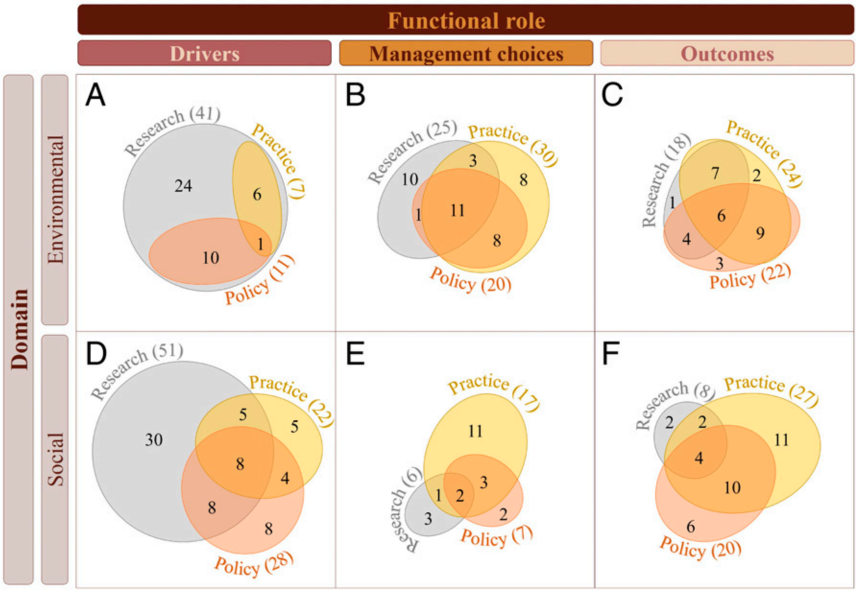

Fig. 4. Degree of overlap of 239 agricultural system variables covered in European research (69 peer-reviewed articles), policy (5 policies), and practice (7 agricultural sustainability assessment tools). Drivers (*A*), management choices (*B*), and outcomes (*C*) in the environmental domain (*Upper*); and drivers (*D*), management choices (*E*), and outcomes (*F*) in the social domain (*Lower*). The number of variables in each diagram segment is shown. Variables found in the three-part overlap in each diagram segment are listed in Fig. 3, with the full list of variables and their classification in Dataset S1. Proportional Venn diagrams were created using eulerAPE (25).

The variables that distinguished each of the four research approaches generally aligned poorly with the 32 variables shared among research, policy, and practice (*SI Appendix*, Fig. S12, Panel 3 consensus taken from Fig. 3) and related to predominant data sources and methodologies within each approach (*SI Appendix*, Table S3). Physical and landscape drivers not shared among all three perspectives typified the environmental determinism approach and reflect the dominance of maps, remote sensing, and statistical modeling in this type of research (*SI Appendix*, Table S3). Surveys, interviews, and participatory methodologies were mostly employed within the production management approach (*SI Appendix*, Table S3), which may explain the good coverage of consensus outcomes in this approach. The focus on production management variables (e.g., livestock density) in this approach likely reflects those variables relevant to the practitioners surveyed/interviewed, but the approach typically lacked coverage of contextual drivers that can affect outcomes and trade-offs. The sociopolitical approach showed good coverage of typical political drivers (e.g., indicators of agricultural policy) and occasionally demographic and cultural drivers (*SI Appendix*, Fig. S12, Panel 6), reflecting the common use of statistical data (e.g., census data); however, consensus management choices and outcomes received little attention. The quasi-systematic approach contained a wide range of variables, data sources, and multivariate analyses but was limited in coverage of consensus management choices or outcomes.

Agricultural land systems research in Europe is not focusing on many of the variables considered relevant in policy and practice, which might limit the ability of research to create knowledge on trade-offs in agricultural systems relevant for and usable by policymakers and practitioners. Research covering a wide range of environmental and social drivers, management choices, and outcomes (e.g., ref. 26) is currently rare; such research should become more mainstreamed to support achieving the SDGs. Methodological paradigms appear to be constraining such research, which may be addressed by coupling participatory approaches (found in only two of 69 articles reviewed) with traditional geographic information system (GIS) and statistical approaches that currently dominate.

Discussion

We identified 32 consensus variables currently shared across research, policy, and practice, yet we showed that agricultural land systems research in Europe largely does not include key priorities from policy and practice. We suggest that research designed to include these 32 variables would be an important starting point for better understanding and guiding agriculture's contribution to the SDGs, which could be systematically expanded using the hierarchical classification of land system components presented in ref. 22. Ultimately, a systems and codesigned approach to research will enable holistic evaluation of interactions and trade-offs among competing goals. We suggest that researchers can achieve this by going beyond current methodologically limited paradigms to using a systems approach to research design, taking advantage of existing data to include both the environmental and social domains and system components across functional roles, and that they codesign and conduct research with stakeholders.

The four dominant land systems research approaches we identified tend to focus within either the environmental or social domain and within one functional role of system components (e.g., drivers or outcomes). This limits the ability of research to achieve a holistic understanding and evaluation of trade-offs in agriculture, because the SDGs represent the environment and society as inextricably linked, and understanding system function is key to evaluating policy and management options in order to change the system toward more desired outcomes. Agricultural land systems research has great potential to lead holistic research on agriculture for the SDGs (1, 2, 21), but we posit that these four research approaches may reflect the prevailing paradigms of research design and data analysis, as opposed to the systematic and deliberate selection of policy- or practice-relevant variables (22). Thus, European land systems research may continue to focus on commonly available land cover data, remote sensing, and GIS due to data availability and spatial-analytical paradigms, without a deliberate consideration of the needs of policymakers and practitioners in research design (22).

To address the current divergence of agricultural land systems research from policy and practice, we encourage systems approaches to agricultural research in the context of sustainability and the SDGs (2, 14, 20, 27). To achieve a systems approach, researchers could expand beyond traditional paradigms to achieve balance among environmental and social components and to consider the functional role of variables as system drivers, management choices, and outcomes. We have gone beyond previous documentation of the research gaps in the social domain of agricultural systems (28–30) to identify the social variables important from policy and practice perspectives currently overlooked in European agricultural land systems research (Fig. 4 and Dataset S1). We recommend that researchers expand the current limited inclusion of social outcomes in agricultural land systems research (Fig. 2) through better use of existing data for social variables relevant to agricultural systems (for a guide to

Box 1. Four prevailing approaches to agricultural land systems research in Europe

Environmental determinism. Focuses on environmental drivers—specifically, topographic and landscape variables, with occasional climatic variables—influencing soil and/or landscape composition outcomes and, occasionally, demographic variables. The lack of management-choice variables typical of this approach suggests a system understanding that agricultural system drivers directly affect outcomes, with only limited regard to management choices.

Production management. Emphasizes the effects of agricultural production management choices on a range of environmental and economic outcomes, generally with limited or no focus on specific drivers influencing the management choices. This approach relates to the practitioners' focus on what they can do on the farm to create desired outcomes, evidenced by the focus of the reviewed assessment tools on management choices and outcomes (Fig. 2 *B* and *C*).

Sociopolitical. Stresses the importance of political drivers affecting agricultural systems, especially agricultural, environmental, and climate policies; policy reform; subsidies; laws; and land ownership. Occasionally, demographic or cultural drivers are included. However, no particular categories of management choices or outcomes are typical of this approach to research (although present in the research articles, they are highly varied), indicating a general lack of a functional system perspective within this approach.

Quasi-systematic. Comes the closest to a holistic approach to agricultural land systems research in Europe because it contains system components of all functions (drivers, management, outcomes) and across both environmental and (more limited) social domains. This approach underlines the same outcomes as the environmental determinism approach but also encompasses a diversity of social and environmental drivers as well as agricultural production management choices. Although some individual studies take a more holistic approach, the general lack of social management choices and outcomes limits this from being a truly holistic systems approach.

available data, see table 2 in ref. 22), as well as using big-data applications for extracting social variables from remotely sensed data (31), which are commonly used in agricultural land systems research. Researchers can account for system function in research design by constructing conceptual diagrams of the interactions among drivers, management choices, and outcomes in agricultural systems (e.g., figure 4 in ref. 20), which enables the subsequent testing of hypothesized interactions using data, as well as simulation modeling of system dynamics over time.

Going beyond a systems approach to research design by codesigning research that answers relevant questions from policymakers and practitioners in collaboration with these stakeholders throughout the process [i.e., from research design through dissemination (32, 33)] can also contribute to an improved alignment among research, policy, and practice in agriculture. The current gap among the priorities of research, policy and practice goes both ways. While we see great potential for researchers to design more relevant research to meet needs from policy and practice, we also note that there may be potential for researchers to better communicate the importance of environmental and social drivers of agricultural systems in Europe, which are currently well researched (Fig. 2) but largely missing from policy and practice (Fig. 4). Consideration of these drivers may be fundamentally important when the success of policy and practice depends on the environmental and social drivers that set the context of a place (34, 35), and when trade-offs manifest differently under different drivers (14, 27). While not all drivers have the potential for intervention (e.g., many topographic constraints on production cannot easily be modified in the short term), many drivers (e.g., market or institutional factors) have important potential to elicit desirable change in management choices and outcomes (36), and research on drivers that could be adjusted is likely to be more relevant for policymakers (37). If data limitations remain a problem, policymakers can commission data collection on those variables they consider important for agriculture and the SDGs to ensure their inclusion. Further research into whether our results reflect more broadly (e.g., beyond agricultural systems to food systems) the dynamics of how stakeholders seek and use scientific information should also be a priority.

Our work highlights that agricultural land systems researchers, policymakers, and practitioners in Europe currently share a small set of variables core to agricultural systems, which will play an important role in achieving the SDGs. At the same time, most other variables are currently included from only one perspective. While it may be appropriate to have many perspective-specific variables, achieving the SDGs will require greater communication and collaboration among these three perspectives to ensure that crucial variables have been included and assessed. We advocate that researchers take a systems approach, starting with the 32 consensus variables we identified here, to achieve greater relevance for policy and practice and to reveal and assess synergies and conflicts from pursuing different management approaches and policies. Even greater relevance for guiding agriculture toward achieving the SDGs could be achieved through codesigning research with stakeholders and aligning variables and the indicators used to measure them to the SDGs in order to determine which goals are well monitored and which currently lack attention (38). Although we have developed and used this quantitative, systems approach to assess the alignment among current research, policy, and practice for agricultural systems in Europe, our results are likely relevant for identifying shared priorities and evaluating trade-offs among the SDGs in agriculture in other regions, and the method can be used for other sectors to support achieving the SDGs.

Methods

Conceptualizing Agricultural System Components. We view agricultural systems within a conceptual model of environmental and social components, which could take the functional role of drivers, management choices, or outcomes. This conceptual model is a simplification of similar agricultural and food systems models (e.g., refs. 2 and 23) and could be applied at multiple scales (Fig. 1).

We define drivers as the environmental or social system components that directly or indirectly affect agricultural land use. Some drivers may be altered through policy (e.g., subsidies), whereas others are relatively fixed over short timescales (e.g., topography). Examples of drivers include topography, climate, markets, subsidies, and cultural values, depending on the context of interest. Defining drivers depends on spatial and temporal scales (39), because outcomes may themselves be drivers at other scales or in other contexts and, over time, feedbacks from outcomes could also influence drivers (e.g., ref. 20).

We define management choices as the agricultural human activity that can be influenced by drivers and can subsequently affect environmental and social outcomes. Such choices are predominantly on-farm (i.e., farm-scale) decisions and the resultant use of agricultural land or resources. Examples of management choices include crop choice, fertilizer application, volumes of irrigation water, use of machinery, and stocking rates. We consider management choices to be predominantly implemented at smaller spatial and temporal scales (e.g., fields to farms and days to months, respectively). However, they may be repeated over larger scales (e.g., regions and years) and may be influenced by drivers and outcomes from multiple scales.

We define outcomes as the (positive or negative) results of agricultural activities observable in the environmental or social domains, which can be used to assess agricultural system performance against socially desired goals, including the SDGs. Examples of outcomes include greenhouse gas emissions, soil erosion, food production, farm income, and farmer health and well-being. Outcomes feed back into the environmental and social domains within which agricultural systems operate.

Comparing Perspectives Using the Conceptual Model. We used our conceptual model to compare the focus of: (*i*) regional- or larger-scale agricultural land systems research literature in Europe; (*ii*) the 17 SDGs contained in the United Nation's 2030 Agenda for Sustainable Development, as well as EU agricultural and sustainability policies; and (*iii*) agricultural sustainability

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assessment tools, which are mostly targeted at the farm scale and have been applied extensively (e.g., ref. 40) (see *SI Appendix, Supplementary Methods* and Table S1 for full details). Our context and scope were agricultural systems at regional to continental spatial scales (e.g., 10^3 to 10^6 km^2) in Europe and short- to medium-term temporal scales (e.g., months to decades), appropriate to the national to global scale for the SDGs. We examined alignment among research, policies, and assessment tools related to European agricultural systems using Winkler et al.'s (22) hierarchical classification of environmental and social components of agricultural systems (*SI Appendix*, Fig. S1) and our conceptual model of drivers, management choices, and outcomes (Fig. 1). We cataloged over 800 individual operationalized indicators from the reviewed research, policies, and assessment tools into a final group of 239 environmental and social variables (*SI Appendix, Supplementary Methods* and Dataset S1). The variables were then characterized as drivers, management choices, or outcomes based on our interpretation of how they were conceptualized in the original source and using the classification in ref. 22. The relative importance of these variables (e.g., soil type vs. precipitation) may differ across scales, but we made no assertions in this regard (see ref. 39 for a discussion on scale sensitivity of drivers in particular). We identified variables that appeared in research, policies, and assessment tools and termed them consensus variables.

Although the number of research articles reviewed was far greater than the number of policies and assessment tools reviewed, we do not believe that this contributed to a bias in the alignment and comparison. On average, research articles contained four variables (ranging from 1 to 31 per paper), whereas the policies reviewed covered as many as 232 indicators (as in the SDGs) and the assessment tools covered an average of 60 (ranging from 25 to 116). Thus, it was necessary to review many research articles to reveal the full scope of variables considered in agricultural land systems research in Europe.

Lastly, we identified dominant approaches to agricultural land systems research in Europe using a suite of multivariate analyses. Two multivariate hierarchical cluster analyses were employed to determine distinct groups of research articles based on the variables included in each study. We then used three quantitative techniques to determine which categories of driver, management choice, or outcome variables were contributing to the distinction among cluster groups (see *SI Appendix, Supplementary Methods* for full details). The statistical significance and validity of cluster solutions was also evaluated (*SI Appendix, Supplementary Methods*). The focus of these dominant approaches to research was then compared with the categories of consensus variables identified to determine whether the prevailing research paradigms aligned with policies and assessment tools.

Data Availability. All data and R code are available in Datasets S1–S3.

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