Sjournals
Scientific Journals
Scientific Journal of Review (2014) 3(1) 34-45
ISSN 2322-2433
doi: 10.14196/sjr.v3i1.1069

Contents lists available at Sjournals
Scientific Journal of REVIEW
Journal homepage: www.Sjournals.com

Original article

Modeling of the vulnerability of "biomass energy" sub-sector to climate change in Togo.

J.K. Fontodji[a],*, P.B.I. Akponikpe[b], K. Kokou[a]

[a]*Laboratoire de Botanique et Ecologie Végétale, Université de Lomé, BP : 1515 Lomé, Togo.*
[b]*Unité de Physique du sol et d'Hydraulique de l'Environnement (PSHE), Faculté d'Agronomie, Université de Parakou, 03 BP 351 Université, Parakou, Bénin.*

*Corresponding author; Laboratoire de Botanique et Ecologie Végétale, Université de Lomé, BP : 1515 Lomé, Togo.

A R T I C L E I N F O

Article history,
Received 22 December 2013
Accepted 14 January 2014
Available online 29 January 2014

Keywords,
Scenario
Fuelwood demand
Fuelwood potential
Vulnerability
Togo

A B S T R A C T

Biomass energy accounts for 80 % of total energy consumed in Togo. But its potential decreases exponentially as a result of population growth and the fact that the techniques of production and consumption are still archaic and climate change. The aim of this work is to contribute to the assessment of vulnerability and adaptation to climate change in the sub-sector of biomass energy in Togo by a modeling approach. Specifically, it is i) to study the evolution of the household demand for fuelwood and ii) to analyze the vulnerability to climate change of sub-sector of biomass energy (mainly charcoal and firewood) in Togo. Demand scenarios of fuelwood were developed from the LEAP model. The vulnerability analysis is made by coupling the demands and the potential of fuelwood and by taking into account the parameters of climate change. At the end of this study, it appears that the fuelwood demands evolve exponentially and that the sector is vulnerable to future climate change. In addition, the potential of fuelwood is very deficient compared to the demand for years to come and will be exhausted before the year 2025. The current energy and forestry policies are far from fill this gap.

1. Introduction

The global energy consumption is dominated by fossil fuels, but the traditional use of biomass energy is still high (10-15% of global energy consumption) (Arnold et al., 2003). With the exception of South Africa, biomass accounts for 75% of final energy consumption in sub-Saharan Africa and wood (in the form of firewood and charcoal) is the most common type of biomass used (Byer, 1987; Energy Information Agency (EIA), 1999; Hall and Moss, 1983).

In Togo, the energy sector is composed of four sub-sectors namely the sub-sectors of biomass energy, hydropower, fossil fuels and renewable energy. Biomass energy accounts for 80% of the national energy balance (Kokou et al., 2009). This form of energy is mainly used for cooking food, water heating, restoration activities, etc. Contrary, hydropower accounts for 3-4% and fossil fuels for 20 to 25%. Renewable energy (solar, wind, biogas, biofuel) remain undeveloped in Togo. In 2000, the potential of biomass energy has been estimated at 1,772,975 m3. This potential decreases exponentially as a result of climate change in recent years and will tend to "extreme" situations before the year 2050 if no action is taken (DCN-Togo, 2010).

The reduction of biomass energy potential in Togo is due partly to the fact that the characteristic parameters of climate between the latitudes of the country became very variable in the recent decades due to an increase of concentration in the atmospheric greenhouse gas emissions and secondly, the fact that the population is growing while the techniques of production and consumption of biomass energy are still traditional in this country. Between 1961 and 1990, temperatures have risen by about 1°C between the latitudes of Togo and precipitation decreased overall from 36.7 mm to 113.9 mm (DCN-Togo, 2010). This variation of the characteristic parameters of the climate which are very crucial for biomass energy has a strong influence on the potential of this energy source. In addition, the kilns used for charcoal production are archaic with very low yield of about 11% (Fontodji et al., 2013). This is a very high source of wasted wood products involving the slaughter of many trees. The production of charcoal alone has led to a deforestation rate of about 5000 hectares per year in Togo (MEMEPT , 2002). Today, the increase in the rate of deforestation is becoming increasingly worrying in light of the situation of Togo which is not a forest country like other countries in the sub -region such as Ghana, Côte d'Ivoire and Nigeria (White, 1986). The availability of biomass energy in the coming decades will be severely compromised if appropriate adaptation options are not taken in time to curb the effects of climate change on the sub-sector of biomass energy and streamline logging.

In view of these considerations, a good planning is required for the sustainable management of forest resources for energy purposes. To do so would require a prior perfect knowledge of the quantities of fuelwood (charcoal and firewood) harvested or consumed and make a comparison to the existing potential of fuelwood. In addition, there must be a prediction of the impacts of climate change in the medium and long terms in this sub-sector for the vulnerability assessment. This requires the use of appropriate modeling approach for making realistic forecasts. The aim of this work is to contribute to the assessment of vulnerability and adaptation to climate change in the sub-sector of biomass energy in Togo. Specifically, it is i) to study the evolution of the household demand for fuelwood (charcoal and firewood) and ii) to analyze the vulnerability to climate change of sub-sector of biomass energy (mainly firewood and charcoal) in Togo.

2. Materials and methods

2.1. Study area

Togo is a country in West Africa located along the sea (Figure 1). It covers an area of 56,600 km² and limited in the south by the Atlantic Ocean, in the north by Burkina Faso, in the west by Ghana and in the east by Benin. Situated between 6° and 11° north latitude and between 0° and 2° East latitude, it extends over a length of 600 km from north to south and a width of 50 km from the West to the East. The country is divided into five ecological zones (Ern, 1979) and five administrative regions (Figure 1). Ecological Zone 1 consists of the northern plains and has a sudanian climate with an annual average temperature of 27.8°C and an annual average rainfall of 1191.5 mm (Tcheroten, 2004). Ecological Zone 2 is the area of the northern mountains and has a humid tropical climate with an annual average temperature of 25.5°C and an annual average precipitation of 1330 mm (Salassi 1995). Ecological Zone 3 consists of the central plains. It has a tropical climate with temperatures ranging from 20 to 32°C and rainfall ranging between 1000 and 1600 mm (Tchangani 2004). Ecological zone 4 corresponds to the southern part of Togo Mountains with a transitional subequatorial climate. Precipitations exceeds 1500 mm and temperatures ranging from 21.5 to 28.1°C (Kouya 1996). Ecological zone 5 is the coastal area which has a sub-equatorial climate characterized by low rainfall (800 mm / year).

The impact of poverty in Togo is estimated at 61.7% of the population (DSRP-C, 2009). Poverty is more predominant in rural areas where the incidence is estimated at 74.3%. The incidence of poverty is higher in Savanna region (92.5%), Central region (84%) and Kara region (80%). To this is added a rapid increase in urbanization due to rural exodus which rate is increasingly growing. Togolese population is extremely young and characterized by an unemployment rate estimated between 25% and 33%. This is why the production of charcoal is one of the main activities in all rural areas of the country.

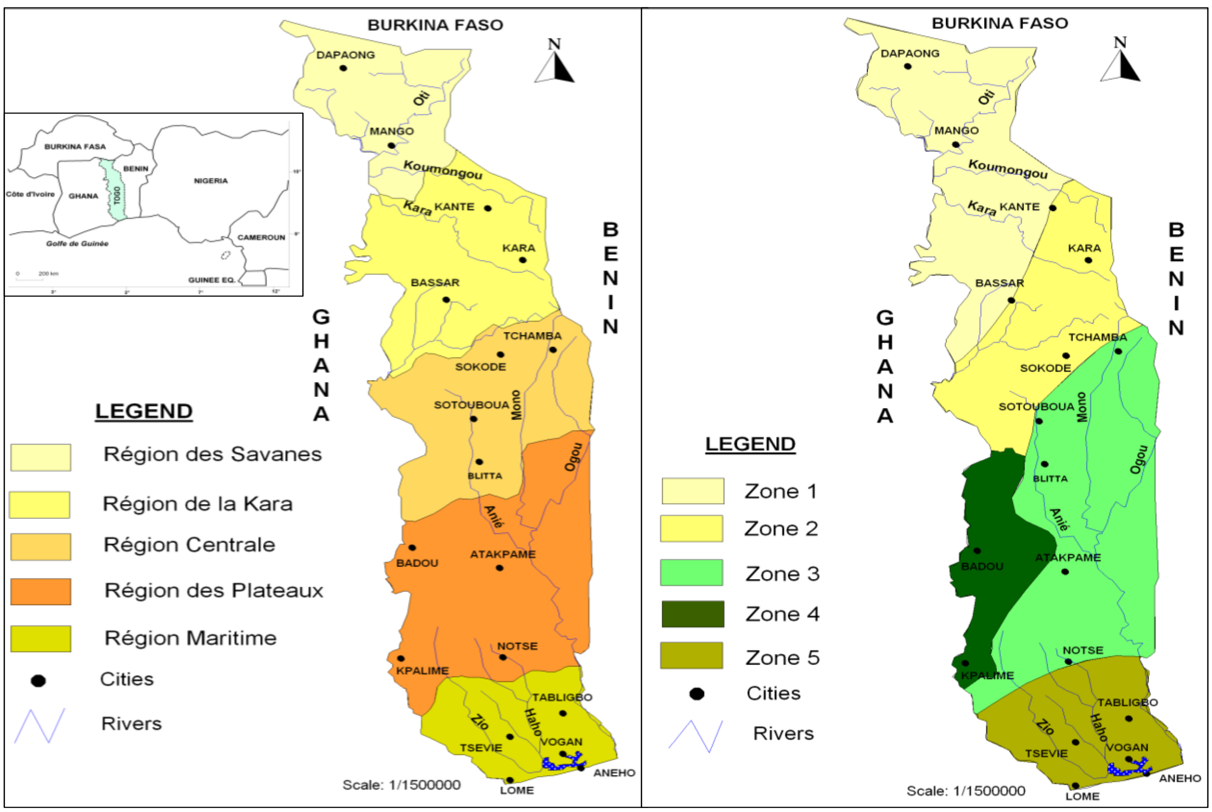

Fig. 1. Administrative regions and ecological zones of Togo.
Source : Fontodji et al. (2011).

2.2. Collection and production of data

2.2.1. Socio-economic data

Data on the consumption of cooking energy in the households (firewood, charcoal, LPG), population (data from the fourth census of the population and housing) and energy policy (validated in 2012) were collected by documentary research and in the technical departments for the development and analysis of demand scenarios for cooking energy and especially fuelwood.

Moreover, to estimate the potential of biomass, data were collected on the areas of forest formations (Table 1) as well as their productivity (Table 2). Forest Policy and National Forest Action Programme (PAFN) elaborated in 2011 established that the forest cover of Togo will reach 20% and 30% of the country area respectively in 2035 and 2050 (PAFN, 2011), or 452.8 km² per year between 2010 and 2035 and 377.3 km² per year between 2035 and 2050. It should be noted that the base year throughout the study for the scenarios is 2010.

Table 1
Evolution of the natural forests area (km²).

Years	Semi-deciduous forests	Dense dry forests	Forest regrowth	wooded savanna	Shrub and herbaceous savanna	Total
1990	3104	399	782	7923	3154	15362
1991	3049	383	753	7574	3077	14836
1992	2995	369	726	7241	3002	14333
1993	2943	354	698	6923	2929	13847
1994	2891	341	673	6618	2858	13381
1995	2840	328	648	6327	2788	12931
1996	2790	315	625	6049	2720	12499
1997	2740	302	601	5771	2652	12066
1998	2692	290	578	5505	2585	11650
1999	2644	279	556	5252	2521	11252
2000	2597	268	535	5010	2458	10868

Source : Adapted from the Tropical Forestry Action Program (1990).

Table 2
Annual productivity (per hectar) of forest formations in Togo.

Type de forêts	Principal and secondary species (m3)	Additional species (timber and fuelwood) in m3
Dense humid forests	0,021	2,9
Dense dry forests	0,015	2,6
Tree savanna	0,008	1,13
Average	0,015	2,21

Source: Report of Togo on achieving the ITTO Objective 2000.

2.1.2. Weather data

To evaluate the potential of fuelwood due to climate change, future climate data including temperature and precipitation is essential. These data were generated using specific models based on currently observed data (minimum and maximum daily temperatures, daily precipitation and daily radiation) for three weather stations namely Kouma Konda (in the area of dense humid forests or Kpalimé), Sodoké (in the area of dense dry forests) and Mango (in the area of savannas) (Figure 1). The daily maximum and minimum temperatures as well as daily precipitation were collected at the National Service of Weather over 30 years, from 1981 to 2010.

Data on solar radiation are nonexistent, they were estimated from the maximum and minimum temperatures using the weather site-specific model (Ball et al, 2004. Sellers, 1965; Allen et al, 1998.; FAO, 2007). All these observed data (minimum and maximum daily temperatures, daily precipitation and daily radiation) made it possible to generate climate change scenarios from a stochastic weather generator, the LARS-WG.5 (Racsko et al, 1991; Semenov & Barrow, 2002 ; Semenov & Brooks, 1999 ; Semenov & Stratonovitch, 2010, Semenov et al, 1998). Three scenarios were considered for each weather station for the years 2025, 2050 and 2100 (Table 3), year 2075 is not available in the model version of LARS-WG.5. These are "high scenario", " medium scenario" and " low scenario" respectively based on the SRES A2, A1B and B1 of the IPCC. It is these climate scenarios that are used to evaluate the potential of fuelwood related to climate change.

Table 3
Evolutions of future climate under different scenarios.

Weather Stations	Type of scenario	Baseline year (2010)		Year 2025		Year 2050		Year 2100	
		P (mm)*	T (°C)**	P (mm)	T (°C)	P (mm)	T (°C)	P (mm)	T (°C)
	Baseline	1670,4	24,46	-	-	-	-	-	-
Kouma	A1B	-	-	1710,93	24,95	1710,08	26,03	1781,07	27,21
Konda	A2	-	-	1723,92	24,95	1820,63	26,13	1719,99	27,75
	B1	-	-	1711,07	24,93	1696,67	25,71	1723,3	26,35
	Baseline	1226,15	26,89	-	-	-	-	-	-
Sokodé	A1B	-	-	1270,38	27,44	1284,18	28,69	1298,8	30,06
	A2	-	-	1273,71	27,44	1325,38	28,81	1295,08	30,67
	B1	-	-	1273,77	27,41	1275,2	28,31	1298,54	29,04
	Baseline	1028,49	28,98	-	-	-	-	-	-
Mango	A1B	-	-	1076,33	29,54	1092,17	30,85	1103,76	32,27
	A2	-	-	1074,55	29,54	1127,77	20,97	1125,15	32,91
	B1	-	-	1079,94	29,50	1094,05	30,42	1107,97	31,2

*P = Precipitation, **T=Temperature.

2.2. Method for developing demand scenarios for fuelwood

LEAP (Long range Energy Alternatives Planning system) model is used to generate demand scenarios for fuelwood. LEAP is a widely-used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute (SEI). It is an integrated modeling tool that can be used to monitor energy consumption, production and resource extraction in all sectors of the economy (SEI, 2011). In this study, it is used for the development of scenarios of energy demands. The principle is based on the representation of the current energy situation for a given zone for the elaboration of future projections under certain assumptions. Thus, an overview of the current situation of cooking energy in Togo is created by specifying the data for the base year (current population size, average household size, proportion of urban and rural households using different types of cooking energy, energy consumed per household per year and type of cooking energy). In addition, a baseline scenario is developed assuming a continuation of current trends and specifying the rate of population growth. Moreover, a second scenario called policy scenario is developed based on the current energy policy approved in 2012. The results of these various energy scenarios were used as a basis for vulnerability analysis of biomass energy to climate change.

2.3. Analysis of vulnerability to climate change in the sector of biomass energy

To analyze the vulnerability to climate change of sub-sector of biomass energy, the potential of biomass energy was estimated taking into account the setting of climate change and the fuelwood demand. To do this, three models of fuelwood potential have been developed in this study. This is a reference potential (ie without policy or climate change), a potential due to climate change (taking into account scenarios of future climate change) and a policy potential (taking in account the energy and forest policy and climate change). The reference potential is estimated by multiplying the forest area (Table 1) by their annual productivity (Table 2). Forests regrowth are assumed to have the same productivity as semi-deciduous forests. Similarly, wooded savanna and herbaceous and shrub savannas are assumed to have the same productivity as tree savannas. The temporal evolution of this potential is estimated by coupling it to the baseline of fuelwood demand and assuming that natural revegetation provides 10 % of the fuelwood potential. The potential related to climate change for its part is obtained by multiplying the forest area (Table 1) by the productivity due to climate change. Productivity due to climate change is assessed by the Miami Model (Grieser et al., 2006 ; Lieth, 1972) which is a function of temperature and precipitation. Weather data from Kouma Konda, Sokodé and Mango are used respectively for the dense forests, dry forests and savannas for the Miami model estimation. The policy potential of fuelwood is obtained by multiplying the productivity due to climate change by the rate of vegetation cover provided in forest policy and by coupling this with the policy scenario of fuelwood demand. Also, the following hypothesis is emitted, the charcoal used is produced at 50% by the Casamance improved mound kiln (with yield of 26%) and 50% by the traditional mound kiln (with yield of 11%) in 2025 and 100% by the Casamance improved mound kiln from 2050.

2.4. Data analysis

Productivity of forest formations related to climate change is estimated by the Miami model (Lieth, 1972):

$$\mathrm{Pr} = \min\left[\mathrm{Pr}(T), \mathrm{Pr}(P)\right]$$ where,

$$\mathrm{Pr}(T) = \mathrm{Pr}_{\max}(1 + EXP(\alpha + \beta T))^{-1} \quad [1]$$

$$\mathrm{Pr}(P) = \mathrm{Pr}_{\max}(1 - EXP(\delta P)) \quad [2]$$

Whith,
Pr : productivity
T : average annual temperature (°C)
P : annual precipitation (mm)
Prmax : maximum productivity

Productivity data are rare in Togo. They are only available for areas of dense humid forests, dense dry forests and savannas (Table 2) corresponding to stations of Kouma Konda, Sodoké and Mango. According to the Tropical Forestry Action Programme (1990), the maximum productivity of forest formations (Prmax) is estimated at 5 m3/ha/year. The assumption was made that for each station, the maximum annual rainfall (minimum, respectively) coupled to the maximum average annual temperature of the available series induces maximum productivity (minimum, respectively). One composite series that includes the data from all stations was established. The formula [1] and [2] have been adjusted using the R software (R Development Core Team, 2012) on the basis of non-linear models (Crawley , 2007) (Figure 2). Of the fact that it was found that Pr(T) are always higher than Pr (P), the results are shown only for Pr (P) (Figure 2).

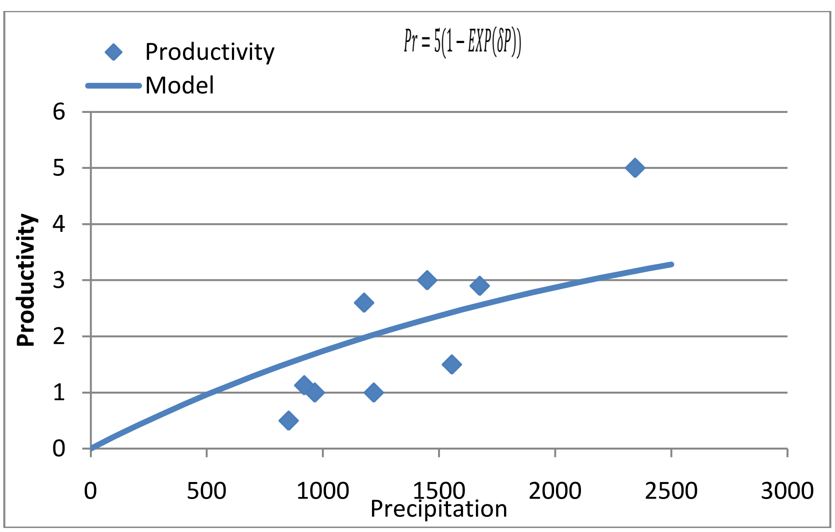

Fig. 2 . Evolution of productivity as a function of rainfall.

It follows from the graph (Figure 2):

$$\Pr(P) = 5(1 - EXP(\delta P))$$

With,

$\delta = -0{,}0004275$

P : annual precipitation

3. Results

3.1. Evolution in cooking energy demands

The reference scenario (ie without intervention of policies) shows that the total cooking energy demand will rise from 29.8 million gigajoules (GJ) in 2010 to 45.4 million GJ, 91.4 million GJ, 184.1 million GJ and 370.6 million GJ respectively in 2025, 2050, 2075 and 2100 (Figure 3). The demand for cooking energy will be multiplied by 12 after 90 years without the policy intervention. However, the quote share of each type of cooking energy evolves differently. The reference scenario shows that consumption of charcoal will increase from 12.1 million GJ (or 418,974.6 tons) in 2010 to 18.6 million GJ (or 644,043.6 tons) in 2025, to 37.8 million GJ (ie 1.31 million tons) in 2050 and to 156.2 million GJ (or 5.41 million tons) in 2100 (Figure 3), or an average annual increase of 55,456 tons between 2010 and 2100. In addition, the same scenario predicts that consumption of firewood will rise from 17.6 million GJ (or 1.14 million tons) in 2010 to 53.4 million GJ (or 3.45 million tons) in 2050 and to 213.5 million GJ (or 13.77 million tons) in 2100 (Figure 3), or an average annual increase of 140,333 tons between 2010 and 2100. Moreover, this scenario indicates that the consumption of gas (LPG) will increase from 0.1 million GJ in 2010 to 0,2 million GJ in 2050 and 1 million GJ in 2100 (Figure 3), which is equivalent to an average annual increase of 0.01 million GJ between 2010 and 2100. It should therefore be noted that the charcoal will occupy more space in the balance of cooking energy in the years to come. This is mainly explained by the fact that the urban population will continue to grow based on current trends.

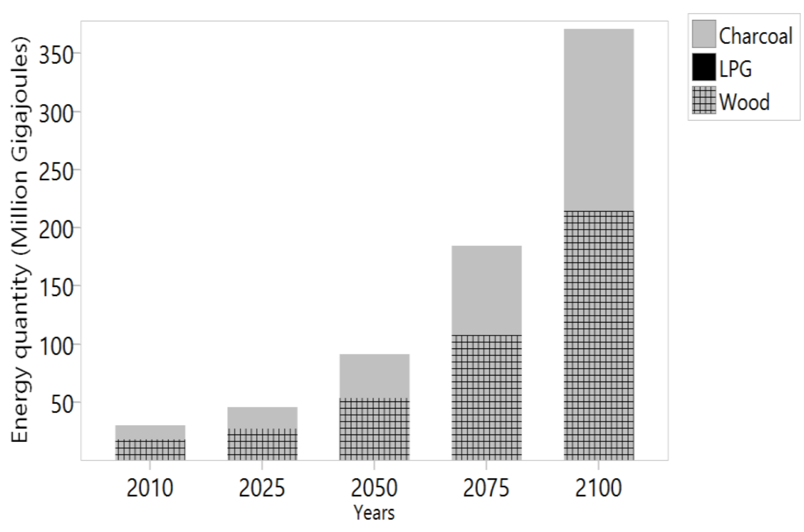

Fig. 3. Evolution of the cooking energy demand (Reference Scenario).

However, the implementation of energy policies currently available will significantly reduce the demand for fuel wood and therefore the total energy demand for cooking. The policy scenario indicates that the total demand for charcoal will pass from 12.1 million GJ in 2010 to 10.5 million GJ or 363,573 tons in 2025, to 21.4 million GJ or 740,996.4 tons in 2050, to 43.6 million GJ or 1.51 million tons in 2075 and 88.6 million GJ or 3.07 million tons in 2100 (Figure 4). In addition, the demand for firewood will pass from 17.6 million GJ in 2010 to 15 million GJ or 967,740 tons in 2025, to 30.1 million GJ or 1.94 million tons in

2050 and 120.1 million GJ, or 7.75 million tons in 2100 (Figure 4). Otherwise, the LPG will increase from 0.1 million GJ in 2010 to 1.4 million GJ in 2050 and 5.8 million GJ in 2100. So, the implementation of energy policy will result in the fuelwood saving about 3 million tons between 2010 and 2025, about 7 million tons between 2025 and 2050 and about 27 million tons between 2075 and 2100, a total saving of 50.7 million tons of wood equivalent between 2010 and 2100 (or 0.56 million tons per year) (Table 4).

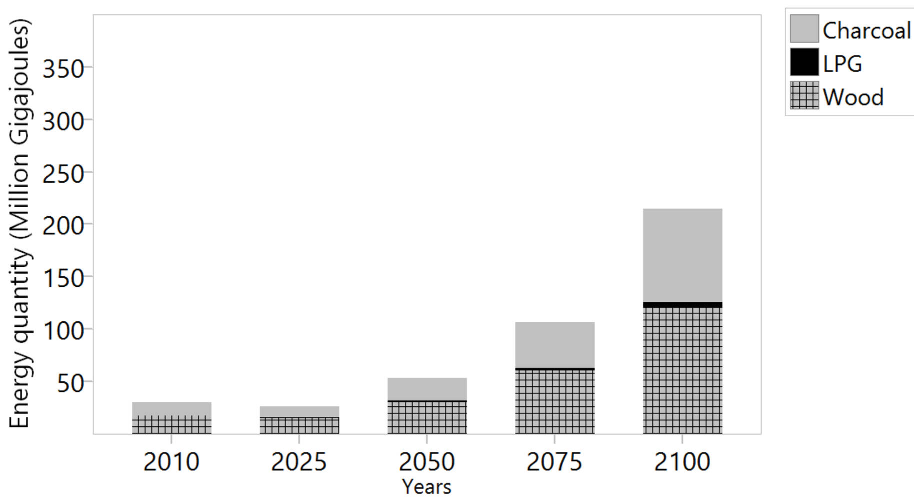

Fig. 4. Evolution of the cooking energy demand (Policy Scenario).

Table 4
Quantity of fuelwood to be saved by the implementation of energy policy of 2012.

Type of energy Period of time	Charcoal			Woodfuel		Total equivalent wooden (million tons)
	Million GJ	Equivalent in million tons	Equivalent in wooden (million tons)	Million GJ	Equivalent in million tons	
2010-2025	8,1	0,28	2,55	11,7	0,75	3,30
2025-2050	16,4	0,57	5,16	23,3	1,50	6,67
2050-2075	33,2	1,15	10,45	46,7	3,01	13,46
2075-2100	67,6	2,34	21,28	93,4	6,03	27,31
Total	125,3	4,34	39,44	175,1	11,30	50,74

3.2. Evolution of the potential of fuelwood under different scenarios

The potential of fuelwood is 1.46 million m3 in 2010. In the absence of climate change and the expansion of vegetation cover, the baseline (reference) shows a drastic reduction of this potential which will be exhausted before year 2025 (Figure 5). Under this scenario, the fuelwood potential will be in deficit of 8.99 million m3, 19.70 million m3 and 85.36 million m3 respectively in 2025, 2050 and 2100.

Potential scenarios related to climate change (CC-A1B, CC-A2 and CC-B1) on their part, provide all a slight increase of the potential relative to the baseline scenario (Figure 5). If rainfall is 1710.93 mm, 1723.92 mm and 1711.07 mm respectively for scenarios A1B, A2 and B1 at Kouma Konda, of 1270.38 mm, 1273.71 mm and 1273.77 mm respectively for these same scenarios at Sokode and 1076.33 mm 1074.55 mm and 1079.94 mm respectively for these scenarios at Mango, the deficit of fuelwood potential in the country will be reduced to 8.83 million m3 (or an increase of 0.16 million m3 compared to the reference potential) for medium scenarios (CC- A1B), high (CC- A2) and low (CC- B1) in 2025. The trends are the same for 2050 and 2100 horizons ie these scenarios show an increase of the potential relative to the reference potential in these horizons (Figure 5). This increase in the potential is related to the increase in precipitation. But it is far from meeting the demands of fuelwood given that these scenarios also indicate a potential deficit that is almost the same order of magnitude as the reference potential for horizons 2025, 2050 and 2100. This deficit is 19.53 million m3 for scenarios CC-A1B and CC- A2 and 19.48 million m3 for the CC- B1 scenario by 2050, and 85.16 million m3 for scenarios CC- A1B and CC-A2 and 85.17 million m3 for the CC- B1 scenario by 2100 (Figure 5).

In addition, if the current forest policy of Togo and the National Forestry Action Plan (PAFN) as well as energy policy are implemented, the potential deficit will be significantly reduced, however, without being fully compensated. The policy scenario (Policy) evaluates the potential deficit of fuelwood to 3.08 million m3 in 2025, to 2.86 million m3 in 2050 and to 23.21 million m3 in 2100 (Figure 5).

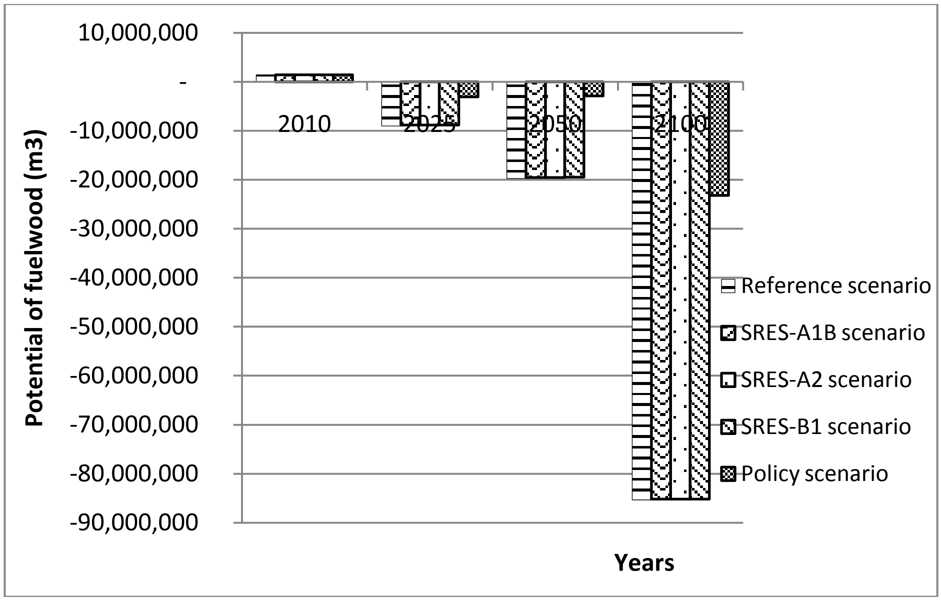

Fig. 5. Scenario of fuelwood potential.

4. Discussion

In Togo, the consumption of fuelwood evolves exponentially as a result of the population explosion. The baseline scenario (of cooking energy demand) shows that the consumption of charcoal will increase by 55,440 tons and that of firewood by 140,430 tons per year on average between 2010 and 2100. This considerable increase in the demand of fuelwood is not unique to Togo. Other studies have shown increased consumption of fuelwood in other countries, including Uganda, where per capita consumption is estimated at 1.77 m3 of fuelwood (Brouwer and Falcao, 2004). The Ugandan National Forest Autority projected that the current national consumption rate of 20 million tons of wood per year is expected to triple by 2025 (GTZ, 2005). In Tanzania, the consumption of charcoal is estimated at 140 kg / person / year (Mwampamba, 2007). In all developing countries, the quantity of charcoal increases and the number of those who depend on fuelwood will continue to grow. The International Energy Agency estimates that, although shifts to other sources of energy could be expected to substantially reduce the share of these fuel by 2030, the biomass energy will still account for an estimated three quarter of total residential energy in Africa in that year, and that the number of people using fuel wood and other biomass fuel in that region will rise by more than 40% during 2000-2030 (IEA 2002).

Unfortunately, the current potential of fuelwood decreases drastically and will be exhausted before the year 2025 according to the baseline scenario. These results are similar to those of Mwampamba (2007) which stipulates that in Tanzania, the potential of fuelwood will be exhausted toward 2028 according to the worst scenario and toward 2048 for the medium scenario. These results also corroborate those of Kassambara et al. (2010) who consider that if the current trend of consumption of fuelwood does not change in Mali, the projections for 2025 can not be provided.

Moreover, the scenarios indicate that increased precipitation are conducive to increased productivity and thus the fuelwood potential. But rising temperatures between latitudes of Togo will have a negative impact on the potential (DCN-Togo, 2010). According to IPCC (2007), the increase in temperature and thus heat waves will lead to lower yields in warmer regions (Africa) due to thermal stress and an increased risk of uncontrolled bush fires. In addition, rising temperatures will increase evapotranspiration and could make the water balance deficient for plants and thus reduce productivity (DCN-Togo, 2010). All this will have a negative impact on the fuelwood potential. The fuelwood sector remains vulnerable to the effects of future climate change. This vulnerability is not specific to the fuelwood sector. In agriculture, Tchinguilou et al. (2013) indicate a reduction in maize yields of 5-25% due to unfavorable climate conditions in 2050 in Togo. To reverse the trend, the solution does not lie in prohibiting the use of fuelwood. Indeed, from Kenya to Mauritania, the prohibition policies of production or consumption of charcoal have been ineffective but make that producers become stowaway, making it difficult to establish a control procedure for production (Girard, 2002). On the contrary, the solution should be the definition and implementation of good energy policy that promotes diversification of energy sources especially in urban households (Sokona, 1999) and the use of new technologies for energy efficiency (Nkoua 2010). The effective implementation of current energy policies will enable Togo to reduce the demand for fuelwood of 50.7 million tons (39.4 million tons of equivalent wooden for the charcoal and 11.3 million tons of firewood) between 2010 and 2100. This will greatly reduce the pressure on wood resources which are in perpetual degradation. In addition, the implementation of the forest policy that provides for the extension of forest areas and the popularization of the Casamance improved mound kiln will greatly increase the potential of fuelwood. These two policy scenarios show the importance of good planning of activities both at the production level of fuelwood and at consumption level. However, in their current state, these two policies (especially energy policy) are not sufficient to meet the total demand for fuelwood. Indeed, the policy scenario of the fuelwood potential indicates a deficit of 3.07 million m3 in 2025, 2.86 million m3 in 2050 and 23.21 million m3 in 2100. The current energy policy deserves to be reviewed to incorporate sufficient diversification of sources of energy for cooking in households and the rapid dissemination of improved stoves.

5. Conclusion

At the end of this study, it should be noted that the energy demands of cooking and especially fuelwood evolves exponentially. The demand scenarios indicate an annual average increase of 55 456 tons of charcoal and 140 333 tons of firewood between 2010 and 2100. Unfortunately, the scenario of the potential indicate that the potential of fuelwood is deficient in relation to the demand. This deficit is of 8.99 million m3, of 19.70 million m3 and of 85.36 million m3 respectively in 2025, 2050 and 2100 for the baseline scenario. The current potential of fuelwood is going to run out before the year 2025. Admittedly, the rainfall of years to come will have a beneficial effect on the potential of fuelwood. However, this positive effect is far to fill the gap and will even be quickly neutralized by the increase in future temperatures making the sector of biomass energy vulnerable to climate change. The implementation of current energy and forestry policies will significantly reduce the deficit without fill the gap completely. This deficit will remain at 3.08 million m3 in 2025, 2.86 million m3 in 2050 and 23.21 million m3 in 2100 with the implementation of policies. Major efforts remain then to be made by the Togolese government especially for energy policy to meet the needs of populations in cooking energy.

Acknowledgment

This study was conducted with the financial support of ACCFP (African Climate Change Felloship Program).

References

Allen, R.G., L.S. Pereira, D.R., Smith, M., 1998. Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrig. and Drainage Paper 56, FAO, Rome.
Arnold, J.E.M., Köhlin, G., Et Persson, R., 2006. Woodfuels, livelihoods, and Policy Interventions: Changing Perspectives. World Dev., 34 (3), 596-611.
Brouwer, R., et Falcao, M.P., 2004. Wood fuel consumption in Maputo, Mozambique. Bioenergy., 27, 233-245.
Byer, T., 1987. Review of Housewold Energy Issues in Africa, Bank International Memorandum. World Bank, Washington, DC.
Ball, R.A., Purcell, L.C., Carey, S.K., 2004. Evaluation of Solar Radiation Prediction Models in North America. Agron. J., 96, 391–397.
CNI., 2001. Communication Nationale Initiale, République Togolaise / CCNUCC, 2001.
Coomes, O.T., Burt, G.J., 2001. Peasant charcoal production in the Peruvian Amazon: rainforest use and economic reliance. Forest Ecol. Manag., 140, 39-50.
Crawley, M.J., 2007. The R Book. Imperial College London at Silwood Park., ISBN-13, 978-0-470-51024-7, UK.
DCN-Togo (Deuxième Communication Nationale)., 2010a. Etude de la vulnérabilité et de l'adaptation aux changements climatiques, secteur de l'Energie. Rapport, République Togolaise, 97 p + Annexes.
DCN-Togo., 2010b. Deuxième Communication Nationale, République Togolaise / CCNUCC, 2010.
DGSCN (Direction Générale de la Statistique et de la Comptabilité Nationale)., 2011. Quatrième recensement de la population et de l'habitat. Rapport définitif, République Togolaise, 57 p.
DSRP-C., 2009. Document Complet de Stratégie de Réduction de la Pauvreté. Version préliminaire, Rép. Togolaise, 87 p.
Energy Information Agency (EIA)., 1999. Major African Envirenmental Challenge: use of biomass energy. URL: (http://www.eia.doe.gov/emeu/cabs/chapter7.html).
Ern, H., 1979. Die vegetation Togo. Gliederrung, Gefâhrdung, Erhaltung. Willdenowia., 9, 295-312.
FAO., 2013. Annuaire FAO des produits forestiers de 2007 – 2012. Rome, Italie., ISBN : 9789250075907.
FAO., 2007. ExtraRad, Annual Cycles of Extraterrestrial Incoming Solar Radiation. FAO/NRC, Italy.
Fontodji, K.J., Atsri, H., Adjonou, K., Radji, A.R., Kokutse, A.D., Nuto, Y., Kokou, K., 2011. Impact of Charcoal Production on Biodiversity in Togo (West Africa) in López-Pujol J., The Importance of Biolog. Int. Study of Biodiversity, chapitre., 12, 215-230.
Fontodji, K.J., Tagba, M.S., Akponikpe, I.P.B., Adjonou, K., Akossou, A.Y.J., Akouehou, G., Kokutse, A.D., Nuto, Y., Kokou, K., 2013. Diagnostic analysis of the techniques of carbonization inTogo (West Africa). Press.
Grieser, J., Gommes, R., Bernardi, M., 2006. The Miami Model of climatic net primary production of biomass. The Agromet Group, SDRN FAO of the UN, Viale delle Terme di Caracalla, 00100 Rome, Italy.
GTZ (Gesellschaft fur Technische Zusammenarbeit)., 2005. Let us save a tree today. The New Vision, Kampala, Uganda, p.8.
Hall, D.O., Moss, P.A., 1983. Biomass for energy in developing countries. GeoJournal., 7, 5-14.
International Energy Agency (IEA)., 2002. Energy and poverty, Chapter 13. In World Energy Outlook., 2002, Paris, OECD.
IPCC., 2007. Climate Change 2007. Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, [Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.)]. IPCC, Geneva, Switzerland, 104 p.
Kassambara, A., Gautier, D., Gazull, L., 2010. La problématique du bois-énergie au Mali: Bamako. In Abhervé-Quinquis, A.G., Foresterie urbaine et périurbaine en Afrique. Quelles perspectives pour le bois-énergie? Document de travail sur la foresteire rubaine et périurbaine., N°4, 73-78.
Kokou, K., Nuto, Y., Atsri, H., 2009. Impact of charcoal production on woody plant species in West Africa: A case study in Togo. Scientific Res. Essay., 4(9), 881-893.
Kouya, A., 1996. Les principaux facteurs de l'évolution des formations végétales sur le plateau d'Akposso. Mémoire de Maîtrise, FLESH, UL-Togo, 129 p.

Lieth, H., 1972. Modelling the primary productivity of the world. Nature and Resources, UNESCO, VIII, 2:5-10.

Ministère de l'Equipement, des Mines de l'Energie, et des Postes et Télécommunications., 2002. Analyse, stratégie et programme d'action du sous-secteur des énergies traditionnelles. Rapport national, 100 p.

Ministère des Mines et de l'Energie., 2012. Document de politique de l'énergie. Politique Nationale de l'Energie, République Togolaise, 61 p.PAFN, 2011. Plan d'Action Forestier National du Togo, Phase 1 (PAFN1-Togo) 2011 - 2019. Version complète, MERF/Rép. Togolaise, 164 p.

Mwampamba, T.H., 2007. Has the woodfuel crisis returned? Urban charcoal consumption in Tanzania and its implications to present and future forest availability. Energy Pol., 35, 4221-4234.

Nkoua, M., 2010. Foresterie périurbaine, resources bois-énergie et approvisionnement de Pointe-Noire. In Abhervé-Quinquis, A.G., Foresterie urbaine et périurbaine en Afrique. Quelles perspectives pour le bois-énergie? Document de travail sur la foresteire rubaine et périurbaine, N°4:79-87.

Racsko, P., Szeidl, L., Semenov, M., 1991. A serial approach to local stochastic weather models. Ecological Mod., 57, 27-41.

R Development Core Team., 2012. R : A language and environment for statistical computing. R foundatin for statistical computing, Vienna, Austria. ISBN3-900051-07-0, URL http://www.R- project.org/.

Salassi, D., 1995. Les problèmes de la contiguïté des aires protégées avec les zones agricoles au Togo : Crise d'espace ou crise d'aménagement ? (Exemple de la région de Fazao). Mémoire de Maîtrise, UB, Lomé, Togo, 122 p.

SEI (Stockholm Environment Institute)., 2011.Long-range Energy Alternatives Planning System.User Guide, first draft, 301 p.

Sellers, W.K., 1965. Physical climatology. Univ. of Chicago Press, Chicago.

Semenov, M.A., Brooks, R.J., Barrow, E.M., Richardson, C.W., 1998. Comparison of the WGEN and LARS-WG stochastic weather generators in diverse climates. Clim. Res., 10, 95-107.

Semenov, M.A., Brooks, R.J., 1999. Spatial interpolation of the LARS-WG stochastic weather generator in Great Britain. Clim. Res., 11, 137-148.

Semenov M.A., Barrow, E.M., 2002. LARS-WG : A Stochastic Weather Generator for Use in Climate Impact Studies. Version 3.0, User Manual, Rothamsted Res., Harpenden, Hertfordshire, AL5 2JQ, UK and Canadian Climate Impacts Scenarios (CCIS) Project, c/o Environment Canada - Prairie and Northern Region, Atmospheric and Hydrologic Science Division, 2365 Albert Street, Room 300, Regina, Saskatchewan S4P 4K1, Canada.

Semenov, M.A., Stratonovitch, P., 2010. The use of multi-model ensembles from global climate models for impact assessments of climate change. Clim. Res., 41, 1-14.

Tchangani, T., 2004. Les activités commerciales et la dégradation de l'environnement: le cas du marché de Pagala-Gare dans la préfecture de Blitta. Mémoire de Maîtrise, UL, Togo, 139 p.

Tcheroten, K., 2004. Principales pratiques humaines destructives de l'environnement dans le secteur Ouest de la préfecture de la Kéran: cas des villages de Ossacré et de Pangouda. Mémoire de Maîtrise, UL, Togo, 87 p.

Tchinguilou, A., Jalloh, A., Thomas, T.S., Nelson, G.C., 2013. Chapitre 13 : Togo. In Jalloh A., Nelson G.C., Thomas T.S., Zougmoré R., and Roy-Macauley H., West African Agriculture And Climate Change : A Comprehensive Analisys, International food Policy Research Institute (IFPRI), Washington DC, ISBN 978-0-89629-204-8, DOI : http://dx.doi.org/10.2499/9780896292048.

White, H., 1986. La végétation de l'Afrique. Mémoire accompagnant la carte de végétation d'Afrique. UNESCO / AETFA / UNSO.