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BIOMASS ENERGY POTENTIAL FROM AGRICULTURAL PRODUCTION IN SUDAN

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Abstract

The objective of this study is to determine the agricultural residues potential regarding type and quantity in Sudan. Sudan was divided into six main regions. The amounts of crops cultivated in Sudan in tons of dry matter per year, were calculated and estimated using production data crops with Food and Agriculture Organization Statistical Databases of United Nation (FAOSTAT) for the 2016 seasonal year. The annual gross potential of agricultural residues was determined by using residue to product ratio. The energy potential of crop residues for each region was calculated by multiplication of the calorific values of agricultural residues with available residue amount. The total amount of unused agricultural crop residues was approximately 11.2Mt. It was found that the total calorific value of agricultural residues were around 154PJ for the production period of 2016 in Sudan. When regions were placed in order according to amount of agricultural residues, the top three regions of the country are central Sudan (4.5Mt), eastern Sudan (4.2Mt), and northern Sudan (1.4Mt). The major crops included in the ratio of the total calorific value were sorghum (43.2%), mango (28.1%), millet (13.6%) and wheat (6%).

Anahtar Kelimeler
Agriculture, renewable energy, residue, Sudan.

Özet

Sudan'da Tarımsal Üretim Sonucu Oluşan Biyokütle Potansiyeli

Bu çalışmanın amacı, Sudan'da çeşit ve miktar bakımından tarımsal atık potansiyelini belirlemektir. Sudan altı ana bölgeye ayrılmıştır. Sudan'da yıllık üretilen ürün miktarları kuru madde olarak ton biriminden FAO'nun 2016 yılına ait istatistiksel veri tabanı kullanılarak hesaplanmıştır (FAOSTAT). Tarımsal atıkların yıllık brüt potansiyeli atık/ürün oranına göre tespit edilmiştir. Her bölge için ürün atıklarının enerji potansiyeli, tarımsal atıklarının ısıl değerlerinin mevcut atık miktarı ile çarpılmasıyla hesaplanmıştır. 2016 yılı için kullanılmayan toplam tarımsal atık miktarı yaklaşık olarak 11.2 Mt ve bu atıkların toplam ısıl değeri yaklaşık olarak 154 PJ olduğu hesaplanmıştır.Bölgelere göre en fazla tarımsal atık miktarları Sudan merkezi (4.5 Mt), doğu (4.2 Mt) ve kuzey Sudan (1.4 Mt) olarak belirlenmiştir. Toplam ısıl değerioluşturan olan başlıca ürünler sorgum (%43.2), mango (%28.1), darı (% 13.6) ve buğdaydır (%6).

Keywords
Tarım, yenilenebilir enerji, atık, Sudan.

1. INTRODUCTION

Energy is central to economic development, and there is a clear correlation between energy consumption and living standards. Energy sources are divided into three categories: fossil fuels, renewable sources and nuclear sources (Karaca, 2015).The demand for energy resources is increasing day by day and human beings for the desire of living modernly parallel to the technological changes in the world (Demirel and Gürdil, 2014). Energy consumption with no doubt increases rapidly with the increase in population; increase in comfort standards, and with developments in industry and technology. Fossil fuel resources is exhausting day by day and nuclear energy still has security problems so, the best way is to focus on renewable energy sources which we have everywhere and every day. Concerning huge agricultural production in the world, biomasses in terms of agricultural residues will a useful solution (Demirel and Gürdil, 2018).

Sudan relies mainly on fossil fuels, which are limited resources, collected in few regional areas of the world. Sudan's rapid population growth and its increasing pressure on these resources are posing a considerable challenge. Available biomass energy resources in Sudan should be a major issue for the future strategic energy planning for the alternative to the fossil conventional energy to provide part of the local energy demand (Abdeen, 2005; NEA, 1998)

The economic development of a country is dependent upon sustainable use of natural resources. Sudan recognizes the need to pursue the development of policies and strategies that are friendly to the environment in order to ensure sustainable growth, but more support (technical and financial) is needed to overcome the major obstacles by central government (FAOSTAT, 2016).

Sudan meets approximately 87% of its energy needs with biomass. During the last two decades, there was a problem of drought and desertification, which was the result of the removal and cutting of the vegetation for the purpose of mechanized agriculture and fuel-wood production. The total area and volume of Sudan's forestry resource are 190,355 km^2 and 1.966Mm^3, respectively (FAO, 2016). About 70% of this was located in the southern region, and the forestry area decreased towards the north of Sudan (GTZ, 1985).

Sudan, like most of the oil importing countries, suffered a lot from sharp increases in oil prices in the last decades, spending most of its hard currency earnings on importing oil, whilst failing to meet the increasing demand. The oil bill consumes more than 50% of the income earnings. The oil share is only 12% of the total energy consumption. Biomass (wood-fuel, agricultural residues and animal waste) utilized as fuel source is dominating Sudan's energy picture, accounting for about 87% of the country total energy consumption (Abdeen, 2005; Hood, 1994).

In this study an estimation of the amount of energy production from agricultural residues was calculated.

2. MATERIALS AND METHODS

The total agricultural land of Sudan is 136245x10^3hectares, arable land (19823160 hectares), land under cereal production 12424860 hectare, and forest area (192099 km^2). Sudan has good resources especially in water, land agriculture and livestock. These dimensions show the potential of biomass energy resources in Sudan (Omer, 1998; NEA, 1985).

Biomass is the most consumed type of energy (i.e. wood fuel, animal waste, and agricultural residues). Sudan has a significant crop residue base. The main crop residues suitable for energy use in Sudan are cotton stalks, groundnut shells, sugar, wheat, sorghum, millet, sesame tobacco, and many other different crops. (NEA, 1998).

The amounts of residues from the main crops cultivated in Sudan were calculated using production data of crops with Food and Agriculture Organization Statistical Database (FAOSTAT) for the 2016 seasonal year. The annual gross potential of agricultural residues was determined by using residue to product ratio (RPR) Table1 (Karaca, 2015).

The net potential of residues was determined by using the availability of residues. The availability of residues is unused and completely wastes part of residues (Table 1). The available potential of the agricultural residues in each region in Sudan was calculated based in Equation1 (Karaca et al., 2017a; Karaca et al., 2017b).

$$(AAR) = (AAP) * (RPR) * (A) \quad (1)$$

Where (AAR) is the available amount of agricultural residues of crop in ton, (AAP) the amount of agricultural product in tons, (RPR) residue-to product ratio and (A) the availability of residues.

Table 1. The ratio of product to residue, Availability and heating values of a selection of agricultural residues (Abdeen, 2008; Adams, 1995; ECN, 2010)

FC	R	RPR	A(%)	LHV(MJkg^{-1})
Cotton	Stalks	2.70	60	18.61
Groundnut	Shells	0.48	40	15.66
Sugar cane	Tops	0.30	40	18.00
Wheat	Straw	0.80	15	18.20
Sorghum	Straw	1.25	60	12.38
Millet	Straw	1.75	60	12.39
Sesame	Straw	0.50	56	12.40
Tobacco	Stalks	0.70	60	17.30
Fruit Crops				
Bananas	L/S	0.70	60	15.9
Mango	Seeds	0.50	80	15.0

FC: Field Crops, R: Residues RPR: Ratio of Product to Residue, A: Avability, LHV; Lower Heating Value (MJ.kg^{-1}), L/S: Leaves/Stems

After any agricultural production, there are Agricultural residues left over the field, some of which have already been used for domestic purpose like: heating, feed for animals, bedding, and as firewood. The residues from the production of Agricultural, industrial products are left over the field.

The energy potential of residues for each region was calculated by multiplication of the heating values of selection of agricultural residues which was taken

heating value per each residues(Table1) with the available residue amount (Equation2) (Karaca et al., 2017a; Karaca et al., 2017b).

(THV) = (AAR) * (LHV) (2)

Where (THV) the total heating value of agricultural residues of crop in GJ, (AAR) is the available amount of agricultural residues of crop in tons and (LHV) lower heating value of air dry residues of crop in $MJ.kg^{-1}$.Sudan was divided into six main regions. The energy content of the selected product for each region was calculated using the above equations.

3. RESULTS AND DISCUSSION

The total amount of agricultural residues, including annual crop residues (wheat, groundnut, sugarcane, cotton, sorghum, millet, sesame, tobacco) and fruit residues (bananas, mango), were calculated to be about 11.2 million tons in Sudan (Table 2).

Table 2. The amount of agricultural product and available residues in Sudan

FC	AAP	R	AR
Cotton	4572	Stalks	7406.64
Groundnut	186000	Shells	350592
Sugar cane	5525059	Tops	663007
Wheat	516000	Straw	61920
Sorghum	6466000	Straw	4849500
Millet	525000	Straw	1521450
Sesame	525000	Straw	147000
Tobacco	182888	Stalks	76813
TOTAL			**7677688.64**
Fruit Crops			
Bananas	910110	Leaves/Stems	382246
Mango	7885940	Seeds	3154376
TOTAL		Residues	**11214310.64**

FC; Field crops, AAP; Amount of agricultural product (tons), R; Residues AR; Available residues (tons)

The residues distribution by the source is field crops (68.5%) and fruit crops (31.5%). Major crops that included in the ratio of the total residue amount are sorghum (43.2%), mango (28.1%), millet (13.6%) and wheat (6%).

When all regions of Sudan aligned according to the amount of agricultural residues, an alignment was as in Table3.

Table 3. The alignment of regions according to amount of agricultural residues

Regions	FCR	TR	STR	STR
Central	3838162	630867	4496029	40.1
Eastern	3828141	382246	4210387	37.5
Northern	288	1433705	1433993	12.7
Southern	1464	630867	632331	5.6
Darfur	6901	305958	312859	2.7
Kurdufan	2733	152979	155712	1.4
Total	**7677689**	**3536622**	**11214311**	**100**

FCR; Field crop residues (tons), TR; Total residues (tons), STR; Share in total residues(tons), STR%; Share in total residues (%)

The total production of agricultural residues in Sudan regions is about 11.2million tons annually, but it may be noted that there is a wide variability of crop residues within the regions. Central Sudan and Eastern Sudan regions produce maximum crop residues (about 4.5Mt, 4.2 Mt, respectively) followed by Northern Sudan region (1.4Mt), Southern Sudan (0.63Mt). The majority of agricultural residues are produced from these areas due to the existence of the large agricultural schemas. It is clear that there is no any shortage of raw materials in Sudan to produce energy from agricultural residues. It was calculated that the total heating value of agricultural residues was about (154PJ) for the production period 2016 in Sudan. The heating value of agricultural residues that calculated separately for each product is given in Table 4.

Table 4. Total heating values of agricultural residues in Sudan Region

Field Crops	Residues	Total Heating Value (GJ/kg)
Cotton	Shells	137837.6
Groundnut	Shells	5490270.7
Sugar cane	Tops	11934126
Wheat	Straw	1126944
Sorghum	Straw	60036810
Millet	Straw	18850765
Sesame	Straw	1822800
Tobacco	Stalks	1328864.9
Fruit Crops		
Bananas	Leaves/Stems	6077711
Mango	Seeds	47315640
TOTAL		**154121769**

4. CONCLUSION

The aim of this study was to calculate the amount of agricultural residues in Sudan. Although there are many alternative energy sources in Sudan, Sudan imports energy from abroad, this is why this paper is very important. Now a day the best solution for developing countries is to convert energy from agricultural residues and use it to reduce energy shortage problems. In this study crops like (Sorghum, Millet, Sugarcane, Groundnut, Sesame, Cotton, Tobacco, Wheat, Bananas and Mango) have been identified for energy production. Despite the biomass density varies among different crops and regions in Sudan, the total biomass amount can produce a significant amount of renewable energy. In this paper, the total heating value of agricultural residues was about (154 PJ) for the mentioned crops in six regions of Sudan. It is worth mentioning here that agricultural residues are a very important and economical source of energy production in Sudan.

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