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Estimation and Efficient Utilization of Straw Resources in Ghana

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Abstract: The significance of this research is on maize, rice, sorghum, millet, groundnut, soybeans and cowpea straw for stronger sustainability in Ghana's economic development. Quantifying and re-use of crop straw resources in Ghana is still at the infancy stage hampering the efficient recycling of these resources in a sustainable manner. Sustainability is straw as a renewable resource to improve soils, livestock production, generate renewable energy and reduce pollution for development. The aim of this research was to estimate the crop straw yield from 2006 to 2016 and identify the various utilization modes for major cereals and legumes in Ghana. In addition the distribution of maize, rice, sorghum and cowpea straw across major producing regions was calculated. Results obtained showed that 77,404,709.75 tonnes of cereals and legumes straw were produced in Ghana from 2006 to 2016. Cereal straw recorded a 72.3% yield whilst legume straw recorded 26.8%. Maize and groundnut straw recorded the highest yield of 37,323,264.16 and 12,495,288.96 tonnes respectively. Brong Ahafo region of Ghana had the highest maize straw yield with the Northern region recording readily availability of both cereals and legumes straw resources. The major re-use methods of straw in Ghana are as livestock feed, fertilizer, cooking fuel, for sale and as a substrate for mushroom production. We recommend strategies the government can adapt to develop policies geared towards the accurate recording of straw and their comprehensive utilization in Ghana. The efficient utilization of straw resources will reduce soil erosion, improve soil fertility, serve as feed for livestock, reduce pollution, generate biofuels plus generate employment to benefit the rural economy.

Keywords: crop straw; estimation; efficient utilization; re-use; Ghana

1. Introduction

Crop straw burning in Africa is increasing and causes atmospheric pollution and soil degradation [1]. In Ghana about 60%–70% of agricultural biomass, which includes straw, is produced yearly [2], however its resourceful management and re-use is a challenge resulting in negative environmental impact. Large quantities of crop residues such as maize stover, sorghum and millet stover, groundnut haulm and rice straw are generated from farms in Ghana [3,4]. After, harvest crop straw is often abandoned in heaps on farms, in some cases it is burnt during or before preparing the land for the next cropping season [3]. Effective quantitative estimation, assessment and utilization of straw generated from these crops have not been prioritized by the government. However, the foundation and profitability of comprehensive utilization of crop straw lies on reliable assessment and distribution of these resources [5,6]. Estimation of the amount of straw resources is the basis for the comprehensive utilization of straw resources. Crop straw estimation is mostly based on statistical data, which involves thorough spatial and statistical count of the types of straw available. Most estimations of straw in developing countries are done based on existing literatures with the majority of straw generated

from cereals and legumes [7]. Adequate quantitative estimation of crop straw in some countries like Ghana is a major challenge. On the whole 1.5 tonnes of straw is generated for every ton of cereals produced [8]. Crop straw has often been ignored based on the problems associated with measuring it [9], the statistical estimation and evaluation of straw resources will establish straw supply chain for effective management of straw resources in Ghana. Management of straw resources is gaining attention worldwide particularly in countries where high quantities of straw is generated [8] with cereal straws being one of the important crop resources available [10]. The huge availability of straw resources in Ghana provides a great potential generating biofuels from these resources [11]. The effective utilization of straw resources is an ecological project to achieve sustainable development of agriculture, which can ease the pressure of overgrazing and decrease tree consumption [12]. Sustainability in this case means conversion of crop straw into a renewable resource [13] as soil management option, livestock feed and energy. Incorporating straw into the soil or as mulch will serve as a mitigation strategy to check erosion particularly in highly eroded soils. The reduction in erosion will improve on soil health and promote plant growth [14,15]. Generation of energy from straw as a biomass fuel [16] will ensure the supply of biofuels to promote rural development. Efficient utilization of straw strengthens sustainability [17] by reducing pollution caused by open field burning of straw, creates employment opportunities and develops the rural economy. Accurate estimation and comprehensive utilization of straw resources is being practiced in many advanced countries with crop straw being a valuable renewable resource, which holds a potential of being developed further. Some countries like China have progressed in the comprehensive management of straw for different techniques such as fertilizer, livestock feed, for cultivation of edible fungus (mushroom), energy-oriented use (fuel), as industrial raw materials and for biological reactor technology [18,19], which has led to diversified development. China attaches great importance to straw resources with a comprehensive utilization rate of 80% or more [20].

In Ghana, limited research has been carried out on the estimation of crop residue biomass with more focus on second generation of biofuels [11,21–24] but more needs to be done for efficient utilization of crop straw since straw can be found in almost every region or farming community in Ghana. Even though few research has been done on agricultural residues for some of the major cereals in Ghana, periodic estimation of the national straw yield from these resources has not been done over the years, on the other hand the different utilization methods of straw is unavailable in a holistic form but rather scattered information on it is available thereby limiting their effective utilization. Information on the total straw yield as well as the level of straw utilization for Ghana is unknown resulting in less focus on the efficient recycling of crop straw. However, efficient utilization of straw resources in Ghana will ensure environmental sustainability coupled with promoting a less hazardous atmosphere, which will lead to economic and social development of Ghana in a sustainable direction.

This necessitates the need for accurate research in this direction for Ghana to prioritize the quantification of straw resources and its efficient utilization. The aim of this research is to estimate the crop straw yield for cereals and legumes in Ghana and assess the various ways of utilizing them. In addition, the distribution of the average straw yield for maize, rice, sorghum and cowpea for a three year period across major producing regions in Ghana was analyzed.

2. Materials and Methods

2.1. Estimation of Total Crop Straw Yield on Regional Basis

The estimation of straw resources from major cereals and legumes (maize, rice, sorghum, millet, groundnut, cowpea and soybeans) was carried out according to the straw to grain ratio (SG) or residue to product ratio (RPR) by [22] in Table 1. The theoretical estimation included all straw resources that can be collected and used. This was calculated by the annual crop yield by the straw to grain ratio (SG)/residue to product ratio (RPR). Straw to grain ratio can also be referred to as crop byproduct production/residue to product ratio (RPR). For the purposes of this research SG and RPR were used interchangeably since most research on biomass yields in Ghana uses RPR. Crop yield data for straw

estimation was obtained from the Ministry of Food and Agriculture (MoFA), Statistics, Research and Information Directorate (SRID) in Ghana and the Food and Agriculture Organization (FAO) database. The estimation of straw resources was done from the year 2006 to 2016. The proportion of straw to grain varies from one crop to another and this depends on the level of yield. The crop yield is a function of total biomass and the straw to grain ratio. Straw to grain ratio (SG) or residue to product ratio (RPR) for crops varies from one crop to the other. Variations in the values of RPR is influenced by many factors such as varieties of seed planted, moisture content of crops and method of harvesting [25] as well as climatic factors.

Table 1. Residue to product ratio of major cereals and legumes cultivated in Ghana.

Crop	Residue	RPR (g/g)
Maize	Stalks	1.59
	Husks	0.2
	Cobs	0.29
Rice	Straw	1.66
	Husks	0.26
Millet	Stalks	1.83
Sorghum	Straw	1.99
Groundnut	Straw	2.15
	Shells	0.37
Cowpea	Shells	1.75
Soya beans	Straws and Pods	3.50

Source: [22].

The straw-to-grain ratio (SG) refers to the yield and economic yield of above-ground stalks of crops [26]. Estimating of straw resources in Ghana was calculated by the formula:

$$W_S = W_P \times S_G, \quad (1)$$

where W_S = crop straw yield, W_P = crop economic output/crop yield and S_G = ratio of crop straw yield to economic output.

Following the examples of some previous research [11,27], we estimated the straw yield for major cereals and legumes with RPR obtained from [22] who used the mean value for [11,28,29].

Microsoft Excel was used to calculate the straw yield of the various crops and percentage of straw yield, represented in a pie chart. Variation in crop and straw yields is represented with a graph.

2.2. Methods of Crop Straw Utilization in Ghana

This paper also reviewed various literatures on the utilization of straw in Ghana to ascertain the major utilization modes. An intensive search of literature was done on Google, Google scholar and Web of Science to support this study. Further literature was thoroughly reviewed to support recommendations for comprehensive straw utilization in the country. Diagram of the various utilization modes were drawn with Microsoft word.

2.3. Data Sources

The production yield data for major cereals and legumes cultivated in Ghana that was used are shown in Tables 2 and 3. A ten-year crop yield data were used from 2006 to 2016 since data for the major cereals and legumes in this research were available within this time frame. Yield data source was obtained from FAOSTAT [30–33].

Table 2. Major cereals.

Year	Maize (Tonnes)	Rice (Tonnes)	Millet (Tonnes)	Sorghum (Tonnes)
2006	1,189,000	250,000	165,000	315,000
2007	1,219,600	185,340	113,040	154,830
2008	1,470,080	301,920	193,840	330,950
2009	1,619,590	391,440	245,550	350,550
2010	1,871,695	491,603	218,952	324,422
2011	1,683,984	463,975	183,922	287,069
2012	1,949,897	481,134	179,684	279,983
2013	1,764,477	569,524	155,131	256,736
2014	1,762,000	604,000	155,000	259,000
2015	1,691,644	641,492	157,369	262,652
2016	1,721,910	687,679	159,017	229,604
Total	17,943,877	5,068,107	1,926,505	3,050,796

Source: [30–33].

Table 3. Major legumes.

Year	Groundnut (Tonnes)	Cowpea (Tonnes)	Soya Beans (Tonnes)
2006	520,000	167,000	54,000
2007	301,770	119,000	50,000
2008	470,100	180,000	75,000
2009	526,040	205,000	113,000
2010	530,887	219,000	145,000
2011	465,103	237,000	165,000
2012	475,056	223,000	152,000
2013	408,814	200,000	139,000
2014	426,280	201,000	141,000
2015	417,199	203,000	142,000
2016	417,199	206,000	143,000
Total	4,958,448	2,160,000	1,319,000

Source: [30–33].

3. Results

3.1. Estimation of Total Straw Yield and Variation in Straw Yield

Our results show that straw yield for major cereal and legumes in 2006 to 2016 recorded a total yield of 77,404,709.75 tonnes. Maize straw amounted to 37,323,264.16 tonnes representing 48.2% of the total straw generated. The output of groundnut straw was the second highest, which amounted to 12,495,288.96 tonnes representing 16.1% whilst millet straw recorded the least yield of 3,525,504.15 tonnes representing 4.6% (Table 4). The abundance of maize straw can be attributed to the fact that maize straw is widely produced across all regions in Ghana. As the major crop straw generated, maize straw holds the potential of being developed.

Figure 1 shows the total percentage of cereals and legumes yields in Ghana within 2006 to 2016. Cereal legumes recorded the highest yield of 56,650,617.79 tonnes representing 72.3% whiles legume straw gained 20,754,091.96 tonnes resulting in 26.8%. The results showed that there was abundant cereal straw in Ghana than legume straw.

Table 4. Total straw yield for major cereals and legumes cultivated in Ghana.

Type of Straw	Straw Yield (Tonnes)	Percentage (%) Straw yield
Maize Straw	37,323,264.16	48.2
Rice Straw	9,730,765.44	12.6
Millet Straw	3,525,504.15	4.6
Sorghum Straw	6,071,084.04	7.8
Groundnut Straw	12,495,288.96	16.1
Cowpea Straw	3,642,303	4.7
Soybeans Straw	4,616,500	6.0
	77,404,709.75	

Residue to Product ratio (RPR) was obtained from table 1 [22].

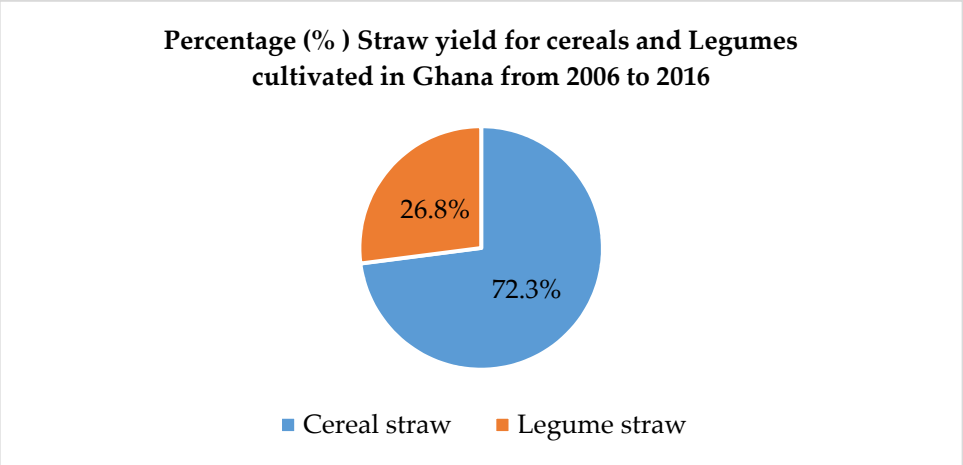

Figure 1. Percentage yield for cereals and legume straw in Ghana (2006–2016).

Figure 2 shows the temporal variation in crop and straw yields produced in Ghana from 2006 to 2016. The annual production of straw from the major cereals and legumes cultivated in Ghana increased steadily for the 10 year period from 5,673,570 tonnes in 2006 to 7,452,299.03 tonnes in 2016.

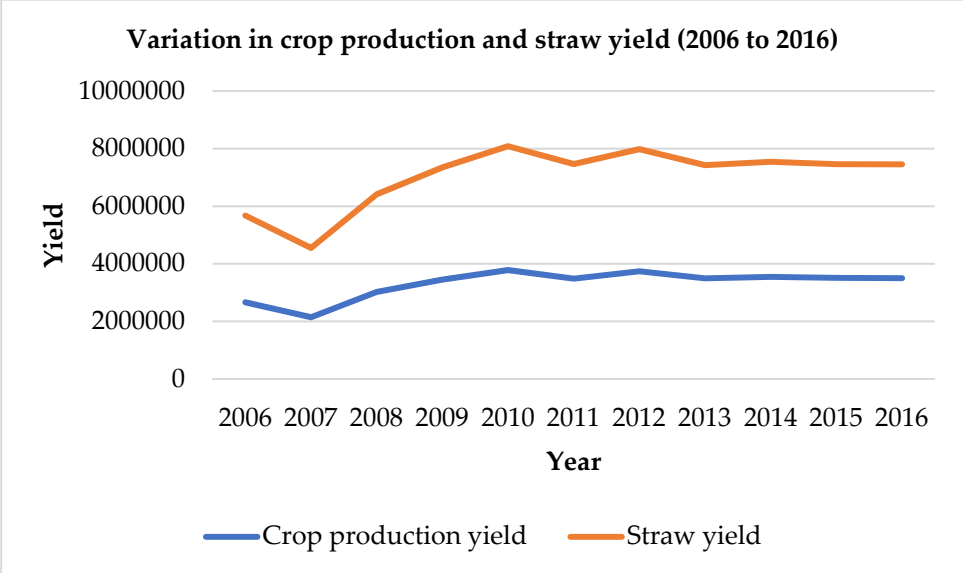

Figure 2. Variation of production and straw yields in Ghana from 2006 to 2016.

3.1.1. Estimation of Straw from Major Cereals in Ghana

Maize straw recorded the highest straw yield of 37 million tonnes within the ten (10) year period from 2006 to 2016, followed by rice straw (nine million), sorghum straw (six million) and finally millet straw, which recorded three million tonnes (Table 5). The results of maize straw recording the highest can be attributed to the fact that maize is the number one cereal cultivated in Ghana across every region in the country. The results show that maize, rice, sorghum and millet straw were readily available in Ghana and could be considered as renewable natural resources, which could be utilized in many forms.

Table 5. Straw yield from major cereals cultivated in Ghana (maize, rice, millet and sorghum).

Year	Maize (Tonnes)			Rice (Tonnes)		Millet (Tonnes)	Sorghum (Tonnes)
	Stalks	Husks	Cobs	Straw	Husk	Stalks	Straw
2006	1,890,510	237,800	344,810	415,000	65,000	301,950	626,850
2007	1,939,164	243,920	353,684	307,664.4	48,188.4	206,863.2	308,111.7
2008	2,337,427.2	294,016	426,323.2	501,187.2	784,99.2	354,727.2	658,590.5
2009	2,575,148.1	323,918	469,681.1	649,790.4	101,774.4	449,356.5	697,594.5
2010	2,975,995.05	374,339	542,791.55	816,060.98	127,816.78	400.682.16	645,599.78
2011	2,677,534.56	336,796.8	488,355.36	770,198.5	120,633.5	336,577.26	571,267.31
2012	3,100,336.23	389,979.4	565,470.13	798,682.44	125,094.84	328,821.72	557,166.17
2013	2,805,518.43	352,895.4	511,698.33	945,409.84	1,480,76.24	283,889.73	510,904.64
2014	2,801,580	352,400	510,980	1,002,640	157,040	283,650	515,410
2015	2,689,713.96	338,328.8	490,576.76	1,064,876.72	166,787.92	287,985.27	522,677.48
2016	2,737,836.9	344,382	499,353.9	1,141,547.14	178,796.54	291,001.11	456,911.96
Total	37,323,264.16			9,730,765.44		3,525,504.15	6,071,084.04

Residue to product ratio (RPR) was obtained from table 1 [22].

3.1.2. Estimation of Major Legumes in Ghana

Groundnut straw recorded the highest straw yield of 12 million tonnes as against four million tonnes and three million tonnes observed of soybeans and cowpea respectively. Unlike the cereals straw for millet and sorghum, which are only found in Northern Ghana, the legumes straw (groundnut, soybeans and cowpea) is spread across the entire country. This makes the utilization of the latter more effective, relative to its abundance on farms in the dry season. Table 6 clearly shows that groundnut, soybeans and cowpea straw were available in Ghana for any utilization methods.

Table 6. Straw yield from major legumes cultivated in Ghana (groundnut, cowpea and soybeans).

Year	Groundnut (Tonnes)		Cowpea (Tonnes)	Soybeans (Tonnes)
	Shells	Straw	Shells	Straw and Pods
2006	192,400	1,118,000	292,250	189,000
2007	111,654.9	648,805.5	208,075	175,000
2008	173,937	1,010,715	314,825	262,500
2009	194,634.8	1,130,986	358,400	395,500
2010	196,428.19	1,141,407.05	358,400	507,500
2011	172,088.11	999,971.45	414,400	577,500
2012	175,770.72	1,021,370.4	390,600	532,000
2013	151,261.18	878,950.1	350,700	486,500
2014	157,723.6	916,502	352,012.5	493,500
2015	154,363.63	896,977.85	352,012.5	497,000
2016	154,363.63	896,977.85	250,628	500,500
Total	12,495,288.96		3,642,303	4,616,500

Residue to product ratio (RPR) was obtained from table 1 [22].

3.1.3. Top Five Regional Distribution of Straw from Maize, Rice, Sorghum and Cowpea

Tables 7–10 shows the regional distribution of maize, rice, sorghum and cowpea straw for two "three year periods". The table shows that Brong Ahafo, Eastern, Ashanti, Central and Northern

produced maize straw in high quantities while rice straw was abundant in the Volta, Northern, Upper East, Eastern and Ashanti. Sorghum straw was abundant in the Northern, Upper West, Upper East and Brong Ahafo and Ashanti regions. Cowpea recorded the lowest straw yield readily available in the Northern, Upper West, Upper East, Brong Ahafo and Ashanti regions.

Table 7. Three years average of top five regions in Ghana producing maize straw.

Region	2013–2015		2014–2016	
	Straw Yield (Mt)	% Straw Yield	Straw Yield (Mt)	% Straw Yield
Brong Ahafo	912,457.936	31.5	870,465.024	30.3
Eastern	833,464.944	28.8	838,382.896	29.2
Ashanti	433,210.544	15.0	432,794.544	15.1
Central	360,959.456	12.5	366,344.784	12.8
Northern	355,022.304	12.3	361,195.744	12.6
Total	2,895,115.184		2,869,182.992	

Yield data source; [33]. Residue to product ratio (RPR) was obtained from table 1 [22].

Table 8. Three years average of top five regions in Ghana producing rice straw.

Region	2013–2015		2014–2016	
	Straw Yield (Mt)	% Straw Yield	Straw Yield (Mt)	% Straw Yield
Volta	353,816.256	34.5	397,264.32	36.3
Northern	323,342.016	31.5	340,731.84	31.1
Upper East	220,228.224	21.5	227,040.576	20.7
Eastern	62,088.384	6.1	65,798.592	6.0
Ashanti	66,666.24	6.5	64,648.896	5.9
Total	1,026,141.12			

Yield data source; [33]. RPR was obtained from table 1 [22].

Table 9. Three years average of top five regions in Ghana producing sorghum straw.

Region	2013–2015		2014–2016	
	Straw Yield (Mt)	% Straw Yield	Straw Yield (Mt)	% Straw Yield
Northern	206,983.4	38.7	184,110	38.7
Upper West	173,380.6	37.1	176,654.2	37.1
Upper East	100,910.7	21.6	102,499.4	21.6
Volta	10,650.4	2.3	10,827.8	2.3
Brong Ahafo	1685.1	0.3	1522.1	0.3
Total	493,610.2		475,613.4	

Yield data source; [33]. RPR was obtained from table 1 [22].

Table 10. Three years average of top five regions in Ghana producing cowpea straw.

Region	2013–2015		2014–2016	
	Straw Yield (Mt)	% Straw Yield	Straw Yield (Mt)	% Straw Yield
Northern	168,697	49.4	166,119	48.1
Upper West	129,416	37.9	135,393	39.2
Upper East	21,393	6.3	21,628	6.3
Brong Ahafo	13,443	2.3	13,289	3.8
Ashanti	8712	3.9	9000	2.6
Total	341,661	49.4	345,429	

Yield data source; [33]. RPR was obtained from table 1 [22].

The top five regional distributions of three major cereals (maize, rice and sorghum) and cowpea showed various straw yield percentages across the major regions where these crops are cultivated.

The results show that among the five major regions where maize was cultivated the Brong Ahafo region recorded the highest percentage in straw yield of 31.5% between 2013 to 2015 and 30.3% (2014 to 2016) respectively. Notably, there was a drop in straw yield between the two "3 year periods" maize straw still had the highest straw yield percentage in the Brong Ahafo region than any of the other four regions. However the Central and Northern regions recorded the least percentage yield in maize of 12.5%; 12.8% and 12.3%; 12.6% respectively. Rice straw however recorded the highest straw yield percentage of 34.5% and 36.3% while the Ashanti region recorded the lowest straw yield percentage of 6.5% and 5.9% for the periods 2013–2015 and 2014–2016 respectively. Sorghum straw yield percentage was high in the Northern region of Ghana whiles the Brong Ahafo region recorded the straw yield percentage of 0.3 within these periods. On the other hand production of cowpea straw in the Northern region recorded the highest straw percentage of 49.4% and 48.1% as against the Ashanti region recording the lowest yield of 2.5% and 2.6% respectively. The result shows that large quantities of maize straw can be found in the Brong Ahafo and Eastern regions. Abundant availability of rice straw can be found in the Volta and Northern regions. The largest producer of sorghum and cowpea straw in Ghana are the Northern region, which is ranked first followed by Upper west region as the second largest producer. Among all the regions that the maize, rice, sorghum and cowpea are cultivated, the Northern region was the only region that cultivated all these crops in higher quantities. The Northern region recorded the highest straw yield percentage of 38.7% for sorghum (2013 to 2015; 2014 to 2016), 31.5% and 31.1% for rice straw (2013 to 2015; 2014 to 2016) and 12.3% and 12.6% for maize straw (2013–2015; 2014–2016) respectively. For cowpea straw production, the Northern region recorded the highest straw yield of 49.4% and 48.1% for both "3 year periods" respectively. Remarkably, our results indicate that the Northern region had majority of the different straw resources readily available. The abundance of these straws in some regions in Ghana unveils the need to focus on the effective utilization of such crop straw in those areas. Map of Ghana with major regions is shown in Figure 3.

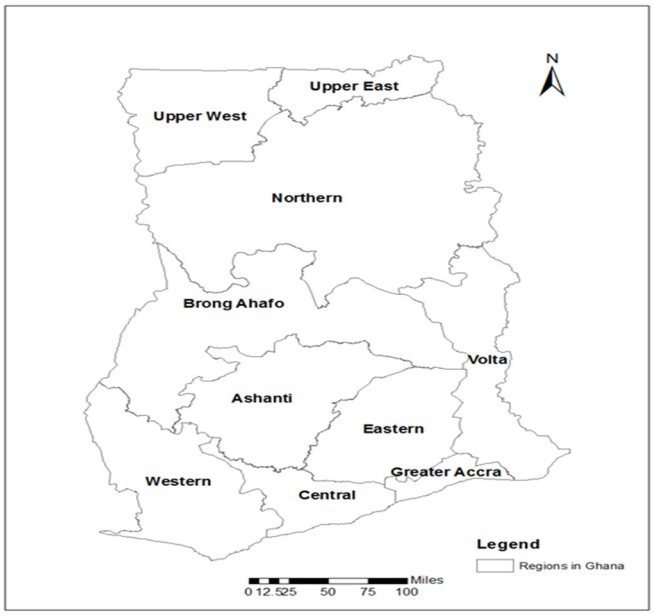

Figure 3. Map of Ghana.

3.2. Utilization of Straw in Ghana

The utilization of straw in Ghana is not very competitive as compared to other countries. Even though straw is used for different purposes across the country, traditional utilization is the most prominent as against industrial utilization of straw in other advanced countries. The utilization methods of straw can be grouped into agricultural and non-agricultural uses [34]. Some of the utilization modes practiced in Ghana (shown in Figure 4) are as feed for livestock, as a source of

fertilizer to enrich soil, fuel for cooking, as a substrate for mushroom production and other local uses including burning. Most of these modes of utilization has been in existence over decades and have not been explored into their fullest potential.

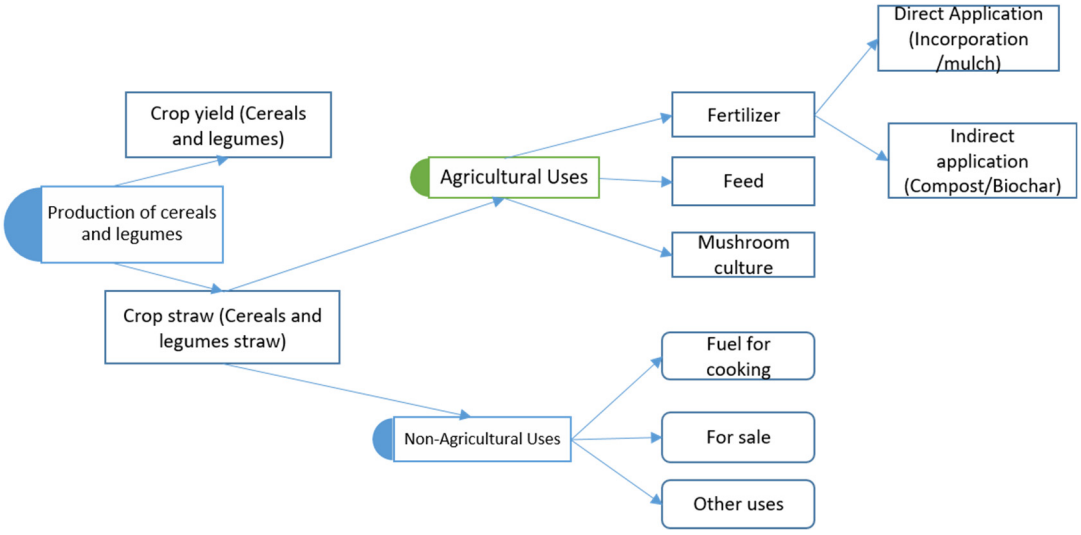

Figure 4. Methods of crop straw utilization in Ghana.

3.2.1. Feed for Livestock

The livestock sector contributes to 6.2% of Ghana's gross domestic product (GDP) with cattle, sheep, goat, pigs and poultry being the major livestock reared in Ghana [33]. Notably, livestock production contributes significantly to the livelihood of farmers and enhances food security in Northern Ghana [35]. In Northern Ghana 60% of the rural people engage in livestock production with access to a sustainable supply of feed being a major constraint facing the development of the livestock industry [36]. The common livestock reared are cattle, sheep and goats under three distinct management systems; herding, tethering and confinements [4]. Livestock production normally relies on farmlands where these animals graze on left over straw abandoned on the field. Crop straw has become an abundant resource used as animal feed in some parts of the country, using straw as livestock feed is more superior due to the fact that it adds value to the herd [37]. Majority of livestock raised in Ghana can be found in the northern part of the country. Crop straw utilization as feed for ruminants has been practiced over the years especially in the rural areas where ruminants are mostly reared under the extensive system whiles the ruminants are confined in the cities and fed with other products such as plantain and cassava leftovers [38]. Over the years, the use of crop straw has been practiced in Ghana, a report on the Livestock Development Project in Ghana indicated that ruminants are left to extensively graze on crop straw generated after harvesting [39]. Crop straw, which has no nutritional value to humans, is consumed by ruminants and transformed into useful byproducts such as meat and milk for human consumption. Northern Ghana generates about 5.2 million tonnes of straw annually and is characterized by the use of straw as animal feed but less attention is paid to the efficient management, utilization and its impact on the environment. However the straw generated accounts for only 20%–30% rate of supplementary feed in the dry season [40]. Direct feeding of animals with crop straw is mostly practiced in Ghana even though it provides low nutritional value to ruminants. Untreated cereal straw such as rice straw has low nutritional quality in proteins, energy, minerals and vitamins coupled with low palatability. Cereal straw supplemented with legume straw is an alternative method of improving the nutritional content of straw as animal feed for livestock [41]. In some instances farmers also transport their legume straws (groundnut, cowpea and soya beans haulms) using the 'cut and carry' system to feed their animals. Even though they feed their animals with cereal straw particularly (rice, maize, sorghum and millet), they prefer the legume straw since the animals find it more palatable

and easy to consume coupled with its nutritional benefits as against the cereal straws. Research in the Yendi Municipality of the Northern region of Ghana by Ansah et al. [4] indicated that 91% of livestock farmers use legume crop straw for feeding in the dry season. The authors further assessed the knowledge level of farmers in the utilization of crop residues and agro byproducts for feeding ruminants, their research highlighted that 91.7% out of 60 farmers interviewed use legume straw (groundnut vines) while 31.7% of the respondents use cereal straw (maize stover) as supplementary feed for their animals. Farmers normally collect the straw from September to December, which is considered as the peak period of straw abundance (after harvesting). The basic preservation methods used by farmers are chopping and drying. Even though extension education encourages farmers to treat straw with alkali and urea before feeding it to animals, it seems this has been ignored by the majority of farmers within the Yendi municipality. The findings showed that there are limitations in the use of maize stover as feed since it is also used as cooking fuel. In view of this the research proposed that rice straw could help solve the shortage of feed in the dry season since farmers indicated that they allow their livestock to feed on untreated rice straw, which is normally left on the field after harvesting. The straw are collected, stored and fed as supplements to animals.

Ghana's first Food and Agriculture Sector Development Policy (FASDEP I) was developed in 2002 as a guide for the promotion of modern agriculture however after four years of implementation it was reviewed and the second Food and Agriculture Sector Development Policy (FASDEP II) was developed. FASDEP II emphasizes on the sustainable utilization of all resources and commercialization of activities in the sector with market-driven growth. Albeit the livestock development policy aims at resolving the challenges of inadequate availability of quality feed, poor management practices and low productivity facing the livestock industry [42], has not been realized but continues to increase. Due to the scarce nature of livestock feed in the dry season, especially in the northern part of Ghana, farmers are also trained on forage preservation and utilization for feed to be available throughout the year. Under forage preservation, farmers are encouraged to dry and store feed resources such as straw, agro byproduct and other crop residues. Farmers are also encouraged to establish fodder banks by planting some leguminous plants and to use them to feed their livestock. In addition to these farmers are also encouraged to treat their crop residues especially rice straw with urea in order to increase their nutrient content [43]. Supplementary feeding using crop residues such as straw can be accessed by ruminants but are unavailable especially in the dry season. Sheep and goats are normally let loose to graze in some communities where farming activities is carried out in immediate surroundings [44]. Ruminants feed on groundnut, corn and cowpea straw as well as other agricultural residues, in some instances commercial farmers are able to store some of the straw for later use even through there are constraints of inadequate straw bailers in the Northern region of Ghana. Findings reveal that the Northern region can boast of only one functional mechanical bailer, which is a limitation factor in storing straw in large quantities. Feed processing companies are not engaged in commercial feed production for ruminants but only centered on the poultry industry. However these companies produce salt licks and bricks for ruminants [45]. In Northern Ghana, crop straws are mostly abundant in the early dry season especially from September to December where animals are allowed to graze on them freely without restrictions. During the dry season in some parts of the country feeding of straw to livestock is considered as a luxury where animals used for traction by farmers are fed with straw either early in the morning before they are allowed to go out grazing or in the evening when they return from the field. In Doku in the Savelugu district of the Northern region of Ghana farmers feed their draught livestock with legume straw in the dry season [46]. Though millet, maize, sorghum stovers and rice straw, groundnut haulms, cowpea haulms and soya beans haulms can be processed into pelleted feed for dry season feeding of livestock [47], most farmers do not practice this but rather store them in heaps in corners of their houses. Ansah and Issaka [48] disclosed that the available feed resources from straw produced per household (HH) yearly in Kumbungu district of the Northern region of Ghana were maize stover (325 kg/HH/annum), rice straw (411 kg/HH/annum), while millet groundnut, cowpea and soya beans haulm recorded 85 kg/HH/annum, 86 kg/HH/annum, 195 kg/HH/annum and 133 kg/HH/annum, which

gave an average of 1236.3 kg of crop straw per year produced in the district. The integration of the crop livestock system helps to ensure that ruminants are fed with cereal and legume straw particularly in the dry season [36]. Table 11 shows the advantages of using crop straw as animal feed. However the method of feeding ruminants with unprocessed straw has been in existence since time in memorial with farmers still relying on their indigenous knowledge of feeding their livestock, which demands more intervention and innovative ways of recycling straw as animal feed.

Table 11. Advantages of straw as livestock feed.

Mode of Utilization of Straw as Feed	Advantages
Untreated cereal straw	Serve as supplementary feed for ruminants particularly in the dry season when feed is scarce Adds value to herd Cheaper
Untreated legume straw	High nutritional content More palatable Available in the dry season as supplementary feed Easy to consume Cheaper
Treated cereal and legume straw with alkali and urea	High palatability and digestibility High nutritional value: Proteins, energy, minerals and vitamins Increases productivity Serve as supplementary feed Less costly compared to other feeds

3.2.2. Fertilizer as Soil Fertility Management

The use of crop straw as a soil nutrient management option can be categorized into direct and indirect manuring. Direct manuring is when straw is incorporated into the soil or as mulch. On the other hand the indirect soil nutrient management option is either through composting or biochar formation. McIntire et al. [37] emphasized that straw as a soil nutrient management option is either done through incorporation, surface mulching, composting and fertilization. A survey done by Quansah et al. [49] across six regions in Ghana on farmers perception and management of soil organic matter indicated farmers believe crop straw as mulch or fertilizer (compose, biochar) helps to improve upon the organic matter content of the soil. In the humid forest zones (southern zone) 23% of farmers admitted the use of straw as mulch improves the organic matter (O. M) content of the soil while 25% of farmers in the savannah zone equally admitted to this. 43% of the farmers in the savannah zone practice composting with crop residues, which includes the crop straw agreed to the fact that straw compost also amends the soil.

Findings by Dugan et al. [50] suggests that maize stover biochar can help to retain soil moisture content of Ghanaian soils between 349%–481% particularly in sandy textured soils. Indicating that maize stover biochar can be applied at five tonnes per hectare as a soil enriching material. Straw that is readily available locally improves the soils capacity to increase yield. Issaka et al. [3] showed that 366,975.2 Mt rice straw produced contains 1834.9 Mt of nitrogen (N), 587.2 Mt of phosphorus (P_2O_5) and 5137.7 Mt of potassium (K_2O). Other nutrients such as calcium and magnesium are also potentially available. Over 50% of these nutrients are available in the large amounts of rice straw produced in the Northern region. Logah [51] indicated that maize straw amended with chemical fertilizer could increase the nitrogen and phosphorous nutrient level of maize straw with lower polyphenol, which will translate into increasing the productivity of crops. Quartey and Chýlková [24] equally emphasized that straw is being used as a fertilizer to help in the productivity of crops in Ghana. Thus, continues that the application of straw helps to retain the nutrient and moisture content of the soil. Biochar production and application in soils has a very promising potential for the development of sustainable agricultural systems in Ghana. This is because there is availability of biomass resources in the country as potential feedstock for biochar production [52]. According to Issaka et al. [3] ashed straw with a pH

level of over 11.0 is good for acidic soils, which is common with most Ghanaian soils. This straw helps to improve both the physical and chemical properties of the soil, particularly soils in the Northern region, which are low in phosphorous content. Rice straw as a mulching material in cultivating onion "white Creole" helped to increase the yield and productivity compared to no mulching [53] this is a result of the impact of moisture on mineralization, which is 50% effective in soils amended with maize and groundnut straw. Direct application of rice straw to rice fields' results in higher yields as compared to the pretreatment of rice straw before application. In Northern Ghana, there is variation in rainfall patterns but the temperature is relatively stable, hence, it is crucial to pay more attention to the soil moisture content and the type of straw used as a soil management option [54]. Mulching with straw especially rice straw on cultivated fields helps to check erosion and weed infestation as well as maintains the temperature of the soil [55]. Research done by Tobita and Nakamura [56] reveals that the annual abundance of rice straw was estimated to be 367,000 tonnes. Rice straw is regarded as a prominent source of organic matter in the Northern region of Ghana where it is in abundance, likewise, the availability of other crop straws such as maize, millet, sorghum, groundnut, cowpea and soybeans are equally important sources of organic matter in Ghana. Rice straw produces nitrogen (N), phosphorus (P) and potassium (K) at 2500, 1000 and 5500 tons annually. Amendment of soil with rice straw improves the NPK content of the soil by 20% compared to inorganic fertilizer. Straw resources are abundant in Ghana with its nutrients rich properties, effective utilization of these resources to enrich the soil will reduce the use of inorganic fertilizers and improve the soil structure and productivity. Advantages of using crop straw as soil fertility management option are shown in Table 12. The use of crop straw either directly or indirectly as a soil management option is a cheaper alternative for farmers with easier application rate, which is environmentally friendly and less hazardous to human health.

Table 12. Advantages of straw for fertilizer as a soil management option.

Mode of Utilization of Straw as Fertilizer	Advantages
Direct Manuring (Incorporation)	Cheaper alternative for farmers Improves organic matter content Improves soil capacity to increase yield Retains nutrient and moisture content of the soil Improves the NPK content of the soil Reduces the use of inorganic fertilizers Environmentally friendly
Indirect Manuring (Mulching)	Improves organic matter content Reduces erosion of top soil and soil nutrients Checks soil temperature Reduces evaporation Reduces leaching Reduces soil degradation Controls weed infestation Cheaper alternative for farmers Environmentally friendly
Compost	Improves organic matter content Amends soil Improves soil structure and productivity Reduces the use of inorganic fertilizers Cheaper alternative for farmers Environmentally friendly
Biochar	Improves organic matter content Retains soil moisture content particularly in sandy soils Improves on the physical and chemical properties of the soil Cheaper alternative for farmers Reduces the use of inorganic fertilizers Good for acidic soils Environmentally friendly

3.2.3. Fuel for Cooking (Energy)

Research by Karbo and Agyare [40] indicated that the stalks of most cereals are used as fuel. An example is the use of rice straw by women for firing kilns, which are used in making pottery. Most of these stalks are used as fuel for cooking especially in instances where firewood is scarce. Even though firewood is the main source of cooking fuel in rural communities in Ghana, cereal straw particularly sorghum straw is mostly used in parts of Northern region of Ghana as a source of fuel. Sorghum straw is preferred to other crop straw because it is much harder, burns well and lasts longer than other straws. However in some cases where sorghum straw is not readily available, millet and maize straw is used as a replacement. Kombiok et al. [57] emphasized that the Northern region of Ghana uses crop straw as a source of energy. The percentage of crop straw used for cooking against other cooking fuels in Ghana from 1990, 2000 and 2010, was 1.4%, 1.6% and 1.2% respectively [58]. According to Hagan [59], despite the fact that 50% of Ghana's energy source is derived from biomass at the household level, straw from maize, sorghum and rice constitutes the use biomass as cooking fuel. Research done by Akolgo [60] across all the 10 regions of Ghana reveals that 74% of the Ghanaian population use biomass such as charcoal, firewood, maize stalk and sawdust as cooking fuels. Out of a total of 74% of the Ghanaian population using biomass as fuel for cooking, the research disclosed that 2% of these population use maize stalk as cooking fuel. The use of maize stalk ranked fourth (4th) as a preferred cooking fuel nationwide. Maize stalk as fuel is mostly used in the northern part of Ghana specifically the Upper East and Upper West regions with a percentage use of 0.80% and 1.30% respectively. The survey indicated that apart from these two regions none of the remaining eight regions use maize straw as cooking fuel. A total of 73.9% women use maize stalk as cooking fuel as against a total of 26.1% men. Findings by Ansah and Issaka [48] in the Kumbungu District of the northern region of Ghana confirmed that maize straw is equally used as a source of fuel in these areas. Utilization of straw as a cooking fuel is still at the infancy stage, which has received less development over the years. Table 13 shows the advantages of straw as cooking fuel. The efficient recycling of straw as cooking fuel will help reduce the rampant cutting down of trees as fuel wood and charcoal, which will help to preserve the natural environment.

Table 13. Advantages of straw as cooking fuel.

No.	Advantages
1	Use as fuel to replace fuel wood and charcoal
2	Readily available in communities
3	Straw alternative source of fuel helps to reduce the rampant cutting down of trees for fuel wood and charcoal
4	Cheaper source of cooking fuel

3.2.4. Bedding for Mushroom Production

In Ghana, the production of mushroom has been in existence for ages. Since 1995, a total of 750 farmers have been trained in mushroom production. The Ministry of Food and Agriculture (MoFA) trains farmers on mushroom production at Asuansi, Adidome and Wenchi farm institutes. However, mushroom consumption in Ghana is very minimal making the demand for mushrooms lesser than the supply [61]. Mushrooms can serve as a substitute for meat with good nutritional content. It can also be used in curing diseases such as its application in traditional Chinese medicine, and currently about 6% of mushroom species are used for medicinal purposes [62]. Li and Zhou [19] noted that cultivating mushroom with straw is good technology, albeit the use of straw is small. However, with time as people's awareness of food safety and nutrition awareness grows, the mushroom industry enjoys a promising prospect with the use of straw as substrate in Ghana.

To increase the awareness and demand for mushrooms in the country, various educational programs on mushroom production is being organized for students by some educational institutions to inculcate the importance of mushroom production and also increase its consumption rate. Substrates

for mushroom production can be obtained from crop straw such as maize, wheat, cowpea and cotton straw in producing various types of mushroom particularly oyster mushroom. Practically, in Ghana, the use of sawdust (derived from wood) is a common substrate in producing mushrooms. Sawdust is not readily available in every corner of the country. However, the few people who cultivate mushrooms prefer to use sawdust instead of crop straw. The sawdust is already in its final state to be used as a medium for mushroom production unlike the straw, which needs to be processed to obtain a suitable texture as a growing medium. The production of mushrooms is not in high quantities compared to other advanced countries like China, which is the number one producer of mushrooms in the world. Even though sawdust is the common substrate for mushroom production in Ghana, some research has also focused on the use of straw as a growing medium. Adjapong et al. [63] researched on the use of sawdust, maize stalk and husk as a substrate for oyster mushroom. The maize stalk produced the highest number of fruiting bodies of 5.17 as against maize husk, which produced the least fruiting bodies (3.38). The outcome of the findings suggested that straw such as maize stalk has the potential of yielding good fruiting bodies either used solely or used as a supplement. The researchers suggested that using straw as a replacement for sawdust, which is a popular substrate in mushroom production in Ghana, would help address environmental and transportation issues involved in using sawdust. Sawdust needs to be transported from long distances to mushroom production centers, while straw is readily available in these vicinities. The study revealed that maize stalk is a suitable substrate for commercial mushroom production in Ghana and farmers can easily use it as a replacement for sawdust since it is readily available in every farming community in Ghana.

Kortei and Wiafe-Kwagyan [64] assessed the nutritional and anti-nutritional qualities of two varieties of mushrooms *Pleurotus ostreatus* and *Pleurotus eous* cultivated on rice straw substrate and the results were successful. Confirming the use of straw as a potential substrate in Ghana. *Pleurotus* spp. are highly nutritious and so the authors proposed that they can be adapted in Ghana and included in nutritional projects. A survey done by Kavi et al. [65] in the Greater Accra region of Ghana showed that about 92.6% of farmers cultivate oyster mushrooms (*Pleurotus ostreatus*). Table 14 shows the advantages of using straw as bedding for mushroom production. Given that the use of straw as substrate for mushroom production has been researched in Ghana, it has received minimal attention and not often practiced in Ghana.

Table 14. Advantages of straw as bedding for mushroom production.

No.	Advantages
1	Cheaper alternative
2	Readily available
3	Great potential of yielding fruiting bodies either solely or use as a supplement
4	Can be use as a replacement for saw dust
5	Addresses environmental and transportation issues involved in using saw dust

3.2.5. For Sale

Crop straw is considered a valuable farm asset in some parts of Ghana and serves as a source of income for farmers. Karbo and Agyare [40] indicated that most of the densely populated parts of Northern Ghana especially in the Upper East region generate income from crop straw by selling them or trading them for other goods. Most important among the straws are those of legumes (especially groundnut) and cereal stalks. The findings of their survey indicated that rice straw was sold normally in bales at 10 Ghana cedis (2 US dollars) for 100 Kg while sorghum or millet straw was sold at 50 Ghana cedis (9 US dollars) per 100 Kg in the northern part of Ghana. Other research by Amole and Ayantunde [46] indicated that pigeon pea haulms was one of the preferred straw sold at 0.50 Ghana cedis (0.08 dollars) for 150 Kg. Konlan et al. [66] researched findings outlined that the three northern regions in Ghana namely the Northern, Upper East and Upper West have witnessed the development of feed markets, which plays a pivotal role in the alleviation of feed shortage in urban areas. It was

revealed that feed sellers engage in the sale of straw from legumes and potato vines throughout the year particularly in the early dry season (November to January), late dry season (February to April), early wet season (May to July), late wet season (August to December) and also during special festivities. A total of 71.9%, 17.2% and 10.9% of the people interviewed in the Upper West (Wa), Upper East (Bolgatanga) and Northern (Tamale) regions admitted they make sales throughout the year. Groundnut haulms recorded the highest sales while sorghum straw was the least purchased. The peak sales of straw are in the dry seasons to meet feed demand for animal fattening and feed shortages where straw are sold in bundles packaged in bags. Cowpea and groundnut haulm recorded the highest mean price of 1.00 Ghana cedis (0.2 US dollars) and 0.62 Ghana cedis (0.1 US dollars) respectively in the Upper East region. The main reason for straw trading was due to income generation and feed shortage. Apart from these feed markets, most people indicated that the majority of straw is purchased at the community centers rather than the urban markets. 94% of the respondents indicated there is potential growth in feed trading due to increasing the livestock population.

Akolgo et al. [60] disclosed that part of the Ghanaian population is willing to purchase maize stalk as a cooking fuel while others are not. Out of the total Ghanaian population interviewed, 1.00% are willing to pay less than 20 Ghana cedis (>4 US dollars), 0.5% are willing to pay between 20–40 Ghana cedis (4–7 US dollars) and 0.10% are willing to pay between 41–60 Ghana cedis (7–11 US dollars) for maize stalk. Establishing the fact that people are willing to pay for straw as a form of cooking fuel. Table 15 highlights the advantages in selling straw. Sale of straw is a promising venture and a source of generating income for farmers. Albeit it is mostly practiced in the northern sector of Ghana, which needs to explored further.

Table 15. Advantages of selling straw.

No.	Advantages
1	Good source of generating income particularly in the dry season when farm activities are less
2	Sale of straw helps to meet feed demand for fattening ruminants
3	Addresses environmental issues related to straw burning
4	Can be traded in exchange for other goods at the community level

3.2.6. Other Uses

Crop straw is used for numerous purposes in some rural areas of the Northern region of Ghana and helps to improve the livelihood of farmers. Sorghum straw is the most common resource used for most of these other practices and the categories are:

- Fencing: The use of straw as a fencing material in peoples home or backyard gardens helps to prevent intruders or grazing animals, which are left on the free range system, to easily invade people's homes and gardens to destroy their crops. This is a common practice in the northern part of Ghana.
- Weaving mats and baskets: Straw materials are also used by local farmers and the weaving industries use them to manufacture mats popularly called "sori ko ejuma" (literally translated as wake up and go to work). Straw is equally used in weaving baskets [40]. Foodstuffs harvested from the farms are normally carried in these baskets, mostly on the heads of women and transported home. In some cases, the baskets are woven in the form of nests for fowls, which is used to transport them from one place to the other. Normally farmers prefer the use of sorghum stalk in weaving these products since it is more durable and flexible to weave, and also lasts longer. These mats and baskets are either woven for sale or for the household.
- Building and roofing material: Straw is also used as building materials in rural communities in Ghana where livestock are raised particularly in the northern part of Ghana. Amole and Ayatunde [46] indicated that in Duko in the Savelugu district in the Northern region, mud houses with straw roofing are provided for all classes of animal throughout the year where animals sleep

at night. The straw is also use in roofing huts, which serves as shelters for people to rest and relax. The roofs of these hats/sheds are also used as a platform for drying and storing farm produce such as cassava and cereals. Straws are also used as beddings in kraals for cattle especially in the savanna zone [49].

The numerous uses of straw to support human livelihood attest to the fact that it is an important resource, which needs to be focused on. There is the need to explore the efficient utilization of this resource to promote and support the daily needs of Ghanaians particularly the rural folks who are mostly deprived.

4. Discussion

4.1. Total and Regional Straw Yield Estimation

Our results showed that maize straw had the highest yield (48.2%) across the ten-year period (2006–2016) and this corroborates an earlier report by Otchere-Appiah and Hagan [23]. Majority of rural people of Ghana are engaged in maize farming and 90% of the national food consumption needs are met by local maize production [23]. Elsewhere, Cooper and Laing [67] reported that maize straw had a higher yield (3,753,465 metric tonnes) than rice straw (687,980 metric tonnes). This study revealed that the three principal crops used for straw production in Ghana were maize, groundnut and rice, accounting for 48.2%, 16.1% and 12.6% of the total straw generated in the country. This finding lends support to earlier reports [67,68] that maize, wheat and rice are the major straw producing crops in China and Africa. However groundnut is a major legume, which is cultivated and consumed throughout Ghana and this might have accounted for it being the second principal straw generating crop since wheat is hardly cultivated in Ghana. There was a steady growth rate in straw yield across the ten-year period. Notably, a similar result has been reported for China from 2000 to 2009 [68]. The percentage straw yield of 73.2% for cereals and 26.8% for legumes recorded agrees with Amoale and Ayantude [69] who indicated that the quantity of cereal straws generated yearly is more than legume straws generated. Similarly in China Ai et al. [5] showed that in 2013 there was higher records in the collectable amount of straw resources for maize and rice than any other straw representing 35.2% and 25.3% with an annual yield of $21{,}481.0 \times 10^4$ tonnes and $15{,}420.1 \times 10^4$ tonnes. The great variation in straw yield may be a result of low yields in Ghana due to the hoe and cutlass system of farming and over dependence of rainfall as against the mechanized and irrigation system of farming practiced in China. Estimation of the total straw yield of both cereals and legumes showed that groundnut straw recorded the second highest yield. However, this is not in agreement with other literatures and might be as a result of groundnut being cultivated in almost every region in Ghana with its high consumption rate compared to any other legume crop. The Brong Ahafo region of Ghana recorded the highest average straw yield of 697,503.9 and 665,403.3 in 2013–2015 and 2014–2016 respectively. This indicates the abundance of maize straw in this region, which can be used for developmental projects such as renewable energy [23].

The three years regional distribution of rice straw showed that the Volta region recorded the highest yield followed by the Northern region of Ghana. In addendum to this, a study by Issaka et al. [3] showed an estimated rice straw yield (quote the value) for the year 2007 in Ghana indicating that large amounts of rice straw is produced in the Northern region followed by the Volta. This might be a result of the difference in the number of sampling years. The Upper East region and Eastern regions also produced substantial quantities of rice straw. Our results affirm the availability of straw resources in Ghana, particularly in the major producing regions: Northern, Brong Ahafo and Volta regions for further exploration. Therefore, judicious utilization of these resources is a key to promoting sustainable development in the country.

4.2. Utilization of Straw in Ghana

We found that the current utilization of crop straw in Ghana is basically traditional and includes fuel for cooking (either directly or by producing briquettes, which are produced by compressing the material), animal feed, building material, mushroom production and animal bedding [34,70]. Similarly [71] pointed out that agricultural waste such as crop straw is mainly used for feed, fuel and also serves as an income source. Remarkably, crop straw is subjected to various use in different countries such as compost and mulch in South Asia [72], energy source in Mali [73], fertilizer in Egypt [25] and wind erosion control, roof construction, fences, granaries, beds and doormats in semi-arid sub-Saharan Africa. Omari et al. [74] alluded to the fact that a significant percentage (55%) of farmers leave crop residues as mulch after harvest. Our result strengthens the report by Turmel et al. [75] that the use of crop straw for soil management is bidirectional vis-avis surface retention and incorporation into the soil. Despite of the fact that there are variations in the benefits of retaining straw in the soil at every regional level, there are positive effects in the application of straw to the soil, which includes soil health and environmental benefits in the developing world there. The combination organic fertilizer made of crop straw and inorganic fertilizers as a best alternative to improving the nutrient content of the soil was alluded by Nigussie et al. [71] who highlighted that the integration of mineral fertilizers and organic amendments such as crop straw is the most sustainable option to increase agricultural production and soil organic matter. The use of biochar for yield enhancement agrees with Yang et al. [76] who indicated that the biochar application may enhance crop yield by holding more water in the soil in Northern China.

The use of crop straw as dry season feed for livestock as found in this study has been reported earlier [69]. A study by Kemausuor et al. [77] found that maize straw in some rural communities in Ghana have no competing uses and would be available for energy purposes. Bogale et al. [78] reiterate that crop straw is one of the major feed resources for livestock in Ethiopia particularly in the Sinana sub district. Their study recorded 81.4% responses of crop straw as the main feed source for livestock during the dry period January to April. The practice of farmers not treating straw before feeding their livestock was confirmed by Mclntire et al. [37] who stated that efforts to implement practices such as urea treatment have failed base on reasons that the practices might have been too laborious. The use of straw as a substrate for mushroom production has gained popular attention in tropical and subtropical countries. Highlighting that rice straw is a vital substrate for growing mushrooms and most commercial mushroom cultivation is usually carried out on straw [25]. Yang et al. [79] restated that in China straw is used to cultivate edible mushrooms in Tongcheng County, Anqing City and Lujiang County and Hefei City. Similarly Li and Zhou [19] also reaffirmed that the utilization of straw as a substrate for dibble fungi has been successful in China. The findings proved that in general 100 kg of straw could produce 160 kg of wet mushrooms or 60 kg black fungus. 100 kg corn stalk could produce 50–100 kg white fungus and 100–150 kg oyster mushrooms. In India research done on straw as a substrate for mushroom production also indicated that straw is a potential substrate for mushroom production in India where paddy straw recorded higher yield *Pleurotus platypus* and *Pleurotus ostreatus* when compared to other substrates with a bio efficiency percentage of 86% and 70% respectively [80].

4.3. Major Problems of Straw Utilization in Ghana

Currently the utilization of crop straw in Ghana is faced with numerous problems and has gained little attention over the years. Some of the challenges hindering the effective utilization of straw in Ghana can be categorized as:

4.3.1. Inadequate Policies and Incentives from the Government

There has been minimal attention from the government to invest in the different methods of straw utilization. The problem of straw utilization for fuel is solely based on direct combustion. Accurate estimation of crop straw yield at the districts, regional and national level is not available in Ghana

making it difficult to ascertain the yearly production of crop straw. The level of crop straw utilization is not precisely known and this makes it difficult to track its production and utilization. Hence, it is difficult to know the percentage growth of each utilization method. Financial support from the Government to research scientists on the quantification of straw resources and its efficient utilization is minimal likewise farmers are not provided with any incentives to promote straw utilization. This is because there has been less support from the government in promoting efficient and industrial utilization of straw. A draft on the bioenergy strategic document developed by Ghana does not prioritize second generation biofuels [21] confirming the less attention is paid to using straw as feedstock to produce biofuel. This development demands more research and financial support from the government to improve the efficient utilization of crop straw.

4.3.2. Underutilization of Straw

Straw is underutilized with its technology of utilization still at the infant stage. In Ghana, a significant percentage (55%) of farmers leave crop residues as mulch after harvest and such materials subsequently fuel the bush burning activities during the harmattan season [74]. Occasionally, farmers consciously or unconsciously burn crop straw either at the beginning of the farming season or through the spread of bushfires generated as a result of hunting. The burning of straw is hazardous to human health and ends up causing environmental pollution. However, in instances where straw is used as fodder, it is untreated making it difficult to digest and in some cases infesting livestock with diseases. Few farmers practice composting with majority of the farmers relying on direct application of straw on the farm. Decomposition of straw is difficult without the aid of inorganic fertilizer. This is because straw nitrogen content is low and the addition of nitrogen to soils will improve upon the decomposition of soil microorganisms. Straw is composed of cellulose, hemicellulose and lignin and it is difficult to digest [18]. Most of the utilization methods are at the traditional level and mostly practiced by rural farmers. Straw is considered as a byproduct and only used for simple methods of straw use [19], making the burning of straw a major challenge to tackle with.

4.3.3. Inadequate Education and Training

Farmers rely on indigenous knowledge gained over the years in practicing straw utilization with little education from agriculture extension agents or other stakeholders. In Ghana few farmers get access to agriculture extension trainings. Most of the trainings given to farmers are based on improving productivity based on good agronomic practices with less attention of the management of straw resources.

4.3.4. Difficulties in Collection and Storage

Majority of farmers in Ghana are small-scale farmers with their farms spread out in different locations. The distance from their homes to farms is also very far and most women farmers normally travel to their farms by foot while the men use either bicycles or motorbikes. This long distance between a farmer's home and their farms makes it the transportation of straw back home difficult because less attention is given to straw utilization, and this is further exacerbated by the lack of straw storage systems. Further, the bulky nature of straw makes their transportation difficult and this inhibits the use of straw to feed animals.

5. Conclusions

Crop straw is an important biomass, which is readily available in Ghana. Our result for the 10-year period (2006 to 2016) shows that there were abundant straw resources in Ghana particularly in the Brong Ahafo and Northern regions where cereals and legumes straw were available in large quantities. We found that within the 10-year period, maize, groundnut and rice were the principal crops used to generate straws in Ghana at 48.2%, 16.1% and 12.6% respectively. However there was a steady growth in the production of straw in Ghana within this period. Crop straw is however underutilized in Ghana

and this is mainly due to the traditional methods of utilization currently being practiced. Recycling of crop straw will be an environmentally friendly and good alternative source of rural energy for the country.

Efficient utilization of crop can play an important role in the socio-economic development of Ghana in a sustainable fashion. The continuous availability of a crop straw resource will improve the viability of efficient straw utilization in Ghana. For the past years agriculture continues to be the mainstay of Ghana's economy, which has been growing progressively. There is the need to combine old and new methods of straw utilization to help improve upon Ghana's agricultural tradition. Efficient recycling of crop straw will reduce pollution and ensure a less hazardous environment, since there will be a decline in the high rate of burning, which normally occurs after farmers harvest their crops mostly in the dry season or at the beginning of the farming season. However the use of straw should translate into increased food productivity and ensure that farmers earn more income hence, the need to efficiently promote straw as a soil management option. Within the rural settings in Ghana the second source of income for farmers is the rearing of livestock, which receives more attention in the dry season when there are no farming activities. Investment in straw as an important resource in the livestock industry will go a long way to relieve farmers of their financial burdens. The tree industry has faced major crises over the years since rural farmers mainly rely on firewood and charcoal as a source of cooking fuel. Meanwhile, promoting the use of straw as a source of fuel can bring a huge relief to the tree industry. Therefore, the government should encourage and promote new and improved technologies of using straw as a cooking fuel to reduce the rate of deforestation. The effective utilization of crop straw in Ghana will help the country to achieve sustainable development through the agriculture, environment and the energy sectors (shown in Figure 5).

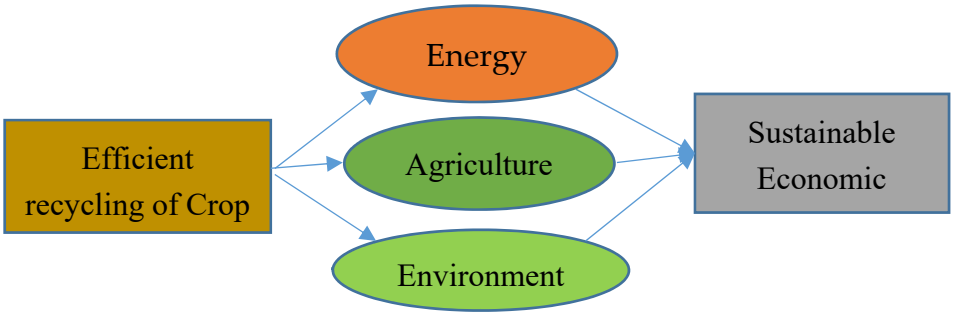

Figure 5. A framework of benefits of efficient recycling of crop straw.

However, the government needs to play an active role to ensure this is achieved. We put forward the recommendations for governments' intervention in two categories, namely:

- Agriculture and Environment;
- Energy.

Agriculture and Environment

- There is need for policies on the comprehensive utilization of straw by considering this resource as an important input for organic fertilizer production (compost, biochar), as well as feed supplements for livestock. Efficient utilization methods of straw as a soil and livestock management option will benefit the nation's agricultural sector and promote the production of more food to feed the nation, with export opportunities.
- The combined use of fungi and enzymes through physical and chemical treatments to improve the nutritive value of straw will make it more edible for livestock [81].
- Develop policies to promote industrialization of crop straw and start a baseline survey to record straw yield at the district, regional and national level coupled with documentation of the methods

of utilization. This will help the government to know the percentage growth in the various utilization methods and the necessary gabs that need to be filled.

- Provide financial support to scientists who research into crop straw to be able to come up with new and innovative ways of straw utilization as well as standardize the quantity of straw that needs to be incorporated into the soil. More field surveys are needed to strengthen Ghana's straw research field.
- The government through the Ministry of Food and Agriculture (MoFA) should sensitize and train farmers on the importance and methods of crop straw utilization. Demonstration plots should be established to this effect.
- Enact policies to ban crop straw burning and illegal cutting down of trees.

The government needs to improve upon the transportation system in rural areas where most of these straws are produced. The poor and inaccessible nature of roads in these areas makes the transportation, usage and storage of straw difficult for farmers.

Energy: Improving on the energy sector through renewable energy. The use of straw as a raw material in the energy sector is a laudable idea since it is readily available in the country. Ghana's Renewable Energy Act promotes the use of biomass as a source of energy, particularly in rural settings. The field of using second generation feedstock as a renewable source of energy is a handicap even though agricultural residues such as straw is readily available in almost every part of the country [77]. Crop straw charcoal briquettes: Producing crop straw charcoal briquettes can be used for direct combustion as a cooking fuel. It can be used to replace wood charcoal that encourages the constant cutting down of trees. Straw charcoal briquettes are smokeless with a longer burning duration and its cost of production is less compared to wood charcoal briquettes [2].

- Biogas: Promote the use of crop straw for biogas and as a second generation biofuel. Biogas technology creates/provides a way to renew agricultural residues such as crop straw into a sustainable form of energy, which has no negative impact on human health and the environment [82].
- Electrification and Gasification: Develop policies to decentralize electrification and gasification using crop straw. For Ghana to achieve universal electrification and produce 10% of electricity from renewables, there is a need to consider crop straw for decentralized electrification, as a measure to improve upon its rural electrification system. Rice straw combustion is a viable grid-connection option in all regions, as the bio-energy feed-in-tariff is 29.5 US cents/kWh in Ghana [83].

Gasification, which converts crop straw into to combustible gas, can be used for small-scale decentralized power generation projects. This is a potential for more efficient conversion process when generating power [84]. The Brong-Ahafo and Northern regions are potential areas for the establishment of straw processing plants since there are abundant straw resources in these areas. Establishing the straw processing plants will serve as a source of income for some people and ensure its effective processing and utilization. These processing factories at the district levels can also help to generate power, which can help resolve the current energy crises Ghana is facing at the district level without depending solely on hydroelectric power from the national grid. Ghana's energy crises have reached a critical stage, which has resulted in it being referred to as "DUMSOR" (meaning off and on). The efficient utilization of straw will help resolve the countries energy crises and improve upon the agricultural sector. The establishment of the straw biomass industry to generate energy in Ghana will help create employment for people especially at the district levels and this will help address the high rate of unemployment Ghana is currently facing.

- Partnership with other countries like China who are into comprehensive utilization of straw to learn lessons from them and tap into other areas of straw utilization such as paper-making is worthwhile. There is a great potential in the utilization of straw in the paper industry, hence, the government should promote key technologies for its efficient utilization and gain more opportunities to

diversify in other fields. This will help to reduce the high rate of paper importation Ghana is currently facing.

The continuous development of an economy must translate into viable technologies that are capable of sustaining its growth. Hence the effective utilization of crop straw resources in Ghana will reduce soil erosion and degradation to help transform the agriculture, environment and energy sectors to ensure there is a successful growth in the socio economic development of the country.

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