AGROCYCLE FACTSHEET

Straw production and value chains

This information is taken from an in-depth study; "Agricultural production systems and sustainable value chains", written by the NNFCC as part of the Agrocycle project.

Availability of Cereal and Oil seed straw

Straw is the second largest unavoidable food supply chain waste, and is produced at significant levels (0.58 billion tonnes) in the EU.

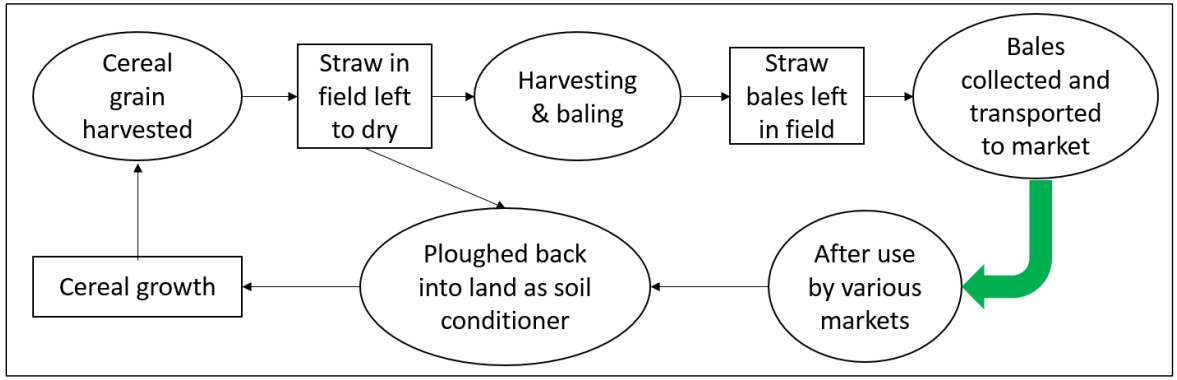
- France was the top producer of straw in the period of 2010-2013 (122 million tonnes annually on average), particularly from wheat and maize crops. Germany is the next largest producer (83 million tonnes/year), mainly wheat and oilseed rape straw.
- Wheat and maize straw were the most abundant resources, with 173 million and 154 million tonnes produced in the EU respectively.
    - However, in the EU maize is mainly fed to cattle as whole crop silage so, there would be very little straw residue actually available.

Typical management and uses of straw

Depending on the selected management system, straw generated after harvesting may either be left in the field and incorporated back to the land (often after being chopped into smaller pieces); collected, baled and used on farm; or sold to livestock and agricultural markets.

- ➢ The time window to collect straw may be tight as it needs to be relatively dry (around 18% moisture) after harvesting the grain.

1. Production and Management



System map of the typical straw management practises in agriculture

Cost to collect straw

There are many direct and indirect costs associated with straw baling, which have been estimated by several projects and range from 25 to 45 € per tonne.

- Machinery is the largest cost as the price of a high-density baler is around €170,000, which corresponds to a cost around €2.11/bale.
- Regarding labour costs, it takes around 4 min/tonne on average to bale straw, labour costs may range from €0.07-1.20/tonne, depending on the EU member state.
- The removal of straw also costs in terms of carbon and nutrients, as unharvested straw may otherwise be ploughed back into the land to improve soil structure and nutrition. However, typically the stump of straw is not harvested, leaving 40% of the stalk and leaves still in the field after straw collection, which appears to be sufficient enough to maintain ample levels of soil carbon.

March 2019

Cereal production systems - Triticeae tribe

Wheat is the most dominant cereal crop grown across Europe, with significantly important applications in food (e.g. bread and pasta), alcohol, and biofuels. Wheat is a grass (Poaceae family) in the Triticeae plant tribe and is predominately planted in autumn, typically, from mid -September to early October. Wheat straw is a very abundant resource, that is typically used for animal bedding or soil conditioner.

Barley is another major cereal crop in the grass family and Triticeae tribe, grown across Europe for food and alcohol markets (e.g. beer and whiskey). Barley straw produced has good nutritional value, and is typically used as an animal forage, otherwise it is used as animal bedding or incorporated back into the land as a soil conditioner.

Rye is another grass in the Triticeae tribe, grown for its grain, for food and alcohol markets, or as a cover or forage crop. Rye is the hardiest cereal, growing well in infertile or sandy soils and cold climates, compared to other cereal grain crops. Rye is closely related to barley and wheat (all in the wheat plant tribe Triticeae), so its straw can be used in traditional markets of animal bedding, feed, and bioenergy. However, rye straw is tough and fibrous and can also be used for thatching, mattresses, hats, and paper.

Triticale is a cross between wheat and rye, having the high-quality grain of wheat and requiring the low input of rye. Triticale can be grown on all types of soil and is very popular in Poland, Germany and France. Triticale typically forms more biomass than wheat due to its greater number of stems and greater biomass per stem. Triticale takes a shorter time to flower, and has a longer grain filling period to fill the extra grains. Triticale typically commands a lower grain price, but due to its higher yields, it can become more profitable, especially if grown for straw. Triticale is increasingly being grown for animal feed and as a feedstock for biofuel and AD. When grown for AD the whole crop is typically harvested and then ensiled, for an easier digestion. This includes the stalks, so there would be minimal by-product straw if utilised for AD.

2.1 Cereal Production systems resulting in straw

Barley crop (left) and rice paddy (right)

Rice production systems

Rice is a grass cereal crop grown for its grain, mainly for food and drink markets. In Europe, rice is mainly grown in southern member states, due to the requirement of rice for warm growing conditions. In Europe, rice seeds are typically sown mechanically, directly into the water around April and May. After vegetation, reproduction and ripening, paddies are drained and dried before harvest around October or November. Grain is then dried by utilizing the sun to dehydrate grains on mats or pavements for example, or where necessary by blowing heated air across harvested paddy. Grains are typically stored with husks remaining to avoid spoilage until grain is required, in vacuum packed bags or in bulk in large refrigerated containers, and later milled as required.

Oat production systems

Oat is also a grass, but in the *Avena* genus. Oat grains are mainly used for animal feed but also for human consumption (e.g. porridge and flapjacks). Winter oats are typically planted in September and harvested in early August, spring oats are planted in late March/ early April and harvested in early September.

Maize production systems

Maize is a versatile grass crop grown in many climates, typically planted in spring. It is a C4 plant, meaning it has more efficient photosynthesis, for fixing carbon, and water use than C3 grass crops, such as cereals. Maize grown for silage is harvested when green and fruit immature, and then chopped into pieces and ensiled. Maize grown for grain is harvested later as it should be mature and dry to avoid spoiling. In the EU, around 63% of maize is used whole (including grain and stalks); 15 million ha (59 %) as forage to feed livestock, and 1 million ha (3.9%) for AD. Both of these applications normally require ensiling to make the stalks easier to digest, while they result in little or no straw by-product. The remaining 37% is grown for the grain, for feed (83%), starch (15%) and semolina (2%) markets, which do produce a stalk by-product. Maize straw or 'corn stover' makes up around half of the crop, and is similar to other straws from cereal grasses. Maize straw is often used as animal feed, bedding, soil amendment and bioenergy, similar to cereal straws. An increasing amount is also being used in the USA in second generation biofuel production.

Sunflower production systems

Sunflower is a major commodity crop grown for seed oil and meal. The EU is a major sunflower producer, along with Russia, Ukraine, and Argentina. Sunflowers are typically drilled in spring (March-April) in warm soil, as soil under 6-8˚C will delay germination. Sunflowers are suitable for many soil types and they are also drought tolerant, and they need sun and warmth while growing, making them suitable for well-drained sunny areas. Harvest takes place when seeds are less than 30% moisture, and the leaves and stem are dry and have senesced. Only a small amount of stem is cut, to avoid admixture. The stubble (straw) is typically chopped by the combine, or by foragers or heavy discs. Sunflower stalks can be used as forage, but due to their high fibre and low protein content, they must be supplemented with energy rich, protein and mineral feed.

2.2 Other production systems resulting in straw

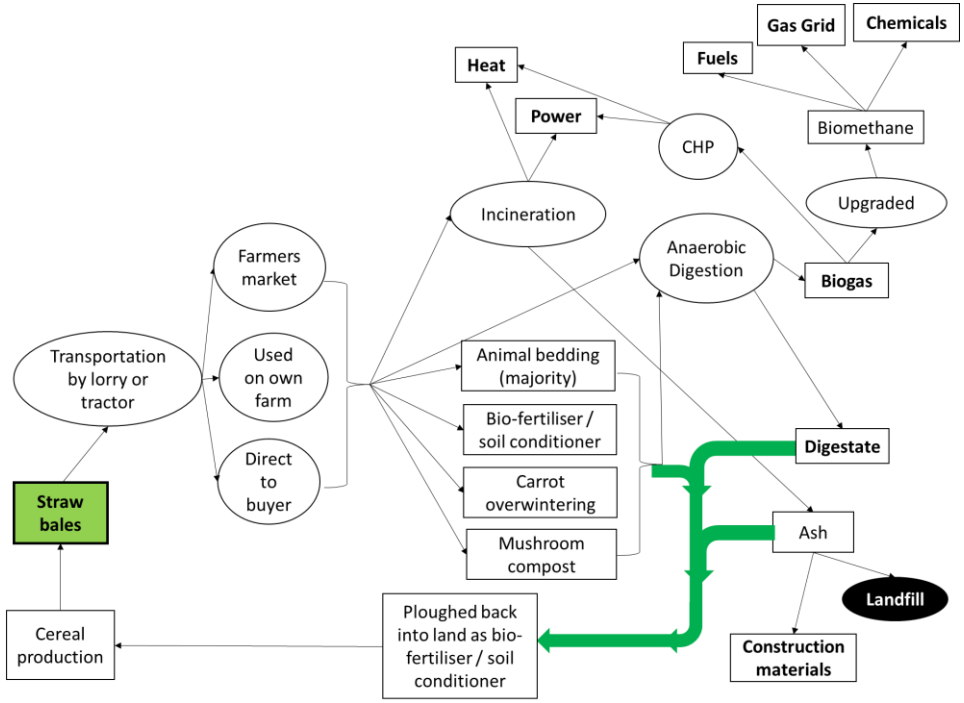
Sunflowers (left) and rape seed oil field (right)

Estimated value of straw nutrition in UK arable farming, data from HGCA

Crop	Phosphate		Potash		Magnesium		Total	
	t/ha	kg/ha	£/ha	kg/ha	£/ha	kg/ha	£/ha	£/ha
Winter wheat	3.4	4.1	3	32.3	17	4.4	15	35
Spring wheat	3.4	5.1	4	42.5	23	4.1	14	41
Winter barley	2.8	3.4	2	26.6	14	3.6	12	28
Spring barley	2.5	3.8	3	31.3	17	3	10	30
Oats	3	4.8	4	50.1	27	6.6	22	53
Oilseed rape	1.8	4	3	23.4	13	nd	nd	16

Oil seed rape production systems

Oilseed rape is a major crop grown for its seed oil, for food and fuel markets. It is a widely grown break crop in the *Brassica* genus along with cabbage and cauliflower and in the Brassicaceae family. The vast majority of the crop is autumn planted with just a few small pockets of spring production. It is very popular due to increasing demand for vegetable oil, however, production has fallen in recent years. Rapeseed straw is typically brittle and not ideal for animal bedding, but it is increasingly being baled with interest for bioenergy applications, particularly combustion to power.



Animal bedding and Horticulture

One of the biggest uses of straw is in **animal bedding**. Straw is an effective material for bedding, as it has good thermal and absorption properties. It also provides comfort for animal welfare. The main livestock species using straw bedding in Europe is the dairy cow. Other cattle include, buffaloes, goats, sheep and horses.

- Wheat straw is the most common cereal straw used for bedding, as it is the least palatable straw to feed animals and is relatively cheap.
- Barley straw is also used as bedding and is softer than wheat straw, but it is the least absorbent straw. It also has a higher nutritious value compared to wheat and is therefore more expensive.
- Oat straw is also a soft bedding material, and the most absorbent straw. But it can be more expensive as it is a highly palatable feed.
- Rye, rice and triticale straw are also suitable where available.

In the **horticultural sector**, straw is commonly used to protect carrot crops overwinter, as a mulch to suppress weeds. However, this is a relatively small market compared to animal bedding.

3. Typical value chains

Straw used in soft fruit production (left), and Straw use as animal bedding (right)

Incineration and Anaerobic Digestion

Straw can be **combusted** to heat up water in biomass boilers for heating systems and to produce steam for power electricity generation. Where both heat and power are generated, a combined heat and power (CHP) engine is used.

- Many straw types can be used in energy production, although some are more suitable than others when taking into consideration factors such as boiler compatibility.
- Across Europe, the use of straw for power generation represents a small proportion of the total straw demand, but can have significant local impacts, in the radius of an energy facility.

Straw can also be processed through **anaerobic digestion**, to generate biogas for multiple energy outputs, and biofertilizers in the form of digestate.

- In wet-AD, straw can slow the digester and cause problems. Straw is a lignocellulosic material, and anaerobic microbes are not very good at breaking down lignin.
- Alternatively, dry-AD systems are more efficient at breaking down lignocellulosic material and are therefore better at processing materials like straw. These systems are designed for a higher proportion of dry matter (25-40%) and can tolerate higher levels of contaminants (e.g. plastics) compared with wet-AD.

Constraints to maximise utilisation of straw

Straw has the potential to be used in multiple applications and reach higher value markets. However, it is not always profitable to bale straw, and often large proportions are incorporated back into the land after grain harvest.

- In areas where livestock is prevalent, the vast majority of straw is baled and used for bedding or as animal feed, which are relatively high value markets for farmers.
    - However, in areas where there is low market demand from livestock producers, the price of straw generally decreases, and, in many cases, it is below the cost of nutrients are available within.
- Straw has also potential to be valorised into a very wide array of high value products, like ethanol.
    - However, it is not always profitable to bale straw, due to high baling costs, and often large amounts are incorporated back into land.
- Therefore, the issue on using straw in the most sustainable manner often depends on local demand and the economics, how much a farmer values straw as a soil conditioner compared to how much they can gain from the market.
    - If a farmer can sell straw and make a profit, money can then be used to invest in better soil conditioning methods.

4. Constraints and actions for further exploitation

Photo credit: Gold for Krone Premos

In field straw pelleting machine (left) and Straw bales (right)

Indicative actions for more sustainable exploitation

Making farmers aware of the opportunities of higher value markets, sharing profits across the value chains and supporting cooperatives to pool resources, were key actions identified to improve the baling rates and availability of straw for valorisation. In addition, industry have already begun overcoming barriers to straw valorisation challenges. Indicatively:

- New technology is available to produce pellets directly from the field. This should reduce time and costs to bale and subsequently process pellets, for fodder, bedding or energy generation
- Biorefineries converting lignocellulosic AWCB to ethanol are beginning to be deployed across the world, but they could still learn from more developed industries to realise the full possibility of their feedstocks and to gain greater value.

Acknowledgements

AgroCycle is an €8 million Horizon 2020 research and innovation project which addresses the recycling and valorisation of agricultural wastes, co-products and by-products (AWCBs). This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 690142.

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