Journal of Agriculture, Biology and Applied Statistics
Vol. 2, No. 1, 2023, pp. 11-24

URL : www.arfjournals.com
https://DOI:10.47509/JABAS.2023.v02i01.02

A Study on Trend of Wood Fuel Production in World

Lakshmi Narsimhaiah[1], Krishne Gowda K[2], Uma K[2], Ramakrishna Hegde[3], Syed Ali[3], Isiri N P[4], Madhurya Gowda S R[4], Guddappa M Devagiri[5], C G Kushalappa[4], Anantha Krishna[1] and Bhagirathi L[1]

[1]Department of Basic Sciences and Humanities, College of Forestry, KSNUAHS (Shivamogga), Karnataka, India
[2]College of Forestry, KSNUAHS (Shivamogga), Karnataka, India
[3]Department of Silviculture and Agro-Forestry, College of Forestry, KSNUAHS (Shivamogga), Karnataka, India
[4]Department of Forest Biology and Tree Improvement, College of Forestry, KSNUAHS (Shivamogga), Karnataka, India
[5]Department of Natural Resource Management, College of Forestry, KSNUAHS (Shivamogga), Karnataka, India
Corresponding Author: lakshmi.narasimhaiah1988@gmail.com

To cite this article

Lakshmi Narsimhaiah, Krishne Gowda K, Uma K, Ramakrishna Hegde, Syed Ali, Isiri N P, Madhurya Gowda S R, Guddappa M Devagiri, C G Kushalappa, Anantha Krishna and Bhagirathi L. (2023). A Study on Trend of Wood Fuel Production in World. Journal of Agriculture, Biology and Applied Statistics. Vol. 2, No. 1, pp. 11-24. *https://DOI:10.47509/JABAS.2023.v02i01.02*

Abstract: The primary biomass energy source is wood fuel, which is important for human economic and social development worldwide. Wood fuels come from a variety of sources, including forests, trees found outside of forests, other areas that are forested, byproducts of the processing of wood, processed wood-based fuels, and post-consumer recovered wood. The present study was conducted to understand the per se performance and trend analysis of wood fuel production in the world. The secondary data on production of Wood Fuel was collected from FAO for the period of 1961 - 2020. The top five countries such as India, China mainland, Brazil, Ethiopia and Democratic Republic of Congo were selected for analysis based on total production of wood fuel. Results shows that the estimated production of non-coniferous wood fuel is higher than coniferous wood fuel in all the five countries. In case of India, wood fuel production shows increasing rate and rapidly except at some period, in case of China, there is a gradual decrease in wood fuel production in recent decades which may be due to increase in per-capita income shifted to other sources. There is a sudden decrease in wood fuel production in case of Brazil. Whereas there is an exponential increase in wood fuel production of Ethiopia. This shows the change in the trend along the decade, the decreasing trend may be due to availability of rich conventional sources of energy and increasing trend may be ascribed to crisis in conventional energy sources and sustainable environmental development perspective.

Article History Received : 12 January 2023; Revised : 18 February 2023; Accepted : 22 February 2023; Published : 22 March 2023

Introduction

Wood is considered as the very first source of energy for humankind. It is the most important source of renewable energy providing about 6% of global total primary energy supply (Sreevani, 2018). Wood fuel is the major form of biomass energy; it plays a critical role in the economic and social well-being of people all around the world. Wood fuels are arising from the multiple sources which includes forests, trees outside forests, other wooded land, co-products from wood processing, processed wood-based fuels and post-consumer recovered wood. In developing countries approximately 2.4 billion people use wood fuel as their primary energy source predominately. Traditional use of wood fuel and other bioenergy has a share of 10 - 15% energy supply (Hilring, 2006).

Forest resources are spread all over the globe. It is estimated that about 30% of the earth's land is covered with forest, of which about 95% are natural forests and 5% are plantations. Tropical and subtropical forests comprise 56% of the world's forests, while temperate and boreal forests account for 44% (Parikka, 2004). The global use of wood fuel and round wood is 3271 (106) m^3 per year. About 55% is directly used as fuel, e.g. split firewood, mainly in developing countries. Remaining 45% is used as raw materials individually, but about 40% of wood fuel is used as primary or secondary process residues, suitable only for energy production, e.g. for production of upgraded bio fuels (Hillring and Trossero, 2006). About 70 -75% of the global wood harvest is potentially available as a renewable energy source.

The trend of wood fuel is an increased use of wood in different markets - first in lower-quality and low-cost wood, and later more expensive, processed products. This is true for both the energy industry and for the forest product industry. This trend also influences new quality regulations or certification. The competition starts with low-value fibre, possibly without any other commercial use, and when demand rises, other wood or better timber qualities will be impacted.

Despite the social, economic, and environmental importance of wood fuel, many developing countries lack reliable data to estimate the patterns and trends of wood fuel consumption and production. Indeed, production and traded of wood fuel is predominant and it is an important source of income for the poor. The wood fuel production on local livelihoods and economies were largely underestimated and ignored. The absence of the reliable data on wood fuel production and consumption also hinders assessment of its impact on forests and the environment, and the formulation of effective policies for the wood fuel sector.

The rate of forest increment varies between regions and countries worldwide. The annual increment of forests is positive in most of the countries and offers the opportunity to expand the market for wood. Due to dense and fast growing population the demand for timber products is very high. This is the basic driving force for the trade in timber.

The purpose of this study is to give a broad picture of the trade in wood fuel in five different countries and to show the trend patterns in last six decades. Since timber production is assumed to be well connected and reflect forest resources. This also indicate the pattern of shift in energy consumption. Production is expected to increase and this study will give a better understanding on trend line with the objectives to know the per se performance and the trend analysis

Data and Methodology

Design of the Study- The secondary data, on production of wood fuel was collected from FAO for the period of 1961-2020. The top five countries were selected for analysis based on total production of wood fuel. The top five countries were India, China mainland, Brazil, Ethiopia and Democratic Republic of Congo.

Tools for Analysis- Total of three graphs with wood fuel production (m^3) on y-axis and time (year) on x-axis were plotted for each country (i.e., wood fuel coniferous, wood fuel non-coniferous and total wood fuel) using the FAO data. The five different models were chosen for trendline setting i.e., linear, logarithmic, polynomial (quadratic and cubic) and exponential.

1. **Linear trendline:** This trendline is used mostly when the data sets are linear in nature.
   It is of type: $y = mx+c$ where, m: slope of line y
   c: Intercept of the line

2. **Logarithmic trendline:** It is mostly used for data sets that either increases or decreases and then maintains a constant level.
   It is of the type: $y = a \times \log(x) + a^1$

3. **Polynomial trendline:** It is used when data set is changing rapidly.
   It is of the type: $y = a + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + ... + a_n x^n$
   - Quadratic trendline: $y = a + a_1 x + a_2 x^2$
   - Cubic trendline: $y = a + a_1 x + a_2 x^2 + a_3 x^3$

4. **Power trendline:** It is mostly used for datasets that increases at particular rate.
   It is of the type: $y = a_1 x^{(a2)}$

5. **Exponential trendline:** It is mostly used where there is a rise or fall in the data set exponentially.
   It is of the type: $y = a_1 e^{a_2 x}$

Out of all the trendlines the trendline with high R^2 value, significance of ANOVA, closeness to graph of Wood fuel production, less number of coefficients and significance of coefficients were selected.

Country	Type of wood fuel	Equation	Co-efficient of determination (R^2)
India	Coniferous	$WF = 4375301.699 + 138879.149*t + 3.324*t^2 - 16.916*t^3$	0.987
	Non Coniferous	$WF = 141113570.583 + 4479553.632*t + 85.637*t^2 - 545.287*t^3$	0.987
	Total(C+Non-C)	$WF = 145488872.282 + 4618432.781*t + 88.961*t^2 - 562.203*t^3$	0.987
China Mainland	Coniferous	$WF = 103852612.480 + 3470814.979 * t - 141852.604*t^2 + 1221.354*t^3$	0.987
	Non Coniferous	$WF = 152562350.475 + 5098726.232 * t - 208385.535*t^2 + 1794.204*t^3$	0.987
	Total(C+Non-C)	$WF = 256414962.955 + 8569541.212 * t - 350238.139*t^2 + 3015.558*t^3$	0.987
Brazil	Coniferous	$WF = 8634593.243 + 12033.301*t + 9528.770*t^2 - 201.832*t^3$	0.813
	Non Coniferous	$WF = 73669941.082 + 1501911.917*t - 13544.999*t^2$	0.835
	Total(C+Non-C)	$WF = 79900047.750 + 1968289.501*t - 22483.868*t^2$	0.774
Ethiopia	Coniferous	$WF = 1060754.241 * \exp(0.037*t)$	0.923
	Non Coniferous	$WF = 30299116.560 + 1265855.565*t$	0.994
	Total(C+Non-C)	$WF = 30221416.658 + 1403587.210*t$	0.991
D_R_Congo	Non Coniferous	$WF = 18301210.826 * \exp(0.029*t)$	0.979

Results

1. India

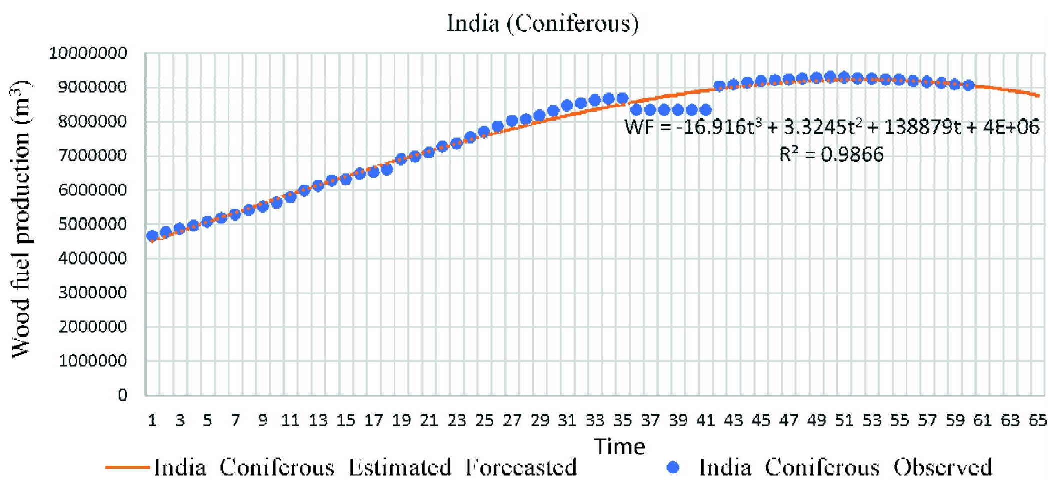

Figure 1: Trend in production of Coniferous Wood fuel in India

Table 1: Per Se of Coniferous Wood fuel produced in India

Mean	7.67 million
Standard Error	195720.1569
Median	83.24 million
Mode	83.42 million
Standard Deviation	15.16 million
Sample Variance	2.29838E+12
Kurtosis	-1.020
Skewness	-0.624
Range	4648419

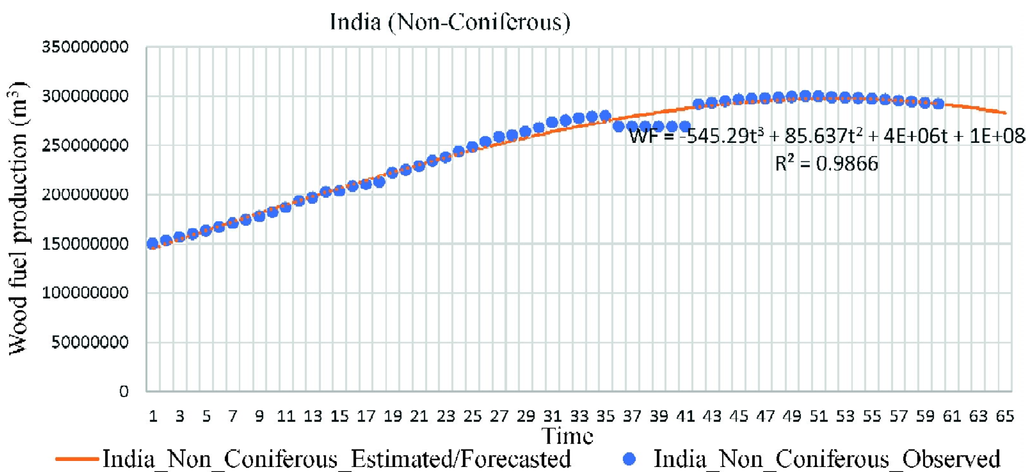

Figure 2: Trend in production of Non-Coniferous Wood fuel in India

Table 2: Per Se of Non-Coniferous Wood fuel produced in India

Mean	2474.10 million
Standard Error	6312399.59
Median	2684.85 million
Mode	2690.38 million
Standard Deviation	488.95 million
Sample Variance	2.39078E+15
Kurtosis	-1.020
Skewness	-0.624
Range	149923299

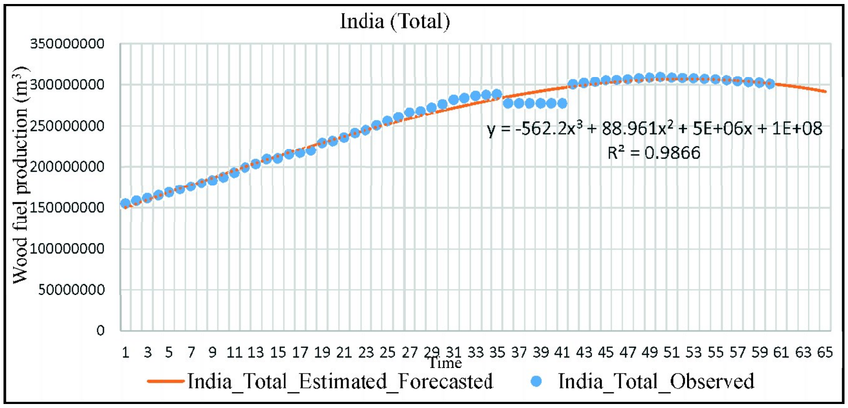

Figure 3: Trend in production of Wood fuel in India

Table 3: Per Se of Wood fuel produced in India

Mean	2550.81 million
Standard Error	6508119.746
Median	2768.09 million
Mode	2773.80 million
Standard Deviation	50.41million
Sample Variance	2.54134E+15
Kurtosis	-1.02
Skewness	-0.62
Range	154571718

From figure 1, 2 and 3: The estimated production of coniferous wood fuel in India is 8771073.06864 m^3, non-coniferous wood fuel is 282896907.70667 m^3 and the total production is 291667980.77531 m^3. The mean of coniferous wood fuel produced is 247410105.4 , of non-coniferous wood fuel produced is 247410105.4 and total mean of wood fuel produced is 255081172.2 . All the graphs have negative skewness and kurtosis.

2. China, Mainland

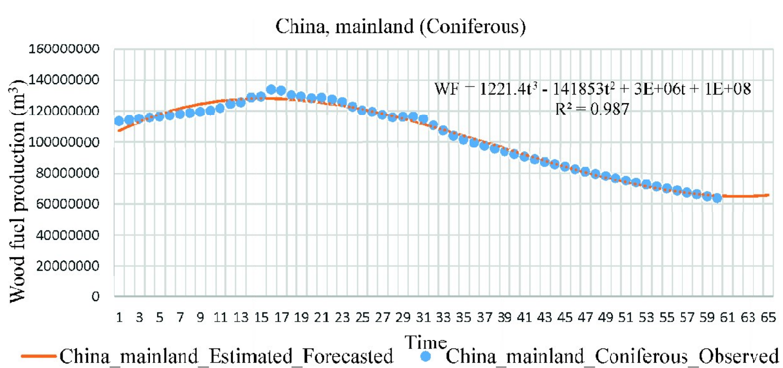

Figure 4: Trend in production of coniferous wood fuel in China, mainland

Table 4: Per Se of coniferous wood fuel produced in China, mainland

Mean	1033.79 million
Standard Error	2818188.042
Median	1137.32 million
Mode	#N/A
Standard Deviation	218.29 million
Sample Variance	4.76531E+14
Kurtosis	-1.27
Skewness	-0.42
Range	70239918

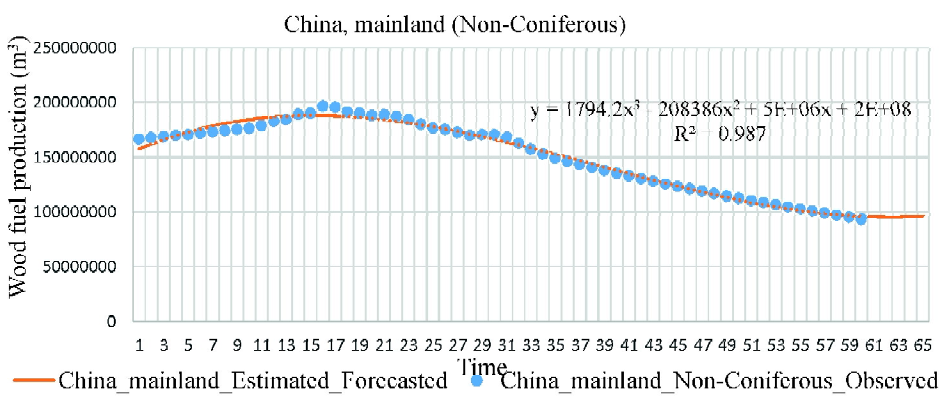

Figure 5: Trend in production of non-coniferous wood fuel in China, mainland

Table 5: Per Se of non-coniferous wood fuel produced in China, mainland

Mean	1518.68 million
Standard Error	4139996.979
Median	1670.76 million
Mode	#N/A
Standard Deviation	320.68 million
Sample Variance	1.02837E+15
Kurtosis	-1.27
Skewness	-0.42
Range	103184385

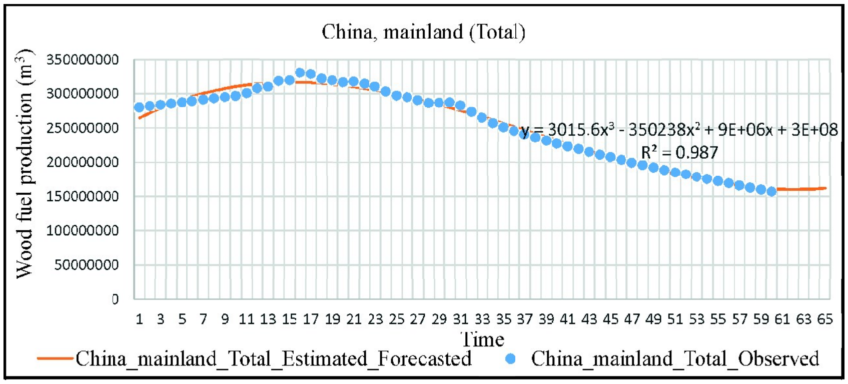

Figure 6: Trend in production of total wood fuel in China, mainland

Table 6: Per Se of total wood fuel produced in China, mainland

Mean	2552.48 million
Standard Error	6958185.021
Median	2808.09 million
Mode	#N/A
Standard Deviation	538.98 million
Sample Variance	2.90498E+15
Kurtosis	-1.27
Skewness	-0.42
Range	173424303

From the figures 4, 5 and 6, the estimated production of coniferous wood fuel in mainland China is 65542626.75352 m^3, non-coniferous wood fuel is 96283952.30067m^3 and total production is 161826579.05419 m^3. The mean of coniferous wood fuel produced is 103379987.6 , mean of non-coniferous wood fuel produced is 151868059.7 and total mean of wood fuel produced is 255248047.3 . All the graphs have negative skewness and kurtosis.

3. Brazil

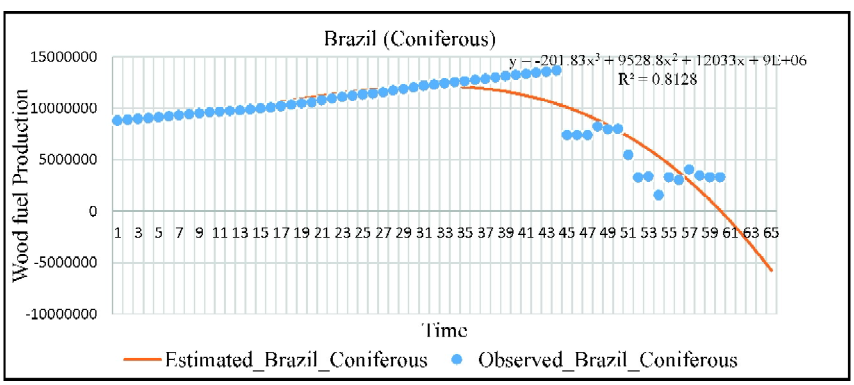

Figure 7: Trend in production of coniferous wood fuel in Brazil

Table 7: Per Se of coniferous wood fuel produced in Brazil

Mean	94.58 million
Standard Error	415725.9001
Median	99.08 million
Mode	73.71 million
Standard Deviation	32.20 million
Sample Variance	1.03697E+13
Kurtosis	-0.05
Skewness	-0.89
Range	12101449

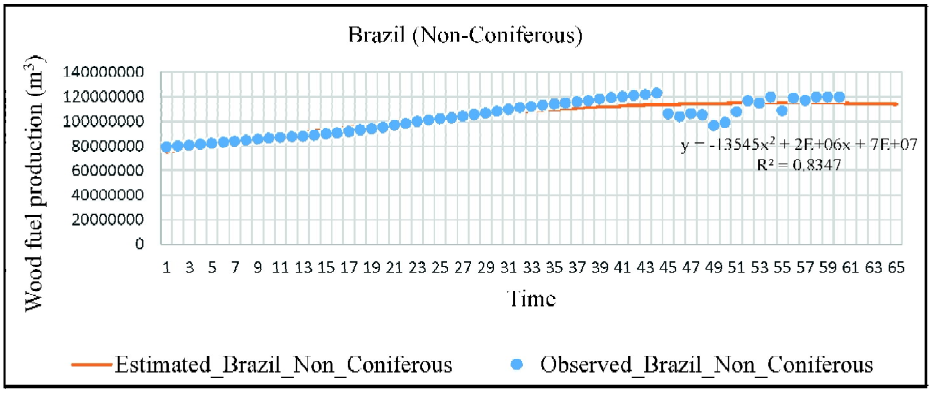

Figure 8:Trend in production of non-coniferous wood fuel in Brazil

Table 8: Per Se of non-coniferous wood fuel produced in Brazil

Mean	1028.15 million
Standard Error	1745911.629
Median	1047.92 million
Mode	1200.00 million
Standard Deviation	135.23 million
Sample Variance	1.82892E+14
Kurtosis	-1.28
Skewness	-0.21
Range	43908936

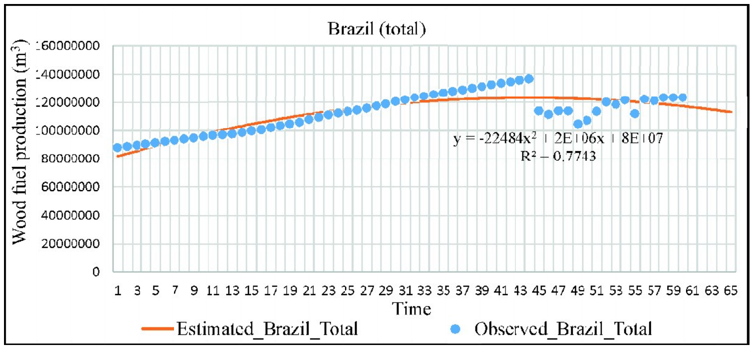

Figure 9: Trend in production of total wood fuel in Brazil

Table 9: Per Se of total wood fuel produced in Brazil

Mean	1122.73 million
Standard Error	1770191.222
Median	1134.42 million
Mode	1232.99 million
Standard Deviation	137.11 million
Sample Variance	1.88015E+14
Kurtosis	-1.04
Skewness	-0.10
Range	48785241

From the figures 7, 8 and 9, the estimated production of coniferous wood fuel in Brazil is 0m^3, non-coniferous wood fuel is 114066593.58597 m^3 and the total production is 112844524.24745 m^3. The mean of coniferous wood fuel produced is 9458325.033 , of non-coniferous wood fuel produced is 102815647.9 and the total mean of wood fuel produced is 112273972.9 . All the graphs have negative skewness and kurtosis. The decrease in wood fuel production in Brazil is maybe due to the reforestation activities

4. Ethiopia

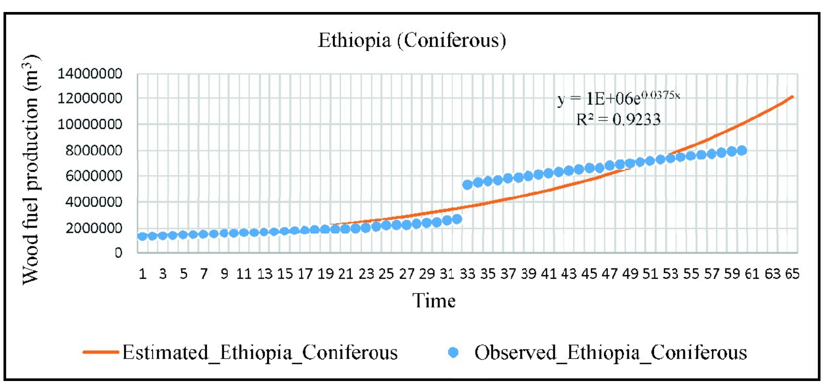

Figure 10: Trend in production of coniferous wood fuel in Ethiopia

Table 10: Per Se of coniferous wood fuel produced in Ethiopia

Mean	41.23 million
Standard Error	326825.1886
Median	25.41 million
Mode	66.09 million
Standard Deviation	25.31 million
Sample Variance	6.40888E+12
Kurtosis	-1.78
Skewness	0.23
Range	6698686

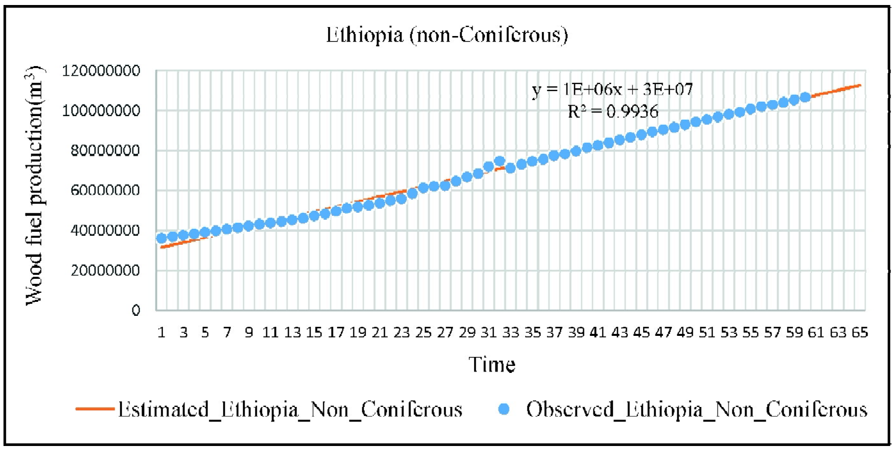

Figure 11: . Trend in production of non-coniferous wood fuel in Ethiopia

Table 11: Per Se of non-coniferous wood fuel produced in Ethiopia

Mean	689.07 million
Standard Error	2863235.905
Median	697.16 million
Mode	#N/A
Standard Deviation	221.78 million
Sample Variance	4.91887E+14
Kurtosis	-1.35
Skewness	0.10
Range	70387404

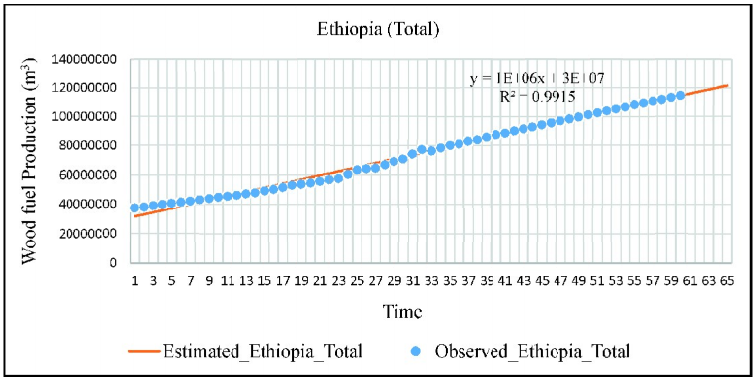

Figure 12: Trend in production of total wood fuel in Ethiopia

Table 12: Per Se of total wood fuel produced in Ethiopia

Mean	730.30 million
Standard Error	3178105.736
Median	726.70 million
Mode	#N/A
Standard Deviation	246.17 million
Sample Variance	6.06021E+14
Kurtosis	-1.39
Skewness	0.12
Range	77086090

From the figures 10, 11 and 12, the estimated production of coniferous wood fuel in Ethiopia is 12102060.42682 m^3, non-coniferous wood fuel is 112579728.26495 m^3 and the total production is 121454585.3156 m^3. The mean of coniferous wood fuel produced is 4123115.28 , of non-coniferous wood fuel produced is 68907711.28 and total mean of wood fuel produced is 73030826.57 . All the graphs have negative kurtosis and positive skewness.

5. Democratic Republic of Congo

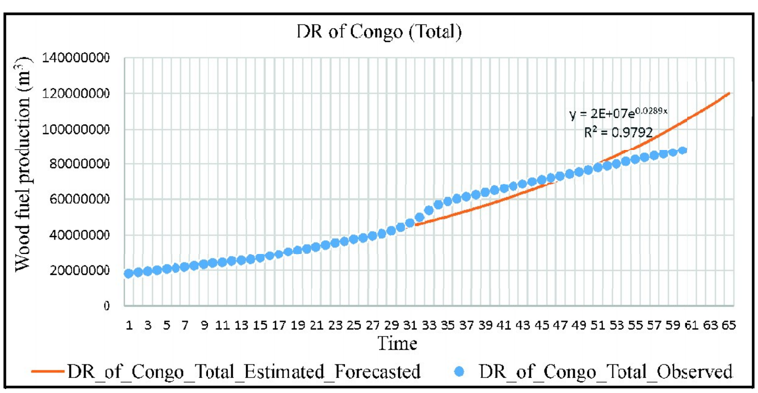

Figure 13: Trend in production of non-coniferous wood fuel in Democratic Republic of Congo

Table 13: Per Se of non-coniferous/ total wood fuel produced in Democratic Republic of Congo

Mean	498.49 million
Standard Error	2984642.473
Median	454.29 million
Mode	#N/A
Standard Deviation	231.18 million
Sample Variance	5.34485E+14
Kurtosis	-1.50
Skewness	0.16
Range	69600148

From the figure 13, the estimated production of non- coniferous wood fuel and/or total wood fuel is 119924758.11m^3. The mean of non-coniferous wood fuel and/or total wood fuel produced is 49849683.57. The graph shows negative kurtosis and positive skewness.

Discussion and Conclusion

Out of five countries, in all the countries non-coniferous wood fuel production was higher than coniferous wood fuel production. In case of India, wood fuel production was at increasing rate rapidly except at some period. In case of China, there was a rapid decrease in wood fuel production in recent decades which may be due to increase in per-capita income shifted to other sources or due to raising concerns for environment and climate change. In case of Brazil, there is a sudden decrease in wood fuel production which may be due to reforestation activity. In case of Ethiopia, there is an exponential increase in wood fuel production. This shows the change in the trend along the decade, the decreasing trend may be due to availability of rich conventional sources of energy and increase in per-capita income shifted to other sources whereas increasing trend may be ascribed to crisis in conventional energy sources and sustainable environmental development perspective. This has the implication that one should anticipate a drop in the national use of wood fuel as economic of developing countries expand (Girard, 2002). As a result of the strong economic expansion during the 1980s, this has been seen throughout Asia, where the use of wood fuels is diminishing in favour of alternative fuels. But economic progress in Africa, one of the world’s most disenfranchised continents, has been sluggish, and wood fuel consumption is rising (Kituyi, 2002).

Usage of wood fuel is very essential to mitigate climate change, as wood is made up of carbon sequestration process via photosynthesis. Thus, carbon which is present in the atmosphere is captured, used, reuse, reduce and emitted to the atmosphere without adding more carbon dioxide and carbon monoxide as like in conventional energy sources where carbon is removed from earth crust and emitted to atmospheres. Application of wood fuel to meet energy demand not only boost socio-economic status of the nation and rural economy but also play a major role in climate change mitigation and meeting Sustainable Development Goals (SDGs).

Refereces

Gangadharan, L and Valenzuela, M. R. (2001). Interrelationships between Income, Health and the environment: Extending the Environmental Kuznets Curve hypothesis. *Ecol. Econ.* 36, 513–531. [CrossRef]

Girard P (2002). Charcoal production and use in Africa: What Future? Unasylva 211(53): 30-34.

Hillring, B. and Trossero, M., (2006). International wood-fuel trade – an overview. *Energy for Sustainable Development*, **10**(1): 33-41

Hillring, B., (2006). World trade in forest products and wood fuel. *Biomass and Bioenergy*, 30: 815-825.

Kituyi E (2002). Towards Sustainable Charcoal Production and Use: a Systems Approach. Proceedings of a Regional Workshop on Woodfuel Policy and Legislation in Eastern and Southern Africa. RELMA, Nairobi, Kenya.

Lambe, F, Jürisoo, M., Wanjiru, H and Senyagwa, J. (2015). Bringing Clean, Safe, Affordable Cooking Energy to Households across Africa: An Agenda for Action. Available online: https://newclimateeconomy.report/workingpapers/wp-content/uploads/sites/5/2016/04/NCE-SEI2015-Transforming-household-energy-sub-Saharan-Africa.pdf (accessed on 5 June 2019).

Maji, I. K., Sulaiman, C and Abdul-Rahim, A. S. (2019). Renewable energy consumption and economic growth nexus: A fresh evidence from West Africa. Energy Rep. 5, 384–392. [CrossRef]

Parikka, M., (2004). Global biomass fuel resources. *Biomass and Bioenergy*, **27**: 613-620.

Rehfuess, E., Mehta, S., Prüss-Üstün. A. (2006). Assessing household solid fuel use: Multiple implications for the Millennium Development Goals. Environ. Health Perspect. 114, 373–378. [CrossRef] [PubMed]

Seevani, P., (2018). Wood as a Renewable Source of Energy and Future Fuel. *International Conference on Renewable Energy Research and Education*, Andra Pradesh, India. https://doi.org/10.1063/1.5047972

Sulaiman, C., Abdul-Rahim, A. S., Chin, L. and Mohd-Shahwahid, H. O. (2017). Wood fuel consumption and mortality rates in Sub-Saharan Africa: Evidence from a dynamic panel study. Chemosphere. 177, 224–231. [CrossRef] [PubMed]

WHO. Fuel for Life—Household Energy and Health; World Health Organization, 2005; Available online: https://www.who.int/indoorair/publications/fuelforlife/en/ (accessed on 5 June 2019)

Yeh, E. (2004) Indoor Air Pollution in Developing Countries: Household Use of Traditional Biomass Fuels and the Impact on Mortality; University of California: Berkeley, CA, USA.