Industrial Crops & Products 148 (2020) 112281

Contents lists available at ScienceDirect

Industrial Crops & Products

journal homepage: www.elsevier.com/locate/indcrop

Miscanthus in the European bio-economy: A network analysis

N. Ben Fradj[a,*], S. Rozakis[b], M. Borzęcka[a], M. Matyka[a]

[a] Institute of Soil Science and Plant Cultivation – State Research Institute, Dept. of Bioeconomy and Systems Analysis, 24-100 Pulawy, Poland
[b] School of Environmental Engineering, Technical University of Crete, Chania Crete 73100, Greece

A R T I C L E I N F O

Keywords:
Bio-economy
Biomass
Miscanthus
Systematic review
Social network analysis
Research orientation

A B S T R A C T

There is a need to conceive and support bioeconomy strategies within the context of sustainable development in the European Union. A holistic vision regarding the deployment of research on promising biomass crops, such as miscanthus, for bio-based industries, is therefore required to identify the actors, the drivers and the barriers shaping the sector's development outlook. Despite the large number of research studies on miscanthus, doubts remain about its interest from agronomic, socio-economic and technological aspects. A policy-based analysis is firstly developed to understand the research orientation in the period from 1953 to 2019. Combining literature review with network analysis, a comprehensive approach is performed to investigate the research interactions and orientation. Through analysis of research funding, the key factors in propelling the development of miscanthus sector are also identified. Having been in stand-by for many years, the growth of miscanthus supply chain has recently been accelerated with the rise of biorefinery concept by the end of 2009 as well as with the implementation of climate-energy framework agreed in 2014. Though, regional disparities in terms of number of research studies exist between the North, the Centre and the South of Europe, the creation of research and development support programmes notwithstanding. Furthermore, research orientation and funding mechanisms strongly depend on national strategies and priorities, and the barriers hampering the sector's development. The efforts were generally pushed towards assessing the agronomic, environmental and economic potential and identifying sustainable and cost-efficient biomass conversion technologies as well. Policies, collaborations and research funding are still shaping the sector, thereby coping with existing barriers to bring about competitive and breakthrough technologies.

1. Introduction

In response to the growing world's population and climate change concerns, questions still hang over the adaptation of production systems to the increasing food and energy demands, and the identification of the most efficient and sustainable production schemes. Interest towards bio-based economy has, therefore, been increased by aligning policies relating to central and interdependent sectors, ranging from agriculture and forestry, food, feed, bioenergy, to bio-chemistry (El-Chichakli et al., 2016). A bio-based economy focuses primarily on the development of new prospects in conventional and new bio-based sectors, while meeting the requirements of sustainable development (EU Council, 2014b), from economy, food and energy security to ensuring an effective management of natural resources. Facing these strategic challenges requires a phased-in substitution, on a large scale, of fossil carbon with renewable one that can be produced from biomass as well as a changeover to biological processes that can be deployed for the transformation of resources into bio-based materials and bioenergy (Albrecht et al., 2010; Scarlat et al., 2015). Thus, a successful transition relies, firstly, on the availability of large quantities of biomass produced in a sustainable way and efficiently mobilised to achieve economy of scale, and secondly, on developing alternative and innovative production technologies that ensure cost-effectiveness in biomass transformation (Scarlat et al., 2015).

Over the years, the continuous use of conventional renewable carbon has led to land-use conflict with food supply, to growing competition for water resources, and to pressures on biodiversity and the environment. Several research studies and projects have dealt with the potential contribution of different biomass feedstock to replace conventional resources and improve energy efficiency, while lessening greenhouse gas (GHG) emissions and alleviating climate change effects. There is evidence that perennial energy crops, such as miscanthus, have the largest technical potential for such purpose. Miscanthus has a strong yield potential through its low nutrient requirements and high efficiency in the conversion of solar energy into biomass, thus being suitable for marginal areas (Quinn et al., 2015).

* Corresponding author .
E-mail addresses: nosrabenfradj@iung.pulawy.pl (N. Ben Fradj), srozakis@isc.tuc.gr (S. Rozakis).

https://doi.org/10.1016/j.indcrop.2020.112281
Received 7 October 2019; Received in revised form 22 February 2020; Accepted 25 February 2020
Available online 03 March 2020

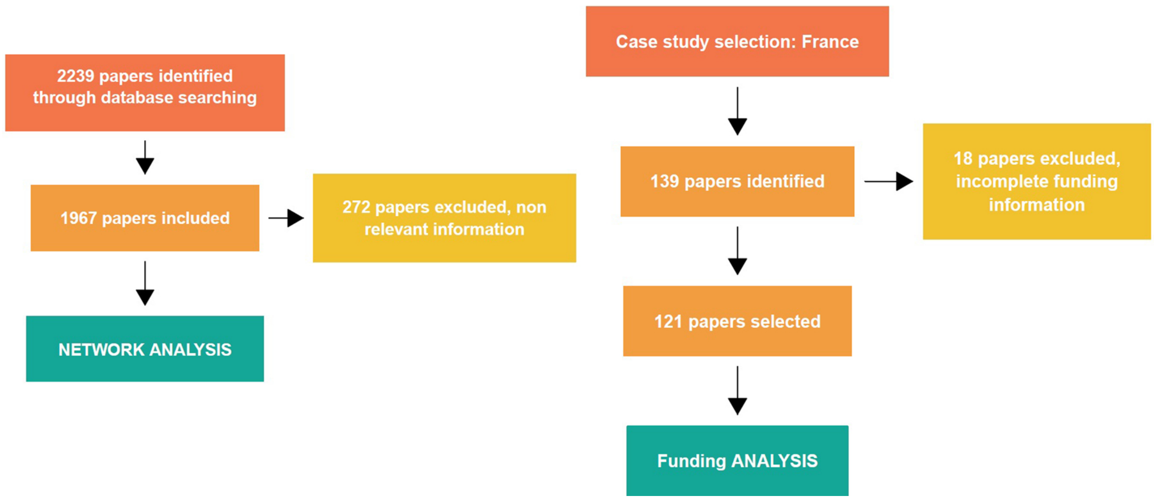


Fig. 1. Flow diagram showing the selection process for network and funding analyses. The diagram is generated by the plot_PRISMA() function from METAGEAR package for R.

Native to Asia, miscanthus, also called 'Giant Miscanthus' was first brought into Europe in the 1930s. Miscanthus is a particularly promising C_4 crop plant thanks to its highly efficient use of nitrogen, water and sunlight. It is a perennial crop that uses vegetative propagation methods, harvested each year for up to 25 years due to rhizomes, underground storage organs that produce buds which develop to become stems. Despite the drawback of a large genome it has the tremendous advantage of being very close, taxonomically, to sorghum and secondly to maize, which dramatically expands the genomic resources available for miscanthus genetics and breeding. Reported applications of miscanthus biomass refer to (ranked by descending order of use in Europe): bioenergy (combustion for heat and electricity or gasification), building material (light concrete, wall and wind-protection covering, loam walls, insulation, roofing), car parts (steering wheels, oil binder), horticulture (pots, culture substrates, mulch and bedding for fruits and vegetables), and animal husbandry (horse bedding) (Lewandowski et al., 2018).

In the light of the above, miscanthus has clearly aroused interest amongst researchers over the years. Numerous research studies have thus been carried out to promote its development as well as to assess and improve its potential and performance. These studies have been mostly funded by a multitude of projects and programmes conducted to provide solutions to barriers hampering the widespread use of bio-based energy and materials from miscanthus and to promote its environmental features as well. Though, its future, in Europe, is still unclear and doubts remain about its interest from agronomic, socio-economic and technical perspectives. Hence, the authors propose to investigate the literature on the deployment of different research aspects related to miscanthus in order to provide evidence on whether and for which usage the promotion of its production should continue and strengthen.

To this purpose, by bringing a multi-disciplinary approach, a systematic literature review is used to assess the current position of miscanthus in the economy. A methodological protocol is developed to identify and analyse the relevant research studies. Results of policy-based analysis are presented in chronological order to understand the past, current and future research orientation. In the next section, a network analysis is performed to discuss the development of miscanthus as a raw material for the production of bio-based materials and visualise the interactions between countries in terms of collaborations. Progress on research and relationship between research fields and funding sources is then discussed by presenting the French experience to identify the key factors in propelling forward the development of miscanthus sector. Finally, bio-based applications of miscanthus are reported and orientation of miscanthus-related research is discussed.

2. Methodology

The sequence of the systematic review is organised around three steps. Firstly, after selecting the reference database and the appropriate search terms, the authors outline the relevant studies according to inclusion and exclusion criteria to minimise selection bias. Secondly, a methodological review protocol is built to analyse the content of selected references. Lastly, the findings are evaluated, synthesised and discussed.

2.1. Identification of the most relevant references

In the literature, miscanthus has been referred to in different ways. The only hybrid genotype commercially available in Europe is *Miscanthus × giganteus*. Nevertheless, different genotypes have been tested to optimise biomass potential, i.e. *Miscanthus sinensis*, *Miscanthus sacchariflorus* and other hybrids. Then, the bibliographic search was arranged and limited to the following terms: "*Miscanthus × giganteus*", "*Miscanthus sinensis*", "*Miscanthus sacchariflorus*" and "*Miscanthus hybrids*". The references are provided by Scopus database linked to the most important publishers, such as Elsevier, Springer, and Blackwell, among others.

The query search had resulted in 2985 papers. The search was then restricted to 12 (out of 25) Scopus' subject areas: "*agricultural and biological sciences*", "*environmental science*", "*energy*", "*chemical engineering*", "*biochemistry*", "*materials science*", "*social sciences*", "*computer sciences*", "*multidisciplinary*", "*business, management and accounting*", "*mathematics*", "*economics, econometrics and Finance*", and "*decision science*". The search was limited to English and included only journal articles, book chapters, books and conference proceedings. However, no restriction has been put on the year of publication.

Given that the bibliographic search had generated a large number of studies (2239 papers), a GUI screener from METAGEAR package for R (Lajeunesse, 2017), was used to screen the abstracts and titles, thus selecting the most relevant references. After the screening, data were extracted from 1967 selected studies, first, to carry out a network analysis, and second, to analyse funding orientation in Europe (Fig. 1).

The majority of selected references are mainly published in a wide range of journals (94.2%). Conference proceedings and book chapters account for only 4.2% and 1.6%, respectively. The journals' scopes extend to different aspects including management, environment, socio-economics, policy, bioenergy process and utilisation, and breeding (Fig. 2). Most of the papers are published in *GCB Bioenergy* (10.1%), *Biomass & Bioenergy* (8.3%), *Bioresources technology* (5.9%), and

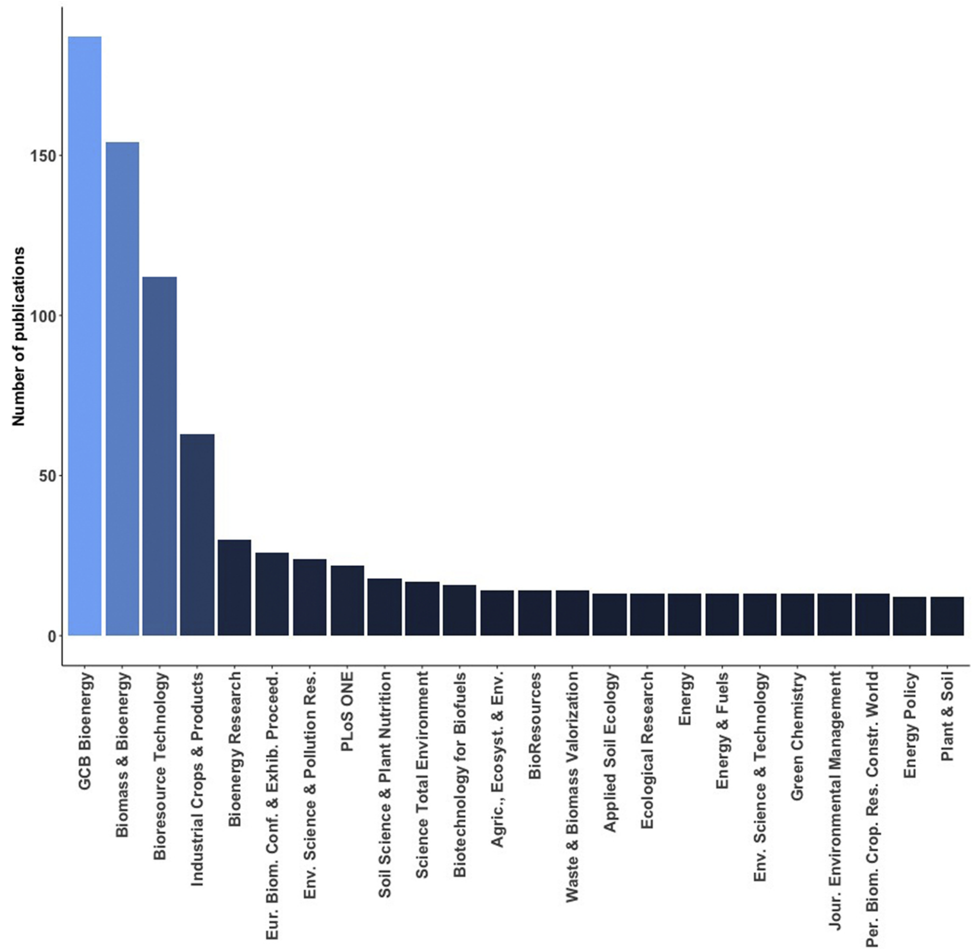


Fig. 2. Classification of selected references according to publication sources.

Industrial Crops and Products (3.3%).

2.2. Bibliometric network analysis

Network analysis has its origins in social science since the 1930s, and it was mainly developed to understand the structure of social relations among individuals (Moreno, 1953). Later, the concept has broadened and nowadays researchers are rather interested in analysing relational data to bring about the structure of relationships established between social entities or actors, i.e. individuals, groups, organisations, etc. (Oliveira and Gama, 2012). Through the years, many tools have been developed to examine and understand the contents and patterns of interactions among them. These tools allow to extract knowledge from networks, thus helping to identify the most influential or central actors. In general, the analysis encompasses social networks, but it can include information networks, technological networks, and biological ones (Oliveira and Gama, 2012). In this study, a Social Network Analysis (SNA) is undertaken, involving collaboration network and keywords co-occurrence network. The former is a network of co-authorship, in which researchers are linked if they co-author one or more papers. The latter is formed when two keywords appear together in a study. Through these analyses, the authors attempt to construct network maps, based either on co-authorship relations or on text mining features used for co-occurrence network of keywords extracted from the selected studies. These maps help to make the identification of the pioneer actors or countries that have developed interrelated research groups on miscanthus easier, and the implications of these relationships clearer.

In this study, networks or graphs are constructed and displayed using VOSviewer software (www.vosviewer.com; Van Eck and Waltman (2010, 2014)). Bibliometric networks are built based on bibliographic database downloaded from Scopus. Graphs are composed of vertices and edges. Vertices, also called nodes, represent countries, publications, or terms. An edge is the line that links a pair of vertices. Each edge is represented by a non-negative value. A higher value means stronger relationship between entities. The edge weight indicates the number of publications two nodes have in common (co-authorship network) as well as the number of publications that contain two co-occurred terms (co-occurrence network). Similar vertices are grouped into clusters, also called modules, that are labelled with numbers and colours. The VOS clustering technique is based on a resolution parameter (a positive value) that determines the clustering level. The higher the resolution value, the larger the number of clusters.

Indicating their importance, clusters are also designed by weights restricted to positive values. In the graph, more important vertices (with higher weight) are notably displayed against the less important ones (with lower weight). The edge weight between vertices can be normalised according to three methods, i.e. the association strength, fractionalisation, and LinLog/modularity. To calculate bibliometric indicators, two approaches have been used, i.e. the full counting methods and the fractional counting methods. For instance, when two researchers co-author a publication, the weight attributed to each researcher is equal to 1 (full) in the first case and to 1/2 (fractional) in the second (Perianes-Rodriguez et al., 2016). Although, the full counting is by far the most commonly used method in the literature (Perianes-Rodriguez et al., 2016), fractional counting offers a valid approach for normalised comparisons, so that each unit of analysis is equally representative (Van Eck and Waltman, 2014; Perianes-Rodriguez et al., 2016).

To locate vertices in a graph, attraction and repulsion parameters are taken into account. Both of these parameters are represented by integer values between − 9 and + 10 for the former and between − 10 and + 9 for the latter. According to VOSviewer's developers, it is recommended to set the attraction and repulsion parameters to 2 and 1, respectively. Good results can also be generated for values of (2, 0) or (1, 0).

Networks or graphs can be directed or undirected according to the direction of their links. Directed networks are those whose all edges have direction, and thereby indicating a one-way relationship. In undirected networks, edges do not have a direction and each of them connects simultaneously a pair of vertices. Each network is structured around an adjacency matrix, denoted by A ($n \times n$), where n represents the number of vertices. With zeros in the diagonal, matrix elements indicate whether a pair of vertices are joined or not in the network. As for undirected network, the adjacency matrix is therefore symmetric.

As mentioned above, two types of networks are displayed using VOSviewer software (Van Eck and Waltman, 2010):

1. **collaboration network**, in which countries are linked to each other on the basis of the number of publications jointly authored. For each country which meets the minimum threshold of publications, the total strength of the authorship links with other countries is calculated. Only countries representing the greatest total link strength are displayed in the network.
2. **co-occurrence network**, which represents publications containing two terms occurring together. Terms are mainly extracted from authors' keyword lists. For each keyword whose occurrence is above a certain threshold, the total strength of the co-occurrence links with other keywords is calculated. Keywords with the greatest total link are selected.

These networks are analysed and discussed in the following section to point out the most important countries and research fields in which miscanthus has been given particular interest. For better understanding of the research orientation, a funding analysis is also provided. Additionally, the policy context that triggered the development of research on such a crop, is discussed.

3. Results and discussion

This section provides an analysis of the past, current, and future situations of the development of miscanthus, exploring literature with focus on policy, agronomic, environmental, socio-economic and industrial areas. Yet, important features related to yield, management and economic aspects of miscanthus are firstly detailed in order to make the reader familiar with this crop. The description below involves *Miscanthus giganteus* referred to as *M. giganteus*, which is an hybrid derived from crossing *Miscanthus sinensis* with *Miscanthus sacchariflorus*. *M. giganteus* is the only genotype available on the European market because of its high potential, good environmental profile, and minimal risk of invasiveness (Lesur et al., 2014; Jørgensen, 2011).

3.1. Main characteristics of M. giganteus production

Being a sterile and non-invasive crop, the propagation method of *M. giganteus* is *via* rhizomes or micro-propagated plantlets (Anderson et al., 2011), the plantation of which takes place in spring. The plantation is followed by a 3-year establishment phase, during which limited yields are recorded. The slow growth pattern and the low planting density make miscanthus highly exposed to weed risks. Therefore, weed control is recommended in the first two years. In Europe, since miscanthus is still grown on small areas, few diseases are reported (Lewandowski et al., 2018). So far, measures for pest and disease control are not necessary. As regards the N-fertilisation, it is not recommended during the first three years because the roots are not too deep to retain N. As of the third year, the plant maturity is reached. Plantations grow up to 3–4 meters (m) tall and roots reach nearly 1.8 m deep (Lewandowski et al., 2003; Anderson et al., 2011). As regards fertilisation, it highly depends on soil properties and nutrient removal. The lifespan of *M. giganteus* ranges from 10 to 25 years, depending on economic conditions (Ben Fradj and Jayet, 2018). At the end of its lifespan, herbicides are applied to kill the plants and below-ground parts are removed (Witzel and Finger, 2016).

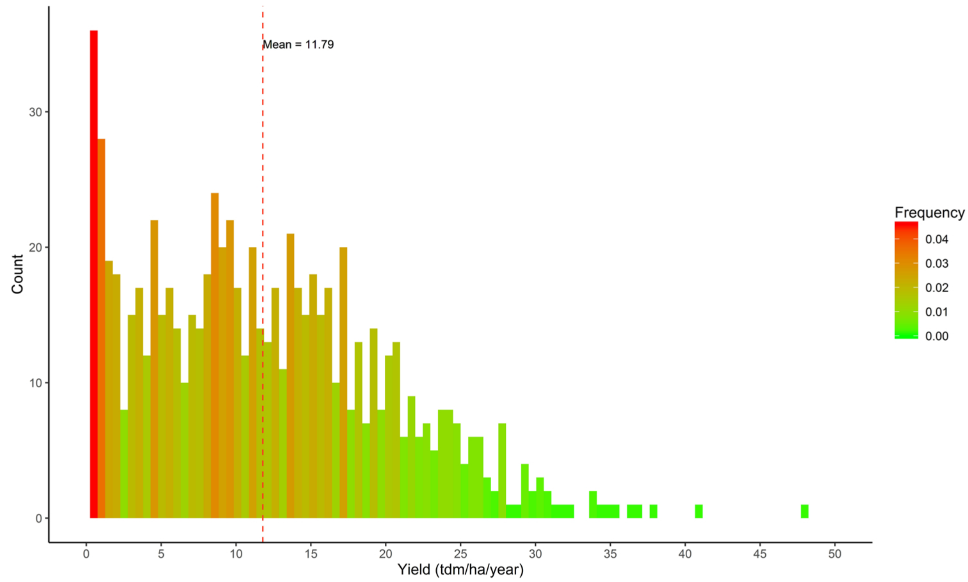
Miscanthus is a thermophilic plant with C_4 photosynthesis pathway, which makes it less suitable for cold and water limited regions. On the one hand, optimal growth temperature is 28–32 °C and plants stop growing at temperature below 6 °C. The stands can be damaged in frost periods, especially when the latter occur during the establishment phase. Miscanthus growing season is particularly limited by spring frosts which cause yielding decrease. Therefore, for a successful plantation, miscanthus requires medium and light soils that can be easily warmed, rather than heavy and catchment soils located in depression zones. In addition, snowfalls can provoke a delay in harvest and cause leaf drop which significantly reduces yields (Matyka and Kus, 2016). On the other hand, miscanthus is characterised by an efficient water use due to its low transpiration. Though, to avoid low biomass yielding, it is not recommended to grow miscanthus on areas with annual rainfall lower than 500–600 mm.

3.1.1. The yield

In Europe, a wide range of yields are reported depending on the harvest time, soil and climate conditions, and management practices, e.g. irrigation, fertilisation. Yields range from 20 to 50 tdm $ha^{-1}\,y^{-1}$ for early harvest (in October) (Clifton-Brown et al., 2004; Lewandowski et al., 2000), and from 10 to 30 tdm $ha^{-1}\,y^{-1}$ for late harvest (in February–April) (Lesur et al., 2013; Miguez et al., 2008). Recently, a global dataset of multiple field experiments was compiled to describe the biomass yields of major lignocellulosic crops (Li et al., 2018a,b). According to this database, an average yield of 11 tdm $ha^{-1}\,y^{-1}$ is revealed (Fig. 3). A comparison between different *Miscanthus sp.* shows that *M. giganteus* yields are higher than those of *M. sinensis* and *M. sacchariflorus*.

3.1.2. Nutrient requirements

Miscanthus is characterised by high efficiency of nutrient uptake because of its extensive root system (Beale and Long, 1997; Himken et al., 1997; Monti and Zatta, 2009). Lewandowski and Schmidt (2006) reported also a high use efficiency of nutrients. Those latter are translocated from rhizomes to the above-ground parts during the growth period and mobilised in rhizomes at the end of the growing season (Himken et al., 1997; Cadoux et al., 2012). Nutrient contents are also different in the above-ground parts, being higher in leaves than in stems (Beale et al., 1996; Lewandowski and Kicherer, 1997). Nevertheless, from the third year, nutrients are removed at harvest. In a review study, Cadoux et al. (2012) reported that the removal of 4.9, 0.45 and 7.0 g/kg dm of N, P and K, respectively, should be compensated by fertilisers. In literature, experts agreed that N fertilisation is not usually required to maintain high Miscanthus yields, unless in poor soils. Nevertheless, there is no consensus regarding optimal nutrient requirements, even though the response of yields to N has been examined in many studies. Those latter have shown ambiguous results due to variations in crop management, atmospheric conditions and soil composition. Many authors have indeed reported no yield response to N fertilisation (Christian et al., 2008; Himken et al., 1997; Shield et al., 2012; Strullu et al., 2011) while others have shown significant positive yield responses (Arundale et al., 2014; Ercoli et al., 1999; Haines et al., 2015; Pedroso et al., 2014). In this regard, for late-harvested miscanthus, (Lewandowski et al., 2018) recommend an application of 50 kg ha^{-1} on sandy soils or soils with low organic matter. However, early-harvested stands require higher N-input levels, depending on nutrient removal at harvest.



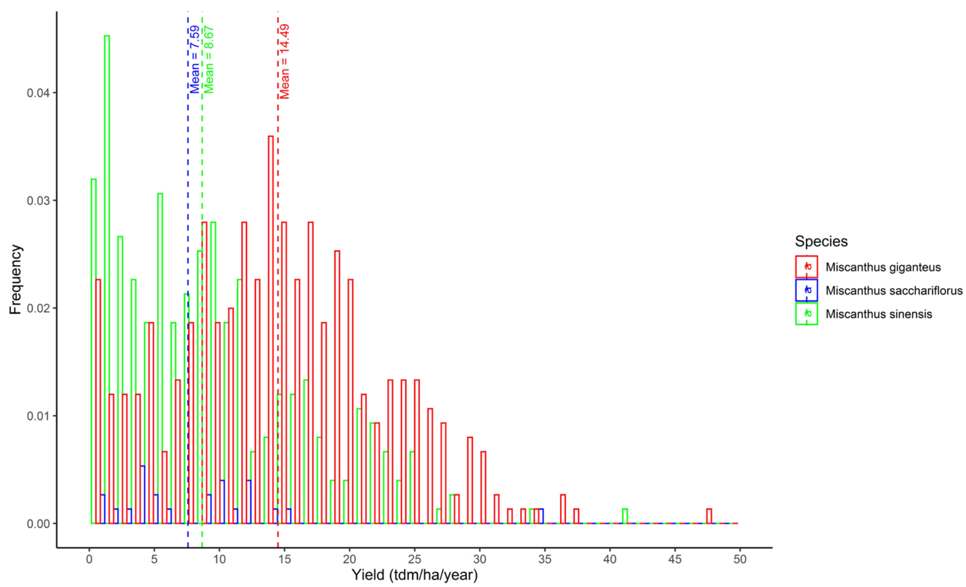


Fig. 3. Biomass yield of miscanthus in Europe. Red vertical lines denote the averages. Values obtained from the "global yield dataset for major lignocellulosic bioenergy crops based on field measurements" published in Li et al. (2018a,b). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.1.3. Economics

In a review paper, Witzel and Finger (2016) undertook an economic evaluation of *M. giganteus* and revealed the unattractive economic aspects of its production. This stems, first and foremost, from the high establishment costs, of which plantation and rhizomes have the largest share. The latter are about €2075 ha^{-1}, thereby representing 80% of total establishment constitute the largest share. The average labour and machinery costs are €420 ha^{-1}, while the average costs related to weed control and fertilisation are €112 ha^{-1}. After the establishment phase, farmers incur also costs ranging from harvest, transport, storage, fertilisation, to land rent. The harvest and transport costs are about €500 ha^{-1} and €5.76 ha^{-1}. Depending on harvest processes, storage cost ranges from €20 ha^{-1} to €95 ha^{-1}. A benchmark application of 60 kg N ha^{-1} is used in Clifton-Brown and Lewandowski (2002) and Khanna et al. (2008). In a few studies, a range of land opportunity costs is reported depending on regions and substitute land uses for *M. giganteus*. For instance, in Germany, hypothetical land opportunity costs are €441 ha^{-1} and €420 ha^{-1} for winter barely and winter wheat, respectively. To annual costs, a closing cost is added at the the end of lifespan to terminate the rotation. Equal to €69 ha^{-1}, the cost does not influence the farmer decision regarding *M. giganteus* adoption.

Furthermore, the profitability of *M. giganteus* is sensitive not only to the market price and yields (Ben Fradj and Jayet, 2018), but also to the support schemes offered to farmers. Compared with conventional crops, *M. giganteus* is less competitive considering low prices assumed in literature. The average price is slightly lower than €80 ha^{-1}. In most cases, assumptions do not take into account price uncertainty due to insufficient price data. Ben Fradj and Jayet (2018) showed that miscanthus profitability is highly sensitive to prices. Prices higher than €90 ha^{-1} ensure a rapid return on investment and a yearly income more or less equivalent to that of conventional crops. A miscanthus grower can also increase his income through subsidies. Cultivated without any support from the Common Agricultural Policy (CAP) until 2017, the crop has finally become eligible to ecological focus areas. Nevertheless, according to Perrin et al. (2017) who investigated the performance of miscanthus-based supply chains at the regional scale, an expansion of

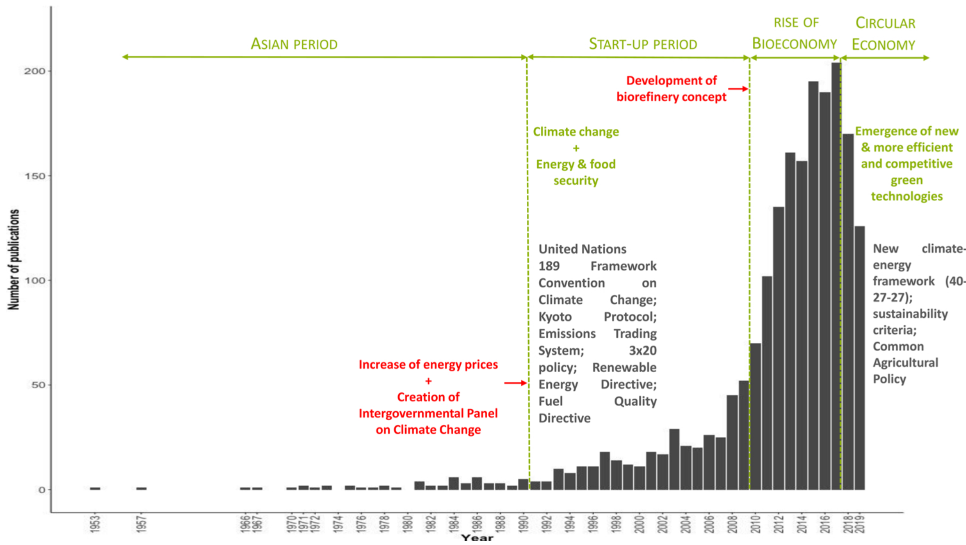


Fig. 4. Worldwide evolution of the annual scientific production of publications on miscanthus from 1953 to 2019.

biomass supply leads to higher environmental impacts rather than to increased profitability.

3.2. Policy context of miscanthus-related research in Europe

Based on the search query, 1974 studies have been identified in the period from 1953 to 2019 in the whole world. According to Fig. 4, four main time intervals are clearly distinguished, i.e. before 1990, from 1990 to 2010, from 2010 to 2018, and after 2018. It is during the last two time periods that miscanthus has aroused much interest amongst researchers producing more than 50 publications per year.

3.2.1. Before 1990: the Asian period

In this period, studies were mainly carried out in Japan, either on *M. sinensis* or *M. sacchariflorus*. Since it had been cultivated as grassland species for several hundred years, *M. sinensis* was first studied to test the effect of grassland and rainfall on soil erosion (Matsuoka and Kawakami, 1953), control the process of vegetative spread (Kawana et al., 1966, 1967; Aonuma, 1970; Haibara et al., 1983) and pests (Matsumoto, 1971; Nakamura et al., 1971). Later, studies focused on assessing the potential productivity (Lieth et al., 1973; Tsuchida and Numata, 1979; Hayashi et al., 1981; Hayashi, 1984) as well as the vegetation growth and recovery in mountainous areas (Takayama, 1982; Sakura and Numata, 1973; Koohei et al., 1984). As for *M. sacchariflorus*, researchers studied the dynamics of reserve substances and nutrients in rhizomes (Masuzawa and Hogetsu, 1977; Sangster, 1985) and the growth response to varying inundation (Yamasaki and Tange, 1981).

In Europe, the increase in energy prices, by the end of 1980s, had triggered research on biomass as a potential source of energy. In this context, the suitability of *M. sinensis* for biofuels' production was investigated by analysing its chemical composition (Faix et al., 1989). Since that time, miscanthus-related research has considerably increased over the years, driven by the EU climate policy on the one hand, and by strategies for reducing dependence on foreign energy resources on the other.

3.2.2. From 1990 to 2010: the start-up period

Over this period, the emergence of international policies and instruments on climate change promoted the use of renewable feedstock with the aim of reducing global warming and tackling climate change consequences. In fact, the Intergovernmental Panel on Climate Change (IPCC), jointly created by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988, played a major role in the creation of action and cooperation frameworks for international agreements, more precisely, the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. From this dual perspective of energy security and climate change, research studies were conducted to test the potential of *M. sinensis* for the development of bio-based industries, (Wegener, 1992; Kordsachia et al., 1993; Papatheofanous et al., 1995; Iglesias et al., 1996; Vega et al., 1997; Oggiano et al., 1997; Szabó et al., 1996; Verkade and Kuijper, 1996; Wagenaar and Van Den Heuvel, 1997). Thus, it was shown that this promising crop may provide energy and bio-based products' sectors with a reliable supply of slightly lower quality than that of other competitive resources. Nevertheless, *M. sinensis* had just been introduced in Europe and its potential as an agricultural crop was not well-known. Hence, research was oriented towards assessing yield potential (Christian, 1994) and plant disease (Christian et al., 1994). Several studies were then focused on breeding for generation of new genetic variations (Greef and Deuter, 1993; Lafferty and Lelley, 1994; Sobral et al., 1994) more suitable to the wide range of European climate conditions and more appropriate biomass for energy uses, with a low risk of invasion. New methods of crop establishment (Otte et al., 1996) and storage (Huisman and Kortleve, 1994) had thus been discovered, and potential yield as well as nutrient accumulation had been assessed in cool temperate climate (Beale and Long, 1995, 1997; Beale et al., 1996) and compared to different *Miscanthus sp.* (Jørgensen, 1997). For better Nitrogen (N) management, more research was needed to assess nitrous oxide (N_2O) emission factors (Jørgensen et al., 1997), to explore bio-fertilisers (Kirchhof et al., 1997), and to study N requirements and yield and emission responses to N fertilisation (Schwarz et al., 1994; Wiesler et al., 1997; Beale and Long, 1997; Christian et al., 1997)

After signing the Kyoto Protocol, in 1997, aiming at averting climate change effects, the European Union (EU) launched, in 2005, within the framework of its climate policy, the Emissions Trading System (ETS) to mitigate global warming by limiting emissions from large energy-using facilities in power, industry and aviation sectors. Two years later, the EU leaders established key "triple 20" targets for 2020 in order to lessen GHG emissions by 20% from their 1990 level, enhance energy efficiency by 20%, and expand the renewable energy share in total energy consumption by 20%. In addition to national plans, the action was reinforced by two Directives: (1) the Renewable Energy Directive (2009/28/EC) which set a 10% target for transport energy demand to be met using renewables by 2020; and (2) the Fuel Quality Directive (2009/30/EC) imposing fuel distributors to reduce, by 2020, GHG emissions of total distributed fuel by at least 6%. Meeting at least a part of these commitments has required an increase of the biomass contribution to the energy generation.

The environmental, economic and geopolitical impacts from first generation biofuels' development and the related support policy led to an ambiguous overall assessment. Direct and indirect land use changes (LUC and iLUC respectively) have been caused indeed by the establishment of biofuels' policies (Rosegrant et al., 2008; Searchinger et al., 2008; Beckman et al., 2011). A fierce food *vs.* fuel debate had consequently emerged, in particular at the time of food crisis in 2007/08. In this context, the research on miscanthus was oriented to investigate the large-scale available potential (Clifton-Brown et al., 2004; Price et al., 2004; Fischer et al., 2005; Stampfl et al., 2007; Richter et al., 2008) on the one hand, and the environmental and economic efficiency of miscanthus-based energy at the agricultural and industrial scales (Collura et al., 2006; Styles and Jones, 2007; Uellendahl et al., 2008; De Vrije et al., 2009) on the other. For instance, several researchers focused on plant improvement through testing new crop management (Jezowski, 2008) and breeding (Hernández et al., 2001; Rothballer et al., 2008). Others assessed the impact of miscanthus production on land use (Haughton et al., 2009; Lovett et al., 2009), storage and quality of soil organic matter (Kahle et al., 2001; Hansen et al., 2004), soil carbon sequestration (Foereid et al., 2004; Clifton-Brown et al., 2007; Borzecka-Walker et al., 2008), N and water supply (Lewandowski and Schmidt, 2006; Cosentino et al., 2007; Richter et al., 2008), energy and GHG balance (Lettens et al., 2003; Styles and Jones, 2007), and biodiversity (Semere and Slater, 2007a,b; Bellamy et al., 2009).

When it comes to the adoption of a perennial crop at the farm-scale, some supply constraints were identified (Sherrington et al., 2008). Most of the studies were about *M. giganteus*, but in many of them other genotypes have been compared with the aim of overcoming the production limitations of the former (Clifton-Brown et al., 2002; Clifton-Brown and Lewandowski, 2002). Furthermore, as a result of the Directive 2003/87/EC establishing a EU GHG emission trading scheme, more efforts had been made to test the efficiency of alternative miscanthus-based industries such as bio-plastics (Johnson et al., 2005) and light weight concrete (Pude et al., 2005). As for ethanol production, different biomass treatment methods were evaluated (Sørensen et al., 2008; Brosse et al., 2009).

3.2.3. From 2010 to 2018: the rise of the bio-based economy

The bioeconomy has been first introduced in 2005 as a central frame to shift from fossil-based to bio-based energy and materials, through the development of the biorefinery concept. This latter has undergone a remarkable rise by the end of 2009, in the miscanthus-related research field, thereby helping the emergence of new and more efficient, and competitive green technologies for biomass transformation. Accordingly, few years later, in 2012, a bioeconomy strategy has been launched in Europe. In this regard, several studies dealt with modelling the potential supply for biorefinery, anaerobic digestion in particular (Wahid et al., 2015; Kiesel and Lewandowski, 2017). Since the final use depends on biomass quality, the sensitivity of chemical composition to crop management as well as to genetic and environmental factors was extensively tested (Hodgson et al., 2010; Allison et al., 2011). In addition, many pre-treatment processes were evaluated for a better and more efficient separation of chemical components (Alriols et al., 2010; El Hage et al., 2010; Toledano et al., 2010; Michalska et al., 2015).

The research has also been shaped by the new climate-energy framework agreed in 2014 (EU Council, 2014a) to widespread and regulate the production of sustainable energy sources and meet 2050 GHG abatement target. The new package aims at reducing GHG emissions by 40% from their 1990 level, enhancing energy efficiency by at least 27%, and expanding the share of renewable energy in the total energy consumption by at least 27%. In order to guarantee the use of environmentally-friendly bioenergy products, the European Commission (EC) has fixed sustainability requirements for more carbon savings and biodiversity protection. These objectives have resulted in promoting the plantation of miscanthus on low carbon stock and biodiversity areas. In this context, attributional and consequential Life Cycle Assessment (LCA) were used to assist public decision makers in evaluating new bioenergy and biorefinery projects (Brandão et al., 2010; Blengini et al., 2011; Dufossé et al., 2013). Several researchers assessed the LUC effects associated to the cultivation of perennial energy crops on soil organic carbon sequestration, GHG emissions, water quality and ecosystem services (Harris et al., 2015; Styles et al., 2015; Chimento et al., 2016; Ferchaud et al., 2016; Milner et al., 2016). As for biodiversity, studies focused on assessing the impacts on the diversity and abundance of insects, e.g. pollinating insects (Stanley and Stout, 2013), beetles and spiders (Dauber et al., 2015). In addition, to evaluate and facilitate establishing miscanthus plantations on contaminated soils and wetlands, mineral uptake, productivity potential, and pollutant removal efficiency were determined (Ollivier et al., 2012; Pavel et al., 2014; Toscano et al., 2015) and new phytoremediation techniques were investigated (Firmin et al., 2015).

Despite the high potential and environmental features of miscanthus, its large-scale plantation is limited by several socio-economic factors. To overcome these barriers, a better understanding of farmer's willingness was needed (Bocquého and Jacquet, 2010; Sherrington and Moran, 2010). Furthermore, economics of miscanthus production were investigated and evaluated at different crop development stages (Krasuska and Rosenqvist, 2012). The sensitivity of the profitability to agronomic and economic assumptions was explored (Witzel and Finger, 2016; Mantziaris et al., 2017) in deterministic and stochastic cases (Ben Fradj et al., 2016; Ben Fradj and Jayet, 2018). While some researchers tested several environmental policy assumptions (Bourgeois et al., 2014) to widespread its production, others pointed out the importance of introducing miscanthus to the greening measures of the common agricultural policy (CAP) for more innovative and effective instruments (Emmerling and Pude, 2017).

3.2.4. From 2018 until now: towards greener, more sustainable and cost-efficient production routes

The reader can notice that the number of miscanthus-related publications started to decline as of 2018 (Fig. 2), thereby pulling the research from the peak down towards the trough of disillusionment just as in the hype cycle. In fact, researchers are making several re-adjustment to come up with innovative answers to expressions of suspicion regarding the interest of miscanthus from agronomic, environmental, socio-economic and technological views. In addition, the research context has been triggered by two international action plans within UNFCCC, namely the Sustainable Development Goals (SDGs) adopted in 2015 and the Paris Agreement signed in 2016 as well as by the EU challenges defined in the updated bioeconomy strategy seeking to develop a circular economy and build a carbon-neutral future. Climate change is the common denominator shared by all these actions, trapping many countries into its vicious circle, and thus threatening present and future generations. In interaction with 6 out of 17 SDGs, the Paris Agreement has emerged to reduce collectively harmful activities to the environment, while maintaining a global average temperature increase below 2 °C and limit the temperature rise to 1.5 °C. Moreover, as part of the bioeconomy strategy, many research projects and collaborations saw the light to address the issues of natural resource and crop management related to sustainable and low carbon production of biomass as well as to identify promising bio-based value chains towards achieving a resource-efficient circular economy. In this regard, miscanthus is being given much interest to develop promising bio-products and bio-based value chains (Kraska et al., 2018; Ogunsona et al., 2018; Záleská et al., 2018; Giorcelli et al., 2019; Kolanowski et al., 2019) that require cross-compliance with the standards of circular economy, so that EU plans for the bio-economy can be satisfied.

Since long-term results start being available, modelling and quantitative assessments have been increasingly carried out to assess the environmental impacts of miscanthus cultivation on soil quality and land use patterns with greater consideration for below-ground C and N, and N_2O emissions. For instance, the assessments have not been focused

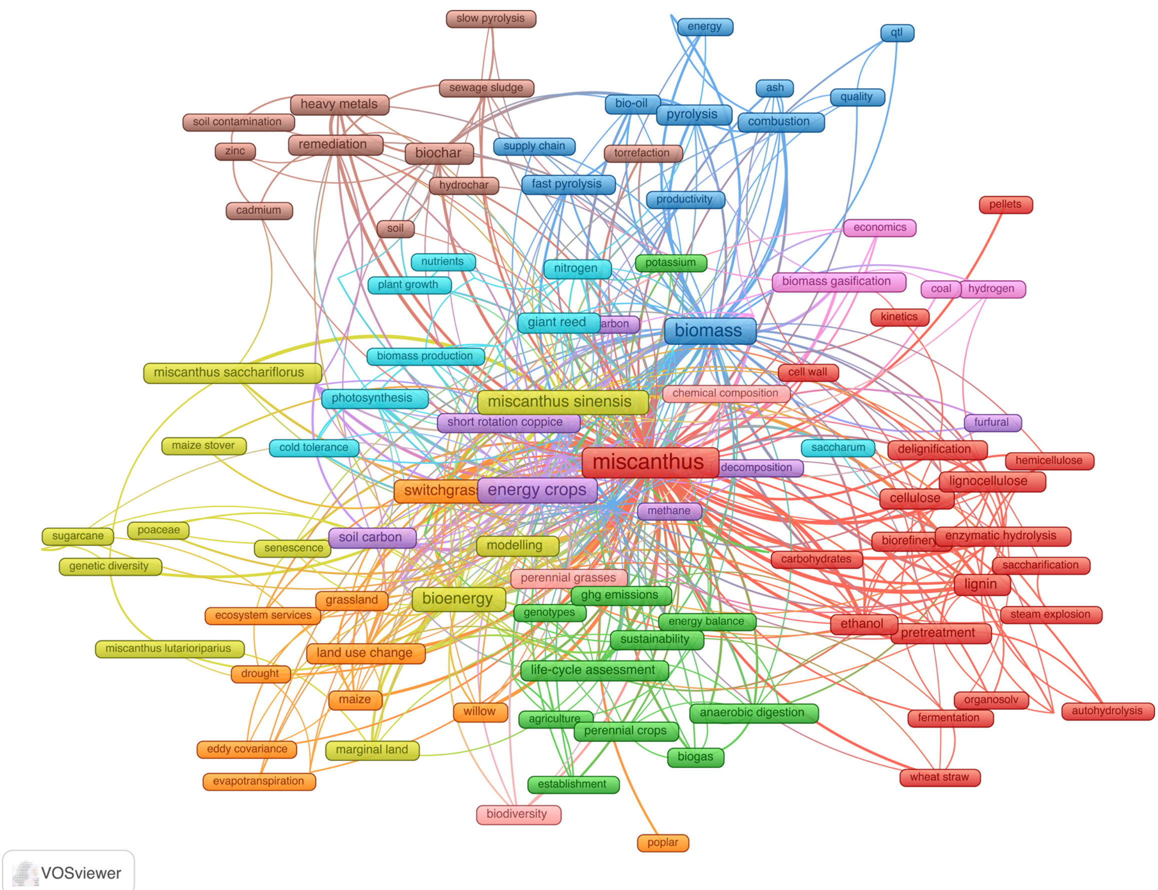


Fig. 5. Map of author keyword co-occurrence network built based on fractional counting method. The weight attribute is represented by the number of keyword occurrences, and attraction and repulsion parameters are set to 1 and 0, respectively. Clusters are displayed with different colours according to their weight. Stated by a decreasing order, the nodes are: *M. giganteus* referred to as miscanthus (red, 624 occurrences), biomass (blue, 234 occurrences), energy crops (purple, 172 occurrences), bioenergy (pear green, 151), switchgrass (orange, 89 occurrences), yield (green, 53 occurrences), biochar (brown, 52 occurrences), giant reed (cyan, 29 occurrences), biomass gasification (pink, 25 occurrences), and perennial grasses (soap orange,15 occurrences). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

on analysing only the seasonal dynamics of below-ground biomass to estimate C:N ratios for SOC stabilisation (Poeplau et al., 2019), but also the impact of miscanthus cultivation on SOC stocks and sequestration (Hu et al., 2018). While Ledo et al. (2018) have presented a generic model for carbon balance and GHG emissions calculations related to farm systems combining energy and food crops, Holder et al. (2019) have taken into account N_2O emissions during establishment phase to assess the impacts of land use change from pasture to miscanthus. Furthermore, for better contribution to sustainable development, miscanthus should be cultivated on marginal land which is less suitable for conventional crop production (Lewandowski, 2015). However, on marginal areas, yield potential cannot be attained because of the abiotic stresses (drought, slope, flooding, etc.) and the lack of essential nutrients (Clifton-Brown et al., 2019). This has brought into question the environmental and economic sustainability of ethanol and biogas produced from miscanthus cultivated on marginal land. LCA have, therefore, been performed to compare the environmental impacts of ethanol processed through different pre-treatment pathways (Lask et al., 2019), and combined with cost analysis to assess the environmental and economic performance of miscanthus for biogas production (Wagner et al., 2019). The research has also been oriented towards coping with the factors limiting miscanthus growth, either through investigating new approaches in searching of mechanisms of cold tolerance (Bilska-Kos et al., 2018) or through testing new crop management (Ashman et al., 2018).

To limit the negative impacts of heavy metals present in contaminated soils, phytoremediation using perennial energy crops, more precisely miscanthus, seems to be an effective pathway. In this regard, several studies have been conducted to determine the remediation peculiarities and the miscanthus-related growth factors (Nurzhanova et al., 2019; Andrejic et al., 2018), and to characterise the fuel properties (Werle et al., 2019) as well. The metabolism production of below-ground parts, and of rhizosphere bacterial communities have been also assessed under different contaminated conditions (Pham et al., 2018). In addition, Liber et al. (2018) have identified the growth parameters influencing the transfer of heavy metals from the soil to above-ground parts of miscanthus with the aim to evaluate its metal extraction capacity. In this regard, it is demonstrated that miscanthus is "*an efficient metal excluder*" (Karer et al., 2018). To improve the SOC stock of degraded areas under miscanthus plantation, application of biowaste and by-products is strongly recommended, and thus representing a successful model for rational management of available resources (Placek-Lapaj et al., 2019; Grobelak et al., 2018).

Many studies have shed light on other different remediation techniques to restore contaminated soils, *via* application of biochar as an improver for metal stabilisation because of its high C content. Regarding miscanthus biochar, microorganisms' activities are rather conditioned by the available C of biochar than by its pH, particularly in very acidic soils (Luo et al., 2018). In terms of effectiveness, it is shown that its application reduces efficiently metal concentrations (Janus et al., 2018; Shen et al., 2018) in different plant parts, and therefore improves the biomass yield (Shahbaz et al., 2018). Moreover, miscanthus biochar can be used not only as a bio-fertiliser to supply bioavailable Silicon responsible for stress alleviation and improvement of photosynthetic activity (Li et al., 2018a,b), but also as a fixative of antibiotics available in pig manure (Ngigi et al., 2019). As for its impact on global warming, although miscanthus biochar is suitable for *C* sequestration in temperate soils under future climate driven by elevated temperature, it may lead to increased N_2O emissions thereby raising soil GHG emissions (Bamminger et al., 2018).

3.3. Analysis of miscanthus-related research orientation

Here, keyword network maps provide the reader with information on the evolution of the scientific jargon related to miscanthus, and the fields in which the latter is more used. According to the bibliometric analysis of our references' sample, out of 4718 identified keywords, only 179 meet the minimum threshold of 5 occurrences. For each of these keywords, the strength of co-occurrence links is computed. 120 selected keywords that represent the greatest total weight, were displayed (see Fig. 5).

Ten clusters are formed around the most frequently occurring keywords. Stated by a decreasing order of the number of occurrences (Table 1, in Appendix A), these nodes are: *M. giganteus* referred to as miscanthus, biomass, energy crops, bioenergy, switchgrass, yield, biochar, giant reed, biomass gasification and perennial grasses. Accordingly, certain features of miscanthus are discussed hereinafter.

3.3.1. Is M. giganteus a viable energy source?

For sustainability reasons, *M. giganteus* is promoted to be grown on marginal and low carbon stock areas in order to limit Food *vs*. Fuel competition. However, its large-scale extension is limited, requiring expansive establishment phase (rhizome). Besides, farmers are reluctant to change their cropping system, particularly when they should reserve a parcel of land for a long rotation period (Ben Fradj and Jayet, 2018). Moreover, crop yield potential is usually sensitive to soil quality so that yield records on marginal land are low. The lower the yield, the more averse is the farmer to plant the crop (Ben Fradj and Jayet, 2018). This leads inevitably to an impasse when this crop is required to be produced and managed sustainably. In addition, due to climate change, periodic drought periods may occur and plants growing on marginal land will frequently face water stress episodes (Quinn et al., 2015). Consequently, a deficit in water availability, characterised by precipitation and soil water supply, explains 70% of miscanthus annual yield variation in the growing season (Richter et al., 2008). Irrigation may therefore be an unsustainable solution to insuring high yield potential and stable technical performance in diverse environments (Van der Weijde et al., 2017).

To overcome these agronomic and economic barriers, several studies showed that growing miscanthus is more cost-effective by enhancing the yield potential and the cultivation methods and by decreasing the plantation cost. Other *Miscanthus sp.* and hybrids were then studied to improve their establishment conditions, having more or less the same yield potential and, above all, a better water-use efficiency and cheaper vegetative multiplication phase (Lewandowski et al., 2016). Furthermore, the chemical composition of biomass differs according to harvest date, i.e. early harvest (from October to December) and late harvest (from February to April), thereby affecting the yield quality and, consequently, the end-use. At early harvest, the yield is higher than at late harvest. However, early harvested biomass represents a strong moisture content, thereby being more compatible with biorefinery processes, e.g. anaerobic digestion, than combustion. Kiesel and Lewandowski (2017) reported a high methane yield of 6000 cubic meters per hectare (m^3/ha) for a harvest in October. Uellendahl et al. (2008) proved that the conversion or pre-treated biomass from miscanthus into biogas is beneficial in terms of costs and energy. This may be a more cost-efficient option for farmers to produce miscanthus, since they can directly deliver the harvest to biogas plants with low storage costs (Wahid et al., 2015). With high and stable yields, early harvested miscanthus may therefore improve the sustainability of biogas sector by substituting for annual energy crops, e.g. maize (Kiesel and Lewandowski, 2017). *M*. giganteus is the most suitable genotype having the best silage quality (Mangold et al., 2019), considering the higher methane yield of ensiled biomass than that of non ensiled biomass.

3.3.2. An environmentally-friendly energy crop

Miscanthus is characterised by an efficient nutrients uptake due to its perennial rhizome system in which nutrients are first accumulated at the end of the vegetative cycle and then translocated to aerial parts in the spring (Amougou et al., 2011). In the case of late harvest, the mulch formed by dead leaves is gradually decomposed and returns nutrients to the soil, thus helping to build and sustain soil organic matter, and consequently decreasing fertiliser inputs (Cadoux et al., 2012). All these characteristics make miscanthus a promising candidate for the production under low-input patterns. However, mineral fertilisation may hence be considered to maintain high production levels during the life span (Cadoux et al., 2012; Dufossé et al., 2014), since some nutrients are removed at harvest, which may lead to a long-term exhaustion of soil nutrient stocks (Dufossé et al., 2014).

Miscanthus has been recognised as a crop whose cultivation is characterised by low GHG emissions as well as high potential of *C* sequestration in soil. The main reason for lower GHG emissions is *N* fertiliser application which is the most important management practice determining GHG balance (Behnke et al., 2012). However, significant variability can be observed in soil *C* sequestration. The pH has a significant influence on *C* retention in soil. The net balance of miscanthus is largely dependent on the region, indicating the importance of local *C* management in the soil (Borzecka-Walker et al., 2008, 2012; Hansen et al., 2004; Beuch et al., 2001; Zimmermann et al., 2012; Zatta et al., 2014). Production of miscanthus drives iLUC related to relocation of food production, and consequently affects GHG emission mitigation resulted from fossil energy substitution. In this sense, to prevent these side effects, Gerssen-Gondelach et al. (2015) highlighted the need for an integrated approach to iLUC mitigation, combining governance and policies and monitoring the implementation measures.

3.3.3. Miscanthus-based biofuel

Although, miscanthus has been promoted as an excellent biomass for energy conversion, there are still some barriers to leverage bioenergy market opportunities. Given that this crop is new to farmers, its cultivation requires further knowledge and technical equipment that most farmers do not have (Lewandowski et al., 2016), which limits its popularity as a biomass crop. Furthermore, depending on socio-economic factors (education, age, farming type, farm size), the willingness to grow new perennial energy crop is currently low (Gedikoglu, 2015). The potential supply depends also on farmer's perception of the risks related to these crops and of the amount and security of the financial return (Bocquého and Jacquet, 2010; Sherrington and Moran, 2010). In addition, unlike annual crops, miscanthus is not integrated into a structured biomass market, which makes farmers more concerned about selling their products at an expected price (Sherrington and Moran, 2010). All these factors make farmers reluctant to change the familiar cropping-system by integrating a new and economically unattractive crop characterised by a long lifespan and involving regulatory risk deriving from agricultural and energy policies (Sherrington and Moran, 2010). Farmers will be only willing to cultivate miscanthus if long-term and appropriate contracts with energy transformers are available and guaranteed by the government (Sherrington and Moran, 2010). In more recent study, Adams and Lindegaard (2016) found that the development of a "confident long-term bioenergy industry" mainly relies on: (1) developing small-scale innovation projects using established technologies, (2) a phased integration of perennial energy crops to ensure a regular development of local supply, (3) balancing supply measures and demand incentives, (4) providing grants with respect to

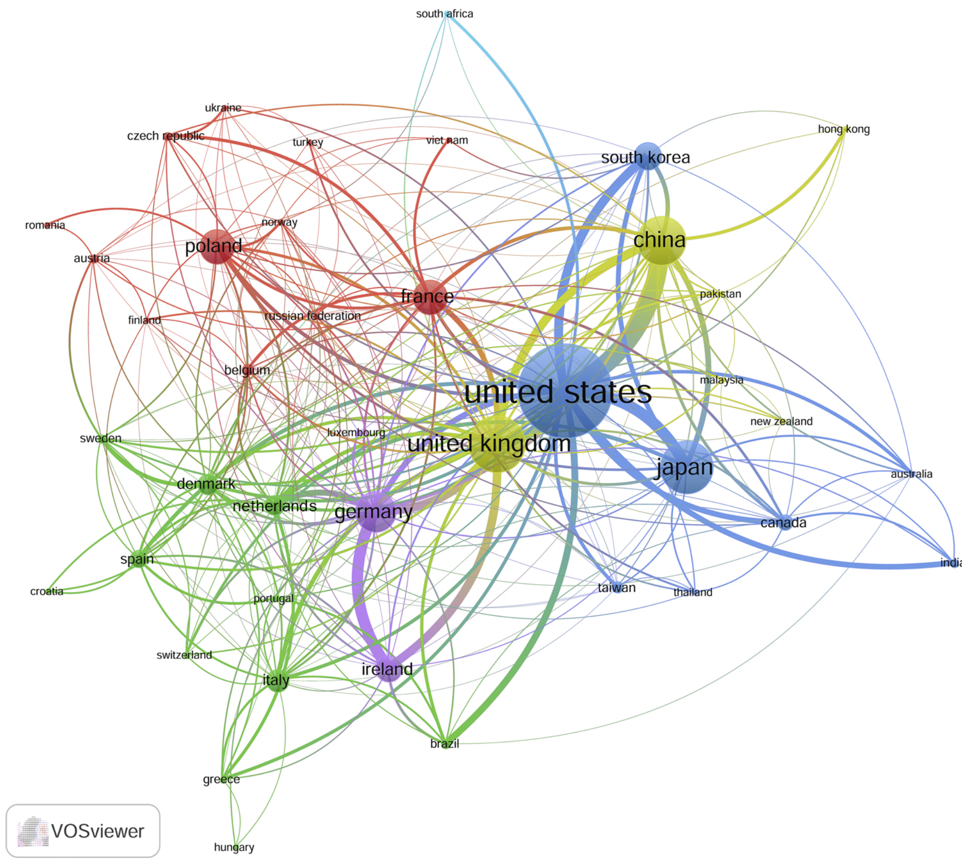


Fig. 6. Map of country co-authorship network built basing on fractional counting method. The weight attribute is represented by the number of publications, and attraction and repulsion parameters are set to 2 and 0, respectively. Clusters are displayed with different colours according to their weight. The nodes are: United States of America (blue, 488 documents), United Kingdom (pear green, 257 documents), Germany (purple, 167 documents), France (red, 138 documents), Italy (green, 77 documents), and South Africa (cyan, 7 documents). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

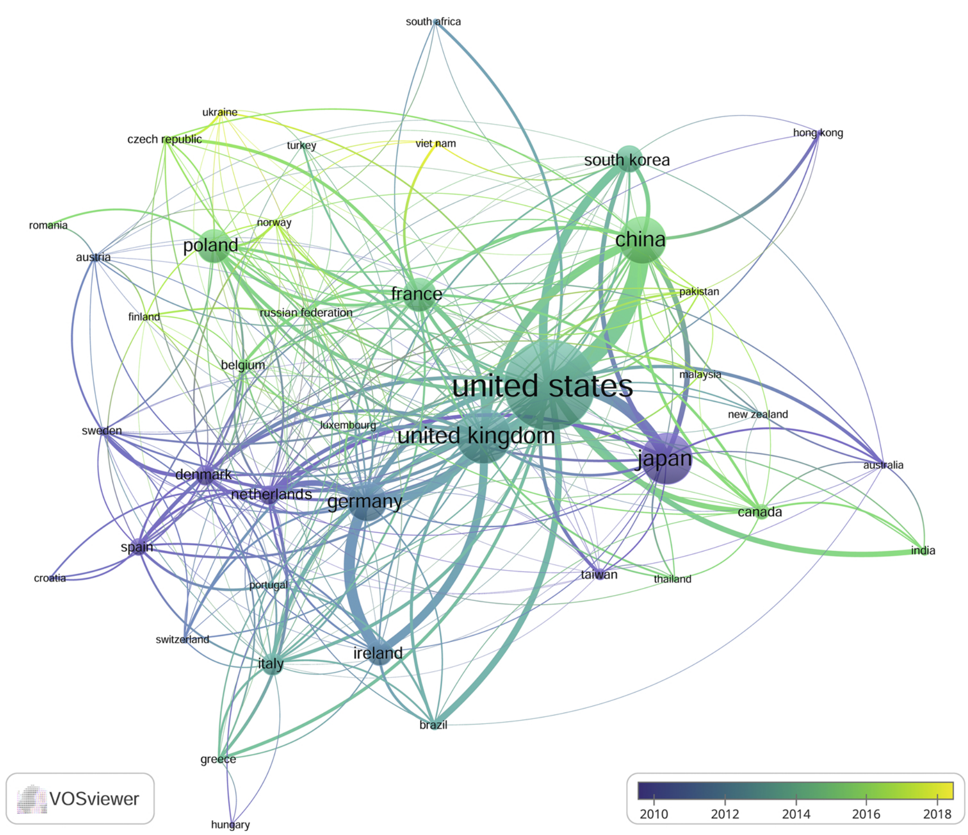


Fig. 7. Map of average publication production per year in the country co-authorship network built basing on fractional counting method. The weight attribute is represented by the number of publications, and attraction and repulsion parameters are set to 2 and 0, respectively. Stated by a decreasing order, the nodes are: United States of America (488 documents), United Kingdom (257 documents), Germany (167 documents), France (138 documents), and Italy (77 documents).

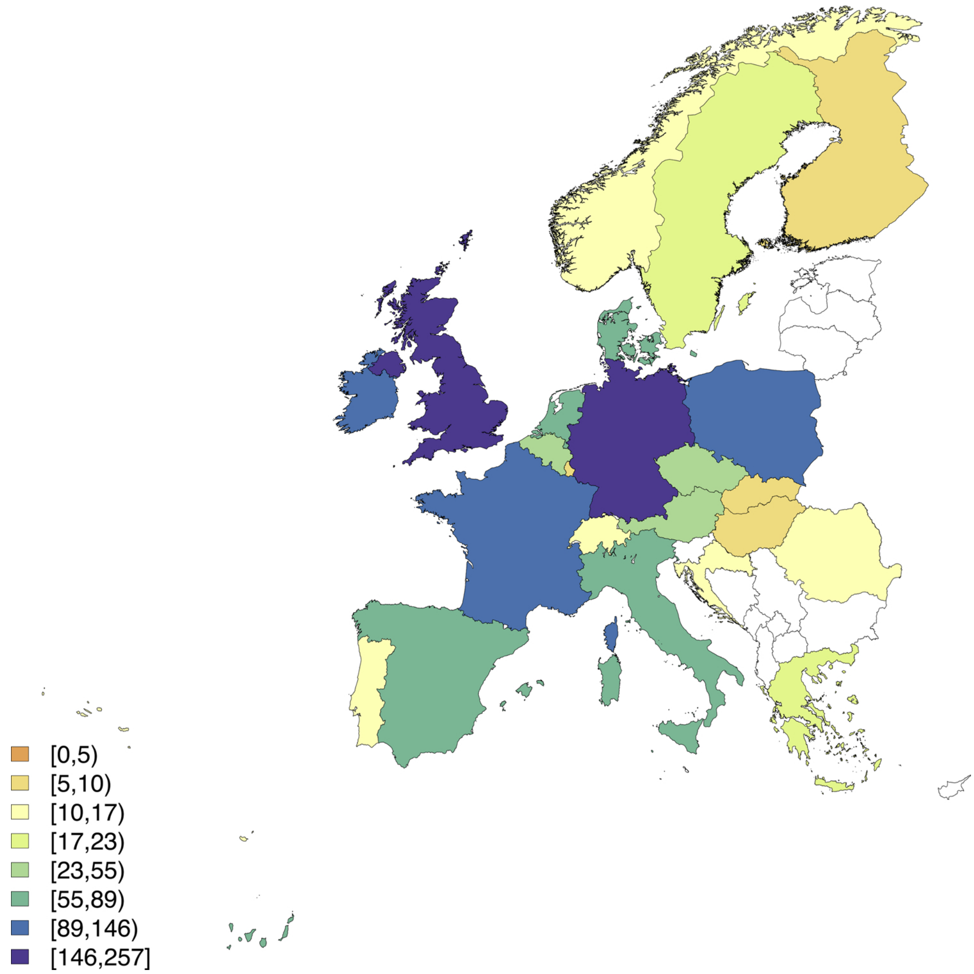


Fig. 8. Spatial distribution of number of papers produced in the EU during the last three decades.

infrastructure size, (5) the design of establishment grant schemes which effectively manage the cashflows and are connected to final user markets, and finally, (6) enhancing the competitiveness of local supply over imports.

To accelerate the development of miscanthus-based fuel sector, certain problems related to quality must be overcome. Despite the crop being a high quality feedstock for cellulosic biofuel production, the decisive quality factors are very sensitive to the combined effect of water stress-marginal land, determining the technico-economic efficiency of the production of fuel from miscanthus (Van der Weijde et al., 2017). The cell wall composition and fuel combustion quality also depend on agronomic treatments. The higher N fertiliser, the lower feedstock quality. Indeed, high N rates distort the cell wall structure and increase the bulk of N and ash in harvested biomass (Hodgson et al., 2010) and, therefore, cause fouling problems (Baxter et al., 2014). In this sense, it was reported that late-harvested miscanthus, managed with low N inputs, provides a higher fuel quality than that in early harvest, but results in lower yield. Farmers may then add N to improve yields, thereby reducing fuel quality. In this case, pre-treatment strategies and changes in boiler system are thus required to prevent from ash-related issues during the combustion process (Baxter et al., 2014).

3.3.4. Biomass conversion technologies

Two main biomass conversion technologies were reported in literature during the last two decades, i.e. direct combustion and thermochemical process. While the former is traditionally used for co-firing biomass with coal, the latter is based on four technological routes: pyrolysis, gasification, combustion, and liquefaction, thereby leading to two different, yet complimentary, types of biomass refining, namely lignocellulosic and syngas biorefineries (Dahmen et al., 2019). Bio-based chemicals and materials can be processed from both types. Producing syngas requires a complete decomposition by gasification under high temperature conditions (Dahmen et al., 2017). This makes syngas synthesis more flexible towards feedstock type and quality than lignocellulosic biorefinery. Since the latter exploits the molecular structure of all biomass components, feedstock type and quality define the refining processes used to preserve the required molecules.

Much interest was given to pyrolysis since it is a prior step in combustion and gasification processes, resulting in the production of charcoal (biochar), bio-oil and syngas, precisely when oxygen is lacking and temperature levels are ranging between 300–700 °C. According to Gaunt and Lehmann (2008), biochars resulted from slow pyrolysis of miscanthus have good potential for energy production, with 2–7 MJ/MJ greater than that of corn-based ethanol. It is also found that land application of biochar reduces GHG emissions by two to five folds (2–19 $Mg\,CO_2\,ha^{-1}\,y^{-1}$) over an exclusive use for fossil energy off-sets, and the retention of carbon (C) in biochar explains 41–64% of this reduction. Bio-oil resulted from fast pyrolysis has similar cost as distillate fuel and processing cost of baled miscanthus is slightly different from that of woodchips (Rogers and Brammer, 2012). Utilised for electricity generation, bio-oil can be transported and stocked, thereby offering the possibility to decouple pyrolysis from generation for better process optimisation. In this regard, Rogers and Brammer (2009) showed that the above-mentioned strategy would be cost-effective only in case of large generation plants. Mainly consisted of Carbon monoxide

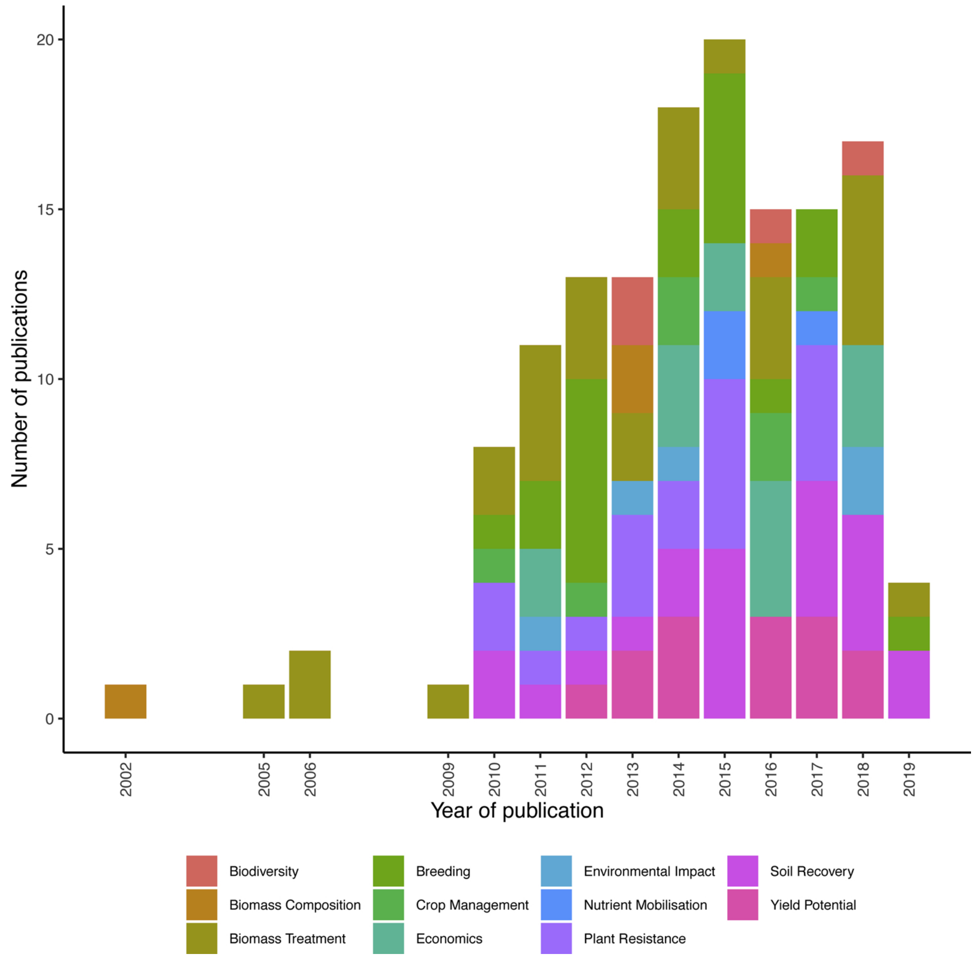


Fig. 9. Evolution of funded publications on miscanthus according to the research field from 2002 to 2018 in France.

(CO) and Hydrogen (H_2), the syngas can be treated by chemical and microbial processes to produce gaseous and hydrocarbon fuels, and fine chemicals (Dahmen et al., 2017). However, the production of these synthetic materials and chemicals is still complex and cost-intensive.

3.3.5. Lignin

The chemical composition of miscanthus is a limiting factor in optimizing biomass conversion to biochemicals and bioenergy. Being a lignocellulosic feedstock, miscanthus consists of three main chemical components: (1) cellulose, principal resource for bio-based materials and energy, (2) hemicellulose, protecting the former from enzymatic hydrolysis, and (3) lignin, the main component responsible for miscanthus recalcitrance to chemical and enzymatic degradation. Brosse et al. (2012) emphasized the importance of better understanding of the chemical composition as well as the different pre-treatment mechanisms to develop future cost-effective technologies in a biorefinery approach allowing an optimum use of all miscanthus' components.

Information on the lignin structure is of utmost importance for the development of strategies regarding bio-based applications (Rohde et al., 2019). Being a complex polymer, lignin consists of three monomers: *p* hydroxyphenyl, guaiacyl and syringyl, joined by esther and *C-C* bonds. Grass lignin is generally a mixture of these monomers (Gellerstedt and Henriksson, 2008). In a recent study, Rohde et al. (2019) illustrated how the molecular sorting of heterogeneous lignin types (softwood Kraft, miscanthus and poplar) into fractions is important for bio-material applications. It is shown that, unlike softwood Kraft, Miscanthus lignin does not contain sulphur. However, *N* content varies from 0% to 1.2% according to fractions. Furthermore, the choice of miscanthus lignin-based applications is conditioned upon molar mass and functional groups (aliphatic and phenolic OH-groups). Compared with softwood Kraft and poplar, miscanthus lignin has lower molar mass and higher phenolic OH-group. On the one hand, besides polymer production, lignin with low molar mass might be relevant for bioscience and medicine industries because of its high antioxidant traits (Calvo-Flores et al., 2015). On the other hand, lignin with high phenolic OH-group is suitable for modification reactions resulting in the formation of polyol used for polyurethane synthesis (Ahvazi et al., 2011).

Several pre-treatment technologies were reported aiming to separate the constituents and to break down the lignin, thereby enhancing enzymatic hydrolysis. Dilute acid and hydrolysis, steam explosion, and organosolv, among other pre-treatments, were assessed with the aim to increase enzymatic digestibility. For a better optimisation of biomass conversion, combinations of pre-treatments were tested. For instance, Brosse et al. (2009) pointed out the importance of pre-soaking step to enhance the dissolution of lignin and then digestibility of cellulose by enzymes. Sørensen et al. (2008) reported the efficacy of acid pre-soaking and direct enzymatic hydrolysis prior to wet oxidation to obtain high sugar yields for bioethanol production. Later, Alriols et al. (2010) combined organosolv and membrane ultrafiltration to extract the different component fractions and, therefore, to optimise the fractionation procedure for increased yields and efficient solvent recovery and energy consumption.

Nonetheless, most of these strategies require expansive installations and thorough processes, and produce large amounts of hazardous wastes, so that they can have negative economic and environmental impacts at a large-scale level. Biological and microwave pre-treatments are then seen as more cost-efficient and environmentally-friendly alternative strategies. Accordingly, the efficacy of micro-organisms and

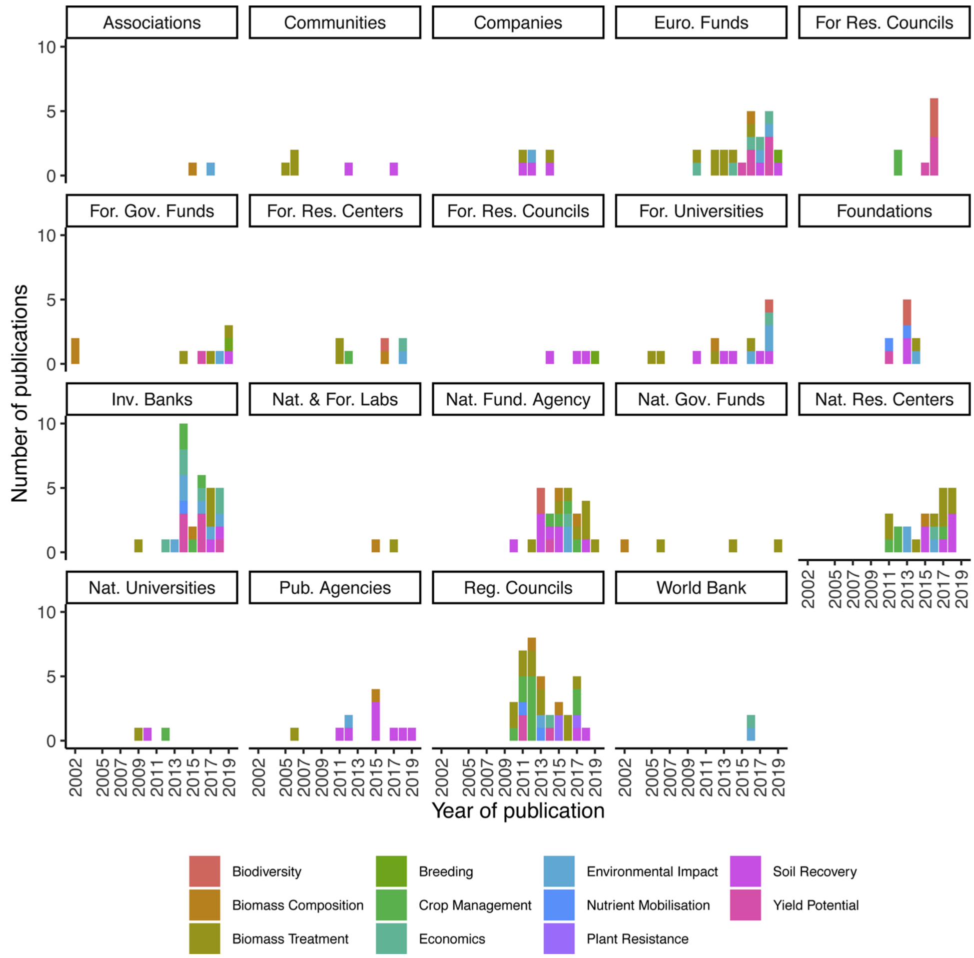


Fig. 10. Public and Private institutions dedicated to funding research on miscanthus from 2002 to 2018 in France.

bacteria as biological agents were explored (Kalinoski et al., 2017; Liu et al., 2015) to enhance the energy efficiency of bio-processes. As regards the microwave pre-treatment, new pathways are being tested for an effective break-down of the biomass structure by, for instance, using water as solvent and eliminating the formed hazardous waste in the treatment process (Irmak et al., 2018).

3.3.6. Impacts on biodiversity

Several studies on perennial grasses, miscanthus in particular, reported its potential to increase wildlife resources in case of LUC, but this strongly depends on the type of management at field scale. According to Felten and Emmerling (2011), earthworm populations are more diverse and higher in miscanthus stands than that in arable land, likewise in grasslands and fallow land. Although earthworm, feeding on miscanthus low *N* leaf litter, have been found to loose mass, the ground litter cover provides an advantageous niche for protection from predators. Miscanthus stands contain also high diversity levels of flies and beetles as well as birds species (Semere and Slater, 2007a,b) in summer (Bellamy et al., 2009) and winter. However, this latter finding diverges from predictions made in Western Europe since habitat preference and bird densities differ from those of Central and Eastern Europe (Kaczmarek et al., 2019). Dauber et al. (2015) showed that when miscanthus is planted on grasslands, it offers higher levels of biodiversity in comparison to the case when it is planted on arable land. In general, these studies emphasized the importance of miscanthus in the agricultural landscape to maintain high levels of biodiversity and to help the soil to recover from intensive production, given its low chemicals requirements and mechanical pressure, and its long lifespan (McCalmont et al., 2017).

3.4. Analysis of countries collaboration network

During the last decade, policies on research have been established to advance the shift towards bio-based economy. Thereafter, innovation and enhancement of scientific knowledge became key priorities in the EU. Yet the success of innovation and its transfer depends on the interaction between numerous actors from government, and research and industrial communities. National and international collaborations have consequently been set up for better resource use and knowledge sharing through the creation of research and development support programmes (El-Chichakli et al., 2016). In what follows, the collaboration network at the international level is therefore presented for better capture of the interactions between the countries.

In the co-authorship network, countries are represented by separate vertices. 84 countries have been identified. Grouped into 5 clusters, only 41 countries meet the threshold of 5 documents per country (Table 2, in Appendix A). According to Fig. 6, Major five clusters are formed around 5 pivotal countries' actors, i.e. United States of America (USA), United Kingdom (UK), Germany (DE), France (FR), and Italy (IT). It also reveals that the research on miscanthus is mainly led by two blocks, i.e. EU and US. For both sides, co-authorships with Japan, China, and South Korea are important. The country's weight in the EU network determined by means of a Degree Centrality measure (the number of ties a node has to other nodes in the network) indicates 10 central actors with high degrees (Table 3, in Appendix A). These countries are, in decreasing order of importance, UK, DE, FR, Ireland (IE), NL, Denmark (DK), Poland (PL), Italy (IT), Spain (ES), and Sweden (SE). One can also notice, from the thickness of edges, that the links between nodes differ in number and in font. The thicker the link, the larger the co-authorships. For instance, co-authorships are important within Europe, particularly in the cases of UK ↔ DE, UK ↔ IE, DE ↔ IE, DE ↔ NL, and UK ↔ FR (see Table 4 in Appendix A for the abbreviation list of countries' names). Likewise, bilateral co-authorships are frequent between UK ↔ USA, DE ↔ USA, PL ↔ USA, ES ↔ USA, UK ↔ CN, and UK ↔ KR.

Within the EU, the least recent studies were mainly carried out in DK, NL and ES, followed by DE, IE and UK (Fig. 7). However, the experience on miscanthus is quite recent (since 2010) in the other European countries. It is, therefore, important to point out that inequalities in terms of productivity still exist in Europe. Fig. 8 shows clearly the regional disparities in terms of number of publications between the North, the Centre and the South of Europe. Indeed, *Miscanthus sp.* were first introduced in the Central Europe, exposed to more or less the same climatic and soil conditions as their native land. Some years later, research was conducted to study and improve species' adaptation to Mediterranean environments (South) characterised by limited water supply (Cosentino et al., 2007). Furthermore, miscanthus was first promoted in countries with insufficient forest resources (e.g. UK and DN). That explains the low number of publications in countries characterised by high wood supply (i.e. FI and SE).

The orientation of research on miscanthus strongly depends on country's own strategies and priorities. In general, the efforts were pushed towards 10 major research fields which are: biodiversity, biomass composition, biomass treatment, crop management, economics, environmental impact, nutrient mobilisation, plant resistance, soil pollution mitigation, and yield potential assessment. In what follows, papers are then classified according to these categories, for better understanding of the relationship between funding and research orientations.

3.5. Analysis of research funding

In the EU, efforts have been made throughout the years in developing miscanthus-related research to reduce productivity gap between countries. This comes together in an imaginary vision (Levidow et al., 2012) which makes Europe the most competitive and vigorous knowledge-based economy on the one hand, and socially cohesive region on the other (EU Council, 2000). As a matter of fact, a large research and development policy has been taken into place with the main objective to enable the take-off of a promising sector, thereby joining the race for competitive and breakthrough technologies (Levidow et al., 2012). Different research and development (R&D) programmes have been indeed launched between European countries as well as with countries representing competitive threat to the European market, in the context of fighting global warming. Thus, funds have been awarded and collaborations have been established to transfer the knowledge and know-how, and to enhance networking.

At the country level, research is increasingly being driven by competitive and diverse funding mechanisms providing more efficient and productive environments among different entities/subunits, i.e. government departments, research centres, and universities. In such entities, research funding is generally composed of public research grants and programme/project-based funds provided by public funding schemes (regional, national, or supra-national) as well as by industrial contracts and grants. As for miscanthus, research orientation and funding mechanisms differ according to governments' priorities and strategies. Thus, a closer look at the distribution of funding among research areas at the country level is necessary. Being one of the European leaders in miscanthus production with more than 4500 ha, France is then selected.

In this sense, an analysis of the relationship between funding sources and research fields is provided. The allocation of research areas and funding from 2002 to 2018 is then shown in Figs. 9 and 10 . 121 papers are clustered into 10 field categories and 20 funding institutions. Because of the multidisciplinary of miscanthus-related research, one paper can belong to more than one field and be funded by more than one institution. While field categories are inferred on the basis of journal title, authors and editors' keywords and abstract, funding sources are aggregated into 20 main institution types. The database is summarised in Table 5 (in Appendix B). In line with the international interest, miscanthus-related research in France shows the same evolution during the last decade (Fig. 9). Most of the studies were led by public research institutes, e.g. the National Institute for Agricultural Research (INRA), collaborating with domestic and foreign organisations and opening funding from various institutions. Fixed-length R&D projects and programmes were therefore launched with specific goal orientations. During the period between 2010 and 2018, the main funding sources were from regional councils (RC, 17%), public investment banks (15%), national funding agencies (13%), and EC (10%). The research was more focused on biomass treatment (33% of the total number of studies), soil remediation (16%), crop management (15%), environmental impact (11%), and yield potential assessment (10%).

Dealing with elaborating the regional climate-air-energy scheme, regional councils (e.g. RC of Picardie, Lorraine and Champagne-Ardenne) were the most involved in the development of miscanthus production at the regional level, thereby orienting their research plans towards basic and industrial fields dealing with crop management and biomass conversion (Fig. 10). Likewise, the National Research Agency (ANR) funded several studies, most of them dedicated to industrial applications and soil recovery, as part of academic-industry partnerships to make researchers' needs more compatible with public research and innovation policy. As regards the European funds, they were mostly awarded within EU's Seventh Framework Programme for Research, Technological Development and Demonstration (FP7) and mainly focused on improving the yield potential.

The French Public Investment Bank, namely BPIFrance, partly funded the most emblematic project, i.e. FUTUROL. Led by PROCETHOL 2G firm, the project was launched in 2008 with the main aim of optimising 2G ethanol production technologies based on lignocellulosic resources. For an environmental and economic optimisation of the production process, many resources have been tested ranging from woody sources, i.e. poplar and willow, to non-food crops, i.e. miscanthus and switchgrass. Inaugurated at the end of October 2011, the industrial pilot prototype is located in the ARD (Agro-industry Research and Development) industrial Pomacle-Bazancourt biorefinery site, in the North-East of France. It has benefited from the support of 11 major partners covering the entire chain from plant to the final use, i.e. R&D actors, industrials, and financial actors. While this partnership has resulted in an environmentally and economically viable process, the successful enzyme production by the ARD Demostrator BioDémo (located at the same site) has emphasized the role of biorefinery in the production of more efficient and effective technologies.

One of several pilot-demonstration (PD) sites in Europe, ARD-industrial Pomacle-Bazancourt biorefinery site is achieving a remarkable success, thereby transposing and enhancing the role and effectiveness of biorefinery approach. This achievement was conditioned upon the key role of actor networks and institutional environment (Hellsmark et al., 2016). Policy is also a key factor influencing public funding and collaborations in the network, thereby shaping research (Policy → Research). Though policy-makers can use the available knowledge or rely on funding of research to implement more effective policies (Policy ⟵ Research). From other perspectives, the relationship between policy and research is more complex than might be expected (Boswell and Smith, 2017), mutually influencing each other in the sense that knowledge does not only address governance issues, but also causes further ones (Policy ↔ Research).

3.6. Orientation of miscanthus-related research in the future

Years of research and innovation efforts have shown the promising potential of miscanthus for bioenergy and bio-based sectors. Different applications of miscanthus are reported ranging from cofiring, heating, power generation, building materials, to animal bedding (Lewandowski et al., 2018). For instance, miscanthus biomass is primarily used for combustion to generate electricity, heat, and combined heat and electricity (Lewandowski et al., 2018). While biogas production from miscanthus is being explored, it is expected that miscanthus becomes a major feedstock to produce biofuels in the short-term due to the increasing number of lignocellulosic biofuel refineries (Lewandowski et al., 2018). In addition to biofuel production, those latter enable the conversion of miscanthus biomass into chemicals that can be used in several applications in food, bioscience, pharmaceutical, and polyurethane industries.

In Germany, building and packaging materials, for example bricks, fibreboards, and plant pots, are the most dominant use applications (Lewandowski et al., 2018). In France, according to France Miscanthus (www.france-miscanthus.org), sustainable miscanthus mulch is being used in horticulture. In fact, besides limiting weeds, miscanthus mulch replaces chemical herbicides and does not cause soil acidification due to its neutral pH (France Miscanthus, 2020b). Miscanthus is also used for animal bedding as a litter for poultry, horses, cattle and pets. Due to its high water absorption, miscanthus litter prevents ammonia formation, thereby ensuring good hygiene and sanitary conditions for animals (France Miscanthus, 2020a). Moreover, the crop shows high potential for phytoremediation of saline and contaminated soils and water, and thus represents an efficient and inexpensive strategy to, for instance, stabilise salt concentrations and remove metals (Pidlisnyuk et al., 2014; Karer et al., 2018).

Further applications were reported by numerous studies, such as light weight concrete (Pude et al., 2005), fibre, pulp and paper (Wegener, 1992; Kordsachia et al., 1993; Papatheofanous et al., 1995; Iglesias et al., 1996; Vega et al., 1997; Oggiano et al., 1997), charcoal (Szabó et al., 1996) and biodegradable geotextiles (Verkade and Kuijper, 1996). Miscanthus shreds, ships and fibers can be used as alternative substrates to Rockwool in soilless culture for horticultural crops (Kraska et al., 2018). Besides, the application of miscanthus biochar can be extended to other fields, including the production of bio-based materials, and can be considered as an eco-friendly and cost-effective substitute, for instance, to carbon fillers in composite (Giorcelli et al., 2019). While miscanthus-based ashes can be used for manufacturing construction composite (Záleská et al., 2018), carbon materials obtained from miscanthus waste are suitable for energy storage making possible the production of electrochemical capacitors (Kolanowski et al., 2019). Interestingly, carbon from miscanthus fibers shows remarkable potential to replace particular polyamides utilised in the automotive industry (Ogunsona et al., 2018).

Miscanthus is considered as one of longer and more extensively studied plant with an uneven interest in different countries. To devise, promote and support strategies for the development of miscanthus-based industries, it is recommended to broaden the common knowledge regarding this crop. The follow-up of past and current orientation of research on miscanthus was therefore imperative to highlight the areas in which further research would still be needed to fully unlock the real potential of this crop for the bio-economy, and thus coping with the major bottlenecks of the entire sector. In this sense, the following paragraphs provide some suggestions regarding the future orientation of research on miscanthus.

Although the huge number of studies and experiments, the uptake of miscanthus is still low. This is due to the lack of appropriate support schemes and the low cost-effectiveness of cultivation routes and biomass conversion techniques. To cope with these shortcomings, miscanthus-related research should henceforth be built around several strategic orientations and transversal projects dictated by market opportunities and policies. Firstly, because of low profitability of *M. giganteus* during the establishment phase, research efforts should focus on examining new planting and management techniques to overcome the high plantation costs (rhizomes). On the one hand, several propagation methods were so far tested such as micropropagation and propagation *via* seeds. While the former is the most expansive technique of propagating miscanthus, the latter, which is recommended for *M. sinensis*, increases the risk of invasiveness (Mangold et al., 2018). For *M. giganteus* and *M. sacchariflorus*, it was shown that collar propagation is a viable alternative to rhizome propagation, but options for improvement of establishment success and storage of collars require further research (Mangold et al., 2018). On the second hand, with respect to agricultural constraints and ecological goals, establishing miscanthus under different crops can help the farmer to compensate the low miscanthus yield in the first years. This allows also to develop sustainable biomass supply chains on rural areas and enhance the implementation of local bioeconomy sectors. The performance assessment of innovative cropping system diversification was reported in few studies considering “miscanthus-maize” and “grass-legume mixture” (Manevski et al., 2018; von Cossel et al., 2019). Enhanced research efforts are then required to develop further cropping systems depending on soil types, regions and market conditions to ensure an ecologically and economically sustainable substitution of fossil carbon.

In Europe, miscanthus area is still small. It approximates 20 000 ha (Lewandowski et al., 2018), located predominately in the Eastern countries (UK, Germany, and France) with suitable conditions for miscanthus growth. By contrast, in Northern and Eastern countries, miscanthus production is limited by cold, frost and drought stresses. Several breeding programs have therefore been set to expand miscanthus production to diverse climatic and soil conditions, while ensuring high yield levels (Lewandowski et al., 2018; Clifton-Brown et al., 2019). Breeding efforts are mainly focusing on genotypes that can outperform *M. giganteus* under cold and drought conditions with low costs and inputs, e.g. *M. sacchariflorus*, *M. sinensis*, and hybrids (Lewandowski et al., 2018). Metal and salinity are also major factors that limit miscanthus growth. The use of miscanthus for phytoremediation of saline and heavy-metal contaminated soils is currently being explored.

Soil contamination is one of the greatest threats facing European soil resources. Highly contaminated soils cover 28.3% of the total surface area of the EU-28 (Tóth et al., 2016). These soils can be exploited for biofuel production since they are not suitable for food production. Given its excellent features for both phytoremediation and biofuel production, miscanthus could therefore be a promising candidate for heavy-metal contaminated areas. Miscanthus could also be extended to saline soils, which cover 11.8% of the total surface area of the EU-28 (Stavridou et al., 2017). Different approaches are currently explored to search for mechanisms of tolerance, metal removal, and saline stablisation, but in limited areas. Then, there is a need to characterise the pattern growth and development of miscanthus to a wide range of metal and salt concentrations. In addition, the impacts of salinity and metal stresses on fuel properties should be assessed to back up the anticipated development of biofuel industry.

Given the wide range of potential bio-based applications of miscanthus, the competitiveness of different value chains should be thoroughly explored in order to meet current and future challenges of the bioeconomy. In this regard, various approaches can be used to decide upon the most promising and effective value chains, including meta-analysis, multiple-criteria decision analysis (MCDA) and network analysis. For instance, meta-analysis can be performed to statistically analyse and compare the performance of miscanthus for different end-uses. It provides summary and precise performance estimates for policy-makers and stakeholders seeking information about the effectiveness of specific end-uses. Since stakeholders and policy-makers generally deal with a large number of studies on which they need to support their decision, the estimates facilitate the decision and policy making processes.

Based on environmental, technical, economic and social indicators, the MCDA framework is useful to support the identification of sustainable bio-based value chains towards achieving a resource-efficient circular economy, both at local and national levels. In this regard, Lokesh et al. (2018) have presented a methodological approach for the selection and mapping of the most promising circular value chains. The methodology used enables a systematic analysis and transparency given that a series of decisive parameters is dissimilarly weighted by the various actors involved in the entire value chain. The selected bio-based value chains are firstly identified and ranked based on selection criteria that are relevant for the application of circular economy principles. Secondly, they are mapped to investigate the scope and performance of bio-based business models.

Network analysis can be used as a tool for investigation of countries' strategies regarding the development of the bioeconomy. The approach serves to comprehend the ties within and between value chains that might result from cascading use of biomass. It also allows to identify the different actors involved in the value chains and to capture the links between them as well. Such approach was used in (Scheiterle et al., 2018) to analyse the opportunities and challenges facing the sugarcane-based value chains in Brazil's bioeconomy. Using two conceptual tools, i.e. “biomass-based value web” and “national innovation system”, the authors highlighted the drivers and barriers affecting the international competitiveness of sugar and ethanol sectors and suggested potential solutions to foster the development of sugarcane-based value chains.

4. Conclusion

In this study, a comprehensive review regarding the research status of a promising biomass species for bio-based industries, was provided based on published material. Miscanthus was selected since it is one of the longer and more extensively studied perennial non-food crop with an uneven development in different countries. The analysis and discussion were framed using Social Network Analysis performed on more than 2000 articles, completed with a systematic review to make sense out of numerous pieces of information. Collaboration and co-occurrence networks as well as research funding have revealed the most important actors and research fields in which miscanthus has been given much interest. By this token, we were able to underline the key factors in propelling its development in the emerging circular bioeconomy context. Economic, environmental, energy and geopolitical concerns have shaped the development of the miscanthus sector.

This work contributes to articulate and broaden the common knowledge regarding miscanthus. For this purpose, the status of miscanthus-related research was updated and the major bottlenecks as well the dynamics of the entire sector were identified as detailed in the discussion section. The goal was to shed also light upon the large spectrum of sustainable final uses driven by innovative applications. Furthermore, this research can inspire similar exercises in the field of second generation biomass crops completing the puzzle in order to assess the relative contribution of miscanthus in the universe of lignocellulosic perennial non-food crops. Such study would assist stakeholders in following up on past and current research orientation and to pinpoint the areas in which further research would still be needed to fully unlock the promising potential of these crops for the bioeconomy. This can be beneficial both to scientific teams to target their research plan but also to the governing bodies to prepare oriented strategic documents as a component in Research and Innovation Agendas in Europe and elsewhere.

Declarations of interest

None declared.

Acknowledgment

The authors gratefully acknowledge the financial support brought by the BioEcon project funded by EU Horizon 2020 research and innovation programme: Grant agreement n: 669062 (2015–2020). They also warmly thank Małgorzata Wydra for proofreading this article and the three anonymous reviewers for their valuable comments.

Appendix A

Network name: countries.net Actors: 41

In undirected networks, the DC index is the sum of edges attached to a node u. In directed networks, the index is the sum of outbound arcs from node u to all adjacent nodes (also called “outDegree Centrality”). If the network is weighted, the DC score is the sum of weights of outbound edges from node u to all adjacent nodes. Note: To compute inDegree Centrality, use the Degree Prestige measure. DC’ is the standardized index (DC divided by $N - 1$ (non-valued nets) or by sumDC (valued nets)).

DC range: $0 \leqslant \text{DC} \leqslant \infty$

DC’ range: $0 \leqslant \text{DC'} \leqslant 1$

DC Sum = 922.000000

Max DC’ = 0.187636 (node 40) Min DC’ = 0.001085 (node 15) DC’ classes = 25

DC’ Sum = 1.000000 DC’ Mean = 0.024390 DC’ Variance = 0.001270

Table 1
Representation of author keywords' network.

Keywords	x	y	Cluster	Links	Total link strength	Occurrences
Miscanthus	0.1123	−0.0227	1	114	521	624
Lignin	0.8962	−0.3121	1	36	52	55
Ethanol	0.6178	−0.4057	1	35	38	42
Pretreatment	0.7993	−0.4264	1	35	36	38
Lignocellulose	0.9197	−0.0677	1	28	28	31
Cellulose	0.7411	−0.1083	1	32	27	29
Enzymatic hydrolysis	0.9468	−0.1974	1	21	24	26
Biorefinery	0.7307	−0.21	1	23	15	16
Delignification	0.7911	0.005	1	13	13	14
Cell wall	0.4853	0.1892	1	21	11	11
Saccharification	1.0353	−0.2668	1	12	11	11
Hemicellulose	1.0558	−0.0192	1	11	10	10
Steam explosion	1.0593	−0.3836	1	13	9	10
Wheat straw	0.7977	−0.7688	1	10	9	10
Carbohydrates	0.5079	−0.2531	1	19	9	9
Pellets	0.9523	0.5859	1	8	6	9
Fermentation	0.8232	−0.6278	1	10	7	8
Organosolv	0.9185	−0.5852	1	13	8	8
Autohydrolysis	1.1924	−0.6104	1	8	7	7
Fractionation	1.067	−0.615	1	8	7	7
Kinetics	0.7012	0.3197	1	13	7	7
Yield	0.0107	0.1105	2	42	50	53
Life-cycle assessment	−0.0179	−0.5142	2	38	38	39
Anaerobic digestion	0.3588	−0.6162	2	31	23	26
GHG emissions	0.0438	−0.3388	2	26	21	21
Sustainability	0.1304	−0.4423	2	31	20	21
Biogas	0.2201	−0.7199	2	22	16	17
Rhizome	−0.2091	−0.5315	2	19	14	17
Perennial crops	0.0561	−0.6576	2	23	12	14
Energy balance	0.2486	−0.399	2	16	11	11
Establishment	−0.0659	−0.7855	2	12	11	11
Biomass crop	−0.4181	−0.1961	2	10	10	10
Harvest date	0.2468	−0.6294	2	11	10	10
Potassium	0.1634	0.4462	2	14	8	9
Agriculture	−0.1104	−0.629	2	12	7	8
Biomass quality	0.3961	−0.2364	2	19	8	8
Methane yield	0.4224	−0.6167	2	9	7	8
Genotypes	−0.1242	−0.3782	2	13	7	7
Harvest time	0.2008	−0.3104	2	11	7	7
Biomass	0.2548	0.2872	3	87	208	234
Biofuels	0.0252	−0.1252	3	79	94	108
Pyrolysis	0.2174	0.7982	3	25	28	28
Combustion	0.4213	0.7788	3	25	25	26
Bio-oil	0.0729	0.8223	3	13	18	19
Fast pyrolysis	−0.0797	0.6333	3	12	15	19
Ash	0.4087	0.8604	3	10	10	10
Energy	0.2433	1.0054	3	11	9	10
Emissions	0.1643	1.0326	3	8	8	9
Productivity	0.1955	0.5975	3	14	8	9
Quality	0.6022	0.8384	3	14	7	7
QTL	0.6978	0.9907	3	6	6	6
Supply chain	−0.1606	0.7219	3	12	6	6
Bioenergy	−0.3374	−0.346	4	78	139	151
Miscanthus sinensis	−0.0931	0.1207	4	54	80	132
Modelling	−0.1998	−0.2197	4	40	44	45
Miscanthus sacchariflorus	−0.8707	0.1882	4	20	22	33
Marginal land	−0.5426	−0.7036	4	18	18	19
Climate change	−0.4472	−0.4814	4	23	16	17
Genetic diversity	−1.162	−0.27	4	7	11	11
Miscanthus lutarioriparius	−1.0214	−0.4633	4	10	8	11
Senescence	−0.7316	−0.227	4	13	10	11
Sugarcane	−1.2371	−0.1994	4	15	10	11
Poaceae	−1.046	−0.1844	4	6	7	9
Maize stover	−0.9399	0.0144	4	11	7	7
Saccharum complex	−1.3217	−0.2289	4	2	4	6
Energy crops	−0.1531	−0.089	5	88	143	172
Soil carbon	−0.5428	−0.2018	5	31	32	37
Carbon sequestration	−0.6735	0.157	5	28	28	30
Greenhouse gas	−0.0906	−0.0069	5	41	25	25
Short rotation coppice	−0.2219	0.0692	5	28	20	21

(*continued on next page*)

Table 1 (*continued*)

Keywords	x	y	Cluster	Links	Total link strength	Occurrences
Land use	−0.4731	−0.3081	5	19	16	17
Nitrous oxide	−0.0002	0.0061	5	23	15	16
Carbon	0.0222	0.3029	5	21	9	9
Decomposition	0.3646	−0.0377	5	18	7	9
Methane	0.1579	−0.1399	5	16	8	8
Carbon dioxide	0.2469	−0.0131	5	18	7	7
Furfural	0.9223	0.07	5	7	7	7
Giant reed	−0.1027	0.3077	6	40	28	29
Photosynthesis	−0.5372	0.1272	6	30	25	26
Nitrogen	−0.0575	0.4321	6	29	23	25
Feedstock	0.1688	0.2455	6	23	12	14
Cold tolerance	−0.6796	0.0096	6	17	12	12
Biomass production	−0.4157	0.2272	6	13	10	11
Plant growth	−0.4529	0.3946	6	17	11	11
Chlorophyll fluorescence	−0.248	0.2507	6	9	8	9
Nutrients	−0.3759	0.4501	6	11	6	8
Saccharum	0.5573	0.0095	6	10	8	8
Soil organic matter	−0.6226	0.4107	6	7	5	8
Wastewater treatment	−0.2986	0.4121	6	7	5	7
Switchgrass	−0.3715	−0.0926	7	59	87	89
Land use change	−0.5592	−0.4737	7	37	36	37
Grassland	−0.592	−0.3501	7	27	21	23
Willow	−0.2888	−0.6135	7	31	22	22
Maize	−0.582	−0.5841	7	32	21	21
Drought	−0.8055	−0.5238	7	17	9	11
Ecosystem services	−0.8011	−0.3855	7	19	9	10
Eddy covariance	−0.8377	−0.7018	7	14	8	8
Evapotranspiration	−0.8107	−0.7772	7	12	6	7
Poplar	0.1443	−0.9212	7	11	7	7
Water use efficiency	−0.6891	−0.7552	7	14	7	7
Biochar	−0.386	0.7069	8	29	37	52
Remediation	−0.6288	0.7281	8	23	32	35
Heavy metals	−0.621	0.8226	8	19	27	31
Sewage sludge	−0.2746	0.8608	8	14	11	12
Cadmium	−0.8089	0.5702	8	11	8	8
Torrefaction	0.0968	0.707	8	8	8	8
Hydrochar	−0.326	0.6293	8	9	7	7
Soil contamination	−0.8577	0.7786	8	7	6	7
Slow pyrolysis	−0.2619	1.0236	8	5	5	6
Soil	−0.4877	0.5286	8	16	6	6
Zinc	−0.8677	0.7114	8	7	6	6
Biomass gasification	0.5591	0.4014	9	20	21	25
Renewable energy	0.3575	0.3236	9	30	24	25
Economics	0.6539	0.531	9	13	10	10
Coal	0.8003	0.3845	9	12	6	6
Hydrogen	0.9197	0.3847	9	7	6	6
Biodiversity	−0.1984	−0.8564	10	10	11	14
Chemical composition	0.2934	0.1397	10	15	10	10
Perennial grasses	−0.0787	−0.2984	10	20	13	15

Table 2
Representation of countries' network.

Country	x	y	Cluster	Links	Total link strength	Documents	Citations
Austria	−0.749	0.3564	1	15	8.6669	24	484
Belgium	−0.3785	0.0896	1	16	15.0003	33	502
Czech republic	−0.5731	0.6487	1	10	13.6665	23	212
Finland	−0.621	0.2081	1	10	7.0002	9	212
France	0.0541	0.2654	1	25	49.9996	138	1917
Norway	−0.2992	0.4415	1	14	11.9999	12	46
Poland	−0.4544	0.3855	1	20	34	138	1155
Romania	−0.8585	0.4347	1	2	3	11	49
Russian federation	−0.2178	0.2183	1	15	9.0003	17	146
Turkey	−0.2317	0.6323	1	8	4.0003	12	182
Ukraine	−0.4346	0.7149	1	9	6.0003	8	17
Vietnam	0.1001	0.6373	1	4	5	5	10

(*continued on next page*)

Table 2 (*continued*)

Country	*x*	*y*	Cluster	Links	Total link strength	Documents	Citations
Brazil	0.0919	−0.802	2	9	23.9999	25	755
Croatia	−0.8562	−0.4366	2	3	5.0001	12	216
Denmark	−0.4766	−0.1806	2	22	37	70	2166
Greece	−0.4388	−0.8862	2	9	15	17	206
Hungary	−0.4086	−1.0462	2	3	2	7	238
Italy	−0.309	−0.6501	2	25	30.9998	77	2400
Netherlands	−0.3161	−0.232	2	30	47.9999	65	2225
Portugal	−0.3155	−0.4551	2	11	9.9999	12	250
Spain	−0.6394	−0.3611	2	14	27.0001	57	1611
Sweden	−0.7297	−0.0723	2	17	17.9998	22	973
Switzerland	−0.5259	−0.5901	2	9	9.9999	15	201
Australia	1.2063	−0.1564	3	10	12	13	446
Canada	0.9023	−0.2732	3	15	23.9999	49	532
India	1.3049	−0.3707	3	5	13	21	160
Japan	0.6672	−0.1395	3	18	53.9999	231	3137
South Korea	0.5756	0.5992	3	18	34.9998	102	1365
Taiwan	0.5034	−0.4282	3	14	7.9999	33	515
Thailand	0.6895	−0.4387	3	7	8	9	100
United States	0.378	0.0391	3	34	184.0001	488	11 494
China	0.607	0.3983	4	26	95	209	2632
Hong Kong	1.0485	0.6636	4	5	5.9999	6	147
Malaysia	0.7538	0.0675	4	7	5	5	53
New Zealand	0.8973	−0.0334	4	5	3	6	27
Pakistan	0.7501	0.2723	4	12	9.9998	11	107
United Kingdom	0.2126	−0.0859	4	33	114	257	7794
Germany	−0.076	−0.2464	5	32	84.6665	167	4801
Ireland	−0.0455	−0.6195	5	18	48.0001	99	3643
Luxembourg	−0.1149	−0.0581	5	3	2.9999	5	37
South Africa	0.0963	0.9384	6	4	4.9999	7	85

Table 3
Degree centrality of countries' network.

Node	Label	DC	DC'	%DC'
1	Australia	10	0.010846	1.084599
2	Austria	6	0.006508	0.650759
3	Belgium	9	0.009761	0.976139
4	Brazil	20	0.021692	2.169197
5	Canada	20	0.021692	2.169197
6	China	85	0.092191	9.219089
7	Croatia	3	0.003254	0.32538
8	Czech Republic	10	0.010846	1.084599
9	Denmark	28	0.030369	3.036876
10	Finland	3	0.003254	0.32538
11	France	44	0.047722	4.772234
12	Germany	74	0.08026	8.02603
13	Greece	12	0.013015	1.301518
14	Hong Kong	5	0.005423	0.542299
15	Hungary	1	0.001085	0.10846
16	India	13	0.0141	1.409978
17	Ireland	41	0.044469	4.446855
18	Italy	23	0.024946	2.494577
19	Japan	48	0.052061	5.206074
20	Luxembourg	2	0.002169	0.21692
21	Malaysia	3	0.003254	0.32538
22	Netherlands	37	0.04013	4.013015
23	New Zealand	2	0.002169	0.21692
24	Norway	6	0.006508	0.650759
25	Pakistan	6	0.006508	0.650759
26	Poland	27	0.029284	2.928416
27	Portugal	8	0.008677	0.867679
28	Romania	3	0.003254	0.32538
29	Russian	4	0.004338	0.433839

(*continued on next page*)

Table 3 (*continued*)

Node	Label	DC	DC'	%DC'
30	South Africa	3	0.003254	0.32538
31	South Korea	30	0.032538	3.253796
32	Spain	23	0.024946	2.494577
33	Sweden	14	0.015184	1.518438
34	Switzerland	8	0.008677	0.867679
35	Taiwan	5	0.005423	0.542299
36	Thailand	6	0.006508	0.650759
37	Turkey	2	0.002169	0.21692
38	Ukraine	3	0.003254	0.32538
39	United Kingdom	98	0.106291	10.629067
40	United States	173	0.187636	18.763557
41	Vietnam	4	0.004338	0.433839

Table 4
Abbreviation list of countries' names.

Label	Abbreviation
Australia	AT
Austria	AU
Belgium	BE
Brazil	BR
Canada	CA
China	CN
Croatia	HR
Czech Republic	CZ
Denmark	DK
Finland	FI
France	FR
Germany	DE
Greece	GR
Hong Kong	HK
Hungary	HU
India	IN
Ireland	IE
Italy	IT
Japan	JP
Luxembourg	LU
Malaysia	MY
Netherlands	NL
New Zealand	NZ
Norway	NO
Pakistan	PK
Poland	PL
Portugal	PT
Romania	RO
Russian Federation	RU
South Africa	ZA
South Korea	KR
Spain	ES
Sweden	SE
Switzerland	CH
Taiwan	TW
Thailand	TH
Turkey	TR
Ukraine	UA
United Kingdom	UK
United States	USA
Vietnam	VN

Appendix B

Table 5
List of 121 papers used to analyse the funding of miscanthus-based research in France.

Authors	Year	Paper title	Journal title	Funding source
Vigliaturo et al.	2019	Opaline phytoliths in Miscanthus sinensis and its cyclone ash from a biomass-combustion facility	Industrial Crops and Products	INTERREG IVC, European Commission;
Thomas et al.	2019	Methane Production Variability According to Miscanthus Genotype and Alkaline Pretreatments at High Solid Content	Bioenergy Research	ANR French National Research Agency
Konsomboon et al.	2019	Torrefaction of Various Biomass Feedstocks and Its Impact on the Reduction of Tar Produced during Pyrolysis	Energy and Fuels	Thailand Research Fund TR, Royal Golden Jubilee (RGJ) PhD Program; French Government Grants from the French Embassy in Thailand
Ridoskova et al.	2019	Bioavailability of mercury in contaminated soils assessed by the diffusive gradient in thin film technique in relation to uptake by Miscanthus – giganteus	Environmental Toxicology and Chemistry	Ministry of education, Youth abd Sports of the Czek Republic, CEITEC 2020; Grant Agency of Czek Republic GACR; French Agency for the Environment and Energy Management, PHYTENER project
Clifton-Brown et al.	2019	Breeding progress and preparedness for mass-scale deployment of perennial lignocellulosic biomass crops switchgrass, miscanthus, willow and poplar	GCB Bioenergy	BBSRC Biotechnology and Biological Sciences Research Council; Defra Department for Environment, Food and Rural Affairs; CERES Inc. and Terravesta Ltd; DTI Department of Trade and Industry; Brain Gain Program (Rientro dei cervelli), Italian Ministry of Education, University, and Research; US Office of Biological and Environmental Research in the DOE Office of Science; Office of Biological and Environmental Research in the DOE Office of Science; US Department of Agriculture National Institute of Food and Agriculture; DOE Office of Science; Office of Biological and Environmental Research (BER); Center for Advanced Bioenergy and Bioproducts Innovation; Energy Biosciences Institute; FP7 OPTIMISTIC, EC; FP7 WATBIO, EC; H2020 GRACE; Biobased Industries Joint Technology Initiative (BBI-JTI)
Berkley et al.	2018	Influence of bioenergy crops on pollinator activity varies with crop type and distance	GCB Bioenergy	School of Biological and Marine Science and the Faculty of Science and Engineering, University of Plymouth
Teter et al.	2018	Water impacts of U.S. biofuels: Insights from an assessment combining economic and biophysical models	PLoS ONE	California Energy Commission and the Sustainable Transportation Energy Pathways (STEPS) program at the Institute of Transportation Studies, UC Davis; National Center for Sustainable Transportation, for funding the research (JT, SY); DOE Center for Advanced Bioenergy and Bioproducts Innovation (US Department of Energy, Office of Science, Office of Biological and Environmental Research)
Li et al.	2018	Data descriptor: A global yield dataset for major lignocellulosic bioenergy crops based on field measurements	Scientific Data	LUC4C, European Commission; European Research Council;
Hu et al.	2018	Bioenergy crop induced changes in soil properties: A case study on Miscanthus fields in the Upper Rhine Region	PLoS ONE	Innovations for Sustainable Biomass Utilization in the Upper Rhine Region; Young Scientists with Oversea Doctoral Diploma from Department of Human Resources and Social Security of Shaanxi Province, China; Fundamental Research Funds for the Central Universities, China
Li et al.	2018	Phytolith-rich biochar increases cotton biomass and silicon-mineralomass in a highly weathered soil	Journal of Plant Nutrition and Soil Science	UCLouvain; FSR Fonds Special de Recherche; MANDAT ASPIRANT FNRS
Battista et al.	2018	Enzymatic hydrolysis at high dry matter content: The influence of the substrate' physical properties and of loading strategies on mixing and energetic consumption	Bioresource Technology	IFP energies nouvelles
Ben Fradj &Jayet	2018	Optimal management of perennial energy crops by farming systems in France: A supply-side economic analysis	Biomass and Bioenergy	Futurol project, OSEO-BPI France (Public Investment Bank)
Herbaut et al.	2018	Multimodal analysis of pretreated biomass species highlights generic markers of lignocellulose recalcitrance	Biotechnology for Biofuels	INRA French Institute of Agricultural research
Janus et al.	2018	Do biochars influence the availability and human oral bioaccessibility of Cd, Pb, and Zn in a contaminated slightly alkaline soil?	Environmental Monitoring and Assessment	CIRAD Agricultural research for development; Regional council of Hauts-de-Seine; Bpifrance
Lesur-Dumoulin et al.	2018	Co-design and ex ante assessment of cropping system prototypes including energy crops in Eastern France	Biomass and Bioenergy	Futurol project, OSEO-BPI France (Public Investment Bank); FP7, LogistEC, EC, European Commission

(continued on next page)

Table 5 (*continued*)

Authors	Year	Paper title	Journal title	Funding source
Li et al.	2018	ORCHIDEE-MICT-BIOENERGY: An attempt to represent the production of lignocellulosic crops for bioenergy in a global vegetation model	Geoscientific Model Development	LUC4C, European Commission; European Research Council
Liber et al.	2018	Growth parameters influencing uptake of chlordecone by Miscanthus species	Science of the Total Environment	ANR French National Research Agency; INRA; ADEME, French Environment and Energy Management Agency
Pham et al.	2018	Influence of metal contamination in soil on metabolic profiles of Miscanthus × giganteus belowground parts and associated bacterial communities	Applied Soil Ecology	CNRS; ANR French National Research Agency
Rodi et al.	2018	Biocomposites based on poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBHV) and Miscanthus giganteus fibers with improved fiber/matrix interface	Polymers	ANR French National Research Agency
Thierry et al.	2018	Imidazolium-Based Ionic Liquids as Efficient Reagents for the C-O Bond Cleavage of Lignin	ChemSusChem	ANR French National Research Agency
Thomas et al.	2018	Lime pretreatment of miscanthus: Impact on BMP and batch dry co-digestion with cattle manure	Molecules	ANR French National Research Agency
Al Souki et al.	2017	Assessment of Miscanthus × giganteus capacity to restore the functionality of metal-contaminated soilsEx situ experiment	Applied Soil Ecology	ADEME French Environment and Energy Management Agency
Arif et al.	2017	Cytotoxic and genotoxic responses of human lung cells to combustion smoke particles of Miscanthus straw, softwood and beech wood chips	Atmospheric Environment	ATA, American Telemedicine Association
Auxenfans et al.	2017	Understanding the structural and chemical changes of plant biomass following steam explosion pretreatment	Biotechnology for Biofuels	Futurol project, OSEO-BPI France (Public Investment Bank)
Auxenfans et al.	2017	Seeing biomass recalcitrance through fluorescence	Scientific Reports	Futurol project, OSEO-BPI France (Public Investment Bank)
Belmokhtar et al.	2017	Saccharification performances of miscanthus at the pilot and miniaturized assay scales: Genotype and year variabilities according to the biomass composition	Frontiers in Plant Science	Futurol project, OSEO-BPI France (Public Investment Bank); NREL, National Renewable Energy Laboratory, Golden, CO, USA
Bogaert et al.	2017	How the use of nitrogen fertiliser may switch plant suitability for aphids: the case of Miscanthus, a promising biomass crop, and the aphid pest Rhopalosiphum maidis	Pest Management Science	Research project MISCPIC, Regional council of Picardie
Chabbert et al.	2017	Action of lytic polysaccharide monooxygenase on plant tissue is governed by cellular type	Scientific Reports	INRA Estrées Mons; IFPEN IFP energies nouvelles
Chupin et al.	2017	Polyethylene composites made from below-ground miscanthus biomass	Industrial Crops and Products	ANR French National Research Agency
Dufossé et al.	2017	Life-Cycle Assessment of Agricultural Feedstock for Biorefineries	Life-Cycle Assessment of Biorefineries	Futurol project, OSEO-BPI France (Public Investment Bank)
Houben et al.	2017	Effect of biochar on phosphorus bioavailability in an acidic silt loam soil	Biotechnology, Agronomy and Society and Environment	UCL University College London; FNRS National Fund for Scientific Research
Janus et al.	2017	Value of biochars from Miscanthus × giganteus cultivated on contaminated soils to decrease the availability of metals in multicontaminated aqueous solutions	Environmental Science and Pollution Research	CIRAD Agricultural research for development; Regional council of Hauts-de-Seine; Bpifrance
Kaknics et al.	2017	Experimental Study and Thermodynamic Modelling of High Temperature Interactions Between Molten Miscanthus Ashes and Bed Particles in Fluidized Bed Reactors	Waste and Biomass Valorization	Regional Council of Centre; GAMECO, ANR
Laval-Gilly et al.	2017	Miscanthus × giganteus Composition in Metals and Potassium After Culture on Polluted Soil and Its Use as Biofuel	Bioenergy Research	Communauty of Portes de France-Thionville; FEDER European Regional Development Fund
Lesur-Dumoulin et al.	2017	Lower average yields but similar yield variability in organic versus conventional horticulture. A meta-analysis	Agronomy for Sustainable Development	LabEx BASC, ANR French National Research Agency
Perrin et al.	2017	Integrated design and sustainable assessment of innovative biomass supply chains: A case-study on miscanthus in France	Applied Energy	FP7, EC
Wilk et al.	2017	Combustion and kinetic parameters estimation of torrefied pine, acacia and Miscanthus giganteus using experimental and modelling techniques	Bioresource Technology	Polish Ministry of Science and Higher Education; CNRS
Zapater et al.	2017	A Single and Robust Critical Nitrogen Dilution Curve for Miscanthus × giganteus and Miscanthus sinensis	Bioenergy Research	ANR; Regional Council Picardie; INRA
Belandria et al.	2016	Enhanced gasification of woody biomass in oxygen-enriched environment	European Biomass Conference and Exhibition Proceedings	CNRS, national center for scientific research; University of Orleans
Ben Fradj et al.	2016	Competition between food, feed, and (bio)fuel: A supply-side model based assessment at the European scale	Land Use Policy	FP7, Foodsecure, EC, European Comission, EC; Futurol project, OSEO-BPI France (Public Investment Bank)
Drewer et al.	2016	Changes in isotopic signatures of soil carbon and CO2 respiration immediately and one year after Miscanthus removal	GCB Bioenergy	CEH Centre for Ecology and Hydrology Edinburgh

(*continued on next page*)

Table 5 (*continued*)

Authors	Year	Paper title	Journal title	Funding source
Dufossé et al.	2016	Agro-ecosystem modeling can aid in the optimization of biomass feedstock supply	Environmental Modelling and Software	Futurol project, OSEO-BPI France (Public Investment Bank); ENSEMBLE, EC
Ferchaud et al.	2016	The fate of cumulative applications of 15N-labelled fertiliser in perennial and annual bioenergy crops	Agriculture, Ecosystems and Environment	Futurol project,OSEO-BPI France (Public Investment Bank); Regix, ANR French National Research Agency
Ferchaud et al.	2016	Changes in soil carbon stocks under perennial and annual bioenergy crops	GCB Bioenergy	Futurol project, OSEO-BPI France (Public Investment Bank); Regix, ANR French National Research Agency
Gabrielle et al.	2016	Cost-benefit analysis of first-and second-generation biofuels based on an economic valuation of life-cycle impacts	European Biomass Conference and Exhibition Proceedings	ANR French National Research Agency; INRA; WBG, World Bank Group
Garra et al.	2016	Impactors long term collection errors and correction using reflected light microscopy	Journal of Aerosol Science	EC European Commission; Erzincan University
Gea et al.	2016	Functionalization of Miscanthus by Photoactivated Thiol-Ene Addition to Improve Interfacial Adhesion with Polycaprolactone	ACS Sustainable Chemistry and Engineering	ANR French National Research Agency
Haughton et al.	2016	Dedicated biomass crops can enhance biodiversity in the arable landscape	GCB Bioenergy	NERC Natural Environment Research Council; BBSRC Biotechnology and Biological Sciences Research Council; Rothamsted Research; ESRC Economic and Social Research Council
Lesur-Dumoulin et al.	2016	Analysis of young Miscanthus × giganteus yield variability: A survey of farmers' fields in east central France	GCB Bioenergy	Futurol project, OSEO-BPI France (Public Investment Bank)
Morandi et al.	2016	Miscanthus as energy crop: Environmental assessment of a miscanthus biomass production case study in France	Journal of Cleaner Production	FP7, LogistEC, EC, European Comission, EC; Rothamsted Research
Richter et al.	2016	Assessing on-farm productivity of Miscanthus crops by combining soil mapping, yield modelling and remote sensing	Biomass and Bioenergy	BBSRC Biotechnology and Biological Sciences Research Council; Natural England; NERC Natural Environment Research Council; BBSRC Biotechnology and Biological Sciences Research Council; Rothamsted Research
Zamboni et al.	2016	Catalytic gasification of biomass (Miscanthus) enhanced by CO2 sorption	Environmental Science and Pollution Research	CNRS; Regional Council of Alsace and Lorraine
Ameline et al.	2015	Status of the bioenergy crop miscanthus as a potential reservoir for aphid pests	Industrial Crops and Products	Research project MISCPIC, Regional council of Picardie
Arnoult et al.	2015	Miscanthus clones for cellulosic bioethanol production: Relationships between biomass production, biomass production components, and biomass chemical composition	Industrial Crops and Products	Futurol project, OSEO-BPI France (Public Investment Bank); INRA French Institute of Agricultural research; LANO Labortory
Bourgeois et al.	2015	Positive effect of the Miscanthus bioenergy crop on microbial diversity in wastewater-contaminated soil	Environmental Chemistry Letters	ANR French National Research Agency; INRA
Bourgeois et al.	2015	Miscanthus bioenergy crop stimulates nutrient-cycler bacteria and fungi in wastewater-contaminated agricultural soil	Environmental Chemistry Letters	ANR French National Research Agency; INRA
Da Silva Perez et al.	2015	Characterisation of the most representative agricultural and forestry biomasses in France for gasification	Waste and Biomass Valorization	ANR French National Research Agency; ANRT National Association of Research and Technology
Doury et al.	2015	Bioenergy Crops and Natural Enemies: Host Plant-Mediated Effects of Miscanthus on the Aphid Parasitoid Lysiphlebus testaceipes	Bioenergy Research	Regional Council of Picardie
Ferchaud et al.	2015	Soil water uptake and root distribution of different perennial and annual bioenergy crops	Plant and Soil	Futurol project, OSEO-BPI France (Public Investment Bank); Regix, ANR French National Research Agency
Firmin et al.	2015	Arbuscular mycorrhizal fungal inoculation protects Miscanthus × giganteus against trace element toxicity in a highly metal-contaminated site	Science of the Total Environment	ADEME French Environment and Energy Management Agency
Laurent et al.	2015	Using site-specific data to estimate energy crop yield	Environmental Modelling and Software	FP7, LogistEC, EC, European Comission, EC;
Nsanganwimana et al.	2015	Metal accumulation and shoot yield of Miscanthus × giganteus growing in contaminated agricultural soils: Insights into agronomic practices	Agriculture, Ecosystems and Environment	ADEME, French Environment and Energy Management Agency
Pelfrene et al.	2015	Effect of Miscanthus cultivation on metal fractionation and human bioaccessibility in metal-contaminated soils: comparison between greenhouse and field experiments	Environmental Science and Pollution Research	ADEME French Environment and Energy Management Agency
Pintiaux et al.	2015	Hydrophobic cellulose-based materials obtained by uniaxial high pressure compression: In-situ esterification with fatty acids and fatty anhydrides	BioResources	ANR French National Research Agency
Rammal et al.	2015	Weighted-covariance factor fuzzy c-means clustering	2015 3rd International Conference on Technological Advances in Electrical, Electronics and Computer Engineering, TAEECE 2015	Regional Council of Champagne-Ardenne
Schnitzler &Essl	2015	From horticulture and biofuel to invasion: The spread of Miscanthus taxa in the USA and Europe	Weed Research	Water Agency of Rhin-Meuse

(*continued on next page*)

Table 5 (*continued*)

Authors	Year	Paper title	Journal title	Funding source
Strullu et al.	2015	Multisite Yield Gap Analysis of Miscanthus × giganteus Using the STICS Model	Bioenergy Research	EPSRC Engineering and Physical Sciences Research Council
Auxenfans et al.	2014	Efficient enzymatic saccharification of Miscanthus: Energy-saving by combining dilute acid and ionic liquid pretreatments	Biomass and Bioenergy	MESRI, Ministry of Higher Education, Research and Innovation
Bourgeois et al.	2014	How Cost-Effective is a Mixed Policy Targeting the Management of Three Agricultural N-pollutants?	Environmental Modeling and Assessment	Futurol project, OSEO-BPI France (Public Investment Bank); PIREN-SEINE Project, Regional Council of Ile de France
Cadoux et al.	2014	Implications of productivity and nutrient requirements on greenhouse gas balance of annual and perennial bioenergy crops	GCB Bioenergy	Futurol project, OSEO-BPI France (Public Investment Bank); Regix, ANR French National Research Agency
Chauvat et al.	2014	Establishment of bioenergy crops on metal contaminated soils stimulates belowground fauna	Biomass and Bioenergy	ANR French National Research Agency; Total S.A., Petroleum refining company
Dufossé et al.	2014	Effects of a 20-year old Miscanthus × giganteus stand and its removal on soil characteristics and greenhouse gas emissions	Biomass and Bioenergy	Futurol project, OSEO-BPI France (Public Investment Bank)
Gabrielle et al.	2014	Environmental assessment of biofuel pathways in Ile de France based on ecosystem modeling	Bioresource Technology	ENERBIO, TUCK Foundation
Hognon et al.	2014	Comparison of steam gasification reactivity of algal and lignocellulosic biomass: Influence of inorganic elements	Bioresource Technology	IE-Arvalis ONIDOL; Microphyt; Earl Carpio
Houben et al.	2014	Biochar from Miscanthus: A potential silicon fertilizer	Plant and Soil	UCL University College London; FNRS National Fund for Scientific Research
Lesur et al.	2014	Assessing nitrate leaching during the three-first years of Miscanthus × giganteus from on-farm measurements and modeling	GCB Bioenergy	Futurol project, OSEO-BPI France (Public Investment Bank);
Mayer et al.	2014	Assessment of energy crops alternative to maize for biogas production in the Greater Region	Bioresource Technology	FNR, Luxembourg National Research Fund; ENERBIO, TUCK Foundation; FEDER European Regional Development Fund
Rizzo et al.	2014	Miscanthus spatial location as seen by farmers: Amachine learning approach to model real criteria	Biomass and Bioenergy	Futurol project, OSEO-BPI France (Public Investment Bank); FP7, LogistEC, EC, European Commission
Strullu et al.	2014	Simulation of Biomass and Nitrogen Dynamics in Perennial Organs and Shoots of Miscanthus × giganteus Using the STICS Model	Bioenergy Research	Futurol project, OSEO-BPI France (Public Investment Bank);
Domon et al.	2013	Cell wall compositional modifications of Miscanthus ecotypes in response to cold acclimation	Phytochemistry	Regional Council of Picardie; Purdue University
Dufossé et al.	2013	Using agroecosystem modeling to improve the estimates of N2O emissions in the life-cycle assessment of biofuels	Waste and Biomass Valorization	Futurol project, OSEO-BPI France (Public Investment Bank); INRA
Godard et al.	2013	Life-cycle assessment of local feedstock supply scenarios to compare candidate biomass sources	GCB Bioenergy	FranceAgrimer; Regional Council of Picardie
Hedde et al.	2013	Responses of soil macroinvertebrate communities to Miscanthus cropping in different trace metal contaminated soils	Biomass and Bioenergy	ANR French National Research Agency; FRB, Foundation for biodiversity Research
Hedde et al.	2013	Dynamics of soil fauna after plantation of perennial energy crops on polluted soils	Applied Soil Ecology	ANR French National Research Agency; FRB, Foundation for biodiversity Research
Iqbal et al.	2013	Impact of miscanthus cultivation on trace metal availability in contaminated agricultural soils: Complementary insights from kinetic extraction and physical fractionation	Chemosphere	ANR French National Research Agency; HEC Higher Education Commission, Pakistan
Rambaud et al.	2013	Shoot organogenesis in three Miscanthus species and evaluation for genetic uniformity using AFLP analysis	Plant Cell, Tissue and Organ Culture	Regional Council of Picardie
Rammal et al.	2013	Optimal preprocessing of Mid InfraRed spectra. Application to classification of lignocellulosic biomass: Maize roots and miscanthus internodes	Advances in Mass Data Analysis of Images and Signals in Medicine, Biotechnology, Chemistry and Food Industry – 8th International Conference, MDA 2013, Proceedings	Regional Council of Champagne-Ardenne
Strullu et al.	2013	Influence of belowground nitrogen stocks on light interception and conversion of Miscanthus × giganteus	European Journal of Agronomy	MISCAZOTE, Regional Council of Picardie; ENERBIO, TUCK Foundation
Timilsena et al.	2013	Effect of different pretreatments on delignification pattern and enzymatic hydrolysability of miscanthus, oil palm biomass and typha grass	Bioresource Technology	Regional Council of Lorraine; FEDER European Regional Development Fund
Timilsena et al.	2013	Impact of the lignin structure of three lignocellulosic feedstocks on their organosolv delignification. Effect of carbonium ion scavengers	Biomass and Bioenergy	Regional Council of Lorraine; FEDER European Regional Development Fund
Amougou et al.	2012	Miscanthus × giganteus leaf senescence, decomposition and C and N inputs to soil	GCB Bioenergy	INRA, French Institute of Agricultural research; Regional council of Champagne Ardenne; Regional Council of Picardie
Cadoux et al.	2012	Nutrient requirements of Miscanthus × giganteus: Conclusions from a review of published studies	Biomass and Bioenergy	Bioenergy Network of Excellence, INRA; EPSRC, Engineering and Physical Sciences Research Council; BBSRC, Biotechnology and Biological Sciences Research Council; Rothamsted Research

(*continued on next page*)

Table 5 (*continued*)

Authors	Year	Paper title	Journal title	Funding source
Didier et al.	2012	Prospects of Miscanthus × giganteus for PAH phytoremediation: A microcosm study	Industrial Crops and Products	ADEME, French Environment and Energy Management Agency; EDF, Electricity of France; Communauty of Portes de France-Thionville
Lan et al.	2012	Wood adhesives from agricultural by-products: Lignins and tannins for the elaboration of particleboards	Cellulose Chemistry and Technology	Nanjing Forestry University; Regional Council of Lorraine; FEDER European Regional Development Fund
Le Guillou et al.	2012	Changes during winter in water-stable aggregation due to crop residue quality	Soil Use and Management	International Doctoral College, University of Bretagne
Martin et al.	2012	Modelling farmers' choice of miscanthus allocation in farmland: A case-based reasoning model	iEMSs 2012 – Managing Resources of a Limited Planet: Proceedings of the 6th Biennial Meeting of the International Environmental Modelling and Software Society	Futurol project, OSEO-BPI France (Public Investment Bank)
Michel et al.	2012	Physicochemical changes in Miscanthus ash on agglomeration with fluidized bed material	Chemical Engineering Journal	ANR French National Research Agency
Obama et al.	2012	Combination of enzymatic hydrolysis and ethanol organosolv pretreatments: Effect on lignin structures, delignification yields and cellulose-to-glucose conversion	Bioresource Technology	Regional Council of Lorraine; FEDER European Regional Development Fund
Técher et al.	2012	An appraisal of Miscanthus × giganteus cultivation for fly ash revegetation and soil restoration	Industrial Crops and Products	ADEME, French Environment and Energy Management Agency; EDF, Electricity of France
Zub et al.	2012	The frost tolerance of Miscanthus at the juvenile stage: Differences between clones are influenced by leaf-stage and acclimation	European Journal of Agronomy	Regional Councl of Picardie
Zub et al.	2012	An Index of Competition Reduces Statistical Variability and Improves Comparisons between Genotypes of Miscanthus	Bioenergy Research	Regional Councl of Picardie
Zub et al.	2012	Late Emergence and Rapid Growth Maximize the Plant Development of Miscanthus Clones	Bioenergy Research	Regional Councl of Picardie
Amougou et al.	2011	Quality and decomposition in soil of rhizome, root and senescent leaf from Miscanthus × giganteus, as affected by harvest date and N fertilization	Plant and Soil	INRA, French Institute of Agricultural research; Regional council of Champagne Ardenne
Dorge et al.	2011	Thermal degradation of Miscanthus pellets: Kinetics and aerosols characterization	Waste and Biomass Valorization	Regional Council of Alsace; Novabiom France
Le Ngoc Huyen et al.	2011	Saccharification of Miscanthus × giganteus, incorporation of lignocellulosic by-product in cementitious matrix	Comptes Rendus – Biologies	Regional Council of Picardie
Michel et al.	2011	Steam gasification of Miscanthus × giganteus with olivine as catalyst production of syngas and analysis of tars (IR, NMR and GC/MS)	Biomass and Bioenergy	PAN Polish Academy of sciences; CNRS National Center for Scientific Research
Michel et al.	2011	Catalytic steam gasification of Miscanthus × giganteus in fluidised bed reactor on olivine based catalysts	Fuel Processing Technology	PAN Polish Academy of sciences; CNRS National Center for Scientific Research
Strullu et al.	2011	Biomass production and nitrogen accumulation and remobilisation by Miscanthus × giganteus as influenced by nitrogen stocks in belowground organs	Field Crops Research	MISCAZOTE &MISQUAL, Regional Council of Picardie; ENERBIO, TUCK Foundation
Técher et al.	2011	Contribution of Miscanthus × giganteus root exudates to the biostimulation of PAH degradation: An in vitro study	Science of the Total Environment	ADEME, French Environment and Energy Management Agency; EDF, Electricity of France
Zub et al.	2011	Key traits for biomass production identified in different Miscanthus species at two harvest dates	Biomass and Bioenergy	Regional Councl of Picardie
Bocquého &Jacquet	2010	The adoption of switchgrass and miscanthus by farmers: Impact of liquidity constraints and risk preferences	Energy Policy	Bioenergy NoE, EC
Brosse et al.	2010	Dilute sulphuric acid and ethanol organosolv pretreatment of Miscanthus × giganteus	Cellulose Chemistry and Technology	ANR French National Research Agency
El Hage et al.	2010	Effect of autohydrolysis of Miscanthus × giganteus on lignin structure and organosolv delignification	Bioresource Technology	Regional Council of Lorraine; FEDER European Regional Development Fund
Hromádko et al.	2010	Composition of root exudates of Miscanthus × giganteus greef et deu	Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis	Mendel University in Brno; University of Paul Verlaine Metz
Le Ngoc Huyen et al.	2010	Effect of harvesting date on the composition and saccharification of Miscanthus × giganteus	Bioresource Technology	Regional Council of Picardie
Khelfa et al.	2009	Catalytic pyrolysis and gasification of Miscanthus Giganteus: Haematite (Fe2O3) a versatile catalyst	Journal of Analytical and Applied Pyrolysis	Biomasters, MENRT Ministry of National Education, Research and Technology; Credit Mutuel; University of Paul Verlaine Metz
Collura et al.	2006	Miscanthus × giganteus straw and pellets as sustainable fuels: Combustion and emission tests	Environmental Chemistry Letters	Projet Miscanthus', Saint Avold Community; University of London

(*continued on next page*)

Table 5 (*continued*)

Authors	Year	Paper title	Journal title	Funding source
Michel et al.	2006	Miscanthus × giganteus straw and pellets as sustainable fuels and raw material for activated carbon	Environmental Chemistry Letters	ANVAR French Agency for innovation; 'Projet Miscanthus', Saint Avold Community;
Collura et al.	2005	Thermal behavior of Miscanthus grasses, an alternative biological fuel	Environmental Chemistry Letters	Projet Miscanthus', Saint Avold Community; University of London; Biomasters, MENRT Ministry of National Education, Research and Technology
Barba et al.	2002	Synthesis and characterization of carboxymethylcelluloses (CMC) from non-wood fibers I. Accessibility of cellulose fibers and CMC synthesis	Cellulose	Spanish Government; Catalan Regional Government

References

Adams, P., Lindegaard, K., 2016. A critical appraisal of the effectiveness of UK perennial energy crops policy since 1990. Renew. Sustain. Energy Rev. 55, 188–202.

Ahvazi, B., Wojciechowicz, O., Ton-That, T.-M., Hawari, J., 2011. Preparation of lignopolyols from wheat straw soda lignin. J. Agric. Food Chem. 59 (19), 10505–10516. https://doi.org/10.1021/jf202452m.

Albrecht, J., Carrez, D., Cunningham, P., Daroda, L., Mancia, R., Máthé, L., Raschka, A., Carus, M., Piotrowski, S., 2010. The Knowledge Based Bio-Economy (KBBE) in Europe: Achievements and Challenges. Tech. Rep. EU Commission September.

Allison, G., Morris, C., Clifton-Brown, J., Lister, S., Donnison, I., 2011. Genotypic variation in cell wall composition in a diverse set of 244 accessions of Miscanthus. Biomass Bioenergy 35 (11), 4740–4747.

Alriols, M., García, A., Llano-ponte, R., Labidi, J., 2010. Combined organosolv and ultrafiltration lignocellulosic biorefinery process. Chem. Eng. J. 157 (1), 113–120.

Amougou, N., Bertrand, I., Machet, J.-M., Recous, S., 2011. Quality and decomposition in soil of rhizome, root and senescent leaf from Miscanthus × giganteus, as affected by harvest date and N fertilization. Plant Soil 338 (1), 83–97.

Anderson, E., Arundale, R., Maughan, M., Oladeinde, A., Wycislo, A., Voigt, T., 2011. Growth and agronomy of Miscanthus × giganteus for biomass production. Biofuels 2 (1), 71–87. https://doi.org/10.4155/bfs.10.80.

Andrejic, G., Gajic, G., Prica, M., Dzeletovic, Z., Rakic, T., 2018. Zinc accumulation, photosynthetic gas exchange, and chlorophyll a fluorescence in Zn-stressed Miscanthus × giganteus plants. Photosynthetica 56 (4), 1249–1258.

Aonuma, K., 1970. On the competition between planted trees and Japanese pampas grass (Miscanthus sinensis ANDERSS) I: The growth of sugi (Cryptomeria japonica D, DON) forest trees according to the invasion of Japanese pampas grass, and the response to fertilization. J. Jpn. For. Soc. 52 (2), 35–40.

Arundale, R.A., Dohleman, F.G., Voigt, T.B., Long, S.P., 2014. Nitrogen fertilization does significantly increase yields of stands of Miscanthus × giganteus and Panicum virgatum in multiyear trials in illinois. Bioenergy Res.

Ashman, C., Awty-Carroll, D., Mos, M., Robson, P., Clifton-Brown, J., 2018. Assessing seed priming, sowing date, and mulch film to improve the germination and survival of direct-sown Miscanthus sinensis in the United Kingdom. GCB Bioenergy 10 (9), 612–627.

Bamminger, C., Poll, C., Marhan, S., 2018. Offsetting global warming-induced elevated greenhouse gas emissions from an arable soil by biochar application. Global Change Biol. 24 (1), 318–334.

Baxter, X., Darvell, L., Jones, J., Barraclough, T., Yates, N., Shield, I., 2014. Miscanthus combustion properties and variations with Miscanthus agronomy. Fuel 117 (PART A), 851–869.

Beale, C., Bint, D., Long, S., 1996. Leaf photosynthesis in the C4 grass Miscanthus × giganteus, growing in the cool temperate climate of southern England. J. Exp. Bot. 47 (295), 267–273.

Beale, C., Long, S., 1995. Can perennial C4 grasses attain high efficiencies of radiant energy conversion in cool climates? Plant Cell Environ. 18 (6), 641–650.

Beale, C., Long, S., 1997. Seasonal dynamics of nutrient accumulation and partitioning in the perennial C4 grasses Miscanthus × giganteus and Spartina cynosuroides. Biomass Bioenergy 12 (6), 419–428.

Beckman, J., Jones, C.A., Sands, R., 2011. A global general equilibruim analysis of biofuel mandates and greenhouse gas emissions. Am. J. Agric. Econ. 93 (2), 334–341.

Behnke, G.D., David, M.B., Voigt, T.B., 2012. Greenhouse gas emissions, nitrate leaching, and biomass yields from production of Miscanthus × giganteus in Illinois, USA. Bioenergy Res. 5 (December (4)), 801–813.

Bellamy, P., Croxton, P., Heard, M., Hinsley, S., Hulmes, L., Hulmes, S., Nuttall, P., Pywell, R., Rothery, P., 2009. The impact of growing Miscanthus for biomass on farmland bird populations. Biomass Bioenergy 33 (2), 191–199.

Ben Fradj, N., Jayet, P., Aghajanzadeh-Darzi, P., 2016. Competition between food, feed, and (bio)fuel: a supply-side model based assessment at the European scale. Land Policy 52 (March), 195–205.

Ben Fradj, N., Jayet, P.-A., 2018. Optimal management of perennial energy crops by farming systems in France: a supply-side economic analysis. Biomass Bioenergy 116, 113–121.

Beuch, S., Boelcke, B., Belau, L., 2001. Effect of the organic residues of Miscanthus × giganteus on the soil organic matter level of arable soils. J. Agron. Crop Sci. 184 (2), 111–120.

Bilska-Kos, A., Panek, P., Szulc-Glaz, A., Ochodzki, P., Cislo, A., Zebrowski, J., 2018. Chilling-induced physiological, anatomical and biochemical responses in the leaves of Miscanthus × giganteus and maize (Zea mays L.). J. Plant Physiol. 228, 178–188.

Blengini, G., Brizio, E., Cibrario, M., Genon, G., 2011. LCA of bioenergy chains in Piedmont (Italy): case study to support public decision makers towards sustainability. Resour. Conserv. Recycl. 57, 36–47.

Bocquého, G., Jacquet, F., 2010. The adoption of switchgrass and Miscanthus by farmers: impact of liquidity constraints and risk preferences. Energy Policy 38 (5), 2598–2607.

Borzecka-Walker, M., Faber, A., Borek, R., 2008. Evaluation of carbon sequestration in energetic crops (Miscanthus and coppice willow). Int. Agrophys. 22 (3), 185–190.

Borzecka-Walker, M., Faber, A., Syp, A., Pudelko, R., Mizak, K., 2012. Simulation of greenhouse gases from Miscanthus cultivation in Poland using the DNDC model. J. Food Agric. Environ. 10 (2), 1187–1190.

Boswell, C., Smith, K., 2017. Rethinking policy 'impact': four models of research-policy relations. Palgrave Commun. 3 (1), 44.

Bourgeois, C., Ben Fradj, N., Jayet, P.-A., 2014. How cost-effective is a mixed policy targeting the management of three agricultural N-pollutants? Environ. Model. Assess. 19 (5), 389–405.

Brandão, M., Clift, R., Milà, L., Basson, L., 2010. A life-cycle approach to characterising

environmental and economic impacts of multifunctional land-use systems: an integrated assessment in the UK. Sustainability 2 (12), 3747–3776.
Brosse, N., Dufour, A., Meng, X., Sun, Q., Ragauskas, A., 2012. Miscanthus: a fast-growing crop for biofuels and chemicals production. Biofuels Bioprod. Biorefin. 6 (5), 580–598.
Brosse, N., Sannigrahi, P., Ragauskas, A., 2009. Pretreatment of Miscanthus × giganteus using the ethanol organosolv process for ethanol production. Ind. Eng. Chem. Res. 48 (18), 8328–8334.
Cadoux, S., Riche, A.B., Yates, N.E., Machet, J.-M., 2012. Nutrient requirements of Miscanthus × giganteus: conclusions from a review of published studies. Biomass Bioenergy 38, 14–22.
Calvo-Flores, F.G., Dobado, J.A., Isac-García, J., Martín-MartíNez, F.J., 2015. Lignin and Lignans as Renewable Raw Materials: Chemistry, Technology and Applications. John Wiley & Sons, Ltd.
Chimento, C., Almagro, M., Amaducci, S., 2016. Carbon sequestration potential in perennial bioenergy crops: the importance of organic matter inputs and its physical protection. GCB Bioenergy 8 (1), 111–121.
Christian, D., 1994. Quantifying the yield of perennial grasses grown as a biofuel for energy generation. Renew. Energy 5 (58), 762–766.
Christian, D., Lamptey, J., Forde, S., Plumb, R., 1994. First report of barley yellow dwarf luteovirus on Miscanthus in the United Kingdom. Eur. J. Plant Pathol. 100 (2), 167–170.
Christian, D., Poulton, P., Riche, A., Yates, N., 1997. The recovery of 15N-labelled fertilizer applied to Miscanthus × Giganteus. Biomass Bioenergy 12 (1), 21–24.
Christian, D., Riche, A., Yates, N., 2008. Growth, yield and mineral content of Miscanthus × giganteus grown as a biofuel for 14 successive harvests. Ind. Crops Prod. 28 (3), 320–327.
Clifton-Brown, J., Breuer, J., Jones, M., 2007. Carbon mitigation by the energy crop Miscanthus. Glob. Change. Biol. 13 (11), 2296–2307.
Clifton-Brown, J., Lewandowski, I., 2002. Screening Miscanthus genotypes in field trials to optimise biomass yield and quality in southern Germany. Eur. J. Agron. 16 (2), 97–110.
Clifton-Brown, J., Lewandowski, I., Bangerth, F., Jones, M., 2002. Comparative responses to water stress in staygreen, rapid and slow senescing genotypes of the biomass crop Miscanthus. New Phytol. 154 (2), 335–345.
Clifton-Brown, J., Stampfl, P., Jones, M., 2004. Miscanthus biomass production for energy in Europe and its potential contribution to decreasing fossil fuel carbon emissions. Glob. Change. Biol. 10 (4), 509–518.
Clifton-Brown, J., Harfouche, A., Casler, M.D., Dylan Jones, H., Macalpine, W.J., Murphy-Bokern, D., Smart, L.B., Adler, A., Ashman, C., Awty-Carroll, D., Bastien, C., Bopper, S., Botnari, V., Brancourt-Hulmel, M., Chen, Z., Clark, L.V., Cosentino, S., Dalton, S., Davey, C., Dolstra, O., Donnison, I., Flavell, R., Greef, J., Hanley, S., Hastings, A., Hertzberg, M., Hsu, T.-W., Huang, L.S., Iurato, A., Jensen, E., Jin, X., Jørgensen, U., Kiesel, A., Kim, D.-S., Liu, J., McCalmont, J.P., McMahon, B.G., Mos, M., Robson, P., Sacks, E.J., Sandu, A., Scalici, G., Schwarz, K., Scordia, D., Shafiei, R., Shield, I., Slavov, G., Stanton, B.J., Swaminathan, K., Taylor, G., Torres, A.F., Trindade, L.M., Tschaplinski, T., Tuskan, G.A., Yamada, T., Yeon Yu, C., Zalesny Jr, R.S., Zong, J., Lewandowski, I., 2019. Breeding progress and preparedness for mass-scale deployment of perennial lignocellulosic biomass crops switchgrass, miscanthus, willow and poplar. GCB Bioenergy 11 (1), 118–151.
Collura, S., Azambre, B., Finqueneisel, G., Zimny, T., Weber, J., 2006. Miscanthus × Giganteus straw and pellets as sustainable fuels: combustion and emission tests. Environ. Chem. Lett. 4 (2), 75–78.
Cosentino, S., Patanè, C., Sanzone, E., Copani, V., Foti, S., 2007. Effects of soil water content and nitrogen supply on the productivity of Miscanthus × giganteus Greef et Deu. in a Mediterranean environment. Ind. Crops Prod. 25 (1), 75–88.
Dahmen, N., Henrich, E., Henrich, T., 2017. Synthesis gas biorefinery. In: In: Wagemann, K., Tippkötter, N. (Eds.), Biorefineries. Advances in Biochemical Engineering/ Biotechnology 166. Springer, Cham, pp. 217–245.
Dahmen, N., Lewandowski, I., Zibek, S., Weidtmann, A., 2019. Integrated lignocellulosic value chains in a growing bioeconomy: status quo and perspectives. GCB Bioenergy 11 (1), 107–117.
Dauber, J., Cass, S., Gabriel, D., Harte, K., Åström, S., O'Rourke, E., Stout, J., 2015. Yield-biodiversity trade-off in patchy fields of Miscanthus × giganteus. GCB Bioenergy 7 (3), 455–467.
De Vrije, T., Bakker, R.R., Budde, M.A., Lai, M.H., Mars, A.E., Claassen, P.A., 2009. Efficient hydrogen production from the lignocellulosic energy crop Miscanthus by the extreme thermophilic bacteria Caldicellulosiruptor saccharolyticus and Thermotoga neapolitana. Biotechnol. Biofuels 2 (June (1)), 12.
Dufossé, K., Drewer, J., Gabrielle, B., Drouet, J.L., 2014. Effects of a 20-year old Miscanthus × giganteus stand and its removal on soil characteristics and greenhouse gas emissions. Biomass Bioenergy 69, 198–210.
Dufossé, K., Gabrielle, B., Drouet, J., Bessou, C., 2013. Using agroecosystem modeling to improve the estimates of N2O emissions in the lifecycle assessment of biofuels. Waste Biomass Valoriz. 4 (3), 593–606.
El-Chichakli, B., von Braun, J., Lang, C., Barben, D., Philp, J., 2016. Policy: five cornerstones of a global bioeconomy. Nature 535, 221–223.
El Hage, R., Chrusciel, L., Desharnais, L., Brosse, N., 2010. Effect of autohydrolysis of Miscanthus × giganteus on lignin structure and organosolv delignification. Bioresour. Technol. 101 (23), 9321–9329.
Emmerling, C., Pude, R., 2017. Introducing Miscanthus to the greening measures of the EU Common agricultural policy. GCB Bioenergy 9 (2), 274–279.
Ercoli, L., Mariotti, M., Masoni, A., Bonari, E., 1999. Effect of irrigation and nitrogen fertilization on biomass yield and efficiency of energy use in crop production of Miscanthus. Field Crops Res. 63 (1), 3–11.
EU Council, 2000. An Agenda of Economic and Social Renewal for Europe. Aka Lisbon Agenda.
EU Council, 2014a. A Policy Framework for Climate and Energy in the Period from 2020 to 2030.
EU Council, 2014b. Conclusions on 2030 Climate and Energy Policy Framework. EUCO169/14 (October). pp. 1–15. http://www.consilium.europa.eu/en/meetings/european-council/2014/10/23-24/.
Faix, O., Meier, D., Beinhoff, O., 1989. Analysis of lignocelluloses and lignins from Arundo donax L., Miscanthus sinensis Anderss., and hydroliquefaction of Miscanthus. Biomass 18 (2), 109–126.
Felten, D., Emmerling, C., 2011. Effects of bioenergy crop cultivation on earthworm communities – a comparative study of perennial (Miscanthus) and annual crops with consideration of graded land-use intensity. Appl. Soil Ecol. 49 (1), 167–177.
Ferchaud, F., Vitte, G., Mary, B., 2016. Changes in soil carbon stocks under perennial and annual bioenergy crops. GCB Bioenergy 8 (2), 290–306.
Firmin, S., Labidi, S., Fontaine, J., Laruelle, F., Tisserant, B., Nsanganwimana, F., Pourrut, B., Dalpé, Y., Grandmougin, A., Douay, F., Shirali, P., Verdin, A., Lounès-Hadj Sahraoui, A., 2015. Arbuscular mycorrhizal fungal inoculation protects Miscanthus × giganteus against trace element toxicity in a highly metal-contaminated site. Sci. Total Environ. 527–528, 91–99.
Fischer, G., Prieler, S., Van Velthuizen, H., 2005. Biomass potentials of Miscanthus, willow and poplar: results and policy implications for Eastern Europe, Northern and Central Asia. Biomass Bioenergy 28 (2), 119–132.
Foereid, B., De Neergaard, A., HøghJensen, H., 2004. Turnover of organic matter in a Miscanthus field: effect of time in Miscanthus cultivation and inorganic nitrogen supply. Soil Biol. Biochem. 36 (7), 1075–1085.
France Miscanthus, Litière pour animaux, 2020a. https://www.france-miscanthus.org/debouches/litiere-pour-animaux/.
France Miscanthus, Paillage horticole, 2020b. https://www.france-miscanthus.org/debouches/paillage-horticole/.
Gaunt, J.L., Lehmann, J., 2008. Energy balance and emissions associated with biochar sequestration and pyrolysis bioenergy production. Environ. Sci. Technol. 42 (11), 4152–4158.
Gedikoglu, H., 2015. Socio-economic factors and adoption of energy crops. Int. J. Food Agric. Econ. 3 (1), 1–17.
Gellerstedt, G., Henriksson, G., 2008. In: Belgacem, M.N., Gandini, A. (Eds.), Chapter 9 – Lignins: Major Sources, Structure and Properties. Elsevier, Amsterdam, pp. 201–224.
Gerssen-Gondelach, S.J., Wicke, B., Borzecka-Walker, M., Pudelko, R., Faaij, A.P.C., 2015. Bioethanol potential from Miscanthus with low ILUC risk in the province of Lublin Poland. GCB Bioenergy 8 (5), 909–924.
Giorcelli, M., Savi, P., Khan, A., Tagliaferro, A., 2019. Analysis of biochar with different pyrolysis temperatures used as filler in epoxy resin composites. Biomass Bioenergy 122, 466–471.
Greef, J.M., Deuter, M., 1993. Syntaxonomy of Miscanthus × giganteus GREEF et DEU. Angew. Bot. 67 (3–4), 87–90.
Grobelak, A., Rorat, A., Kokot, P., Singh, B.R., Kacprzak, M., 2018. Chapter 28 – mine waste rehabilitation case studies from poland. In: Prasad, M.N.V., de Campos Favas, P.J., Maiti, S.K. (Eds.), Bio-Geotechnologies for Mine Site Rehabilitation. Elsevier, pp. 515–527.
Haibara, K., Aiba, Y., Hidaka, S., Hidaka, S., 1983. Decomposition and nutrient disappearance in leaves of weeds in a young sugi (Cryptomeria japonica) plantation. J. Jpn. For. Soc. 65 (7), 237–242.
Haines, S.A., Gehl, R.J., Havlin, J.L., Ranney, T.G., 2015. Nitrogen and phosphorus fertilizer effects on establishment of giant Miscanthus. Bioenergy Res. 8 (1), 17–27.
Hansen, E., Christensen, B., Jensen, L., Kristensen, K., 2004. Carbon sequestration in soil beneath long-term Miscanthus plantations as determined by 13C abundance. Biomass Bioenergy 26 (2), 97–105.
Harris, Z., Spake, R., Taylor, G., 2015. Land use change to bioenergy: a meta-analysis of soil carbon and GHG emissions. Biomass Bioenergy 82, 27–39.
Haughton, A., Bond, A., Lovett, A., Dockerty, T., Sünnenberg, G., Clark, S., Bohan, D., Sage, R., Mallott, M., Mallott, V., Cunningham, M., Riche, A., Shield, I., Finch, J., Turner, M., Karp, A., 2009. A novel, integrated approach to assessing social, economic and environmental implications of changing rural landuse: a case study of perennial biomass crops. J. Appl. Ecol. 46 (2), 315–322.
Hayashi, I., 1984. Secondary succession of herbaceous communities in Japan: seed production of successional dominants. Jpn. J. Ecol. 34 (4), 375–382.
Hayashi, I., Hishinuma, Y., Yamasawa, T., 1981. Structure and functioning of Miscanthus sinensis grassland in Sugadaira Central Japan. Vegetatio 48 (1), 17–25.
Hellsmark, H., Frishammar, J., Söderholm, P., Ylinenpää, H., 2016. The role of pilot and demonstration plants in technology development and innovation policy. Res. Policy 45 (9), 1743–1761.
Hernández, P., Dorado, G., Laurie, D., Martín, A., Snape, J., 2001. Microsatellites and RFLP probes from maize are efficient sources of molecular markers for the biomass energy crop Miscanthus. Theor. Appl. Genet. 102 (4), 616–622.
Himken, M., Lammel, J., Neukirchen, D., Czypionka-Krause, U., Olfs, H.-W., 1997. Cultivation of Miscanthus under West European conditions: seasonal changes in dry matter production, nutrient uptake and remobilization. Plant Soil 189 (1), 117–126.
Hodgson, E., Fahmi, R., Yates, N., Barraclough, T., Shield, I., Allison, G., Bridgwater, A., Donnison, I., 2010. Miscanthus as a feedstock for fast-pyrolysis: does agronomic treatment affect quality? Bioresour. Technol. 101 (15), 6185–6191.
Holder, A.J., McCalmont, J.P., Rowe, R., McNamara, N.P., Elias, D., Donnison, I.S., 2019. Soil N2O emissions with different reduced tillage methods during the establishment of Miscanthus in temperate grassland. GCB Bioenergy 11 (3), 539–549.
Hu, Y., Schäfer, G., Duplay, J., Kuhn, N.J., 2018. Bioenergy crop induced changes in soil properties: a case study on Miscanthus fields in the upper rhine region. PLOS ONE 13 (July (7)), 1–15.
Huisman, W., Kortleve, W., 1994. Mechanization of crop establishment, harvest, and

postharvest conservation of Miscanthus sinensis Giganteus. Ind. Crops Prod. 2 (4), 289–297.

Iglesias, G., Bao, M., Lamas, J., Vega, A., 1996. Soda pulping of Miscanthus sinensis. Effects of operational variables on pulp yield and lignin solubilization. Bioresour. Technol. 58 (1), 17–23.

Irmak, S., Meryemoglu, B., Sandip, A., Subbiah, J., Mitchell, R.B., Sarath, G., 2018. Microwave pretreatment effects on switchgrass and Miscanthus solubilization in subcritical water and hydrolysate utilization for hydrogen production. Biomass Bioenergy 108, 48–54.

Janus, A., Waterlot, C., Heymans, S., Deboffe, C., Douay, F., Pelfrêne, A., 2018. Do biochars influence the availability and human oral bioaccessibility of Cd, Pb, and Zn in a contaminated slightly alkaline soil? Environ. Monit. Assess. 190 (March (4)), 218.

Jezowski, S., 2008. Yield traits of six clones of Miscanthus in the first 3 years following planting in Poland. Ind. Crops Prod. 27 (1), 65–68.

Johnson, M., Tucker, N., Barnes, S., Kirwan, K., 2005. Improvement of the impact performance of a starch based biopolymer via the incorporation of Miscanthus giganteus fibres. Ind. Crops Prod. 22 (3), 175–186.

Jørgensen, R., Jørgensen, B., Nielsen, N., Maag, M., Lind, A., 1997. N2O emission from energy crop fields of Miscanthus ‘Giganteus’ and winter rye. Atmos. Environ. 31 (18), 2899–2904.

Jørgensen, U., 1997. Genotypic variation in dry matter accumulation and content of N, K and Cl in Miscanthus in Denmark. Biomass Bioenergy 12 (3), 155–169.

Jørgensen, U., 2011. Benefits versus risks of growing biofuel crops: the case of Miscanthus. Curr. Opin. Environ. Sustain. 3 (1), 24–30.

Kaczmarek, J., Mizera, T., Tryjanowski, P., 2019. Energy crops affecting farmland birds in Central Europe: insights from a Miscanthus-dominated landscape. Biologia (Bratisl) 74 (1), 35–44.

Kahle, P., Beuch, S., Boelcke, B., Leinweber, P., Schulten, H., 2001. Cropping of Miscanthus in Central Europe: biomass production and influence on nutrients and soil organic matter. Eur. J. Agron. 15 (3), 171–184.

Kalinoski, R.M., Flores, H.D., Thapa, S., Tuegel, E.R., Bilek, M.A., Reyes-Mendez, E.Y., West, M.J., Dumonceaux, T.J., Canam, T., 2017. Pretreatment of hardwood and Miscanthus with trametes versicolor for bioenergy conversion and densification strategies. Appl. Biochem. Biotechnol. 183 (December (4)), 1401–1413.

Karer, J., Zehetner, F., Dunst, G., Fessl, J., Wagner, M., Puschenreiter, M., Stapkēviča, M., Friesl-Hanl, W., Soja, G., 2018. Immobilisation of metals in a contaminated soil with biochar-compost mixtures and inorganic additives: 2-year greenhouse and field experiments. Environ. Sci. Pollut. Res. 25 (January (3)), 2506–2516.

Kawana, A., Katori, M., Tanaka, S., Sugiura, T., 1966. Study on the chemical control of weeds and trees, V early spring application of DPA, ATA, and TCA on Susuki (Miscanthus sinensis). J. Jpn. Forest. Soc. 48 (1), 1–6.

Kawana, A., Sugimoto, B., Sugiura, T., 1967. Study of the chemical control of weeds and trees (XIV) treatment with DPA on Susuki (Miscanthus sinensis). J. Jpn. Forest. Soc. 49 (5), 187–191.

Khanna, M., Dhungana, B., Clifton-Brown, J., 2008. Costs of producing Miscanthus and switchgrass for bioenergy in illinois. Biomass Bioenergy 32 (6), 482–493.

Kiesel, A., Lewandowski, I., 2017. Miscanthus as biogas substrate – cutting tolerance and potential for anaerobic digestion. GCB Bioenergy 9 (1), 153–167.

Kirchhof, G., Reis, V., Baldani, J., Eckert, B., Döbereiner, J., Hartmann, A., 1997. Occurrence, physiological and molecular analysis of endophytic diazotrophic bacteria in gramineous energy plants. Plant Soil 194 (12), 45–55.

Kolanowski, Ł., Graś, M., Bartkowiak, M., Doczekalska, B., Lota, G., 2019. Electrochemical capacitors based on electrodes made of lignocellulosic waste materials. Waste Biomass Valoriz. 1–9.

Koohei, M., Takeshi, S., Mitsuru, I., Yohtar, A., 1984. Secondary succession on cut slopes of forest roads in Nukumi-daira, at the base of the Iide Mountains, Yamagata Prefecture (IV) floristic composition. J. Jpn. Forest. Soc. 66 (3), 83–92.

Kordsachia, O., Seemann, A., Patt, R., 1993. Fast growing poplar and Miscanthus sinensis-future raw materials for pulping in Central Europe. Biomass Bioenergy 5 (2), 137–143.

Kraska, T., Kleinschmidt, B., Weinand, J., Pude, R., 2018. Cascading use of Miscanthus as growing substrate in soilless cultivation of vegetables (tomatoes, cucumbers) and subsequent direct combustion. Sci. Hortic. 235, 205–213.

Krasuska, E., Rosenqvist, H., 2012. Economics of energy crops in Poland today and in the future. Biomass Bioenergy 38, 23–33.

Lafferty, J., Lelley, T., 1994. Cytogenetic studies of different Miscanthus species with potential for agricultural use. Plant Breed. 113 (3), 246–249.

Lajeunesse, M.J., 2017. Package ‘Metagear’. https://cran.r-project.org/web/packages/metagear/metagear.pdf.

Lask, J., Wagner, M., Trindade, L.M., Lewandowski, I., 2019. Life cycle assessment of ethanol production from Miscanthus: a comparison of production pathways at two European sites. GCB Bioenergy 11 (1), 269–288.

Ledo, A., Heathcote, R., Hastings, A., Smith, P., Hillier, J., 2018. Perennial-GHG: a new generic allometric model to estimate biomass accumulation and greenhouse gas emissions in perennial food and bioenergy crops. Environ. Modell. Softw. 102, 292–305.

Lesur, C., Bazot, M., BioBeri, F., Mary, B., Jeuffroy, M., Loyce, C., 2014. Assessing nitrate leaching during the three first years of Miscanthus × giganteus from on farm measurements and modeling. GCB Bioenergy 6 (4), 439–449.

Lesur, C., Jeuffroy, M.-H., Makowski, D., Riche, A.B., Shield, I., Yates, N., Fritz, M., Formowitz, B., Grunert, M., Jorgensen, U., Laerke, P.E., Loyce, C., 2013. Modeling long-term yield trends of Miscanthus × giganteus using experimental data from across europe. Field Crops Res. 149.

Lettens, S., Muys, B., Ceulemans, R., Moons, E., Garcia, J., Coppin, P., 2003. Energy budget and greenhouse gas balance evaluation of sustainable coppice systems for electricity production. Biomass Bioenergy 24 (3), 179–197.

Levidow, L., Birch, K., Papaioannou, T., 2012. EU agri-innovation policy: two contending visions of the bio-economy. Crit. Policy Stud. 6 (1), 40–65.

Lewandowski, I., 2015. Securing a sustainable biomass supply in a growing bioeconomy. Global Food Secur. 6, 34–42.

Lewandowski, I., Clifton-Brown, J., Kiesel, A., Hastings, A., Iqbal, Y., 2018. Miscanthus. In: Alexopoulou, E. (Ed.), Perennial Grasses for Bioenergy and Bioproducts. Academic Press, pp. 35–59.

Lewandowski, I., Clifton-Brown, J., Scurlock, J., Huisman, W., 2000. Miscanthus: European experience with a novel energy crop. Biomass Bioenergy 19 (4), 209–227.

Lewandowski, I., Clifton-Brown, J., Trindade, L.M., van der Linden, G.C., Schwarz, K.-U., Müller-Sämann, K., Anisimov, A., Chen, C.-L., Dolstra, O., Donnison, I.S., Farrar, K., Fonteyne, S., Harding, G., Hastings, A., Huxley, L.M., Iqbal, Y., Khokhlov, N., Kiesel, A., Lootens, P., Meyer, H., Mos, M., Muylle, H., Nunn, C., Özgüven, M., Roldán-Ruiz, I., Schüle, H., Tarakanov, I., van der Weijde, T., Wagner, M., Xi, Q., Kalinina, O., 2016. Progress on optimizing Miscanthus biomass production for the European bioeconomy: results of the EU FP7 project OPTIMISC. Front. Plant Sci. 7, 16–20.

Lewandowski, I., Kicherer, A., 1997. Combustion quality of biomass: practical relevance and experiments to modify the biomass quality of Miscanthus × giganteus. Eur. J. Agron. 6 (3), 163–177.

Lewandowski, I., Schmidt, U., 2006. Nitrogen, energy and land use efficiencies of Miscanthus, reed canary grass and triticale as determined by the boundary line approach. Agric. Ecosyst. Environ. 112 (4), 335–346.

Lewandowski, I., Scurlock, J.M.O., Lindvall, E., Christou, M., 2003. The development and current status of perennial rhizomatous grasses as energy crops in the us and europe. Biomass Bioenergy 25 (4), 335–361.

Li, Z., Delvaux, B., Yans, J., Dufour, N., Houben, D., Cornelis, J.-T., 2018a. Phytolith-rich biochar increases cotton biomass and silicon-mineralomass in a highly weathered soil. J. Plant Nutr. Soil Sci. 181 (4), 537–546.

Li, W., Ciais, P., Makowski, D., et al., 2018b. A global yield dataset for major lignocellulosic bioenergy crops based on field measurements. Sci. Data 5, 180169.

Liber, Y., Létondor, C., Pascal-Lorber, S., Laurent, F., 2018. Growth parameters influencing uptake of chlordecone by Miscanthus species. Sci. Total Environ. 624, 831–837.

Lieth, H., Numata, M., Suganuma, T., 1973. Studies of the grassland vegetation in the kawatabi special research area of the Japanese IBP – Phytosociological analysis and computer simulation of the table arrangement. Vegetatio 28 (1–2), 41–56.

Liu, H., Tian, Y., Lu, X., 2015. A review of the biorefinery technology of Miscanthus. Energy Sources Part A 37 (22), 2422–2428.

Lokesh, K., Ladu, L., Summerton, L., 2018. Bridging the gaps for a ‘circular’ bioeconomy: selection criteria, bio-based value chain and stakeholder mapping. Sustainability 10 (6).

Lovett, A.A., Sünnenberg, G.M., Richter, G.M., Dailey, A.G., Riche, A.B., Karp, A., 2009. Land use implications of increased biomass production identified by GIS-based suitability and yield mapping for Miscanthus in England. Bioenergy Res. 2 (June (1)), 17–28.

Luo, Y., Dungait, J.A.J., Zhao, X., Brookes, P.C., Durenkamp, M., Li, G., Lin, Q., 2018. Pyrolysis temperature during biochar production alters its subsequent utilization by microorganisms in an acid arable soil. Land Degrad. Dev. 29 (7), 2183–2188.

Manevski, K., Lærke, P.E., Olesen, J.E., Jørgensen, U., 2018. Nitrogen balances of innovative cropping systems for feedstock production to future biorefineries. Sci. Total Environ. 633, 372–390.

Mangold, A., Lewandowski, I., Hartung, J., Kiesel, A., 2019. Miscanthus for biogas production: influence of harvest date and ensiling on digestibility and methane hectare yield. GCB Bioenergy 11 (1), 50–62.

Mangold, A., Lewandowski, I., Xue, S., Kiesel, A., 2018. ‘collar propagation’ as an alternative propagation method for rhizomatous Miscanthus. GCB Bioenergy 10 (3), 186–198. https://doi.org/10.1111/gcbb.12480.

Mantziaris, S., Iliopoulos, C., Theodorakopoulou, I., Petropoulou, E., 2017. Perennial energy crops vs. Durum wheat in low input lands: economic analysis of a Greek case study. Renew. Sustain. Energy Rev. 80, 789–800.

Masuzawa, T., Hogetsu, K., 1977. Seasonal changes in the amount of carbohydrate and crude protein in the rhizome of Miscanthus sacchariflorus. Bot. Mag. Tokyo 90 (3), 181–191.

Matsumoto, T., 1971. Estimation of population productivity of Parapleurus alliaceus Germar (Orthoptera: Acridiidae) on a Miscanthus sinensis Anders. grassland – IIPopulation productivity in terms of dry weight. Oecologia 7 (1), 16–25.

Matsuoka, K., Kawakami, M., 1953. About soil erosion at grass land. J. Agric. Meteorol. 9 (1), 4–6.

Matyka, M., Kus, J., 2016. Influence of soil quality for yielding and biometric features of <i> Miscanthus × giganteus</i. Pol. J. Environ. Stud. 25 (1), 213–219. https://doi.org/10.15244/pjoes/60108.

McCalmont, J., Hastings, A., McNamara, N., Richter, G., Robson, P., Donnison, I., Clifton-Brown, J., 2017. Environmental costs and benefits of growing Miscanthus for bioenergy in the UK. GCB Bioenergy 9 (3), 489–507.

Michalska, K., Bizukojc, M., Ledakowicz, S., 2015. Pretreatment of energy crops with sodium hydroxide and cellulolytic enzymes to increase biogas production. Biomass Bioenergy 80, 213–221.

Miguez, F.E., Villamil, M.B., Long, S.P., Bollero, G.A., 2008. Meta-analysis of the effects of management factors on Miscanthus × giganteus growth and biomass production. Agric. Forest Meteorol. 148 (8–9), 1280–1292.

Milner, S., Holland, R., Lovett, A., Sunnenberg, G., Hastings, A., Smith, P., Wang, S., Taylor, G., 2016. Potential impacts on ecosystem services of land use transitions to second-generation bioenergy crops in GB. GCB Bioenergy 8 (2), 317–333.

Monti, A., Zatta, A., 2009. Root distribution and soil moisture retrieval in perennial and annual energy crops in northern Italy. Agric. Ecosyst. Environ. 132 (3), 252–259.

Moreno, J.L., 1953. Who Shall Survive? Foundations of Sociometry, Group Psychotherapy and Socio-Drama, 2nd ed. Beacon House.

Nakamura, K., Itô, Y., Nakamura, M., Matsumoto, T., Hayakawa, K., 1971. Estimation of population productivity of Parapleurus alliaceus Germar (Orthoptera: Acridiidae) on a Miscanthus sinensis Anders. grassland – IEstimation of population parameters. Oecologia 7 (1), 1–15.
Ngigi, A., Ok, Y., Thiele-Bruhn, S., 2019. Biochar-mediated sorption of antibiotics in pig manure. J. Hazard. Mater. 364, 663–670.
Nurzhanova, A., Pidlisnyuk, V., Abit, K., Nurzhanov, C., Kenessov, B., Stefanovska, T., Erickson, L., 2019. Comparative assessment of using Miscanthus × giganteus for remediation of soils contaminated by heavy metals: a case of military and mining sites. Environ. Sci. Pollut. Res. 26 (May (13)), 13320–13333.
Oggiano, N., Angelini, L., Cappelletto, P., 1997. Pulping and paper properties of some fibre crops. Ind. Crops Prod. 7 (1), 59–67.
Ogunsona, E.O., Codou, A., Misra, M., Mohanty, A.K., 2018. Thermally stable pyrolytic biocarbon as an effective and sustainable reinforcing filler for polyamide bio-composites fabrication. J. Polym. Environ. 26 (September (9)), 3574–3589.
Oliveira, M., Gama, J., 2012. An overview of social network analysis. WIREs Data Min. Knowl. Discov. 2, 99–115.
Ollivier, J., Wanat, N., Austruy, A., Hitmi, A., Joussein, E., Welzl, G., Munch, J., Schloter, M., 2012. Abundance and diversity of ammonia oxidizing prokaryotes in the rootrhizosphere complex of Miscanthus × giganteus grown in heavy metal contaminated soils. Microb. Ecol. 64 (4), 1038–1046.
Otte, C., Schwanke, J., Jensch, P.F., 1996. Automatic Micropropagation of Plants, vol. 2907. pp. 80–87 Boston, MA, USA.
Papatheofanous, M., Koullas, D., Koukios, E., Fuglsang, H., Schade, J., Löfqvist, B., 1995. Biorefining of agricultural crops and residues: effect of pilot-plant fractionation on properties of fibrous fractions. Biomass Bioenergy 8 (6), 419–426.
Pavel, P.-B., Puschenreiter, M., Wenzel, W., Diacu, E., Barbu, C., 2014. Aided phytostabilization using Miscanthus sinensis × giganteus on heavy metal-contaminated soils. Sci. Total Environ. 479-480 (1), 125–131.
Pedroso, G.M., Hutmacher, R.B., Putnam, D., Six, J., van Kessel, C., Linquist, B.A., 2014. Biomass yield and nitrogen use of potential C4 and C3 dedicated energy crops in a Mediterranean climate. Field Crops Res. 161, 149–157.
Perianes-Rodriguez, A., Waltman, L., van Eck, N.J., 2016. Constructing bibliometric networks: a comparison between full and fractional counting. J. Informetr. 10 (4), 1178–1195.
Perrin, A., Wohlfahrt, J., Morandi, F., Østergård, H., Flatberg, T., Rua, C.D.L., Bjørkvoll, T., Gabrielle, B., 2017. Integrated design and sustainable assessment of innovative biomass supply chains: a case-study on Miscanthus in france. Appl. Energy 204, 66–77.
Pham, H.N., Pham, P.A., Nguyen, T.T.H., Meiffren, G., Brothier, E., Lamy, I., Michalet, S., Dijoux-Franca, M.-G., Nazaret, S., 2018. Influence of metal contamination in soil on metabolic profiles of Miscanthus × giganteus belowground parts and associated bacterial communities. Appl. Soil Ecol. 125, 240–249.
Pidlisnyuk, V., Stefanovska, T., Lewis, E.E., Erickson, L.E., Davis, L.C., 2014. Miscanthus as a productive biofuel crop for phytoremediation. Crit. Rev. Plant Sci. 33 (1), 1–19.
Placek-Lapaj, A., Grobelak, A., Fijalkowski, K., Singh, B.R., Åsgeir, R., Almås, Kacprzak, M., 2019. Post – mining soil as carbon storehouse under polish conditions. J. Environ. Manag. 238, 307–314.
Poeplau, C., Germer, K., Schwarz, K.-U., 2019. Seasonal dynamics and depth distribution of belowground biomass carbon and nitrogen of extensive grassland and a Miscanthus plantation. Plant Soil 440 (July (1)), 119–133.
Price, L., Bullard, M., Lyons, H., Anthony, S., Nixon, P., 2004. Identifying the yield potential of Miscanthus × giganteus: an assessment of the spatial and temporal variability of M. × giganteus biomass productivity across England and Wales. Biomass Bioenergy 26 (1), 3–13.
Pude, R., Treseler, C., Trettin, R., Noga, G., 2005. Suitability of Miscanthus genotypes for lightweight concrete. Bodenkultur 56 (14), 61–69.
Quinn, L.D., Straker, K.C., Guo, J., Kim, S., Thapa, S., Kling, G., Lee, D.K., Voigt, T.B., 2015. Stress-Tolerant Feedstocks for Sustainable Bioenergy Production on Marginal Land.
Richter, G.M., Riche, A.B., Dailey, A.G., Gezan, S.A., Powlson, D.S., 2008. Is UK biofuel supply from Miscanthus water-limited? Soil Manag. 24 (3), 235–245.
Rogers, J., Brammer, J., 2009. Analysis of transport costs for energy crops for use in biomass pyrolysis plant networks. Biomass Bioenergy 33 (10), 1367–1375.
Rogers, J., Brammer, J., 2012. Estimation of the production cost of fast pyrolysis bio-oil. Biomass Bioenergy 36, 208–217.
Rohde, V., Böringer, S., Tübke, B., Adam, C., Dahmen, N., Schmiedl, D., 2019. Fractionation of three different lignins by thermal separation techniques – a comparative study. GCB Bioenergy 11 (1), 206–217.
Rosegrant, M.W., Zhu, T., Msangi, S., Sulser, T., 2008. Global scenarios for biofuels: impacts and implications. Rev. Agric. Econ. 30 (3), 495–505.
Rothballer, M., Eckert, B., Schmid, M., Fekete, A., Schloter, M., Lehner, A., Pollmann, S., Hartmann, A., 2008. Endophytic root colonization of gramineous plants by Herbaspirillum frisingense. FEMS Microbiol. Ecol. 66 (1), 85–95.
Sakura, T., Numata, M., 1973. Recovery of vegetation in the area of mountain landslide in the SouthEast part of the Boso Peninsula. J. Jpn. Forest. Soc. 55 (12), 297–303.
Sangster, A., 1985. Silicon distribution and anatomy of the grass rhizome, with special reference to Miscanthus sacchariflorus (Maxim.) Hackel. Ann. Bot. 55 (5), 621–634.
Scarlat, N., Dallemand, J.-F., Monforti-Ferrario, F., Nita, V., 2015. The role of biomass and bioenergy in a future bioeconomy: policies and facts. Environ. Dev. 15, 3–34.
Scheiterle, L., Ulmer, A., Birner, R., Pyka, A., 2018. From commodity-based value chains to biomass-based value webs: the case of sugarcane in Brazil's bioeconomy. J. Clean. Prod. 172, 3851–3863.
Schwarz, H., Liebhard, P., Ehrendorfer, K., Ruckenbauer, P., 1994. The effect of fertilization on yield and quality of Miscanthus sinensis 'Giganteus'. Ind. Crops Prod. 2 (3), 153–159.
Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu, T.H., 2008. Use of U.S. croplands for biofuels increases Greenhouse gases through emissions from land-use change. Science 319 (5867), 1238–1240.
Semere, T., Slater, F., 2007a. Ground flora, small mammal and bird species diversity in Miscanthus (Miscanthus × giganteus) and reed canary-grass (Phalaris arundinacea) fields. Biomass Bioenergy 31 (1), 20–29.
Semere, T., Slater, F., 2007b. Invertebrate populations in Miscanthus (Miscanthus × giganteus) and reed canary-grass (Phalaris arundinacea) fields. Biomass Bioenergy 31 (1), 30–39.
Shahbaz, A.K., Lewinska, K., Iqbal, J., Ali, Q., ur Rahman, M., Iqbal, M., Abbas, F., Tauqeer, H.M., Ramzani, P.M.A., 2018. Improvement in productivity, nutritional quality, and antioxidative defense mechanisms of sunflower (Helianthus annuus L.) and maize (Zea mays L.) in nickel contaminated soil amended with different biochar and zeolite ratios. J. Environ. Manag. 218, 256–270.
Shen, Z., Zhang, Y., Jin, F., Alessi, D.S., Zhang, Y., Wang, F., McMillan, O., Al-Tabbaa, A., 2018. Comparison of nickel adsorption on biochars produced from mixed softwood and Miscanthus straw. Environ. Sci. Pollut. Res. 25 (May (15)), 14626–14635.
Sherrington, C., Bartley, J., Moran, D., 2008. Farm-level constraints on the domestic supply of perennial energy crops in the UK. Energy Policy 36 (7), 2504–2512.
Sherrington, C., Moran, D., 2010. Modelling farmer uptake of perennial energy crops in the UK. Energy Policy 38 (7), 3567–3578.
Shield, I.F., Barraclough, T.J.P., Riche, A.B., Yates, N.E., 2012. The yield response of the energy crops switchgrass and reed canary grass to fertiliser applications when grown on a low productivity sandy soil. Biomass Bioenergy.
Sobral, B., Braga, D., LaHood, E., Keim, P., 1994. Phylogenetic analysis of chloroplast restriction enzyme site mutations in the Saccharinae Griseb. Subtribe of the Andropogoneae Dumort. Tribe. Theor. Appl. Genet. 87 (7), 843–853.
Stampfl, P., Clifton-brown, J., Jones, M., 2007. European-wide GIS-based modelling system for quantifying the feedstock from Miscanthus and the potential contribution to renewable energy targets. Glob. Change Biol. 13 (11), 2283–2295.
Stanley, D., Stout, J., 2013. Quantifying the impacts of bioenergy crops on pollinating insect abundance and diversity: a field-scale evaluation reveals taxon-specific responses. J. Appl. Ecol. 50 (2), 335–344.
Stavridou, E., Hastings, A., Webster, R.J., Robson, P.R.H., 2017. The impact of soil salinity on the yield, composition and physiology of the bioenergy grass Miscanthus × giganteus. GCB Bioenergy 9 (1), 92–104. https://doi.org/10.1111/gcbb.12351.
Strullu, L., Cadoux, S., Preudhomme, M., Jeuffroy, M.-H., Beaudoin, N., 2011. Biomass production and nitrogen accumulation and remobilisation by Miscanthus × giganteus as influenced by nitrogen stocks in belowground organs. Field Crops Res. 121 (3), 381–391.
Styles, D., Gibbons, J., Williams, A., Stichnothe, H., Chadwick, D., Healey, J., 2015. Cattle feed or bioenergy? Consequential life cycle assessment of biogas feedstock options on dairy farms. GCB Bioenergy 7 (5), 1034–1049.
Styles, D., Jones, M., 2007. Energy crops in Ireland: quantifying the potential life-cycle greenhouse gas reductions of energy-crop electricity. Biomass Bioenergy 31 (11–12), 759–772.
Szabó, P., Várhegyi, G., Till, F., Faix, O., 1996. Thermogravimetric/mass spectrometric characterization of two energy crops. Arundo donax and Miscanthus sinensis. J. Anal. Appl. Pyrolysis 36 (2), 179–190.
Sørensen, A., Teller, P., Hilstrøm, T., Ahring, B., 2008. Hydrolysis of Miscanthus for bioethanol production using dilute acid presoaking combined with wet explosion pretreatment and enzymatic treatment. Bioresour. Technol. 99 (14), 6602–6607.
Takayama, H., 1982. Zonation of coastal cliff vegetation on Oshika peninsula, miyagi prefecture Japan. Ecol. Rev. 20 (1), 41–52.
Toledano, A., Serrano, L., Garcia, A., Mondragon, I., Labidi, J., 2010. Comparative study of lignin fractionation by ultrafiltration and selective precipitation. Chem. Eng. J. 157 (1), 93–99.
Toscano, A., Marzo, A., Milani, M., Cirelli, G., Barbagallo, S., 2015. Comparison of removal efficiencies in Mediterranean pilot constructed wetlands vegetated with different plant species. Ecol. Eng. 75, 155–160.
Tsuchida, K., Numata, M., 1979. Relationships between successional situation and production of Miscanthus sinensis communities at Kirigamine Heights Central Japan. Vegetatio 39 (1), 15–23.
Tóth, G., Hermann, T., Szatmári, G., Pásztor, L., 2016. Maps of heavy metals in the soils of the european union and proposed priority areas for detailed assessment. Sci. Total Environ. 565, 1054–1062.
Uellendahl, H., Wang, G., Møller, H., Jørgensen, U., Skiadas, I., Gavala, H., Ahring, B., 2008. Energy balance and costbenefit analysis of biogas production from perennial energy crops pretreated by wet oxidation. Water Sci. Technol. 58 (9), 1841–1847.
Van der Weijde, T., Huxley, L.M., Hawkins, S., Sembiring, E.H., Farrar, K., Dolstra, O., Visser, R.G., Trindade, L.M., 2017. Impact of drought stress on growth and quality of Miscanthus for biofuel production. GCB Bioenergy 9 (4), 770–782.
Van Eck, N.J., Waltman, L., 2010. Software survey: vosviewer, a computer program for bibliometric mapping. Scientometrics 84 (August (2)), 523–538.
Van Eck, N.J., Waltman, L., 2014. Visualizing Bibliometric Networks. Springer International Publishing, Cham, pp. 285–320.
Vega, A., Bao, M., Lamas, J., 1997. Application of factorial design to the modelling of organosolv delignification of Miscanthus sinensis (elephant grass) with phenol and dilute acid solutions. Bioresour. Technol. 61 (1), 1–7.
Verkade, G., Kuijper, H., 1996. The use of biodegradable geotextiles in hydraulic engineering. Balkema.
von Cossel, M., Mangold, A., Iqbal, Y., Hartung, J., Lewandowski, I., Kiesel, A., 2019. How to generate yield in the first year-a three-year experiment on Miscanthus (Miscanthus × giganteus (greef et deuter)) establishment under maize (zea mays l.). Agronomy 9 (5).
Wagenaar, B., Van Den Heuvel, E., 1997. Cocombustion of Miscanthus in a pulverised

coal combustor: experiments in a droptube furnace. Biomass Bioenergy 12 (3), 185–197.
Wagner, M., Mangold, A., Lask, J., Petig, E., Kiesel, A., Lewandowski, I., 2019. Economic and environmental performance of Miscanthus cultivated on marginal land for biogas production. GCB Bioenergy 11 (1), 34–49.
Wahid, R., Nielsen, S., Hernandez, V., Ward, A., Gislum, R., Jørgensen, U., Møller, H., 2015. Methane production potential from Miscanthus sp.: effect of harvesting time, genotypes and plant fractions. Biosyst. Eng. 133, 71–80.
Wegener, G., 1992. Pulping innovations in Germany. Ind. Crops Prod. 1 (24), 113–117.
Werle, S., Tran, K.-Q., Magdziarz, A., Sobek, S., Pogrzeba, M., Løvås, T., 2019. Energy crops for sustainable phytoremediation – fuel characterization. Energy Proc. 158, 867–872 Innovative Solutions for Energy Transitions.
Wiesler, F., Dickmann, J., Horst, W., 1997. Effects of nitrogen supply on growth and nitrogen uptake by Miscanthus sinensis during establishment. J. Plant Nutr. Soil Sci. 160 (1), 25–31.
Witzel, C.-P., Finger, R., 2016. Economic evaluation of Miscanthus production – a review. Renew. Sustain. Energy Rev. 53, 681–696.
Yamasaki, S., Tange, I., 1981. Growth responses of Zizania latifolia, phragmites australis and Miscanthus sacchariflorus to varying inundation. Aquat. Bot. 10 (C), 229–239.
Záleská, M., Pavlík, Z., Pavlíková, M., Scheinherrová, L., Pokorný, J., Trník, A., Svora, P., Fořt, J., Jankovský, O., Suchorab, Z., Černý, R., 2018. Biomass ash-based mineral admixture prepared from municipal sewage sludge and its application in cement composites. Clean Technol. Environ. Policy 20 (1), 159–171.
Zatta, A., Clifton-Brown, J., Robson, P., Hastings, A., Monti, A., 2014. Land use change from C3 grassland to C4 Miscanthus: effects on soil carbon content and estimated mitigation benefit after six years. GCB Bioenergy 6 (4), 360–370.
Zimmermann, J., Dauber, J., Jones, M., 2012. Soil carbon sequestration during the establishment phase of Miscanthus × giganteus: a regional-scale study on commercial farms using 13C natural abundance. GCB Bioenergy 4 (4), 453–461.