Introduction

In the 21st century, a large amount of energy is supplied by fossil fuels which create crucial problems including climate change, and deforestation. Utilization of fossil fuels is one of the environmental deterioration and consequently ecological variations are the essential problems to be solved out. Accumulation of Green House Gas (GHG) emissions in the atmosphere, destruction of ozone layer and accordingly, global warming and a lot of interrelated developments from extinction of biodiversity air and water pollution, have unfortunately become threatening. As being one of the most important GHG emission accumulated in the atmosphere, CO$_2$ causes other environmental problems such as acidification in oceans, besides climate change.

The primary reason of green house gas accumulation in the atmosphere is CO$_2$ emissions. Combustion of fossil fuels causes about 75% of human-caused CO$_2$ emissions (Bilen 2008). Therefore, renewable energy sources are receiving attention because of the environmental advantages they provide in comparison with conventional energy sources. These technologies can be substituted for conventional energy sources and limit damage to the environment (Menanteau 2003).

Among the renewables, biomass is an effective and environmentally friendly source to produce both green energy and useful bio-products. One of the products, biochar is the carbon-rich solid material that occurs during the thermochemical conversion of biomass in the absence of oxygen; namely pyrolysis. As biochar provides significant environmental benefits and contributions to soil fertility, production of biochar for soil improvement can become another essential way to capture carbon dioxide from the atmosphere. A number of small-scale trials, especially on nutrient-poor soils, have demonstrated increased crop yields, improved soil water-holding capacity, reduced fertilizer requirement and significantly reduced emissions of GHG. On the basis of biochar’s properties, there are various undiscovered research subjects in this field. Therefore, biochar production and its soil applications become an attractive research area for many scientists studying the climate change mitigation.

The FOREBIOM is a joint KORANET project under the collaboration of Austria, Turkey and Korea. Our research objectives in this project are to promote biochar activity to mitigate climate change, to supply high efficiency in forestry, and to allow bioenergy sector to progress and succeed in these countries. Moreover, three workshops were organized in Vienna, Busan and Eskişehir to expand the production and utilization of biochar for climate change mitigation in the frame of FOREBIOM project. The 3rd Workshop was held in Eskişehir on June 5-6 of 2014 in order to enhance collaboration among the national and international researchers in this area of research. During this workshop, possibility of further project collaborations and preparations for Horizon 2020 were discussed. An abstract book was published and posted at the web-site of the FOREBIOM. Well known researchers from different countries were participated in FOREBIOM workshops and their knowledge and experiences on the subject were shared in a friendly atmosphere. FOREBIOM workshops led great motivations and exciting research ideas for future studies as a result of broad range of research discussions and diversity of the study areas of the participants.

As one of the consequences of the FOREBIOM project, this country case report presents some information about the evaluation of biochar production in Turkey for soil improvement and mitigation of climate change. Particularly, special emphasize is given to potential biomass sources for bio-energy production and pyrolysis studies and technologies in Turkey.

1. Overview of the energy situation in Turkey

Turkey has been one of the fast growing markets of the world for the past decades, due to its young population, growing energy demand, fast urbanization, and economical development. As a result of this rapid growth, electricity demand of Turkey has also increased by almost two-fold since 2000 and has reached to 250.4 TWh by the end of 2014 (EMO, Toklu 2013). Turkey’s primary energy resources for the production of electricity are natural gas, oil, coal, hydro, and other renewables such as geothermal, wind, solar and biomass. The primary energy consumption by fuel in Turkey between the years
1980–2012 is given in Fig. 1. As seen from the figure, fossil fuels are the main primary energy sources in Turkey and the share of natural gas in the consumption has increased rapidly for the last decade. Energy consumption has been increasing year by year continuously with an average annual increase of 4.3%. Unfortunately, around 74% of total energy consumption met by imported fuels especially natural gas, oil and coal (Kaygusuz 2009). It is clear that renewable energy technologies should be implemented efficiently in Turkey for reduction of the foreign dependency and environmental concerns.

2. GHG emissions and renewables

Turkey is heavily dependent on costly imported fossil energy resources with negative effects on both the economy and air pollution for our country. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey’s geographical location has several advantages for potential and diversity of these renewable energy sources. Although Turkey is very rich in terms of renewable sources which are mainly hydro, biomass, wind, solar and geothermal energy, only 14% of total energy demand was corresponded by renewable energy sources in 2011 (MENS, 2013).

Today, the law in Turkey promotes the using of renewable energy. Therefore, the politics about renewable energy in Turkey are framed with the law on utilization of renewable energy sources for the purpose of generating electrical energy. Within the scope of this law, the utilization of renewable energy sources expands to benefit from these resources in a secure, economic and qualified manner, to increase the diversification of energy resources, to reduce GHG emissions, to assess waste products, to protect the environment and to develop the related manufacturing industries for realizing these objectives (Law No.: 5346).

Turkey uses mainly fossil fuels to produce electricity (Toklu 2013). According to Ministry of Energy and Natural Resources’ strategic plan, it is aimed that 30% of total electricity production will be provided from renewable sources in 2023 (WWF 2011). Moreover, there are incentives given to renewable energy source based industries by government. According to the Table 1, the highest incentive is given to biomass and solar energy based production systems. Production of electricity both biomass and solar based energy would be an economically feasible option for sustainable development in Turkey.

Turkey has been undergoing major economic changes in the 1990’s, marked by rapid overall economic growth and structural changes (OECD). Since 1990, energy consumption has increased at an annual average rate of 4.3%. With respect to global environmental issues, Turkey’s carbon dioxide (CO$_2$) emissions have grown along with its energy consumption. As would be expected, the rapid expansion of energy production and consumption has brought with it a wide range of environmental issues at the local, regional, and global levels. To meet the goals of the Kyoto agreement, Turkey must reduce GHG emissions to a level 7% below the 1990 emissions in 2010 (Keleş 2012). CO$_2$ emissions in 2000 reached 211 million metric tons and increased to 315 million metric ton in 2012. According to Turkish Statistical Institute data, total GHG emissions increased to 422.4 million tonnes CO$_2$.

Table 1: The incentives are given to renewable energy based industries by government in Turkey (CDA 2012)

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Feed-in Rates ($)/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroelectric based</td>
<td>7.3</td>
</tr>
<tr>
<td>Wind energy based</td>
<td>7.3</td>
</tr>
<tr>
<td>Geothermal energy based</td>
<td>10.5</td>
</tr>
<tr>
<td>Biomass energy based</td>
<td>13.3</td>
</tr>
<tr>
<td>Solar energy based</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Figure 1: The primary energy consumption by fuel in Turkey.
equivalent in 2011. Overall, 2011 emissions the energy sector had the largest portion with 71%, followed by industrial, waste and agricultural sectors with 13%, 9% and 7% respectively (TUIK 2015).

In order to mitigate climate change and to alleviate its effects, a drastic reduction of CO\textsubscript{2} emissions is necessary. The main solution is to use renewable, energy efficient, and CO\textsubscript{2}-free power production as soon as possible (Bilen 2008).

3. Biomass potential in Turkey

Biomass has been recognized as a major renewable energy source to supplement declining fossil fuel resources (Önal 2014). Biomass energy involves any organic sources such as fuelwood, agricultural residues, animal wastes etc. Various agricultural residues such as grain dust, wheat straw, and hazelnut shell have high potential in Turkey as the sources of biomass energy. Among these biomass energy sources, woody biomass is one of the most important, because its share of the total energy production of Turkey is about 21% (MFWA 2007).

Turkey’s total agricultural area is 23,063,000 ha and of this, about 38% is plantation, 45% is forest, 10% is fallow area and 7% is vegetable area (GDF 2013). The total forest potential of Turkey is around 940 million m\textsuperscript{3}, with an annual growth of about 25 million m\textsuperscript{3}. The total recoverable bioenergy potential was estimated at 16.8 Mtoe in 2000 and 14.2 Mtoe in 2008. (Toklu 2013).

Main agricultural residues in Turkey with their potentials and calorific values are listed in Table 2. The total energy value of agricultural residues is 228 PJ with mostly corn, wheat and cottonwool (Saracoglu 2008).

Table 2: Total agricultural residues in Turkey with calorific values (Saracoglu 2008)

<table>
<thead>
<tr>
<th>Product</th>
<th>Type of the waste</th>
<th>Useable wastes (ton)</th>
<th>Calorific value (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Straw</td>
<td>3,514,486</td>
<td>17.9</td>
</tr>
<tr>
<td>Barley</td>
<td>Straw</td>
<td>1,344,452</td>
<td>17.5</td>
</tr>
<tr>
<td>Rye</td>
<td>Straw</td>
<td>53,706</td>
<td>17.5</td>
</tr>
<tr>
<td>Oat</td>
<td>Straw</td>
<td>48,115</td>
<td>17.4</td>
</tr>
<tr>
<td>Corn</td>
<td>Stalk&amp;cob</td>
<td>4,126,539</td>
<td>18.5</td>
</tr>
<tr>
<td>Rice</td>
<td>Straw&amp;hull</td>
<td>187,917</td>
<td>15</td>
</tr>
<tr>
<td>Tobacco</td>
<td>Stalk</td>
<td>246,467</td>
<td>16.1</td>
</tr>
<tr>
<td>Cotton</td>
<td>Stalk&amp;gin</td>
<td>2,097,945</td>
<td>17</td>
</tr>
<tr>
<td>Sunflower</td>
<td>Stalk</td>
<td>1,355,472</td>
<td>14.2</td>
</tr>
<tr>
<td>Soybean</td>
<td>Straw</td>
<td>131,123</td>
<td>19.4</td>
</tr>
</tbody>
</table>

For many years especially woody biomass and animal wastes have been used for combustion processes. These sources are utilized as primary fuel in rural and urban poor districts. Conventionally, animal wastes are mixed with straw to increase the calorific value, and are then dried for use (Toklu 2013). However, converting biomass and/or animal wastes into more valuable products via thermochemical processes is more efficient than direct combustion in terms of not only economical aspects but also environmental benefits.

4. Biomass energy technologies in Turkey

Biomass can be converted to different types of final energy such as power (electricity) and...
heat (charcoal and producer gas). There are four main thermochemical conversion methods to gain energy from biomass: combustion, pyrolysis, liquefaction, gasification. In Turkey, direct combustion of biomass has been used for many years by using fuel wood, animal wastes, agricultural crop residues and logging wastes. There have been 32 biomass plants whose licenses granted by EPDK (Energy Market Regulatory Authority), with a total capacity of 158 MW in Turkey (Olgun 2013).

In 2008, Turkey’s first biomass combustion plant was put into operation. The plant with a a 28 MW thermal and 6 MW electrical capacity was built in Caycuma, Zonguldak. The outputs of the plant were utilized by the owner of the plant, OYKA which is a paper production factory. In this plant, electricity and heat energy are produced by burning 70,000 ton biomass annually. By this way, the energy needs of paper factory reduced to about 70%. In Turkey, nearly almost heat and/or power plants based on biomass were established by MIMSAN Group. As shown in Table 3, MIMSAN Group instituted several power plants which have totally 109.5 MW capacity and in these plants wood bark, sunflower seed hulls, tea wastes, cotton hull and sawdust are utilized as the biomass raw materials (Karayilmazlar et al. 2011).

### Table 3. Biomass based plants constituted by MIMSAN Group

<table>
<thead>
<tr>
<th>Plant name</th>
<th>City</th>
<th>Fuel type</th>
<th>Electricity generation (MW)</th>
<th>Heat capacity (MW)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paymar Oil Company</td>
<td>Hatay</td>
<td>Cottonwool waste, oil, coal</td>
<td>-</td>
<td>8.3</td>
<td>2006</td>
</tr>
<tr>
<td>Trakya Birlik Company</td>
<td>Bursa</td>
<td>Sunflower hull, coal</td>
<td>-</td>
<td>5.5</td>
<td>2004</td>
</tr>
<tr>
<td>Çaykur-Pazar Tea Factory</td>
<td>Rize</td>
<td>Tea waste, coal</td>
<td>-</td>
<td>10.4</td>
<td>2006</td>
</tr>
<tr>
<td>Akfa Tea Factory</td>
<td>Giresun</td>
<td>Tea waste, coal</td>
<td>-</td>
<td>10.4</td>
<td>2007</td>
</tr>
<tr>
<td>Meray Oil Factory</td>
<td>Merzifon</td>
<td>Sunflower hull, coal</td>
<td>-</td>
<td>6.9</td>
<td>2008</td>
</tr>
<tr>
<td>Vezirköprü Forest Products</td>
<td>Samsun</td>
<td>Wood shell, sawdust, coal</td>
<td>-</td>
<td>2*12.5</td>
<td>2008</td>
</tr>
<tr>
<td>Oyka Paper Company</td>
<td>Çaycuma</td>
<td>Wood shell, sawdust, cake, coal, natural gas</td>
<td>6</td>
<td>28</td>
<td>2008</td>
</tr>
<tr>
<td>Gitaş Oil Factory</td>
<td>Konya</td>
<td>Sunflower hull, coal</td>
<td>-</td>
<td>6.6</td>
<td>2009</td>
</tr>
<tr>
<td>Marmara Agricultural Oil Factory</td>
<td>Bandirma</td>
<td>Sunflower hull, coal</td>
<td>-</td>
<td>8.4</td>
<td>2007</td>
</tr>
</tbody>
</table>

Another power plant with 20 MW-e capacity was established in Ankara-Mamak. The plant uses landfill gas generated by garbage. It has started with 5 MW and now reached its Maximum capacity of 20 MW. Similar potentials exist in large municipalities such as Istanbul, Izmir, Bursa, Adana and Antalya. The electrical production from usable biomass (about 17 Mtoe/year) has a net impact of $4.4 billion in personal and corporate income and represents more than 160,000 jobs (GDF 2009).

Gasification and pyrolysis are frequently used methods to produce a fuel from biomass as a secondary energy source. Gasifiers are used to convert biomass into a combustible gas (synthesis gas). The produced bio-gas is then used to drive a combined cycle gas turbine efficiently (Demirbas 2002). In Turkey, Marmara Research Institute (TÜBİTAK) has a lot of national and international projects about gasification of biomass and biomass-coal mixtures and fuel characteristics. Moreover, it has many collaborations with industry and universities to develop efficient clean energy systems in pilot scale.

### 5. Pyrolysis and bio-oil

Pyrolysis is the thermal decomposition of organic wastes in absence of oxygen at elevated temperatures. Yields of solid (biochar), liquid (bio-oil) and gaseous products (low- and medium caloric value gases) depend on a number of factors,
such as feedstock type and process conditions. Bio-oil is easier to store and transport than solid biomass material, and it is usually used to generate electricity via combustion (Demirbas 2000). The quantity of the pyrolysis oil varies from 36 to 80% depending on the technology used. Especially, fast pyrolysis (at high heating rates and low residence times) increases the oil yields up to 80%. Design variables such as feed pretreatment, reactor configuration, heat supply and transfer, heating rates, reaction temperature, vapor residence time, secondary cracking, char separation, ash separation, and liquid collection are very important to achieve high liquid production (Mohan 2006). Pyrolysis can also convert biomass into value added chemicals besides fuels such as phenolic oil, a chemical used to produce wood adhesives, molded plastics and foam insulation. Wood adhesives are used to glue together plywood and other composite wood products (Demirbas 2001, Noah 1988, Oksman 1996).

6. Biochar

Biomass had been used as a solid fuel especially for domestical heating from ancient times. However, high ash content and relatively low heating value of biomass makes it inefficient for direct combustion processes. On the other hand, pyrolysis seems to be an advantageous thermochemical conversion processes to convert biomass into valuable products. Biochar is the carbonized solid by-product obtained from the thermal decomposition of biomass under oxygen-free conditions. With its high carbon content and accordingly high calorific value, biochar also had been utilized as an alternative solid fuel for direct combustion as biomass. As a result of industrial development and environmental needs, utilization of biochar is expanded to various areas such as environmental management, soil improvement, waste management, climate change mitigation and energy production. In recent years, the potential role of biochar in improving soil properties while sequestering carbon and reducing GHG emissions to mitigate climate change has garnered attention by researchers (Lehmann 2009, Gwenzi 2015).

When the application of biochar is under consideration, its physical and chemical properties gain attention (Wang 2013). Raw material properties such as composition (cellulose, hemicellulose, lignin content), C content, density, particle size, particle shape, ash (mineral matter) content are the primary factors affecting final product properties. Biochar can be produced from a range of wood materials (Wang 2015), agricultural residues (Zhang 2015), chicken litter (Lin 2013), dairy manure (Cao 2010) and sewage sludge (Song 2014). Also, thermal properties of biomass or process conditions such as pre and post treatment, reactor temperature, reactor type, residence time, heating rate, pressure and atmosphere etc. are the other causes for the properties of biochar. According to these factors, the properties of biochar can vary to a great extent in terms of their elemental composition, ash content, pore size, toxicity, adsorption capacity-surface area, stability, surface properties (physical and chemical), CEC, nutrient content etc.

The characteristic features of biochar are the key indicators for the utilization areas. For example; porosity, pore-size distribution and total surface area of biochar have fundamental importance for a range of effects on soil properties, adsorption capacity and soil microorganisms. Those rich in available nutrients and minerals with high pH and CEC and/or showing high water holding capacity could be better used as soil amendments to improve fertility. Typically, application of biochar as a soil amendment is mainly as a result of its capacity to increase soil pH, cation exchange capacity (CEC), and buffer capacity; improve soil physical structure; and increase soil microbial biomass and nutrient availability. When applied to soil, biochar provides organic carbon which is important for C sequestration and C balance. Addition, relatively high C content of biochar and resistance against microbial decay results in slow return of terrestrial organic C as carbon dioxide to the atmosphere which results in C sequestration against climate change (Lehmann 2009, Gwenzi 2015).

Within the scope of The FOREBIOM project, one of the activities carried out was to investigate the effect of pyrolysis temperature on the properties of biochar. In this manner, different pyrolysis temperatures ranging between 400 and 600°C were applied to Austrian spruce samples using a laboratory scale fixed bed pyrolysis unit details of which were given in our previous studies (Pütün 2005a). Pyrolysis yields were calculated on dry-ash basis and the results are given in Figure 2. It is obvious from the figure that the increase in pyrolysis temperature leads to a decrease in biochar yield which can be attributed to the higher evolu-
tion rate of volatile organic compounds from biomass at higher temperatures. On the other hand, bio-oil yield showed a different behaviour. When pyrolysis temperature increased, bio-oil yield also increased and maximum bio-oil yield of 23.3% was attained at 550°C. With further increase in pyrolysis temperature, bio-oil yield showed a decrement to 21.2%.

Characterization of biochar were carried out in terms of proximate analysis, elemental analysis, pH, point of zero charge, surface functional groups, iodine number, BET surface areas, microporosity, bulk and skeletal density, FTIR spectra and SEM images. Two critical characteristics, C content and BET surface areas of biochar are given in Figure 3 in relation with pyrolysis temperature. C content and surface area increased with pyrolysis temperature significantly. Surface area of biochar gains attention when it is applied to soil. Biochar obtained in this study showed relatively high surface areas when compared with previous studies (Pütün 2005b, Shaaban 2013). The main reason for this porosity can be explained by the structure of raw material and also by the performance of volatile evolution during pyrolysis resulting in a micro-meso porous structure.

7. Conclusion

The Energy sector, which is responsible for more than 70% of total greenhouse gas emissions in the world, is the key sector to reach succeeds for climate change negotiations and policies. In Turkey, according to 2010–2014 Ministry of Energy and Natural Resources’s strategic plan, it is planned that 30% of total electricity will be produced from renewable sources in 2023. Moreover, highest incentive is given to biomass-based energy plants by government. These strategies will lead to development of bio-based technologies in Turkey.

There are currently a limited number of pyrolysis units in Turkey. Although the biochar community in Turkey is relatively small, there are working groups in a number of universities and institutes such as TÜBITAK-MAM, ITU, Ege University, Anadolu University, Gazi University and Ankara University.

Biochar, produced in biomass based energy plants, can be used for soil applications and it has many positive effects on economic and environmental issues. Introducing this method in the forestry sector is one of the fundamental aims of our FOREBIOM project. Realization of efficient pyrolysis units for production of biochar, energy or chemicals is an inevitable solution for sustainable development.

As a result, biochar is able to play a major role in expanding options for sustainable soil management by improving upon existing best management practices. It has the potential not only to improve soil productivity, but also to decrease the environmental impact.
8. Acknowledgement
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