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WOOD AS A BIOFUEL IN ROMANIA: A SOCIO-ECONOMIC PERSPECTIVE ON DISCREPANT REPORTED NUMBERS

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Abstract: *Nearly 50% of Romanian households use wood as a source of heating. A series of contradicting official reports regarding the demand and supply of firewood in Romania indicates that the consumed volume is higher than the available quantity. This study aims to characterise the dynamics of the firewood market and shed light on the officially reported figures. We analysed certain variables and their influence on firewood demand for six consecutive years. The demand was significantly higher than the supply and was strongly correlated with the unemployment rate. This socio-economic facet leads us to believe that abruptly diminishing fuelwood consumption is an unrealistic policy objective of the authorities.*

Keywords: *firewood, consumption, biofuel, supply, demand.*

1. Introduction

Forests have always represented a vital link in the chain of human evolution. Around 300.000 years ago, *Homo erectus* and the ancestors of *Homo sapiens* used fire daily, not only as a source of heat but also as fuel for cooking. Human civilization might have never reached today's evolutionary status without the use of wood as an energy resource [12]. Biomass energy has a broad spectrum of definitions, and it can be represented by multiple types of products, from corn ethanol to methane produced in landfills [9]. Nevertheless, wood is a crucial part of this classification and is preferred over

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energy crops because of its higher efficiency [10].

A study conducted in 2016 [8] showed that firewood and other wood products represented 45% of the total renewable energy resources worldwide. Today, around 3 billion people use biomass energy for cooking and heating [2].

It remains disputable whether the substitution of fossil energy with wood biomass or the use of forests as a terrestrial carbon sink is the best strategy [17]. Although the use of biomass energy has high potential, it could only replace a small percentage of fossil fuels [10].

In Romania, the period following the fall of the communist regime in 1989 was characterised by a long process of forest properties restitutions [5]. As a result, 64,3% of the Romanian forests are under public ownership, mostly managed by the National Forest Administration - Romsilva (75,1%), while 35,7% is private property, administered primarily by private forest management structures (95,5%) [14].

In Romania, traditional fuels (crude oil, coal, natural gas, uranium), and nuclear energy have a higher share than renewable energy, which only represented 24,22% of the energy sources used in 2016 [21]. Only 10% of this amount is solid biomass. In 2016, only 1% of the electric energy consumption was represented by biomass, equivalent to 46 terawatt per hour (TWh), 36 TWh of which was firewood [20]. Numerous studies show an almost complete overlap between solid biomass used for energy and firewood obtained from the forest industry [24].

The Paris Agreement of 2015 imposed higher consumption of biomass to the detriment of fossil fuels [25]. On the other hand, the use of woody biomass is becoming more problematic with increasingly rigid standards for forest management. Moreover, in some rural areas, this resource is used in inefficient heating systems, which is not only harmful to the environment but also to the residents, especially women living in less developed regions [1]. Some of the pollutants emitted by wood burnt in traditional stoves are carbon monoxide, hydrocarbons, free radicals, and organic compounds at concentrations 40-50 times higher than the recommendations of the World Health Organization [11].

In Romania, 45% of the households, 90% of which are located in rural areas, use firewood as a heating source. Moreover, 19% of the Romanian population suffers from the phenomenon called ”energy poverty”, which refers to the incapacity of a household to heat up sufficiently or to cover the expenses for other energy services [23].

Recently, numerous Romanian researchers have addressed the potential of biomass as a heating source, as well as the supply and demand of woody biomass [26]. Some of the studies were conducted at a national level [24], [26], while others have a regional scope [3]. These sources indicate that although the agricultural sector could supply 63% of the energy biomass [6], woody biomass (originated from forestry-specific activities) remains the main source of solid biomass for energy [24].

In Romania, for most of the forest surfaces, the limits of the wood supply are given by the annual allowable cut determined by strictly regulated forest management planning, and not by the potential demand. Properties with a surface lower than 10 hectares are not regulated by the management plan, but owners can harvest a maximum of 5m^3/year/ha [24]. All of these characteristics classify the firewood supply on the Romanian market as inelastic. Data on solid biomass consumption is scarce and sometimes contradictory. Certain studies show an annual supply of 10-13 million m^3, while the demand is 15-22 million m^3 [3], [24], [26], as stated by official sources of the Romanian government. All these facts raise a set of questions on the real dimension of the demand and supply of firewood, as well as on their social impact.

This paper aims to characterise the dynamics of the firewood market (supply and demand) and analyse the way certain contextual factors influence it.

2. Materials and Methods

2.1. Data Collection and Processing

Documentation and statistical analysis are the two research methods used in this study. The information regarding firewood production was extracted from public reports provided by the National Institute of Statistics (INSSE) and the Romanian Ministry of Environment, Waters and Forests. The website www. recensamantromania.ro [28] (census of the population and households) was used for demographic data and www.geo-spatial.org [27] for general vector data.

The analysis was done for each county of Romania for 6 years, from 2011 to 2017. Information on the following variables was extracted or calculated for every county in Romania: consumption of wood for heating (CWH), harvested volume of firewood with heating potential (HWH), surface of the forest fund by types of property (S), resident population (P), rural resident population (RP), gross domestic product (GDP), GDP per capita, net average nominal monthly earning (NME), unemployment rate (U). We made the assumption that the demand for wood for heating is CWH, and the supply HWH. Data on the last two parameters were not directly available, so they were determined through calculus, along with GDP per capita. The rest of the parameters were directly exported from INSSE. CWH and HWH were considered dependent variables, and the rest independent variables.

CWH was available from INSSE only for the year 2010 and only at a national level. Data regarding the total number of households and the number of households with central heating were extracted to find out the number of households without central heating. The result was multiplied by the average consumption of wood for heating per household (4.55 cubic meters [13], [26]). The obtained value is the total consumption of wood for heating, which was assimilated as CWH.

For HWH, data regarding the harvested volume per species, year, and county were extracted from INSSE reports. In order to calculate HWH, we assumed that it is the sum of firewood, bark, and other secondary assortments. Log, split round wood and other round wood assortments were ignored in this calculus.

2.2. Data Analysis

All data described above were included in a database created in Microsoft Office Excel 2007, with every sheet representing one year (starting with 2011 and up to 2017), which was then used for statistical analysis regarding the demand and supply of wood for heating, as well as for thematic maps. The ANOVA statistical analysis was performed using the data analysis options of the MS Office EXCEL program. We assessed the correlations between the demand and supply of wood for heating on the one hand, and other parameters on the other hand.

2.3. Mapping Materials

The maps are necessary for easy data interpretation. They were created in QGIS 3.10.4. The vector layer ”County limits Romania (polygon)” was downloaded from www.geo-spatial.org [27]. The attribute table of the vector layer and the Excel table were joined, and the intervals ”Natural breaks (Jenks)” were used to classify the information. A single colour was assigned to each parameter for both the year 2011 and 2017.

3. Results and Discussions

3.1. The Evolution of the Demand and Supply of Woody Biomass

CWH has higher values than HWH for the entire period (Figure 1). The minimum value was registered in 2011 (21365 thousand cubic meters), and the maximum one in 2017 (22025.8 thousand cubic meters), compared to HWH that had the maximum value in 2013 (7639.79 thousand cubic meters) and the minimum one in 2014 (6803.3 thousand cubic meters).

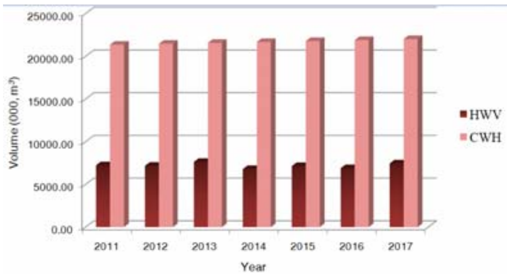

Fig. 1. *The total supply and demand of wood for heating (thousand m^3)*

In some cases, as seen in Figure 2, HWH can be equal to or higher than CWH, for example in Suceava in 2011. However, in most of the counties, such as Dolj, Olt, Galați, Iași, HWH is much lower than CWH (e.g., Dolj: HWH 74.64 thousand cubic meters, CWH 805.7 thousand cubic meters average for the period 2011-2017).

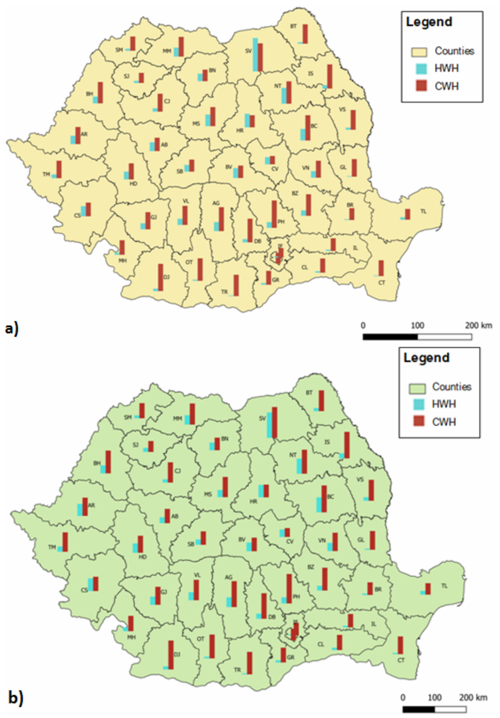

Fig. 2. *Supply and demand for wood for heating by county a) 2011 b) 2017:*
a) CWH and HWH at county level in 2011
b) CWH and HWH at county level in 2017

Overall, in 2011, Covasna had the lowest consumption of wood for heating (244.8 thousand cubic meters), followed by Ilfov (279.1 thousand cubic meters), while Suceava had the highest consumption (823 thousand cubic meters).

The supply is unpredictable but does undergo a slight increase from 2011 to 2017. Although the demand continues to grow, in some counties where the supply had the highest values in 2011, it diminishes until 2017. For example, in Suceava, HWH lowers in value from 2011 to 2017 with 268.23 thousand cubic meters.

3.2. Demand and GDP

The highest GDP value was registered in Bucharest (133584.4 thousand RON in 2011 and 208653.1 thousand RON in 2017), and the lowest in Mehedinți in 2011 (4331.8 thousand RON) and Covasna in 2017 (64151.1 thousand RON). If Bucharest is excluded, because it is the capital of Romania, causing it to have extreme values, the influence between GDP and CWH becomes significant (p-value=0.0039). Once again, other factors influence CWH (R^2=0.104).

GDP/capita also reaches the highest values in Bucharest (70.92 thousand RON/person in 2011 and 114.23 thousand RON/person in 2017). The lowest values are registered in Vaslui (12.77 thousand RON/person in 2011 and 20.32 thousand RON/ person in 2017). However, there is no connection between the two parameters (p=0.323; R^2=0.025).

3.3. Demand and Resident Population

The largest population is in Bucharest for both 2011 (1.883.425 residents) and 2017 (1.826.579 residents). The smallest population size is in Covasna in 2011 (210.177 residents in 2011) and in Tulcea in 2017 (200.706 residents).

By excluding Bucharest from the analysis, for the same reasons as in section 3.2., CWH and P become interconnected (p-value from 0.1 to 0.0000000267; R^2 from 0.06 to 0.55)

3.4. Demand and Rural Population

Iași county has the largest rural population (447.916 in 2011 and 480.545 in 2017), while Hunedoara the smallest one (107.324 in 2011 and 103.462 in 2017).

As observed in Figure 3, the results show a connection between the two variables (p=1.93E-14; R^2=0.772).

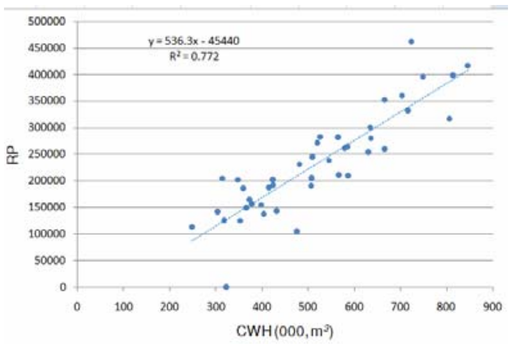

Fig. 3. *Scatter plot for RP and CWH*

3.5. Demand and Net Average Monthly Earnings

Bucharest has the highest values for NME (2.114 RON in 2011 and 3.272 RON in 2017). The lowest values appear in Hunedoara in 2011 (1.043 RON) and Harghita in 2017 (1.796 RON).

Contrary to the other parameters, Bucharest seems not to have an effect on NME (p-value=0.6186, R^2=0.006 with Bucharest, p-value=0.1919, R^2=0.044, excluding Bucharest).

3.6. Demand and Unemployment Rate

Dolj county has the highest number of unemployed individuals, 25.395 in 2011 and 23.331 in 2017, while Ilfov the lowest one, 2.699 in 2011 and 1.207 in 2017.

There is a significant statistical connection between the two variables (p=0.0000192; R^2=0.370). Figure 4 presents the distribution of U and its evolution between 2011 and 2017.

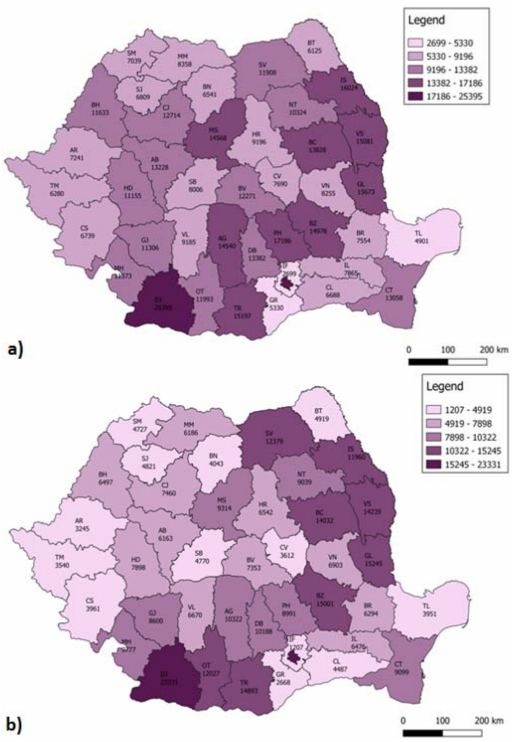

Fig. 4. *Unemployment rate per county: a) U for 2011; b) U for 2017*

3.7. Analysis of Other Factors

The same linear regression method was used to analyse the rest of the possible connections between independent variables and the supply and demand. The results are briefly described in Table 1.

Table 1

Results of the statistical analysis between CWH, HWH, and the other variables

Dep. variable	Indep. variable	R^2	Standard error	p
CWH	S	0.06	105.781	0.116
	S public property	0.105	70.596	0.035
HWH	S	0.766	52.7564	3.36E-14
	S public property	0.606	46.857	1.287E-09
	P	0.002	273791.9	0.766
	RP	0.116	90889.8	0.027
	NME	0.07	241.489	0.09
	U	0.0004	4927.7	0.89

3.8. Discussions

The reports of INSSE indicate consumption levels of wood for heating of 19 million tons for the year 2009 [13]. According to the standard conversion coefficient, 1 ton of wood equals 1.25 cubic meters of wood [24]. The CWH for the year 2009 was 23.75 million cubic meters. The harvested volumes reported in the same year by the forest districts through the SILV3 questionnaire was 16 million cubic meters. According to the same report, out of this volume, only 11.964.200 cubic meters were sold. The difference between what is consumed and what is harvested, in this context, is negative. Moreover, this implies that no round wood is actually merchandised, but instead, all of it is burned.

These confusing findings (deducted from officially reported figures) are completed by other apparently conflicting and debatable public data: INSSE and the National Forestry Inventory (IFN) reported different numbers. The average annual harvested volume indicated by INSSE, of 18 million m^3, differs from the one reported by IFN, of 38 million m^3 annually (between 2012 and 2018). This may be due to independent, distinct reporting methods used by the two entities. Additionally, INSSE separates two ways of reporting: the annual harvested volume is reported by the forest districts through the SILV3 questionnaire and the annual exploited volume, reported by economic agents through the SILV5 questionnaire, which is confidential. These situations can be observed in other countries of the European Union: in France, a difference of almost 10 million cubic meters between reports, and in Germany, 19 million cubic meters [24].

A study conducted at European level by the Hamburg University [18] showed that the exceedance of the supply by the potential demand for the period 2015-2020 was inevitable. The same study emphasises the importance of political and economic efforts, as well as good forest management, to cease the growth of the demand in a more rapid rhythm than the supply.

At a national level, although the studies are not numerous, they confirm the results obtained in section 3.1., namely that no matter the errors in calculus, the differences between the supply and the demand are significant [26]. The same conclusion is drawn in a collaborative study between Transilvania University of Brasov and the Ștefan cel Mare University of Suceava [24]. A study conducted for Suceava county [3] reports similar results: between the demand and supply of wood for heating, there is a deficit of at least 300 thousand cubic meters.

CWH proved to be influenced by the social facet of the market. There was no connection between CWH and GDP/capita, which is supported by a study conducted between 1980 and 2006 on the causality between the two factors in Romania, Hungary, Bulgaria, and Albania [22]. This is also backed by relevant literature regarding the relationship between the standard of living and energetic consumption. Different authors have divergent theories on the topic: the existence of a proportional relationship between the two [4], [19], the hypothesis that high consumption will lead to economic growth [15], the possibility of bidirectional causality between the two, meaning that each is caused by the other [16], while other authors believe there is no relationship between the two [23].

CWH and NME were also not correlated. However, this could be explained by the fact that NME is higher in the urban area since the study proved that the highest CWH is primarily in rural areas. We recommended that future studies find an indicator that shows the average incomes per person in rural areas.

Lastly, the number of unemployed individuals is a good indicator of welfare. The correlation that was highlighted in section 3.6. shows the social facet of CWH, which could potentially explain the differences between reports regarding this parameter.

Section 3.7. shows a slight correlation between CWH and S, meaning that in general, the S dimensions do not affect the consumption levels. This can be explained through commerce between counties.

HWH and S are correlated because a higher surface offers a higher harvesting possibility. It is interesting to notice the connection between HWH and RP. The harvested volume is higher in rural areas than in urban ones.

4. Conclusions

The potential demand, represented by CWH, is influenced to varying degrees by the analysed factors. For the studied period, the potential demand constantly exceeded the supply. The errors caused by different collecting and processing methods, in the absence of publicly disclosed data, do not justify the large differences between CWH and HWH. The possibility that part of CWH was fulfilled through other resources, such as agricultural residues, still does not explain the gap.

Both CWH and HWH were calculated approximately based on incomplete datasets. For example, information on CWH was only available for 2011, and data regarding HWH was missing, which imposed its calculus based on harvested volumes per species and industrial assortments. Similarly, the information regarding S by types of property was only available for the year 2014.

Regardless of these limitations, a large quantity of woody biomass destined for energy production seems to not have been introduced in the official reports or the taxed economic circuit.

The study proved that CWH has a strong social dimension, which is primarily pointed out by the unemployment rate. Although GDP and GDP per capita do not seem to influence CWH, it can be assumed that the Actual Individual Consumption would have better representativeness than GDP. Data on Actual Individual Consumption were not available.

The same case applies to NME. Information on the general income in rural areas would probably prove to be more relevant. This conclusion was drawn from the strong connection between RP and CWH, which proved a higher demand in rural areas.

Wood for heating does fulfil a social need. Consumption is influenced by welfare, which means that despite the strategies that will be implemented by 2030, ceasing consumption might not be possible. Moreover, the rigid legislative framework can be an obstacle for investments [7]. Additionally, the current initiatives to restrict even further the methodology regarding the harvest and commercialisation of wood may worsen the situation, provoking a wood shortage on the market, especially in the context of an ascending trend of the demand.

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