Regional Environmental Change (2022) 22: 43
https://doi.org/10.1007/s10113-022-01899-y

REVIEW

# Typologies of European farmers: approaches, methods and research gaps

**Bartosz Bartkowski**[1] · **Charlotte Schüßler**[1] · **Birgit Müller**[2]

Received: 9 June 2021 / Accepted: 17 February 2022 / Published online: 14 March 2022


## Abstract

Understanding farmers' behaviour and their different responses to environmental change, institutional change and policy interventions is important to facilitate the understanding of the drivers of environmental degradation. Identification of behavioural types can be very useful in informing the design of targeted instruments to support transformation towards sustainable agriculture and facilitating the transferability of findings between contexts, while also pointing out limits to the generalization of behavioural patterns detected in individual studies. However, typologies of European farmers are quite scattered geographically, among contexts and disciplines. Here, we present results from a literature review of empirically derived European farmer typologies from 36 academic studies. We investigate the underlying methodologies for determining the types, the purposes of developing typologies and whether there are recurring farmer types across contexts and locations. Our results show that (i) the field is quite diverse in terms of purposes, methods and variables used to develop typologies; (ii) there is surprisingly little awareness of the broader literature; (iii) while there are recurring types, they are still diverse and difficult to compare across studies. We recommend a stronger embedding of new typologies in the existing literature and improvements in the transparency of reporting of methods and data to increase the potential for comparison, transferability and generalizability of findings. Also, we derive implications for future research and for policy, e.g. regarding the trade-off between the specificity of types and complexity-related transaction costs (due to tailoring them to different farmer types) and legitimacy issues.

**Keywords** Agriculture · Agri-environmental policy · Europe · Farmer behaviour · Farming styles · Farm types · Typology

## Introduction

Farmers' behaviour is key to the societal response to environmental change. Agriculture plays a major role in the multiple sustainability crises faced by humanity (Campbell et al. 2017; Foley et al. 2005), including biodiversity loss (IPBES 2019) and climate change (Clark et al. 2020), while also being strongly dependent on both a stable and predictable climate (Carter et al. 2018) and biodiversity (Seppelt et al., 2021). For agri-environmental policy to be effective in fostering a transformation towards sustainability, it needs to be designed with the behavioural characteristics of its main target group—farmers—in mind (Brown et al. 2021; Dessart et al. 2019). It is increasingly recognized that this group is anything but homogeneous (Malek and Verburg, 2020)—even when focusing on a specific region such as Europe, there is not "the European farmer", but rather a diverse population of different farmers with different behavioural characteristics, even within a country or region (Bartkowski and Bartke 2018; Weersink and Fulton 2020).

The emerging literature on European farmers' behaviour, especially with respect to the adoption of sustainable management practices, draws a rich picture of relevant behavioural characteristics and their diversity (for recent reviews, see Bartkowski and Bartke 2018; Brown et al. 2021; Dessart et al. 2019). A subset of this literature uses empirical data to identify farmer types—groups of farmers

Communicated by Robbert Biesbroek.

✉ Bartosz Bartkowski
bartosz.bartkowski@ufz.de

[1] Department of Economics, Helmholtz Centre for Environmental Research – UFZ, Permoserstraße 15, 04318 Leipzig, Germany

[2] Department of Ecological Modelling, Helmholtz Centre for Environmental Research – UFZ, Permoserstraße 15, 04318 Leipzig, Germany

who share similar behavioural characteristics and similar responses to market, environmental, institutional and policy change. In this context, a type means "a systematic or taxonomic concept, [whose] definition is based essentially on similarities between various individuals" (Kostrowicki 1977, p. 36); a type is expected to be internally homogeneous, while the heterogeneity among types is usually large (Walder et al. 2012). Farmer types are dynamic and may change over time (Landais 1998). Different methods can be used to generate typologies: the spectrum ranges from self-assignment through qualitative methods to strongly quantitative approaches (see Emtage et al. 2006; for an overview of various methods, see Mądry et al. 2013).

Farmer typologies are an attempt to identify reproducible behavioural patterns in the highly heterogeneous farmer population (see Malek et al. 2019; for a related analysis of forest owner typologies, see Ficko et al. 2019). However, empirical studies on farmers' behaviour are often highly context specific. Farmer typologies can also be useful as a basis for generalization and transfer of insights among places and contexts (Kostrowicki 1977), e.g. by means of agent-based modelling (see Arneth et al. 2014; Groeneveld et al. 2017; Huber et al. 2018; Malek and Verburg 2020). This approach allows to simulate responses of heterogeneous agents (such as farmer types) to policy changes in time and to systematically analyze the impact of changing framework conditions. Therewith, they enable to evaluate the possibilities but also the limits for the generalization of empirical insights across space and context. Understanding various farmer types and their different responses to environmental change, institutional change and policy interventions are highly policy relevant and can inform the design of targeted policy instruments (such as advisory services, nudges or collaborative schemes). Emtage et al. (2006) identify design, delivery and monitoring of publicly funded policies and programmes as three important purposes of farmer typology development. However, it is an open question to what extent the existing evidence on farmer types allows for informing policy design. Farmer typologies are usually developed for a specific study context, and different data and methods are applied. Currently, no focused overview of European farmer typologies is available, though Graskemper et al. (2021) recently presented a short overview of the literature. Also elsewhere, such overviews are scarce. Exceptions include Emtage et al. (2006) for natural resource programmes in Australia; Nyambo et al. (2019) for smallholder farms and Mądry et al. (2013) with a focus on pasture-based farming systems.

Currently, the European Union's Common Agricultural Policy (CAP), the major policy framework for the European agricultural sector, does not reflect the behavioural heterogeneity of farmers well (Brown et al. 2021; Dessart et al. 2019). There are few instruments in it that target specific groups (e.g. payments for young farmers, the small farmers' scheme, payments for areas of natural constraints, exemptions for organic farmers); the part of the CAP that addresses environmental protection is largely based on generic instruments such as greening, cross-compliance and agri-environment and climate measures (AECM), which may lead to limited uptake and minimal compliance.

This paper delivers a much-needed review of European farmer typologies. Three overarching research questions guide our analysis: (1) What are the disciplinary foci, methods and types of data used in typology-constructing studies? (2) What are the purposes of typology development? and (3) Are there recurring patterns to be found across typologies and, as far as possible, context-specific differences? Based on the answers to these questions, we derive implications for future research and, tentatively, for agri-environmental policy.

## Materials and methods

### Data

The literature review is based on empirical studies on farmer typologies conducted in Europe that have been published in peer-reviewed journals in English. Terms referring to what we comprehend as farmer typologies are heterogeneous (e.g. farmer typologies, farmer types, farming groups). Because of this terminological heterogeneity and because in many studies, typologies are only a "by-product", not explicitly mentioned in title, abstract or keywords, our literature review is exploratory. As our focus has been on the behavioural characteristics of farmers, we restricted ourselves to the key term "farmer" in combination with variations of the term "type", thus excluding typologies explicitly based solely on farm (business) characteristics. The search strings used for bibliographic database search, applied to Web of Science and Scopus databases, can be found in the Supplementary Material. The application of our original search string resulted in a significant number of articles clearly not relevant for our review with regard to their research fields. Therefore, we excluded irrelevant database categories, such as *Radiology, Nuclear Medicine and Medical Imaging* in Web of Science or *Biochemistry* in Scopus. Furthermore, because farmers' behavioural patterns are culturally shaped (Malek et al. 2019; Malek and Verburg 2020), we restricted our review to studies conducted in Europe. All articles indexed by 30 September 2020 were included, resulting in 43 articles in Web of Science and 79 articles in Scopus matching the search terms. We removed all doublets (articles appearing in both database searches), resulting in a total of 90 papers.

Subsequently, all abstracts were screened to exclude non-relevant articles. Articles selected for further literature analysis are needed to fulfil the following inclusion criteria: the article (a) presents a typology, (b) is based on original research and (c) refers to European data. This resulted in 27 articles, of which 7 were excluded later during the process, because reading the full text showed they did not fit the inclusion criteria. Furthermore, one article was excluded because it used only a single variable to create a "typology" consisting of only two types.[1] On top, we added 16 fitting articles based on our own knowledge, resulting in a total of 36 articles subject to full-text analysis. A PRISMA flowchart and search strings can be found in Supplementary Material 2.

### Content analysis

The following categories were developed to support the extraction of information during the full-text analysis:

a. study region;
b. methods of data collection;
c. methods used for developing the typology;
d. sample restrictions;
e. sample size and response rate;
f. main variables relevant for developing the typology;
g. aim of the study;
h. aim of typology (if substantially different from the aim of the study);
i. resulting typology;
j. policy relevance of typologies as expressed in the publications (high = farmer typologies' policy relevance is discussed in detail, medium = policy relevance of farmer typologies is mentioned, low = policy relevance of farmer typologies is not mentioned);
k. whether the typology was used for agent-based modelling (a common reason for creating typologies, sometimes called agent functional types (Arneth et al. 2014)).

All 36 articles were reviewed and information concerning the research categories was systematically registered. To analyze the sample of farmer typologies, we combined descriptive statistics and qualitative content analysis. In order to draw conclusions and to summarize various results, we inductively developed categories to group the results, specifically for the *main variables relevant for developing the typology* and the *aim of typology*. A spreadsheet with all data derived from the analyzed publications and all the categories created to support the analysis can be found in Supplementary Material 1. Descriptive statistics and figures were generated using the R packages ggplot2 (Wickham 2016), ggraph (Pedersen 2021) and igraph (Csárdi 2019) in R 4.0.3 (R Core Team 2020). Furthermore, to investigate links and interactions within the reviewed sample, we used the graphical bibliometric analysis software VOSviewer, version 1.6.16 (van Eck and Waltman 2010).

To simplify the diversity of variables used to construct typologies (f. above), we grouped the variables (factors) used in the analyzed studies to construct typologies into categories. Starting from a predefined set of categories derived from Bartkowski and Bartke (2018), we iteratively adapted them to best reflect the variables used in the analyzed studies. Finally, we arrived at six categories: farm characteristics (e.g. farm size, arable vs. livestock farming), social-psychological variables (e.g. attitudes, values, identity of the farmer), socio-demographic variables (e.g. age, gender, education of the farmer), business characteristics (e.g. farm income), knowledge-related variables (e.g. farmer's problem awareness, sources of information) and technology uptake (e.g. use of digital technologies). Responding to the increasing attention in the broader literature on agri-environmental policy for technology-related matters (Ehlers et al. 2021; Walter et al. 2017), we added the category technology uptake despite its relatively low frequency in the analyzed studies. We refer here to modern production technologies, particularly those related to digitalization.

Categories g. (aim of study) and h. (aim of typology) were combined and used to inductively assign to each study a "purpose" of typology development. The resulting purposes were then iteratively grouped into broader categories. The resulting categories (practices, policy, ecological awareness, theory and modelling) are of course overlapping and studies could be assigned to multiple purpose categories; for the purposes of our analysis, we selected a predominant purpose for each typology-constructing study.

## Results

### Bibliometric results

The 36 articles were published in a total of 25 different journals, which may be used as a proxy of the disciplinary focus of each study. However, most of the represented journals are not limited to a single discipline, publishing multi- and interdisciplinary research including e.g. sociology, economics, agricultural science and geography (e.g. Land Use Policy; Regional Environmental Change; Journal of Environmental Management; Agriculture and Human Values). Other represented journals are more closely related to individual

[1] Such rudimentary "typologies" are quite common in the literature (e.g. when organic and conventional farmers are compared or farmers participating in an AES with those who do not participate) and do not constitute proper typologies in our sense.

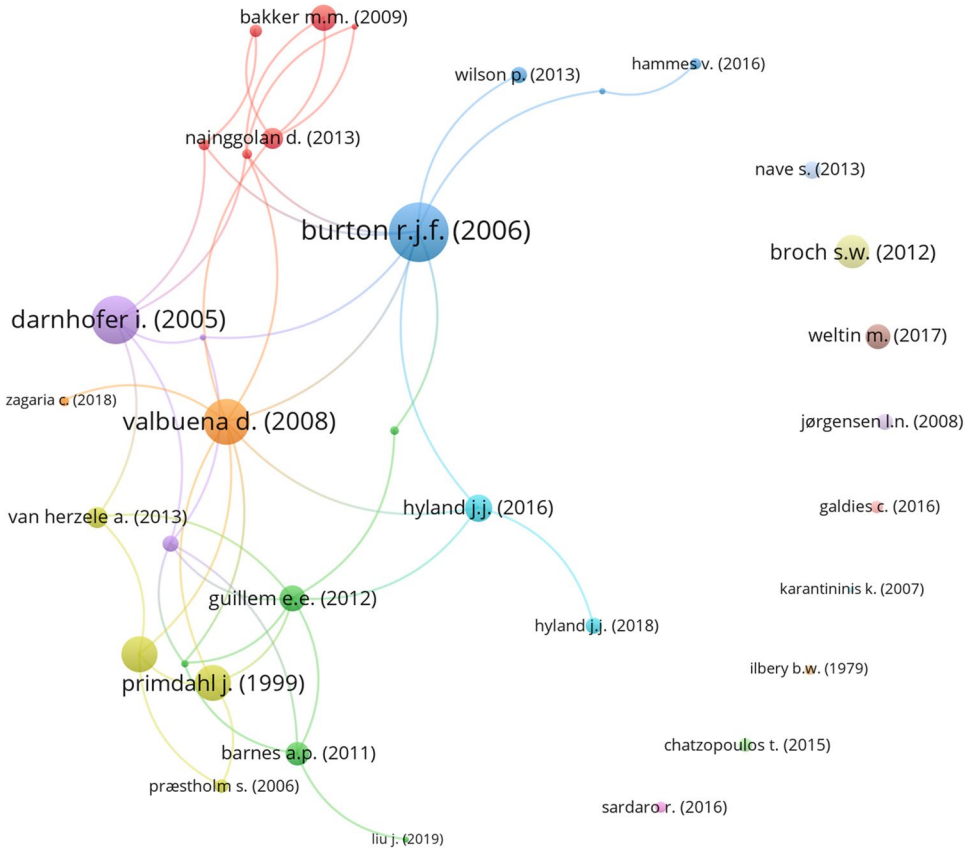


**Fig. 1** Citation network of European farmer typology studies (size of nodes reflects number of overall citations; edges reflect that one of the linked publications cited the other)

disciplines, such as sociology (Sociologia Ruralis), economics (Journal of Agricultural Economics; Ecological Economics; Environment and Resource Economics) and agronomy (European Journal of Plant Pathology; Agronomy for Sustainable Development; European Journal of Agronomy; Agriculture, Ecosystems & Environment), although most of them still publish articles from other, related disciplines. Figure SM2.2 in Supplementary Material 2 shows the distribution of publications across journals.

The graphical analysis of citation-based links within the analyzed study sample (Fig. 1) shows that there is limited "awareness" of each other in the surveyed literature, e.g. only Burton and Wilson (2006) and Valbuena et al. (2008) were cited more than 5 times by other papers, while 9 of the 35[2] included articles were not cited by and did not cite any others. The unconnected articles represent a broad spectrum of publication dates, so the "age" of a publication does not seem to affect its "awareness" of the rest. Both articles from monodisciplinary economic journals (Broch and Vedel 2012; Chatzopoulos and Lippert 2015) are among this unconnected group. Considering bibliographic coupling (joint citations) rather than direct citations within the sample shows a similar picture (see Supplementary Material 2, Figure SM2.3).

## Descriptive results

### Geographical and temporal distribution

The studies included in our analysis are well distributed across Western Europe, with somewhat lower coverage of Eastern Europe, a pattern similar to the one found by Bartkowski and Bartke (2018) for empirical studies of farmers' behaviour in general. Most studies were conducted in the United Kingdom (eight), Denmark (six), Germany (five), Spain (five), Netherlands (four), Ireland (four) and Austria (four). Four studies were conducted in multiple European countries (Karantininis and Zylbersztajn 2007; Præstholm et al. 2006; Soini et al. 2012; Weltin et al. 2017).

Only two of the analyzed articles were published before 2000 (Ilbery 1979; Primdahl 1999). Since then, the number of studies published each year has fluctuated around a slowly rising trend.

### Methods used for determining typologies

Except for two studies relying on data from governmental statistics (Andrade 2016; Chatzopoulos and Lippert 2015),

[2] One article (Acosta et al. 2014) was not included because it is not indexed in either Scopus or WoS, so it was not possible to retrieve citation data for it.

all studies were based on questionnaires, either carried out through face-to-face (50%) or telephone interviews (12%) and through online or postal surveys (6%). Approximately 30% of the studies do not specify how their surveys were implemented. Sample sizes varied from less than 50 in studies mostly conducting qualitative analyses (e.g. Busck 2002; Karantininis and Zylbersztajn 2007; Van Herzele et al. 2013) or applying Q methodology (Braito et al. 2020; Walder and Kantelhardt 2018) to over 1000 in studies conducting solely quantitative analyses (Andrade 2016; Cullen et al. 2020; Daxini et al. 2019; Liu et al. 2019; Præstholm et al. 2006; Weltin et al. 2017).

Across the reviewed studies, there is a wide variety of methods applied, but also of how methods are reported. While some studies report their methods in a very detailed way (e.g. Cullen et al. 2020; Daxini et al. 2019; Hyland et al. 2016; Weltin et al. 2017), other studies fail to give detailed information on their methodological procedures. This concerns the definition and operationalisation of variables (e.g. psychological constructs such as attitude or self-identity; questionnaire items used to measure variables), the description of the data collection process (e.g. sampling procedures and response rates) and the description of the statistical methods used (e.g. which algorithms were used for cluster analysis).

Many studies (~40%) used cluster analyses in order to identify somewhat homogenous groups (clusters) that are distinguishable from each other. Researchers used either single (mostly hierarchical) clustering algorithms or a combination of hierarchical (e.g. Ward's method) and partitional (k-means) clustering algorithms. In some papers, the specific algorithm used for clustering was not specified. Also, in a couple of studies, no rationale is provided as to how the number of clusters was determined. Some papers alternatively used latent class analysis in order to classify farmers into different types (Broch and Vedel 2012; Daxini et al. 2019; Liu et al. 2019; Sardaro et al. 2016). Preliminary to cluster or latent class analysis, many studies applied principal component analysis (Barnes et al. 2011; Daxini et al. 2019; Guillem et al. 2012; Hyland et al. 2016; Ilbery 1979; Nainggolan et al. 2013; Nave et al. 2013; Weltin et al. 2017). Alternative approaches also used to develop typologies are Q methodology (Braito et al. 2020; Walder and Kantelhardt 2018) and decision tree modelling (Darnhofer et al. 2005). Furthermore, only some studies used additional methods (e.g. ANOVA, regression analysis, discriminate function analysis) in order to explore further relations of non-clustering co-variables with clusters/classes (e.g. Andrade 2016; Brown et al. 2016; Daxini et al. 2019; Guillem et al. 2012; Nave et al. 2013; Zagaria et al. 2018).

Not all papers develop new typologies; some used previous typologies instead: Hammes et al. (2016) allocated farmers to predetermined farming styles (Eggers et al. 2015), by rating answers on Likert-scaled statements as being positive, negative or neutral for the specific farming styles, which resulted in four scores for each farmer, each referring to one farming style. The farmers were allocated to the farming style with their highest positive score. Wilson et al. (2013) also categorised farmers into predetermined types (Defra 2008) by following a discursive methodological approach, where farmers needed to self-identify with one of the types.

A summary of the methods employed in all studies included in our review, as well as other information derived from them, is provided in Supplementary Material 1.

### Main factors

Based on the categories of variables described in the "Content analysis" section, we were able to see which variables were used to construct typologies how often and in what combinations (see Fig. 2): farm characteristics were used in 24 studies, followed by social-psychological variables (22 studies), socio-demographic variables (16 studies), business characteristics (nine studies), knowledge-related variables (eight studies) and technology uptake (three studies). Note that within each category, many different variables are present, and studies usually used multiple variables from a category. Nonetheless, at this level of aggregation, a few observations can be made. As can be seen in Fig. 2A, most studies used variables from two categories to construct their typologies, closely followed by typologies based on variables from one category only. The use of variables from three or more categories was much less common, and no typology was based on variables from all six categories.

To see how variables are connected across categories, we created a simple network diagram (Fig. 2B), which shows the joint occurrence of factors from different categories. There are no apparent pronounced patterns or clusters and, in accordance with Fig. 2A, the interlinkages are generally not very strong. The strongest connections are between social-psychological variables and farm characteristics as well as between socio-demographics and farm characteristics, i.e. among the three most common categories.

### Purposes and contexts of typologies

Based on the descriptions of the aim of each study as well as (if explicit) the specific aim of the typology within the study, we identified five purposes that typologies have been developed for uptake of specific practices, responses to policy, ecological awareness of farmers, theory development or testing and modelling. In Table 1, we link these purpose categories to the contexts within which the typologies were developed, such as particular environmental problems. At least in the two largest purpose categories, the heterogeneity of approaches, methods, etc., are still substantial.

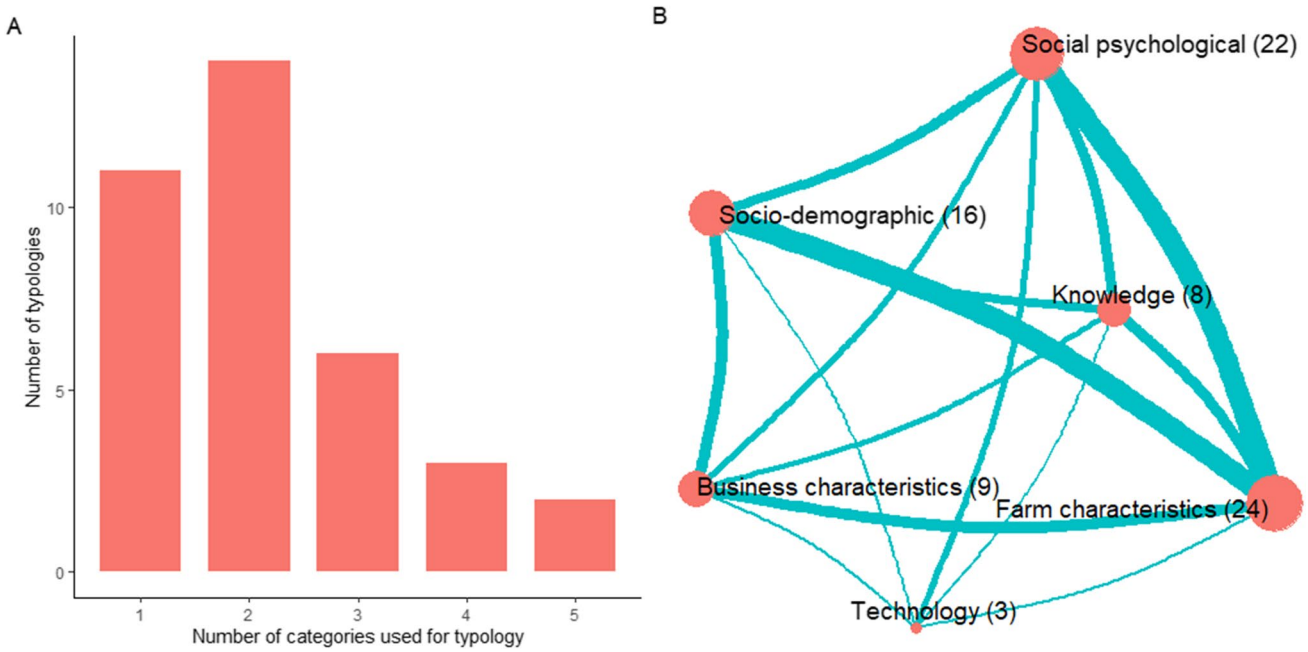


**Fig. 2** Use of categories of variables in typology development. **A** Distribution of categories used for typologies (number of variable categories used per study). Note that we identified six categories of variables. **B** Network diagram of connections between categories (joint occurrence of factors from different categories). The size of the nodes indicates number of studies using variables belonging to a given category (also provided in brackets); the thickness of the links between two variable categories indicates in how many studies they were used jointly. Note that many studies used multiple variables belonging to one category, which cannot be seen in this figure

## Recurring types

The median number of individual types per typology is 4, ranging from 2 to 10 (see Supplementary Material 1). All typologies included in the review differ from each other somehow; no two typologies are exactly the same. It is noticeable, however, that similar farmer types occur repeatedly within different typologies, though under (slightly) different names and based on partly overlapping variables. We therefore attempted to qualitatively cluster farmer types in order to see which types are recurring. We grouped types with semantically related names and

**Table 1** Purposes and context of typologies

| Purposes | Explanation of purpose category | Study contexts | Exemplary papers | *N* |
|---|---|---|---|---|
| Practices | Characterizing farmers' decision-making/behaviour, e.g. farm diversification, technological uptake, pesticide input; in some cases, studying associated (socio-economic or motivational) factors | Bioenergy, land use, climate change, organic farming, pesticides, technology adoption, livestock | Hyland et al. (2016), Liu et al. (2019), Weltin et al. (2017), Daxini et al. (2019) | 14 |
| Policy | Evaluation of existing or future policy measures, e.g. factors related with participation, motivational factors, attitudes towards AES | Water management, agri-environmental programmes, land use, livestock | Barnes et al. (2011), Broch and Vedel (2012), Cullen et al. (2020), Van Herzele et al. (2013) | 10 |
| Ecological awareness | Characterizing farmers' awareness towards ecological problems, e.g. climate change, biodiversity loss | Climate change, biodiversity, multifunctionality | Galdies et al. (2016), Guillem et al. (2012), Hyland et al. (2016), Walder and Kantelhardt (2018) | 4 |
| Theory | Theoretical approach. empirical study of theory, proposing a typology | Structural change, globalization | Andrade (2016), Burton and Wilson (2006), Karantininis and Zylbersztajn (2007), Wilson et al. (2013) | 4 |
| Modelling | Incorporating different agents in models, e.g. ABMs, land use change models | Agri-environmental programmes, land use, bioenergy | Acosta et al. (2014), Bakker and van Doorn (2009), Brown et al. (2016), Valbuena et al. (2008) | 4 |

looked for patterns. The following recurring types are discussed in more detail below: *Productivist*, *Innovator*, *Diversifier*, *Traditionalist*, *Environmentalist*, *Pragmatist*. For each, we use the most common name or a variant thereof; the order of presentation reflects the frequency with which we found each type, from most to least common. Note that we did not find any discernible patterns in terms of methods or variables used to identify a given recurring type. Each type can be found in studies using different data and methods.

The *Productivist* has a strong focus on food production as a profit-oriented business, also referred to as *Agricultural producer*, *Agribusiness person*, *Production enthrone*, *Profit-orientated*, *Entrepreneurs*, *Production oriented* and *Yield optimizer*. Farmers in this group focus on the economic aspects and profitability of farming (Busck 2002; Cullen et al. 2020; Galdies et al. 2016; Guillem et al. 2012; Walder and Kantelhardt 2018), while practicing intensive agriculture (Burton and Wilson 2006; Sardaro et al. 2016). *Productivists* are often described as being unconcerned about or unaware of environmental and climate change (Busck 2002; Cullen et al. 2020; Galdies et al. 2016; Guillem et al. 2012; Hyland et al. 2016). However, there are also studies showing farmers in this group agreeing to the need of environmentally sound production (Braito et al. 2020; Hammes et al. 2016; Walder and Kantelhardt 2018). Farmers in this group usually engage in farming as a full-time activity (Busck 2002; Daxini et al. 2019). This relatively homogenous type (in terms of its descriptions across studies) can be found across study contexts.

The *Innovator* is a farmer type who is open to trying out new approaches and practices, often in response to external drivers. Further names referring to this broad type are *Innovative land owners*, *Forward looking*, *Modernist* or the *Change-promoting viewpoint*. Farmers belonging to this type tend to be young (Bakker and van Doorn 2009; Galdies et al. 2016) and open towards environmental protection. Within our sample, this type has often been found in studies focusing on agri-environmental programmes (though it should be kept in mind that the sub-samples for each recurring type are rather small).

The *Diversifier* does not engage in food production only, but also in other activities. Also known as *Established diversifier*, *Younger educated diversifier* and *Multifunctionalist*. This type is somewhat related to the Innovator, as the underlying understanding of diversification mostly relates to various farm activities (except for Weltin et al. 2017, where the focus is on off-farm income diversification) and is often linked to environmental protection. Regarding socio-demographic patterns, this farmer type seems to exhibit a relatively high share of female farmers (Barnes et al. 2011; Guillem et al. 2012). Regarding age and education, there is no clear pattern—while Barnes et al.'s (2011) *Multifunctionalists* and Nainggolan et al.'s (2013) *Established diversifiers* are relatively old and with low education status, Guillem et al.'s (2012) *Multifunctionalists* are relatively young and highly educated. The *Diversifier* is present across different study contexts.

The *Traditionalist* sticks to what she has been doing historically and is unwilling to change, also referred to as *Conservative*. This type is relatively old (Daxini et al. 2019; Galdies et al. 2016; Guillem et al. 2012), often aware of environmental problems (Galdies et al. 2016; Guillem et al. 2012), yet she does not exhibit high willingness (Braito et al. 2020; Hammes et al. 2016) or ability (Cullen et al. 2020) to respond to environmental change. This type has been found across different study contexts.

The *Environmentalist* is interested and engaged in environmental protection. Corresponding names are *Conservationist*, *Sustainable producer*, *Environmental-conscious*, *Committed organic* and *Nature participant*. This type emphasizes environmental concerns in their farming practices (Burton and Wilson 2006; Soini et al. 2012) and feels somehow responsible for the environment (Braito et al. 2020; Hyland et al. 2016). Braito et al. (2020) describe *Nature participants* as close to nature and keen to improve their soil management. However, the descriptions of types that we classified into this group vary strongly, especially when compared to the relatively homogenous descriptions found for the types summarized as *Productivists*. This type can be found across different study contexts.

The *Pragmatist* is flexible in terms of the motivations guiding her decisions. This type occurs in some studies that look at specific practices, such as the decision for converting to organic farming (Darnhofer et al., 2005) or the keeping of a local breed (Soini et al. 2012). Darnhofer et al. (2005) use the term "pragmatic" in opposition to the term "committed". In their study, *Pragmatic organic* and *Pragmatic conventional* refer to farmers who base their decisions about (not) converting to organic farming rather on economic considerations in terms of income security, than on fundamental or idealistic convictions. *Pragmatists* introduced by Soini et al. (2012) refer to "professional farmers" primarily keeping mainstream breeds. Keeping a few local breeds additionally is not economically profitable, but the *Pragmatists* do it anyway, e.g. in order to contribute to the breeds' conservation. In the study by Wilson et al. (2013), *Pragmatists* account for half the sample. Typical qualitative comments from this group include "restrictions of farming under Full Agricultural Tenancies, no alternative but to continue to farm, being forward thinking, optimistic, making a profit or difficulty making a profit, and placing lifestyle above profit" (p. 153).

Even though there are clear semantic patterns in the names used to describe types across typologies, looking deeper into their descriptions, we found that most

"recurring types" turn out to be rather heterogeneous. The main relatively homogeneous exception seems to be the most frequently recurring type, the *Productivist*. Figure 3 shows the co-occurrence of recurring types. Here, too, there are no clearly discernible patterns. Note that even though most studies treated types as exclusive, it has been noted by some authors that they should be considered overlapping (see Discussion). Also, it should be noted that because different variables were used to identify types and because their descriptions vary in terms of detail, our classification of "recurring types" should be interpreted with caution.

There also are frequently occurring types defined on the basis of the occupational status of the farmer, such as *Hobbyist*, *Part-time* and *Full-time farmers*, *Pensioners* and *Disengaged farmers*, or often occurring types based on demographic variables, such as age, education and farming experience, e.g. *Young farmers in low-capital farms*, *Newcomers*, *Experienced* and *Old farmers*. Finally, many types correspond to specific farming practices, e.g. the adoption of a certain technology or biogas production. However, here we highlight less "generic" yet still recurring types that reflect a broader range of variables and nonetheless seem to occur across study contexts. It should be noted, however, that the types have been differently described across articles, so their comparison is imperfect. Also, method-inherent differences make comparisons challenging—especially when comparing typologies generated from surveys with those generated by means of Q methodology (Braito et al. 2020; Walder and Kantelhardt 2018).

## Discussion

Despite the apparently still limited number of studies that constructed typologies of European farmers, their diversity in terms of purpose, context and approach is high. The literature on European farmer typologies is highly multidisciplinary; at the same time, there is surprisingly little awareness of and explicit reference to each other among the studies we analyzed. In some cases, this may be a side effect of the typologies being "by-products" rather than the main foci of studies; in others, this seems to stem from the very different contexts of application (e.g. participation in agri-environmental schemes versus decisions on the veterinary treatment of livestock) or even disciplinary focus. Of course, there are exceptions, such as Burton and Wilson's (2006) insightful, theory-based study, which has at least been mentioned by multiple subsequent studies. While many studies addressed behavioural change (e.g. adoption of practices or participation in policy programmes), others focused on antecedents of behaviour (e.g. awareness) in order to develop typologies. These differences result in a further compounded diversity in methodological approaches and data used to develop typologies. This implies that there is currently little basis for policy implications from this diverse and heterogeneous body of empirical evidence.

One clear lesson from the literature reviewed here is that the population of European farmers is highly heterogeneous. In fact, one could argue that the literature has only scratched the surface—given the relatively low number of studies, it is currently not possible to say much about possible cultural differences (see also Soini et al. 2012). Are farmers in Poland heterogeneous in a similar way as their colleagues in Sweden or Italy? Probably not, but we do not know how large the differences are nor what they are related to. On the other hand, this heterogeneity suggests that assuming a homogeneous farmer population, e.g. for the purposes of policy design, is likely to be a very strong oversimplification. As mentioned in the "Introduction" section, currently, the CAP as a major agricultural policy framework relevant for most of Europe only includes a very limited number of instruments that somehow reflect this

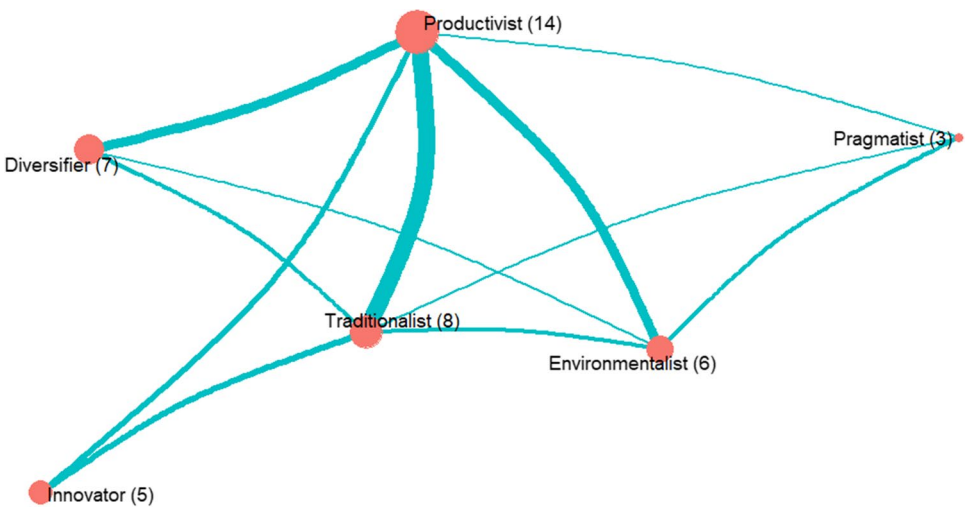


**Fig. 3** Co-occurrence of recurring types. The size of the nodes indicates the number of studies referring to a given type (also provided in brackets); the thickness of the links between two types indicates in how many studies they occurred jointly

heterogeneity. In order to design effective and efficient policy interventions, one would likely need some understanding of this heterogeneity, as reflected in typologies. There is probably a (context specific) trade-off between efficiency gains due to "specificity" of a policy instrument or policy mix (with respect to the heterogeneity in the farmer population) on the one hand and the complexity-related costs of ever more group-specific instruments (transaction costs of identifying groups, legitimacy of differences in treatment across groups, etc.). On the other hand, advances in digitalization may lower the transaction costs of increasingly context-specific instrument design (Ehlers et al. 2021), e.g. for agri-environmental payments (Bartkowski et al. 2021). This highly policy-relevant trade-off between specificity and complexity of instruments (with respect to tailoring them to different farmer types) requires more attention and dedicated research.

More broadly, a typology may have different consequences depending on the policy context. In some cases, it may imply that each type requires a different instrument or different type of incentive (e.g. information, payments, investment support). One could argue that the diversity of instruments within the second pillar of the CAP goes in this direction. In other cases, especially with respect to "soft" instruments such as advisory services, information campaigns or nudges, the types can directly inform the design within such more flexible and more responsive instruments.

Our attempt to identify "recurring types" across studies (on the basis of the names chosen by their authors) has not been particularly successful. Apart from possibly one type, the *Productivist*, often identified as the major challenge for agri-environmental policy (e.g. Burton and Wilson 2006), similarly named farmer types differ strongly between study contexts, and there are no clear patterns as to the extent to which this reflects differences in context, data or methods of analysis. The development of a meaningful typology of European farmers (or even at a regional level) that is comprehensive and at the same time applicable across contexts would need a highly concerted action and is probably quite difficult to achieve. At the same time, the uncoordinated efforts in this field leave much unused potential to develop more coherent, transferable and policy-relevant typologies.

Despite the limitations and challenges, assuming a homogeneous farmer population is not a viable alternative. Farmer typologies are context specific and to some extent "fluid", i.e. there is actually a continuum of overlapping "types" (Burton and Wilson 2006; Cullen et al. 2020; Soini et al. 2012), and the same farmer may belong to different types depending on the context. Seeing typologies from that perspective, it does not seem surprising that some farmers, when asked, struggle to self-identify with one single type (Wilson et al. 2013). However, our attempt to identify recurring types has also shown that many differences may be related to differences in data, methods and reporting. Here, significant progress in terms of comparability and transferability could be made by simply embedding one's newly developed typology more strongly in the existing literature, and reporting as clearly as possible the process of developing it. Furthermore, more systematic descriptions of types could be helpful, e.g. the consistent reference to whether socio-demographic variables (which are usually included in the analysis) are significant and in what way.

Existing farmer typologies are static snapshots. However, given the posited "fluidity" of types, it is likely that, in reality, they are quite dynamic and shifting (see Landais 1998)—not only can the size of a type change over time, also the types themselves can be subject to changes, and new types can emerge. Longitudinal approaches would be required to study the extent of these dynamics. Also, adaptive farm typologies are promising in addressing this issue (Paas and Groot 2017).

With respect to methods, we cannot say that there is "the one best approach" for constructing typologies, as the demands towards generalizability and compatibility of typologies are strongly purpose dependent. Definition of the purpose is therefore an important first step in developing a typology (Mądry et al. 2013). In some cases, it can even be useful to integrate and compare different methods of analysis when constructing typologies (e.g. Alvarez et al. 2018; Berre et al. 2019); for instance, Emtage et al. (2007) suggest that quantitative methods are useful to generate an "underlying structure", while qualitative methods can help provide a more in-depth understanding of the types. Ultimately, which methods (from selecting variables of interest to deciding on (statistical) methods of analyses) are the most suitable, depends on the purpose of a typology.

As can be seen in Table 1, theory development and testing have not played a large role in the European farmer typology literature, even though relevant theoretical approaches are available, such as innovation adoption theory, farming style theory or market segmentation analysis (Emtage et al. 2006). Conversely, if the aim of a typology is to guide the design of policy instruments, differentiation according to publicly inaccessible, difficult-to-elicit data, e.g. social-psychological variables, may be problematic in terms of legitimacy (see Broch and Vedel 2012). This points to the need for more research into how different sets of variables result in different (or similar) typologies. One of the goals of such research could then be the identification of a minimal set of variables necessary to characterize farmer types. In this context, the number of types in a typology is also an important issue. Our attempt to identify recurring types led to a set of six

types—however, some of them were rather uncommon and very diverse (especially the *Pragmatist*). Looking at our overall sample with a median of four types per typology may therefore serve as a first orientation.

## Conclusion

In this literature review of 36 empirical studies developing and presenting European farmer typologies, we showed that (i) the field is quite diverse in terms of purposes, methods and variables used to develop typologies; (ii) there is surprisingly little awareness of the broader literature; (iii) while there are recurring types, they are still diverse and difficult to compare across studies. The purposes range from policy analysis, through more general analysis of adoption of practices and farmers' ecological awareness, to theory testing and modelling. This is reflected by a compounded diversity of methods, data and disciplinary approaches in this quite multidisciplinary and scattered field. Even when seemingly similar types are found across studies, a closer look often reveals significant differences and limited comparability, also due to the very limited embeddedness of studies in the broader literature. Nonetheless, farmer typologies can be an important tool to improve the effectiveness of agricultural and agri-environmental policy—even though currently, the field is still too unsystematic and leaves too many crucial questions open (many of which we discussed in this review).

Based on our interpretation of the reviewed literature, some basic suggestions for future farmer typology studies can be formulated:

- More awareness of and embeddedness in the existing literature is required, including non-European applications (e.g. Hammond et al. 2020; Nyambo et al. 2019; Tittonell et al. 2020); in this context, comparisons with other studies and the types identified there would be helpful, while also keeping in mind the "fluidity" of typologies.
- There is a strong need for transparency in reporting on data and methods (Which variables were used? Was their selection theory driven? How was data collected? Which methods were used for analysis and classification into types? Which variable subset was used for that? How were type descriptions arrived at?); here, standardized protocols, e.g. from modelling could be informative and helpful (such as the ODD + D protocol, especially its + D [decision] part; Grimm et al. 2020; Müller et al. 2013).
- Characterization of types should, wherever possible, be linked to co-variables not used for the typologization itself to improve comparability across studies. This holds especially for socio-demographic variables, which are collected in most studies and then allow for comparing individual types as well as whole typologies across studies and study contexts.
- The still nascent methodological approaches need improvement, e.g. by means of method comparisons (Alvarez et al. 2018; Berre et al. 2019; Guillem et al. 2012), but also use of new methods to address the heterogeneity and scarcity of available data, e.g. machine learning (Graskemper et al. 2021), which can deal with large amounts of data (e.g. from statistical inventories such as IACS), or Naïve Bayesian classification (Paas and Groot 2017), which allows for dynamically updating a typology when new data becomes available. These could possibly contribute to the development of broad (e.g. European or regional) farmer typologies, applicable across contexts.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s10113-022-01899-y.

**Acknowledgements** We would like to thank Meike Will, Robert Huber and two anonymous reviewers for valuable comments on earlier drafts.

**Funding** Open Access funding enabled and organized by Projekt DEAL. The work of BB and CS was funded by the German Federal Ministry of Education and Research (BMBF) in the framework of the funding measure "Soil as a Sustainable Resource for the Bioeconomy – BonaRes", project "BonaRes (Module B): BonaRes Centre for Soil Research, subproject A" (grant 031B0511A). BM acknowledges support by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 817501 (BESTMAP).



## References

Acosta LA, Rounsevell MDA, Bakker M, Van Doorn A, Gómez-Delgado M et al (2014) An agent-based assessment of land use and ecosystem changes in traditional agricultural landscape of Portugal. Intell Inf Manag 06:55–80. https://doi.org/10.4236/iim.2014.62008

Alvarez S, Timler CJ, Michalscheck M, Paas W, Descheemaeker K et al (2018) Capturing farm diversity with hypothesis-based typologies: an innovative methodological framework for farming system

typology development. PLoS ONE 13:e0194757. https://doi.org/10.1371/journal.pone.0194757
Andrade SB (2016) Transition and adaptation: an analysis of adaption strategies amongst Danish farm families from 1980–2008. Sociol Rural 56:371–390. https://doi.org/10.1111/soru.12091
Arneth A, Brown C, Rounsevell MDA (2014) Global models of human decision-making for land-based mitigation and adaptation assessment. Nat Clim Change 4:550–557. https://doi.org/10.1038/nclimate2250
Bakker MM, van Doorn AM (2009) Farmer-specific relationships between land use change and landscape factors: Introducing agents in empirical land use modelling. Land Use Policy 26:809–817. https://doi.org/10.1016/j.landusepol.2008.10.010
Barnes AP, Willock J, Toma L, Hall C (2011) Utilising a farmer typology to understand farmer behaviour towards water quality management: Nitrate Vulnerable Zones in Scotland. J Environ Plan Manag 54:477–494. https://doi.org/10.1080/09640568.2010.515880
Bartkowski B, Bartke S (2018) Leverage points for governing agricultural soils: a review of empirical studies of European farmers' decision-making. Sustainability 10:3179. https://doi.org/10.3390/su10093179
Bartkowski B, Droste N, Ließ M, Sidemo-Holm W, Weller U et al (2021) Payments by modelled results: a novel design for agri-environmental schemes. Land Use Policy 102:105230. https://doi.org/10.1016/j.landusepol.2020.105230
Berre D, Baudron F, Kassie M, Craufurd P, Lopez-Ridaura S (2019) Different ways to cut a cake: comparing expert-based and statistical typologies to target sustainable intensification technologies, a case-study in Southern Ethiopia. Exp Agric 55:191–207. https://doi.org/10.1017/S0014479716000727
Braito M, Leonhardt H, Penker M, Schauppenlehner-Kloyber E, Thaler G et al (2020) The plurality of farmers' views on soil management calls for a policy mix. Land Use Policy 99:104876. https://doi.org/10.1016/j.landusepol.2020.104876
Broch SW, Vedel SE (2012) Using choice experiments to investigate the policy relevance of heterogeneity in farmer agri-environmental contract preferences. Environ Resour Econ 51:561–581. https://doi.org/10.1007/s10640-011-9512-8
Brown C, Bakam I, Smith P, Matthews R (2016) An agent-based modelling approach to evaluate factors influencing bioenergy crop adoption in north-east Scotland. GCB Bioenergy 8:226–244. https://doi.org/10.1111/gcbb.12261
Brown C, Kovács E, Herzon I, Villamayor-Tomas S, Albizua A et al (2021) Simplistic understandings of farmer motivations could undermine the environmental potential of the Common Agricultural Policy. Land Use Policy 101:105136. https://doi.org/10.1016/j.landusepol.2020.105136
Burton RJF, Wilson GA (2006) Injecting social psychology theory into conceptualisations of agricultural agency: towards a post-productivist farmer self-identity? J Rural Stud 22:95–115. https://doi.org/10.1016/j.jrurstud.2005.07.004
Busck AG (2002) Farmers' landscape decisions: relationships between farmers' values and landscape practices. Sociol Rural 42:233–249. https://doi.org/10.1111/1467-9523.00213
Campbell B, Beare D, Bennett E, Hall-Spencer J, Ingram J et al (2017) Agriculture production as a major driver of the Earth system exceeding planetary boundaries. Ecol Soc 22:8. https://doi.org/10.5751/ES-09595-220408
Carter C, Cui X, Ghanem D, Mérel P (2018) Identifying the economic impacts of climate change on agriculture. Annu Rev Resour Econ 10:361–380. https://doi.org/10.1146/annurev-resource-100517-022938
Chatzopoulos T, Lippert C (2015) Adaptation and climate change impacts: a structural Ricardian analysis of farm types in Germany. J Agric Econ 66:537–554. https://doi.org/10.1111/1477-9552.12098
Clark MA, Domingo NGG, Colgan K, Thakrar SK, Tilman D et al (2020) Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. Science 370:705–708. https://doi.org/10.1126/science.aba7357
Csárdi G (2019) igraph: network analysis and visualization. Version 1.2.4.2. Comprehensive R Archive Network (CRAN)
Cullen P, Ryan M, O'Donoghue C, Hynes S, hUallacháin DÓ et al (2020) Impact of farmer self-identity and attitudes on participation in agri-environment schemes. Land Use Policy 95:104660. https://doi.org/10.1016/j.landusepol.2020.104660
Darnhofer I, Schneeberger W, Freyer B (2005) Converting or not converting to organic farming in Austria: farmer types and their rationale. Agric Hum Values 22:39–52. https://doi.org/10.1007/s10460-004-7229-9
Daxini A, Ryan M, O'Donoghue C, Barnes AP, Buckley C (2019) Using a typology to understand farmers' intentions towards following a nutrient management plan. Resour Conserv Recycl 146:280–290. https://doi.org/10.1016/j.resconrec.2019.03.027
Defra (2008) Unterstanding Behaviours in a farming context: bringing theoretical and applied evidence together from across Defra and highlighting policy relevance and implications for future research (Defra Agricultural Change and Environment Observatory Discussion Paper). Department of Environment, Food & Rural Affairs, London
Dessart FJ, Barreiro-Hurlé J, van Bavel R (2019) Behavioural factors affecting the adoption of sustainable farming practices: a policy-oriented review. Eur Rev Agric Econ 46:417–471. https://doi.org/10.1093/erae/jbz019
Eggers M, Kayser M, Isselstein J (2015) Grassland farmers' attitudes toward climate change in the North German Plain. Reg Environ Change 15:607–617. https://doi.org/10.1007/s10113-014-0672-2
Ehlers M-H, Huber R, Finger R (2021) Agricultural policy in the era of digitalisation. Food Policy 100:102019. https://doi.org/10.1016/j.foodpol.2020.102019
Emtage N, Herbohn J, Harrison S (2007) Landholder profiling and typologies for natural resource–management policy and program support: potential and constraints. Environ Manage 40:481–492. https://doi.org/10.1007/s00267-005-0359-z
Emtage N, Herbohn J, Harrison S (2006) Landholder typologies used in the development of natural resource management programs in Australia—a review. Australas J Environ Manag 13:79–94. https://doi.org/10.1080/14486563.2006.10648675
Ficko A, Lidestav G, Ní Dhubháin Á, Karppinen H, Zivojinovic I et al (2019) European private forest owner typologies: a review of methods and use. For Policy Econ 99:21–31. https://doi.org/10.1016/j.forpol.2017.09.010
Foley JA, DeFries R, Asner GP, Barford C, Bonan G et al (2005) Global consequences of land use. Science 309:570–574. https://doi.org/10.1126/science.1111772
Galdies C, Said A, Camilleri L, Caruana M (2016) Climate change trends in Malta and related beliefs, concerns and attitudes toward adaptation among Gozitan farmers. Eur J Agron 74:18–28. https://doi.org/10.1016/j.eja.2015.11.011
Graskemper V, Yu X, Feil J-H (2021) Farmer typology and implications for policy design – an unsupervised machine learning approach. Land Use Policy 103:105328. https://doi.org/10.1016/j.landusepol.2021.105328
Grimm V, Railsback SF, Vincenot CE, Berger U, Gallagher C et al (2020) The ODD protocol for describing agent-based and other simulation models: a second update to improve clarity, replication, and structural realism. J Artif Soc Soc Simul 23:7
Groeneveld J, Müller B, Buchmann CM, Dressler G, Guo C et al (2017) Theoretical foundations of human decision-making in agent-based land use models – a review. Environ Model Softw 87:39–48. https://doi.org/10.1016/j.envsoft.2016.10.008

Guillem EE, Barnes AP, Rounsevell MDA, Renwick A (2012) Refining perception-based farmer typologies with the analysis of past census data. J Environ Manage 110:226–235. https://doi.org/10.1016/j.jenvman.2012.06.020

Hammes V, Eggers M, Isselstein J, Kayser M (2016) The attitude of grassland farmers towards nature conservation and agri-environment measures—a survey-based analysis. Land Use Policy 59:528–535. https://doi.org/10.1016/j.landusepol.2016.09.023

Hammond J, Rosenblum N, Breseman D, Gorman L, Manners R et al (2020) Towards actionable farm typologies: scaling adoption of agricultural inputs in Rwanda. Agric Syst 183:102857. https://doi.org/10.1016/j.agsy.2020.102857

Huber R, Bakker M, Balmann A, Berger T, Bithell M et al (2018) Representation of decision-making in European agricultural agent-based models. Agric Syst 167:143–160. https://doi.org/10.1016/j.agsy.2018.09.007

Hyland JJ, Jones DL, Parkhill KA, Barnes AP, Williams AP (2016) Farmers' perceptions of climate change: identifying types. Agric Hum Values 33:323–339. https://doi.org/10.1007/s10460-015-9608-9

Ilbery BW (1979) Decision-making in agriculture: a case study of north-east Oxfordshire. Reg Stud 13:199–210. https://doi.org/10.1080/09595237900185171

IPBES (2019) Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Service. IPBES Secretariat, Bonn

Karantininis K, Zylbersztajn D (2007) The global farmer: typology, institutions and organisation. J Chain Netw Sci 7:71–83. https://doi.org/10.3920/JCNS2007.x078

Kostrowicki J (1977) Agricultural typology concept and method. Agric Syst 2:33–45. https://doi.org/10.1016/0308-521X(77)90015-4

Landais E (1998) Modelling farm diversity new approaches to typology building in France. Agric Syst 58:505–527

Liu J, Toma L, Barnes AP, Stott A (2019) Farmers' uptake of animal health and welfare technological innovations. Implications for Animal Health Policies. Front Vet Sci 6:410. https://doi.org/10.3389/fvets.2019.00410

Mądry W, Mena Y, Roszkowska-Mądra B, Gozdowski D, Hryniewski R et al (2013) An overview of farming system typology methodologies and its use in the study of pasture-based farming system: a review. Span J Agric Res 11:316. https://doi.org/10.5424/sjar/2013112-3295

Malek Ž, Douw B, Vliet JV, Zanden EHVD, Verburg PH (2019) Local land-use decision-making in a global context. Environ Res Lett 14:083006. https://doi.org/10.1088/1748-9326/ab309e

Malek Ž, Verburg PH (2020) Mapping global patterns of land use decision-making. Glob Environ Change 65:102170. https://doi.org/10.1016/j.gloenvcha.2020.102170

Müller B, Bohn F, Dreßler G, Groeneveld J, Klassert C et al (2013) Describing human decisions in agent-based models – ODD + D, an extension of the ODD protocol. Environ Model Softw 48:37–48. https://doi.org/10.1016/j.envsoft.2013.06.003

Nainggolan D, Termansen M, Reed MS, Cebollero ED, Hubacek K (2013) Farmer typology, future scenarios and the implications for ecosystem service provision: a case study from south-eastern Spain. Reg Environ Change 13:601–614. https://doi.org/10.1007/s10113-011-0261-6

Nave S, Jacquet F, Jeuffroy M-H (2013) Why wheat farmers could reduce chemical inputs: evidence from social, economic, and agronomic analysis. Agron Sustain Dev 33:795–807. https://doi.org/10.1007/s13593-013-0144-y

Nyambo DG, Luhanga ET, Yonah ZQ (2019) A review of characterization approaches for smallholder farmers: towards predictive farm typologies. Sci World J 2019:e6121467. https://doi.org/10.1155/2019/6121467

Paas W, Groot JCJ (2017) Creating adaptive farm typologies using Naive Bayesian classification. Inf Process Agric 4:220–227. https://doi.org/10.1016/j.inpa.2017.05.005

Pedersen TL (2021) An implementation of grammar of graphics for graphs and networks [R package ggraph version 2.0.5]. Comprehensive R Archive Network (CRAN)

Præstholm S, Reenberg A, Kristensen SP (2006) Afforestation of European landscapes: how do different farmer types respond to EU agri-environmental schemes? GeoJournal 67:71–84. https://doi.org/10.1007/s10708-006-9035-y

Primdahl J (1999) Agricultural landscapes as places of production and for living in owner's versus producer's decision making and the implications for planning. Landsc Urban Plan 46:143–150. https://doi.org/10.1016/S0169-2046(99)00038-9

R Core Team (2020) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria

Sardaro R, Girone S, Acciani C, Bozzo F, Petrontino A et al (2016) Agro-biodiversity of Mediterranean crops: farmers' preferences in support of a conservation programme for olive landraces. Biol Conserv 201:210–219. https://doi.org/10.1016/j.biocon.2016.06.033

Seppelt R, Arndt C, Beckmann M, Martin EA, Hertel TW (2021) Deciphering the biodiversity–production mutualism in the global food security debate. Trends Ecol Evol 35:1011–1020. https://doi.org/10.1016/j.tree.2020.06.012

Soini K, Diaz C, Gandini G, de Haas Y, Lilja T et al (2012) Developing a typology for local cattle breed farmers in Europe. J Anim Breed Genet 129:436–447. https://doi.org/10.1111/j.1439-0388.2012.01009.x

Tittonell P, Bruzzone O, Solano-Hernández A, López-Ridaura S, Easdale MH (2020) Functional farm household typologies through archetypal responses to disturbances. Agric Syst 178:102714. https://doi.org/10.1016/j.agsy.2019.102714

Valbuena D, Verburg PH, Bregt AK (2008) A method to define a typology for agent-based analysis in regional land-use research. Agric Ecosyst Environ 128:27–36. https://doi.org/10.1016/j.agee.2008.04.015

van Eck NJ, Waltman L (2010) Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics 84:523–538. https://doi.org/10.1007/s11192-009-0146-3

Van Herzele A, Gobin A, Van Gossum P, Acosta L, Waas T et al (2013) Effort for money? Farmers' rationale for participation in agri-environment measures with different implementation complexity. J Environ Manage 131:110–120. https://doi.org/10.1016/j.jenvman.2013.09.030

Walder P, Kantelhardt J (2018) The environmental behaviour of farmers – capturing the diversity of perspectives with a Q methodological approach. Ecol Econ 143:55–63. https://doi.org/10.1016/j.ecolecon.2017.06.018

Walder P, Kantelhardt J, Freyer B, Penker M (2012) Typologies of farmers: a literature review. In: ÖGA (ed) Ökosystemleistungen und Landwirtschaft: Herausforderungen und Konsequenzen für Forschung un Praxis. BOKU, Wien, 117–118

Walter A, Finger R, Huber R, Buchmann N (2017) Opinion: smart farming is key to developing sustainable agriculture. Proc Natl Acad Sci 114:6148–6150. https://doi.org/10.1073/pnas.1707462114

Weersink A, Fulton M (2020) Limits to profit maximization as a guide to behavior change. Appl Econ Perspect Policy 42:67–79. https://doi.org/10.1002/aepp.13004

Weltin M, Zasada I, Franke C, Piorr A, Raggi M et al (2017) Analysing behavioural differences of farm households: an example of income diversification strategies based on European farm survey

data. Land Use Policy 62:172–184. https://doi.org/10.1016/j.landusepol.2016.11.041

Wickham H (2016) ggplot2: Elegant graphics for data analysis. Springer, New York

Wilson P, Harper N, Darling R (2013) Explaining variation in farm and farm business performance in respect to farmer behavioural segmentation analysis: implications for land use policies. Land Use Policy 30:147–156. https://doi.org/10.1016/j.landusepol.2012.03.006

Zagaria C, Schulp CJE, Kizos T, Verburg PH (2018) Perspectives of farmers and tourists on agricultural abandonment in east Lesvos. Greece Reg Environ Change 18:1467–1479. https://doi.org/10.1007/s10113-017-1276-4