



From waste to wealth: uses of agricultural residues in Africa (A review)
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ABSTRACT

Introduction. This summary report provides an overview of the state of the art regarding the possible uses of crop residues for populations in the sub-Saharan agricultural sector with a view to building their resilience in the face of socio-economic and climate-related challenges.

Literature. Crop residues are present in large quantities on farms and represent real assets for the resilience and sustainability of agricultural systems. Unfortunately, due to the lack of transfer of scientific knowledge to farming practices and problems with the collection and processing of residues, many are underutilised. The main uses of crop residues for those involved in the agricultural sector are: Agronomic uses, with the production of biochar, compost and organic manure from crop residues to improve soil fertility. Zootechnical uses, with crop residues being used in animal feed and in the manufacture of bedding and shelters for animals. Finally, energy uses of crop residues with the production of briquettes; the manufacture of green charcoal, the production of natural biogas and the production of bioethanol.

Conclusion. The wide availability and diverse uses of crop residues can contribute significantly to increasing the sustainability and resilience of agricultural systems in sub-Saharan countries. However, this requires the effective implementation of a system for educating stakeholders on the uses of crop residues.

Keywords: Crop residues, biochar, organic manure, bioenergy, sub-Saharan Africa

RÉSUMÉ
De déchets à la richesse : usages des résidus agricoles en Afrique (Synthèse bibliographique)

Introduction. Ce travail de synthèse est un état de l'art sur les possibles utilisations des résidus de culture pour les populations du secteur agricole subsaharien en vue de leur résilience face à leurs problèmes socioéconomiques et climatiques.

Littérature. Les résidus de cultures sont présents en grande quantité dans les exploitations agricoles et représentent de réels atouts pour la résilience et la durabilité des systèmes agricoles. Malheureusement, à cause du manque de transfert de connaissances scientifiques vers les pratiques paysannes et des problèmes de collecte et de transformation des résidus, beaucoup sont sous valorisés. Les principaux usages des résidus de culture pour les acteurs du secteurs agricoles sont : les usages agronomiques, avec la production de biochar, de compost, de fumure organique à partir des résidus de culture pour améliorer la fertilité des sols ; les usages zootechniques, avec l'utilisation des résidus de culture dans l'alimentation animale et dans la fabrication de litière et d'abris pour les animaux ; enfin, les usages énergétiques des résidus de cultures avec la production de briquettes, de charbon vert, la production de biogaz naturel et de bioéthanol.

Conclusion. La disponibilité importante et les diverses utilisations des résidus de culture peuvent contribuer fortement à accroître la durabilité et la résilience des systèmes agricoles des pays subsahariens. Cependant, cela nécessite une bonne mise en place d'un système de vulgarisation de formation des usages des résidus de culture aux acteurs.

Mots-clés : Résidus de culture, biochar, fumure organique, bioénergie, Afrique subsaharienne.

1. INTRODUCTION

In recent years, sub-Saharan Africa has been facing extreme weather events such as prolonged droughts in the Sahel (Nicholson, 2013), recurrent flooding in Nigeria in 2022 (Ajayi, 2025) and exceptional heatwaves in West Africa in 2019 and 2020 (Ngoungue *et al.*, 2023), which now pose a major threat to societies and ecosystems (Kaboré, 2025). These events are amplified by climate change and affect the inhabitants of sub-Saharan Africa by compromising their food security and socio-economic stability (Sylla *et al.*, 2016).

Added to this is population growth, which reached 1.27 billion inhabitants in sub-Saharan Africa in 2025, representing more than half of the global growth forecast for 2050 (United Nations, 2025). This overpopulation puts greater pressure on natural resources and makes the population more vulnerable to climate hazards. The impacts are felt in all areas and sectors in sub-Saharan Africa.

In the field of health, with the proliferation of mosquitoes (Siraj *et al.*, 2014), the destruction of roads in Nigeria by floods (Ajayi *et al.*, 2025) and rainfall variability causing crop losses (Sylla *et al.*, 2016). The two major problems are the dependence of stakeholders on natural resources and the lack of resilience to climate variations, which make sub-Saharan agricultural systems vulnerable (Chirombo and Pangapanga, 2025). However, it should be noted that most actors in the agricultural sector (farmers and livestock breeders) are often relatively poor and forced to find local solutions to maintain their livelihoods (Tittonell, 2014).

Among the alternatives to address these two major problems is the recovery of crop residues, vegetable biomass or crop co-products as a potential contribution to limiting climate change and socio-economic problems, thereby increasing the sustainability of their agricultural activities (Valbuena *et al.*, 2012; Vanlauwe *et al.*, 2014; Sylla *et al.*, 2016). These sometimes come directly from farms or agricultural industries (Ouattara *et al.*, 2024; Zoungrana, 2025).

These alternatives are already present in the agricultural systems of sub-Saharan countries. However, due to the lack of transfer of scientific knowledge to farming practices (Giller *et al.*, 2009), the perception of residues as waste with no market value (Valbuena *et al.*, 2012), and problems with the collection and processing of agricultural residues (Bationo *et al.*, 2007), residues remain greatly underestimated and undervalued. This deprives many producers of the opportunities that crop residues can offer, such as improving soil fertility or reducing input costs (Vanlauwe *et al.*, 2014).

From an environmental perspective, the use of crop residues also reduces greenhouse gas emissions through the use of alternatives to fossil fuels (Jeffery *et al.*, 2015; Smith *et al.*, 2019; Ye *et al.*, 2020) and carbon sequestration through the incorporation of residues into the soil (Lal, 2005).

The objective of this study is to produce a bibliographic review of the various possible uses of crop residues in sub-Saharan Africa in order to enable stakeholders in the agricultural sector to increase the sustainability of their agricultural systems and also to strengthen their resilience to socio-economic problems.

2. DOCUMENTS SELECTION

A preliminary observation was made to select scientific articles and begin writing this bibliographic summary. We limited the research to Africa, and more specifically to sub-Saharan Africa. Documents were collected from several sites. The scientific databases consulted were Scopus, Web of Science, Science Direct, SpringerLink, Taylor & Francis, and Google Scholar. We then consulted certain peer-reviewed journals with recognised editors, such as Renewable Energy. Finally, we also consulted documents from international organisations such as the FAO.

All the documents used were subjected to a documentary analysis and we selected the most reliable, relevant and recent ones that were relevant to the objectives of the study. We analysed scientific articles presenting case studies, as well as articles from bibliographic review journals, according to their relevance.

To achieve this, specific terms and combinations of keywords were used, namely "use of crop residues, bioenergy, animal feed, recycling, plant biomass, biochar, compost, organic manure, biogas, bioethanol, sub-Saharan Africa".

In total, we selected more than 60 scientific articles for this study on the uses of crop residues in Africa. This article is intended as a purely theoretical contribution on the use of crop residues, highlighting their usefulness for African communities.

3. CROP RESIDUES WITH MULTIPLE USES IN SUB-SAHARAN AFRICA

3.1. Agronomic uses of crop residues

Biochar

Biochar is a carbon-rich product obtained by pyrolysis of residual biomass such as crop residues

(corn, millet, sorghum straw, etc.), forestry waste (Lehmann and Joseph, 2015), organic sludge and any other organic biomass. This transformation of biomass, sometimes considered waste or of little value, allows it to be better utilised, unlike ash, which is the result of complete combustion. Thanks to the processes used to manufacture biochar, the final product has a porous and stable structure, which is a real asset (Lehmann and Joseph, 2015). This property improves soil fertility and allows for better carbon sequestration (Lehmann and Joseph, 2015; Glaser *et al.*, 2002) with more stable storage for centuries (Lehmann, 2007).

It should be noted that obtaining biochar requires a technical biomass conversion process that involves specific ingenuity. To produce it, inputs such as crop residues such as corn, sorghum or rice straw, peanut shells, wood or manure (Glaser *et al.*, 2002) can be used. These are first dried and crushed for better homogenisation (Jeffery *et al.*, 2011), then heated to between 300 and 700 °C in the absence of oxygen (Lehmann, 2007). Depending on the volume and biomass used, heating can vary from a few hours to several days (Woolf *et al.*, 2010). However, a low temperature (around 300 °C) produces biochar that is rich in nutrients but less stable, while a higher temperature between 600 and 700 °C produces biochar that is more stable and richer in carbon (Woolf *et al.*, 2010).

At the end of the process, we obtain a black, porous and light material that will improve soil structure and store carbon more effectively (Lehmann and Joseph, 2015). During the process, it is possible to recover pyrolysed gas and oils that can later be used as energy (Woolf *et al.*, 2010).

The use of biochar in fields has a positive impact on soil health, improving water and nutrient retention (Glaser *et al.*, 2002). It also stimulates microbial biodiversity (Glaser *et al.*, 2002) and contributes to crop resilience by making them more resistant to water stress (Jeffery *et al.*, 2011). Finally, as mentioned above, the use of biochar reduces N₂O and CH₄ emissions (Jeffery *et al.*, 2011).

Producing compost from waste

Composting is an agricultural technique for recycling crop residues or any plant biomass or organic matter, based on the biological decomposition of organic matter by microorganisms in the presence of oxygen (Insam and De Bertoldi, 2007). This agricultural technique transforms fresh organic matter into a rich product called '*humus*', which has properties that improve soil fertility and structure (Epstein, 1997; Bernal *et al.*, 2009).

It should be noted that composting involves several stages and the materials used may vary from one

region to another, but in general, agricultural residues such as straw, stalks, husks, manure and organic sludge (Bernal *et al.*, 2009) are used. The first step is to mix the chopped or unchopped components with water to promote microbial activity (Haug, 2018).

The second phase, known as the thermophilic phase, involves the use of a tarpaulin or a natural covering system, depending on the means available. It is essential that the temperature be monitored during the following days (desired rise between 55 and 65 °C) to ensure sanitisation and proper decomposition of the materials (Insam and De Bertoldi, 2007).

This is followed by the maturation phase, during which the materials gradually transform into *humus* and stabilise (Zmora-Nahum *et al.*, 2005). Finally, after several days, the end product is brown, crumbly and rich in organic matter and nutrients (Epstein, 2017). Compost has several advantages. With the physical and chemical properties obtained from *humus*, compost has a direct impact on soil health by improving its structure and increasing its water retention capacity (Bernal *et al.*, 2009).

Composting is a sustainable solution for agricultural waste management. In particular, it makes it possible to recycle olive pits in Morocco (Oued Lhaj *et al.*, 2024), which are considered to be waste. From an economic perspective, compost reduces farmers' expenses because it provides nitrogen, phosphorus and potassium, which are essential for crops (Epstein, 2017). From an environmental perspective, compost reduces the use of open-air burning techniques, which are most often used to reduce agricultural waste, and helps to reduce emissions (Bayu, 2020). Finally, compost makes amended soils more resilient. Soils amended with compost are more resistant to water stress (Assoh *et al.*, 2025).

Production of organic manure

Organic manure is defined as any fertiliser obtained from natural organic materials such as crop residues, manure, compost, organic sludge and agri-food waste (Palm *et al.*, 1997). They can be produced in manure pits, in piles or even in the open air in animal housing areas (Ouedraogo *et al.*, 2001). Its main purpose is to improve soil fertility by providing nutrients (nitrogen, phosphorus, potassium) and stimulating soil microorganisms through the addition of organic matter (Palm *et al.*, 1997).

There are several categories of organic manure, which differ according to the percentage of manure and biomass residues present in the mixture. There is animal manure, which is a mixture of animal excrement and plant litter from the animals' living

quarters (Palm *et al.*, 1997). It contains as much excrement as agricultural residues. It is most often used in family farming (Palm *et al.*, 1997). When organic manure contains more animal manure and virtually no agricultural residues, we refer to it as farmyard manure. Finally, when there are more biomass residues and very little or no manure, we refer to it as compost (Bekunda *et al.*, 1997; Palm *et al.*, 1997).

3.2. Zootechnical use of crop residues

In animal feed

In West Africa, livestock farmers use crop residues to feed animals during the hot season. Cereal straw (millet, sorghum, maize) and legume tops are the main sources of fodder during the dry season (Zampaligré *et al.*, 2021). Other plant biomass such as husks, seeds and pulp (sugar cane) are mostly used as concentrates or feed supplements (Reed *et al.*, 1988).

Their use reduces crop residue losses but, above all, has a positive impact on the sustainability of agrosylvo-pastoral systems (Ouattara *et al.*, 2024). The recovery process is based mainly on techniques for collecting, drying, grinding and storing residues (FAO, 2017; Zorma, 2017; Ouattara *et al.*, 2024). In order to increase the palatability and digestibility of certain residues, some producers use urea treatments (Ouattara *et al.*, 2024) or heat treatments on cereal straw (Kaboré *et al.*, 2025).

Bedding and shelter management

Crop residues with a high lignin content, such as cereal straw left on the fields after several weeks, which are not very palatable, can be used as bedding to improve animal comfort in pens and also facilitate the collection of manure (Ouattara *et al.*, 2024).

Energy uses of crop residues

Crop residues can be used as an energy source instead of fossil fuels, which cause pollution and are finite resources (FAO, 2017; Goel *et al.*, 2024). Bioenergy refers to all forms of energy produced from plant biomass, such as organic matter of plant or animal origin (Demirbas, 2009). It consists of solid fuels (wood, briquettes, green coal), liquid biofuels (bioethanol, biodiesel) and gases such as biogas and synthesis gas (McKendry, 2002).

It is an inexhaustible alternative to the fossil fuels that have been used for years. This form of energy makes it possible to recover crop residues, forest residues and agro-industrial residues (McKendry, 2002; Demirbas, 2009).

There are four main types of bioenergy obtained, depending on the type of crop residue and the equipment used, based on processes adapted to

local resources and needs (Balat *et al.*, 2008; Adjin *et al.*, 2018; Do, 2024; AVSF, 2025; Njimou *et al.*, 2026).

Briquettes

Briquettes are used as an alternative energy source to gas and firewood. The most commonly used materials are shea sludge (AVSF, 2025) and agricultural residues such as corn, rice and coffee straw (Njimou *et al.*, 2026). Briquettes are actually compressed blocks of plant biomass that may be uncarbonised but require the use of a binder, or they may be carbonised (Do, 2024; Njimou *et al.*, 2026).

The process of manufacturing briquettes from shea sludge, for example, involves crumbling and sorting out impurities, then decanting and crushing the shea residues, followed by extrusion using a screw press and finally cutting and drying the final product in the open air for 6 to 8 days (AVSF, 2025). This process allows for more regular combustion and reduces the use of firewood (AVSF, 2025).

Brikets made from agricultural residues have a high energy content suitable for domestic cooking (Njimou *et al.*, 2026). Indeed, by mixing corn cobs and cassava waste and adding binders, we obtain briquettes with a high energy content, suitable for domestic cooking (Njimou *et al.*, 2026).

In Kenya, for example, briquettes have already been used in households instead of charcoal, slightly reducing pressure on forests (Bosire *et al.*, 2023). This is also the case in Mali, where cooperative producers have turned the sludge from shea processing into bioenergy briquettes (AVSF, 2025) by using them to dry mangoes and cook shea butter (AVSF, 2025).

Producing green charcoal

Green charcoal is a solid product obtained by pyrolysis of plant biomass or agricultural and agro-industrial residues used as an alternative to charcoal (Laval, 2014; Théau and Kinanga, 2021). Among the materials known to be used to produce green charcoal are cocoa pods, cashew shells and shea sludge (AVSF, 2025).

Green charcoal is produced by first collecting, drying and grinding the biomass to make it more homogeneous (Théau and Kinanga, 2021). The residues are then burned in a controlled manner to transform them into charcoal without producing excessive smoke (Laval, 2014). The unfinished product is then mixed with a natural binder such as clay or starch to preserve it for longer (Njimou *et al.*, 2026). Finally, the product is compressed, either manually or with a motorised device, to form briquettes and left to dry for a few days (Do, 2024). In Côte d'Ivoire, for example, some producers and actors in the cocoa sector produce green charcoal

for their households (AVSF, 2025). This is also the case for members of the CPSL cooperative (Cooperative Society with Board of Directors of the SOFOCI LOUHIRI Coffee and Cocoa Producers Collective), who have developed the production of green charcoal from cocoa pods (AVSF, 2025). With only 6 kg of pods, they are able to produce 1 kg of green charcoal, which is often sold or used directly in households (AVSF, 2025).

Green charcoal is also used in West Africa in domestic households. For example, in Ghana, some farmers transform cocoa residues into green charcoal through pyrolysis (Adjin *et al.*, 2018; Do, 2024).

Producing biogas

Crop residues can also be used to produce gas as an alternative to firewood or other fossil fuels, a process known as biogas production. However, due to the lignocellulosic structure of many agricultural residues such as corn stalks, their degradation is slower, sometimes incomplete, and limits methane production during biogas production (Ahmed and Müller, 2025; Ngetuny *et al.*, 2025). To remedy this, several studies show that mixing residues with other organic matter such as animal effluents (manure or slurry) balances the carbon/nitrogen (C/N) ratio, promotes microbial activity and thus increases biogas production (Ahmed and Müller, 2025; Ngetuny *et al.*, 2025).

Biogas is produced from the anaerobic digestion of organic matter (crop residues, manure, agri-food waste) by microorganisms in the absence of oxygen (Angelidaki and Sanders, 2004; Appels *et al.*, 2008; Arthur *et al.*, 2011). It consists mainly of methane (CH₄, 50–70%) and carbon dioxide (CO₂, 30–50 %) and a small amount of hydrogen, nitrogen and hydrogen sulphide (Angelidaki and Sanders, 2004; Appels *et al.*, 2008). Only methane is used as bioenergy.

The biogas production process involves several stages. First, there is a pre-treatment phase where crop residues and manure are crushed and moistened to facilitate their degradation (Onyekaozuoro *et al.*, 2023). This mixture forms a slurry that must be poured into a barrel, cement pit, metal tank or industrial digester to allow anaerobic digestion by microorganisms. This is followed by anaerobic fermentation inside the tanks for several days. The bacteria break down the organic matter through hydrolysis, followed by acidogenesis, acetogenesis and finally methanogenesis (Angelidaki and Sanders, 2004; Appels *et al.*, 2008; Ngetuny *et al.*, 2025).

Finally, the last stage involves the storage and use of biogas. The gas is collected via a pipe and fed into a flexible tank, which may be a balloon or

reinforced plastic bag (depending on the producer's resources), or it may be fed directly into a burner (Ngetuny *et al.*, 2025).

The integration of household digesters for biogas production reduces firewood consumption and improves energy security for rural households. For example, in Ghana, the amount of raw material available in rural areas, such as cattle, pig and poultry manure and agricultural residues, may be sufficient to maintain regular biogas production (Arthur *et al.*, 2011).

The 2011 study 'Biogas as a potential renewable energy source: A Ghanaian case study' by Arthur *et al.* showed that a 6 m³ digester containing manure and maize residues can produce approximately 2.3 m³ of biogas per day, which can cover the cooking needs of a Ghanaian household of five people.

Bioethanol, a biofuel produced from residues

Bioethanol is a liquid biofuel produced from the fermentation of sugars or starches from lignocellulosic residues such as cereal straw or agricultural products such as sugar cane and beet (Cardona and Sánchez, 2007; Balat and Balat, 2009). It is generally used as an alternative to petrol in internal combustion engines (Cardona and Sánchez, 2007; Balat and Balat, 2009).

Its production requires, first and foremost, the grinding and hydrolysis of plant biomass or agricultural residues in order to release fermentable sugars (Balat and Balat, 2009). The extracted sugars are then placed in large, hermetically sealed tanks for fermentation, where yeast is added to convert the glucose into ethanol and carbon dioxide (Goldemberg, 2008; Balat and Balat, 2009). This is followed by the distillation and dehydration stage, where the ethanol is separated from the water in distillation columns (Cardona and Sánchez, 2007) and purified to 99 % using molecular sieves or chemical processes to obtain ethanol that can be used as fuel (Sun and Cheng, 2002). Finally, the bioethanol must be stored in closed tanks for later use, either mixed with E10 or E85 petrol (Cardona and Sánchez, 2007).

This biofuel could be a more sustainable and less expensive solution compared to conventional fuel sold at petrol stations. Indeed, the study 'Recent trends in global production and utilisation of bioethanol fuel' by Balat *et al.* (2008) showed that lignocellulosic residues could be an important source of biofuels for reducing petrol stations' dependence on fossil fuels. The production of bioethanol using rice and wheat straw yields 250 l of bioethanol that can be used as fuel from one tonne of rice straw (Balat *et al.*, 2008).

4. CONCLUSION

Crop residues are good alternatives for the resilience of activities carried out by actors in the agricultural sector in sub-Saharan Africa, but also for alleviating certain socio-economic problems. The study we conducted has enabled us to highlight the existence of various uses of crop residues for the population and actors in the agricultural sector in sub-Saharan Africa. The main uses of crop residues listed are biochar, compost and organic manure for agronomic purposes; animal feed, bedding and shelter management for zootechnical purposes; and finally briquettes, green charcoal, bioethanol and biogas for energy or bioenergy purposes.

The use of agricultural residues in these various ways improves soil fertility, feeds farm animals, provides energy for households and reduces expenditure for those involved in the agricultural sector. This is the case with briquettes made from agricultural residues, whose energy content is suitable for household cooking. Another example is biochar, which improves water and nutrient retention in fields and stimulates microbial activity underground.

Crop residues have a real positive impact on the sustainability of agro-sylvo-pastoral systems thanks to the availability of fodder resources and the reduction in purchases of livestock feed and synthetic fertilisers. Support can be provided to producers with a view to improving the use of their residues for the sustainability of their agro-pastoral systems. To this end, it would be useful to create a tool that highlights the total amount of residues available, the various techniques that can be used for each type of agricultural residue, and the proportion of residues that are not utilized by farms.

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