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Perspective

Perennial Grass Species for Bioenergy Production: The State of the Art in Mechanical Harvesting

Walter Stefanoni [1,*], Francesco Latterini [2] and Luigi Pari [1]

[1] Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria (CREA)—Centro di Ricerca Ingegneria e Trasformazioni Agroalimentari, Via della Pascolare 16, 00015 Monterotondo, Italy
[2] Institute of Dendrology, Polish Academy of Sciences, Parkowa 5, 62-035 Kórnik, Poland
* Correspondence: walter.stefanoni@crea.gov.it; Tel.: +39-069-067-5250

Abstract: Future European strategies to reduce dependence on foreign markets for energy supply and energy production will rely on the further exploitation of the primary sector. Lignocellulosic feedstock for bioenergy production is a valuable candidate, and dedicated crops such as giant reed (*Arundo donax* L.), miscanthus (*Miscanthus* × *giganteus*), reed canary grass (*Phalaris arundinacea* L.), and switchgrass (*Panicum virgatum* L.) have been proven to be suitable for extensive cultivation on marginal lands. The present review aimed at providing a comprehensive picture of the mechanical strategies available for harvesting giant reed, miscanthus, reed canary grass, and switchgrass that are suitable for the possible upscaling of their supply chain. Since harvesting is the most impactful phase of a lignocellulosic supply chain in dedicated crops, the associated performance and costs were taken into account in order to provide concrete observations and suggestions for future implementation. The findings of the present review highlighted that the investigated species have a sufficient technology readiness level concerning mechanical harvesting for the upscaling of their cultivation. All the species could indeed be harvested with existing machinery, mostly derived from the context of haymaking, without compromising the work productivity.

Keywords: *Arundo donax*; *Miscanthus* × *giganteus*; *Phalaris arundinacea*; *Panicum virgatum*; machine performance; supply chain

Citation: Stefanoni, W.; Latterini, F.; Pari, L. Perennial Grass Species for Bioenergy Production: The State of the Art in Mechanical Harvesting. *Energies* **2023**, *16*, 2303. https://doi.org/10.3390/en16052303

Academic Editor: Adam Smoliński

Received: 30 January 2023
Revised: 14 February 2023
Accepted: 25 February 2023
Published: 27 February 2023

1. Introduction

Climate action has become one of the priorities in Europe after the presentation of the new Green Deal policy programme in 2019. As a consequence of the new geopolitical challenges that the EU is facing nowadays, it is even more important for this continent to drive the energy transition and become independent from foreign markets as soon as possible. The overall energy consumption in the EU in 2020 amounted to 37,086 PJ, and 22.1% of this derived from renewable sources [1,2]. However, energy independence is the main goal of Europe, which currently imports 97 and 83.6% of its petrol and natural gas, respectively, for domestic consumption [2]. Nor is the European renewable energy sector completely independent from foreign markets, since, for instance, the majority of photovoltaic panels used in Europe are made in Asia, and uranium for nuclear energy is imported from foreign countries [3].

Therefore, during the last few years, Europe has experienced rising concerns regarding energy security, which have stimulated the adoption of future strategies aimed at reducing dependency on foreign energy supplies [4]. The domestic production of primary sources for bioenergy production is fundamental.

Agriculture could strongly contribute to European energy security by providing renewable energies from both dedicated energy crops and agricultural residues [5–11]. Dedicated energy crops can be subdivided into two main categories: oilseeds and lignocellulosic crops. Among the latter, perennial grasses have gained more and more interest over annual crops as a potential sustainable source of bioenergy in Europe [12]. Their high biomass yield is a favorable characteristic [13,14], but they have also been proven to grow and thrive on marginal lands, thus partially avoiding the competition with food crops while being cultivated, for instance, on polluted soils [15]. Furthermore, perennial grasses require less intensive management and lower agronomic inputs in comparison to annual crops, with subsequently lower environmental impacts in terms of nitrogen leaching and GHG emissions [16]. Finally, scientific research has highlighted how perennial grass cropping promotes greater biodiversity and related ecosystem services—for instance, major pollinator abundance and the greater storage of organic carbon in the soil [17,18]. Furthermore, the possibility of intercropping with other food or non-food crops may help to increase farmers' revenue, farm biodiversity, and the sustainability of agricultural systems.

On the other hand, the sustainable implementation of bioenergy production from perennial grasses still faces some major issues, mostly related to the high production costs, which are largely due to biomass harvesting and logistics [19].

Lignocellulosic feedstocks generally exhibit a low bulk density and high moisture content, two features that contribute to increasing both the supply chain's costs and potential losses during storage [20–22]. The harvesting strategy adopted may play a fundamental role in trying to address these issues.

The goal of the present review was to delineate the state of the art of the mechanical strategies currently adopted for harvesting the following perennial grasses: giant reed (*Arundo donax* L.), miscanthus (*Miscanthus* × *giganteus*), reed canary grass (*Phalaris arundinacea* L.), and switchgrass (*Panicum virgatum* L.). In this way, we wanted to test the following hypothesis: the technology readiness level concerning the mechanical harvesting of these four species is sufficient to allow the upscaling of their cultivation.

The authors aimed at selecting the perennial grass species most suitable for cultivation in Europe and which also allow for mechanical harvesting, in order to provide a clear picture of the possible upscaling of these crops.

2. Materials and Methods

A systematic literature review was carried out within the Google Scholar, Scopus, and Web of Science databases. No time restriction was applied, but only manuscripts in the English language were considered. The research keywords were the scientific and common names of the various species, linked via the Boolean operators "AND" or "OR" with other keywords such as "harvesting", "harvest", "swathing", "chopping", "shredding", "self-propelled forage harvester", "baler", "baling", "mower", "mowing".

After this operation, articles were refined by reading the title, abstract, and (when needed) the main text, in order to select only manuscripts dealing with the mechanical harvesting of the target crops, reporting the working performance and/or the costs of the investigated harvesting system. In this way, 35 papers were selected, and the percentage of papers for each investigated species is reported in Figure 1.

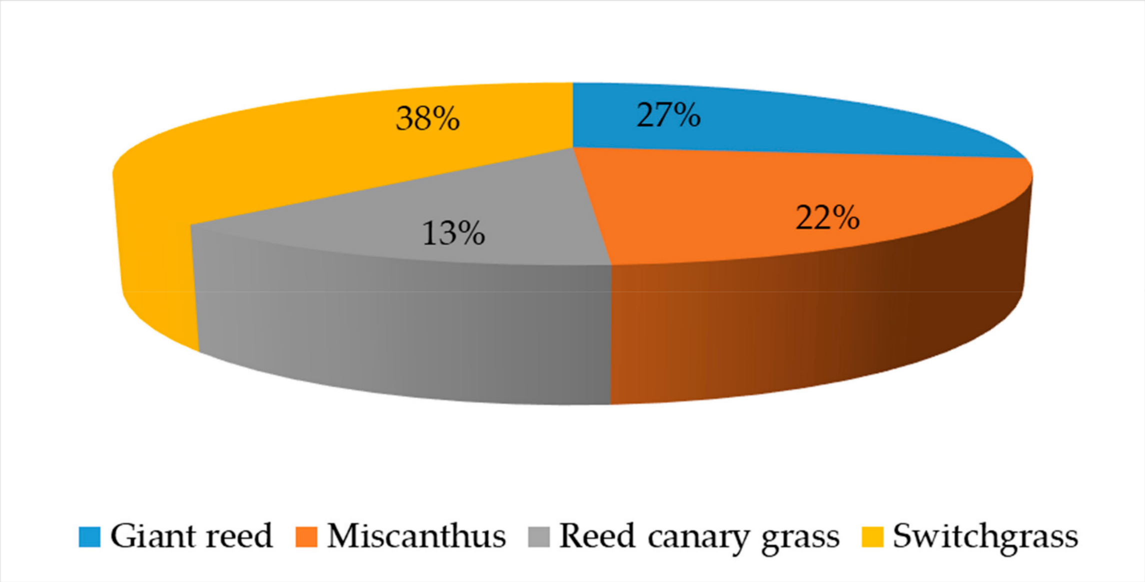

Figure 1. Percentage of papers per species dealing with mechanical harvesting identified after systematic literature search.

3. Results

3.1. Giant Reed

3.1.1. General Features of the Crop

Giant reed is a herbaceous perennial crop belonging to the *Poaceae* family that can tolerate diverse ecological and edaphic conditions, is resistant to many pests and diseases, and can provide relatively high yields of biomass with lower agronomic inputs [23]. These features have made giant reed attractive for bioenergy production in many regions of the world. Giant reed is considered a sterile plant; the propagation is performed via either hydroponic or in vitro techniques [24]. On the other hand, giant reed can act as an invasive species in flooded areas. Currently, this crop is grown for grassland management; phytoremediation; and, mostly, bioenergy production [24–26].

Arundo donax presents several advantages in comparison to other energy crops, for instance, its high plasticity in relation to environmental, soil, and growing conditions; high biomass yield; and ability to be grown as a low-input crop [27,28]. Furthermore, it has been demonstrated that giant reed can also achieve a substantial biomass yield under high-salinity conditions [29]. It is moreover suitable for cultivation on marginal or sub-marginal lands, such as polluted areas and poor soils [30]. The biomass yield of this species is in the range of 30–40 Mg DM ha^{-1} per year [29]. Regarding its bioenergy features, the higher heating value of giant reed ranges between 18 and 20 MJ kg^{-1} [31,32]. The ash percentage is in the range of 5.0–8.0% [28].

3.1.2. Mechanical Harvesting

The first issue to be taken into account when selecting a harvesting system for giant reed is the final destination of the biomass. Indeed, giant reed can be used for both thermochemical processes and second-generation biofuels. In this last case, the biomass can be processed with a high moisture content, while for combustion a drying period is needed [33].

Therefore, *Arundo donax* harvesting can be performed with a single- or double-passage operation [34]. Regarding single-passage harvesting for second-generation biofuel production, harvesting takes place during summer, considering that anaerobic digestion is fostered by a high moisture content and the presence of leaves [35].

The most common system for the single-passage harvesting of giant reed consists of a self-propelled forage harvester (SPFH), a machine commonly applied in silage maize harvesting. In this system, biomass is flanked by a tractor–trailer unit receiving the chopped material, which is then shipped to a collection point [36].

The work productivity of SPFH for giant reed reached a field capacity of 1.34 ha h^{-1} with an operative speed of 3.90 km h^{-1}, thus resulting in harvesting costs of EUR 17.9 Mg $^{-1}$ DM [33]. The same system can, however, be strongly limited in the case of lodged crops, with harvesting costs more than doubled [34]. Furthermore, it is important to underline how the intrinsic developing pattern of giant reed causes the messy development of the cultivation, with a layout not as ordered as maize crop, leading to operational difficulties in applying such harvesting systems in older giant reed fields. To reduce such problems, a row-independent attachment is strongly recommended.

Biomass harvesting for thermochemical conversion takes place during winter, when plants are in quiescence and have a low moisture content. The possible alternatives for giant reed biomass harvesting in winter period consist of mowing and shredding or shredding and baling [34]. A typical haymaking harvesting system consisting of mowing and baling is not applicable to giant reed, considering the dimensions and hardness of the stems. Mowing and shredding can be applied with a conventional mower powered by a tractor, followed by a shredding and collecting phase using a self-propelled forage harvester, which discharges the biomass onto a tractor–trailer. In a field trial with this harvesting system, the field capacity of mowing was 0.86 ha h^{-1}, and that of shredding was 1.01 ha h^{-1}. The consequent harvesting costs were EUR 378.94 ha^{-1} and EUR 26.40 Mg^{-1} DM [33]. A similar harvesting system was also tested in Spain, applying a SPFH equipped with a Kemper header to mow the crop; the header was modified, allowing it to leave the cut and windrowed plants on the ground prior to baling (one and a half months later). This system showed a field capacity of about 1 ha h^{-1} for mowing, crushing, and windrowing and about 0.3 ha h^{-1} for baling, leading to overall harvesting costs of EUR 34.4 Mg^{-1} DM [33].

Regarding shredding and baling systems, the literature reports a working speed of about 4–5 km h^{-1} for a shredder powered by a tractor, with a varying field capacity depending on the working width of the machinery, i.e., 0.69 ha h^{-1} [34] to 1.77 ha h^{-1} [37]. The effective field capacity of baling shredded biomass of giant reed varied as well between 0.44 ha h^{-1} [34] and 0.95 ha h^{-1} [37].

Harvesting costs for this system were reported as about EUR 200 ha^{-1}, corresponding to EUR 10.4 Mg^{-1} DM in an experimental trial carried out in Italy [38]. Interestingly, in the same working conditions, the possibility of single-pass harvesting through shredding and baling was tested. This required a tractor with frontal power take off (PTO), to which the shredder was attached, and the baler was instead linked to the conventional rear PTO. However, the results for the working productivity and costs were poorer than those of the two-passage system [38]. It is interesting to note that the shredding and baling system showed the lowest harvesting costs among the possible alternatives; however, it is important to note that to power a shredder that is able to efficiently work on giant reed, a tractor of at least 200 kW is needed [39].

In summary, technologies for the efficient harvesting of giant reed are already available on the market and do not need modifications, apart from row-independent equipment; only a tractor with sufficient power to manage the hardness and dimensions of giant reed stems is required. Considering that the machinery applicable to this species is derived from silage production, it is possible to recommend the cultivation of giant reed on farms that produce silage maize and already have in their fleet tractors with a power equal to or higher than 200 kW.

3.2. *Miscanthus*

3.2.1. General Features of the Crop

Miscanthus (*Miscanthus* × *giganteus*) is a sterile, rhizomatous perennial C4 grass [40,41]. It shows a very high potential biomass yield of up to 44 Mg ha^{-1} yr^{-1} [28]. In European climate conditions, it shows cold resistance and the ability to grow with low-input management, especially in terms of fertilizers and herbicides [42]. Miscanthus biomass can be used for a wide range of purposes—for instance, combustion, or the production of bioethanol or bio-based products such as paper, materials for the building sector, or basic chemicals [43]. The miscanthus yields reported in the literature also show great variability as a consequence of the plethora of different environmental conditions in which this species has been tested. In an irrigation regime in Southern Europe, the yield could achieve values of up to 30 Mg DM ha^{-1}, while in Central European conditions, the yield was in the range between 10 and 25 Mg DM ha^{-1} [40]. The heating value of miscanthus biomass is generally around 17 MJ kg^{-1} [40]. The ash content reported in the literature is lower than for other herbaceous energy crops, being in the range between 1.6 and 4.0%, with an ash fusion temperature of 1020 °C [40].

3.2.2. Mechanical Harvesting

Biomass harvesting is a crucial phase in miscanthus supply chains [19]. As for giant reed, different harvesting strategies are also applicable for miscanthus. Each of these strategies is based on existing machinery, such as self-propelled forage harvesters (SPFHs) and other silage-making and haymaking machinery. However, it is worth highlighting that these machines usually operate with a lower working productivity than when used for forage, as a consequence of the higher density and hardness of miscanthus biomass [44].

The harvesting strategies for miscanthus can be based on single-passage or double-passage harvesting. In single-phase harvesting, biomass is picked up, chopped, or mowed and directly loaded onto a trailer or a baler (Figure 2). The most common single-phase harvesting system for miscanthus consists of the application of a self-propelled forage harvester. In miscanthus crops that have already experienced a harvesting operation, the original rows are not distinguishable anymore, so a row-independent mowing attachment is required [45].

Figure 2. Miscanthus harvesting in a single pass using a self-propelled forage harvester.

Multi-phase systems consist of mowing and conditioning followed by raking/swathing, picking up, and baling. The typical two-step system requires a mower–conditioner that cuts the crop, rakes it to create a swath on the ground, and bales [46]. A conditioning operation is recommended in order to facilitate the baling operation [47].

The various harvesting systems for this species derive from haymaking or silage-making machinery, but some modifications are needed to optimize the work performance [48]. Focusing on mowers, several studies highlighted that a higher angle of the blades allows one to improve the working productivity and reduce energy requirements [49,50]. The mowing–conditioning productivity for miscanthus biomass was reported to be 1.8 ha h^{-1}, while baling with a large square baler showed a productivity of 1.4 ha h^{-1} [46]. Harvesting costs with this system have been reported to be about EUR 94.00 ha^{-1} [51].

Focusing on harvesting losses, the two-step harvesting system showed losses more than double those of single-passage harvesting, increasing from about 5% to about 12% [52].

Miscanthus can therefore be harvested with conventional machinery, but some modifications are recommended to optimize the working performance. Single-passage harvesting via an SPFH is particularly efficient when a row-independent mowing attachment is applied. Therefore, as is the case for giant reed, miscanthus cultivation could be suitable for farms cultivating silage maize. Double-passage harvesting is applicable based on haymaking machinery, and the productivity can be improved after the modification of the mower's blades. It is, however, expected that the higher hardness of miscanthus stems in comparison to typical haymaking species could increase the rate of deterioration of the machinery elements, thus increasing the maintenance costs. The cultivation of miscanthus is therefore recommended for haymaking farms only in such cases when it is possible to establish a short energy chain using miscanthus biomass to produce energy for the farm itself. A short transport distance between the fields and the main buildings of the farm is required; in this case, the optimization of the costs for energy could overcome the higher expenses needed for machinery maintenance costs.

3.3. Reed Canary Grass

3.3.1. General Features of the Crop

Reed canary grass belongs to the *Gramineae* family. It is a native perennial grass of the temperate regions of Europe, Asia, and North America. In Europe, it is particularly common in Nordic countries. Wet areas such as lake shores are typical environments where this grass can be found.

Reed canary grass (*Phalaris arundinacea*) is used as a forage crop mainly in North America, even if nowadays the main function of interest for this species is energy production [28].

It is particularly suitable for cultivation in poorly drained soils, as it is able to tolerate flooding; however, it also shows good drought resistance [28]. In suitable conditions, the biomass yield ranges between 7.5 and 9 Mg DM ha^{-1} [53]. Heating values for reed canary grass biomass have been reported in the range between 16.6 and 19.3 MJ kg^{-1} [54].

3.3.2. Mechanical Harvesting

In contrast to the reports for giant reed and miscanthus, the harvesting operations for reed canary grass in the current literature are described only with reference to double-passage harvesting carried out with haymaking machinery, consisting of mowing and then baling [55,56].

The harvesting costs for this harvesting system have been reported as about EUR 559 ha^{-1} [55], based on a working productivity in the range between 8 and 21 Mg h^{-1} [57]. It is important to highlight that harvesting reed canary grass with this system can cause harvesting losses of up to 25% DM [54].

Considering the above, the cultivation of reed canary grass could be suitable for farms in Northern Europe that usually carry out haymaking activities.

3.4. Switchgrass

3.4.1. General Features of the Crop

Like reed canary grass, switchgrass also belongs to the *Graminae* family. Its natural range is in North America, from a latitude of 55° North to Central Mexico. In the central USA, it has been largely cultivated as fodder grass [28]. Switchgrass shows adaptability to a wide range of soils and a marked drought tolerance [58]. The highest yields can be reached with one or two harvests per year, with values ranging from 16 to 22 Mg DM ha^{-1} [59]. The heating value for the biomass of this species has been reported as 17 MJ kg^{-1} [60,61]. The percentage of ash after combustion has been reported to range between 4.5 and 10.5%, with an ash melting point of about 1016 °C [60,61].

3.4.2. Mechanical Harvesting

Similarly to other herbaceous energy crops, switchgrass can be harvested with commercially available haying equipment, such as mowers, rakes, and balers. Bales can be either round or square-shaped. Due to the high quantity of fresh biomass produced (higher than 10 Mg ha^{-1}), self-propelled swathers with rotary headers should be preferred, due to their ability to handle a high volume of material. The cutting height is set at 10–15 cm to facilitate air movement in order to decrease the moisture content below 20% before baling. Material losses during outside storage are lower in round bales than in rectangular bales, although the latter shape is easier to handle and transport in cases where there are no width restrictions [62].

The large-scale production of switchgrass was also investigated by [63] in 2009, introducing the possibility of using a loafer instead of a common baler to reduce the cost of production. Loafing is performed through a piece of machinery named a loafer (or stacker), which picks up the switchgrass from the windrow (max moisture content at 15% w/w) and packs the biomass into large packages (2.4 m wide, up to 6 m long, and 3.6 m high) that weigh as much as 4 Mg, approximately. Although loafs have a lower density compared to bales, the transportation costs are lower than those recorded for loose material. In the abovementioned study, the loafing strategy was compared with baling, and the harvesting costs changed significantly according to the yield. Three yield values were considered: 10, 20, and 30 Mg ha^{-1}. The respective costs per Mg of biomass for loafing were estimated to be EUR 14.86, 12.07, and 9.29, whilst for baling, the costs were EUR 22.29, 16.72, and 14.86. The authors of [64] reported EUR 82.20 dry Mg^{-1} for mowing, raking, and baling with large square bales, whilst the authors of [65] reported about EUR 11.15 and 12.07 FM Mg^{-1} for round and square bales, respectively. Additionally, the authors of [38] reported a production cost of EUR 9.9–12.1 Mg^{-1} dry biomass, though they used a prototype for shredding switchgrass before baling.

Depending on the harvest strategy adopted (high-density versus loose chopped material), a partial drying process might be necessary during field operations in order to reduce spontaneous fermentation. The use of both mower–conditioner and tedder harvest treatments promoted rapid switchgrass drying from 67% to 18% moisture content (wet basis) within 48 h after cutting [66]. According to [67], during baling, the loss in DM can range from 1 to 5% depending on the moisture content: the lower the humidity, the higher the loss.

Concerning machinery performance, the mower–conditioner can operate at speeds of up to 16.4 km h^{-1} and process 57 Mg DM h^{-1}. However, in extremely lodged switchgrass, the speed must be reduced to prevent clogging. On the other hand, a high volume of material does not affect the performance of a rotary rake. Once dried, the round baler can bale switchgrass at speeds as high as 14.0 km h^{-1}, corresponding to a material capacity of 48 Mg DM h^{-1} [66].

The authors of [38] proposed the combination of a shredder and a baler connected to the same tractor as a promising strategy for collecting switchgrass in small farms in a single pass. The shredder used was a prototype biotriturator RM 280 BIO, which combined cutting, shredding, and crop windrowing. The strategy proposed provided interesting results in terms of cost and performance; however, in larger farms (>200 ha), the reduced EFC (0.61 ha h^{-1}) dictated by the baler does not allow one to level-off the extra cost for labor in a dual-stage harvesting strategy. Therefore, the two-pass strategy must be adopted.

Alternatively to baling, switchgrass can be transported to the plant as loose chopped biomass. In this case, a self-loading forage-chopping wagon can be used, which picks up windrows prepared by a mower and windrow merger or rake. The effective field capacity ranges between 0.93 and 1.03 ha h^{-1}, whilst the material capacity ranges between 3.58 and 11.86 Mg h^{-1}, depending on the distance from the processing site [68]. Harvesting switchgrass as a loose material with a forage wagon costs EUR 4.10 FM Mg^{-1} [65].

Regardless of the system adopted, harvesting is the most impactful phase of the switchgrass supply chain. Establishment accounts for almost a third of the total cost. In fact, a comprehensive study on lignocellulosic feedstock production performed in 2020 [19] reported the following cost breakdown, expressed as the percentage of switchgrass delivery: establishment 32.46, harvest 41.36, storage 4.77, processing 2.24, and transportation 19.17.

In summary, switchgrass cultivation can be efficiently carried out with haymaking machinery. Considering the high amount of biomass, it is recommended to use self-propelled swathers. This kind of machine is not so common, being typically present only in the fleets of large haymaking farms. This type of farm could therefore be particularly suitable for switchgrass cultivation. Smaller farms could, however, cultivate switchgrass and carry out harvesting with conventional haymaking technology by mowing, raking, and baling.

3.5. Summary Table

In the current literature, a comprehensive review work focused on the topic of the mechanical harvesting of perennial grasses is still missing. This represents an important research gap, considering that harvesting is probably one of the most expensive phases of the cropping cycle [9,10,69,70].

Taking the above into account, we focused our literature review on four perennial grasses: giant reed, miscanthus, reed canary grass, and switchgrass. These are the species that have shown the highest potential in terms of yield and the possibility of successful growth on marginal lands [71].

The main findings of the present review work are presented in Table 1. As is noticeable, the harvesting costs per hectare were rather similar for miscanthus, reed canary grass, and switchgrass, while the costs per surface unit for giant reed harvesting were much higher. However, the costs per biomass unit were very similar among the various crops, considering that giant reed compensates for its high surface unit costs with a very high yield.

Table 1. Harvesting strategies and associated costs per species.

Species	Harvesting Strategy	Machinery Performance	Harvesting Cost	Ref.	Notes
Giant Reed	Self-propelled forage harvester + tractor–trailer unit	1.34 ha h^{-1}	EUR 537 ha^{-1} and EUR 17.9 Mg^{-1} DM	[33]	Row-independent attachment recommended after the first harvesting
	Mowing and shredding or shredding and baling	0.46 ha h^{-1}	EUR 378.94 ha^{-1} and EUR 26.40 Mg^{-1} DM	[33]	A tractor with at least 200 kW is needed to power a shredder able to efficiently work on giant reed biomass
	SPFH equipped with kemper header + baling	0.23 ha h^{-1}	EUR 1032 ha^{-1} and EUR 34.4 Mg^{-1} DM	[33]	To allow for biomass drying, the header has to be modified so that it can leave the cut and windrowed plants on the ground prior to baling
Miscanthus	Self-propelled forage harvesters (single pass)	1.05 ha h^{-1}	-	[46,51]	Row-independent attachment recommended after the first harvesting
	Haymaking machinery (multi-phase)	0.79 ha h^{-1}	EUR 94.00 ha^{-1}	[46,51]	A higher angle of the blades of the mower is recommended. Farmers have to take into consideration possible higher maintenance costs when applying common mowers and balers on miscanthus biomass as a consequence of the higher hardness of the stems in comparison to typical haymaking grasses
Red canary grass	Haymaking machinery (multi-phase)	0.57 ha h^{-1}	EUR 90 ha^{-1}	[55]	High harvesting losses (about 25%) have been experienced

Table 1. *Cont.*

Species	Harvesting Strategy	Machinery Performance	Harvesting Cost	Ref.	Notes
Switchgrass	Haymaking machinery (multi-phase) for round bales, square bales, or loaf production		EUR 89.1 ha^{-1} round bales, EUR 84.3 ha^{-1} square bales, EUR 49.1 ha^{-1} loafs	[63] [64] [63]	Considering the high biomass yield, large machinery such as self-propelled rotary mowers are recommended. Loafs should be preferred in the case of a greater transport distance to the biomass plant in order to lower the transport costs.
	Single pass with biotriturator RM 280 BIO + baler	0.61 ha h^{-1}	EUR 137.7 ha^{-1}	[38]	To feed a shredder suitable for switchgrass, the tractor should have a power of at least 150 kW
	Multi-phase + self-loading forage-chopping wagon	1.0 ha h^{-1}	EUR 49.1 ha^{-1}	[68]	Indicated for very short transport distance

The main contribution of this review work was to highlight how the harvesting operations for all the investigated crops are already well-developed. All the crops can indeed be harvested with widely available machinery taken from forage- or silage-making systems. Some modifications could be helpful to improve the productivity, but such machines could essentially be applied as-is for all the investigated crops without excessively compromising the working performance or increasing the harvesting costs. This is a great advantage of lignocellulosic crops in comparison to several oilseeds, such as castor bean (*Ricinus communis* L.), for which the full development of mechanical harvesting is still a challenging topic [5]. The possibility of applying existing and widely used machines for harvesting operations represents another advantage of lignocellulosic perennial grasses, i.e., its easy integration into intercropping systems [72], with positive effects on biodiversity and the resilience of agro-ecosystems [73,74].

4. Conclusions

Producing renewable energy from agriculture is fundamental to tackle the issue of energy independence for European countries. In this framework, the cultivation of perennial grasses has shown potential, mostly thanks to the presence of species that are fast-growing and can achieve high biomass yields. However, the mechanical harvesting of perennial grasses is still an issue to be comprehensively investigated in the scientific literature. Therefore, we conducted a review of the mechanical harvesting of four perennial grass species that are particularly suitable for cultivation in Europe. These species were giant reed, miscanthus, reed canary grass, and switchgrass. The investigated lignocellulosic perennial grasses are ready for cultivation upscaling from the point of view of the technological readiness level of mechanical harvesting. All the investigated species could indeed be harvested with conventional machinery mostly deriving from forage-making technologies, without an excessive decrease in working productivity or increase in harvesting costs. Concerning the future research directions, it is recommended on the one hand to focus attention on increasing the possibility of growing such species in marginal land conditions, working on agronomic solutions to allow the crop to also reach a sustainable biomass yield in difficult edaphic situations. On the other hand, research in the framework of agriculture engineering should now be focused on the following parts of the supply chain: the optimization of transport and storage operations.

Author Contributions: Conceptualization, W.S. and F.L.; methodology, W.S. and F.L.; formal analysis, W.S. and F.L.; investigation, W.S. and F.L.; data curation, W.S. and F.L.; writing—original draft preparation, W.S. and F.L.; writing—review and editing, W.S. and F.L.; supervision, L.P.; project administration, L.P.; funding acquisition, L.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the European Union's Horizon 2020-MIDAS-Utilization of Marginal lands for growing sustainable industrial crops and developing innovative bio-based products. Grant agreement ID: 101082070.

Data Availability Statement: Data available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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