Food and Agriculture Organization
of the United Nations

WISDOM SERBIA

Spatial wood fuels production and consumption analysis

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The work carried out in the framework of the FAO/Government of Serbia Project: "Wood energy for sustainable rural development" TCP/YUG/3201

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FOREWORD

The Woodfuel Integrated Supply and Demand Overview Mapping (WISDOM) in Serbia form part of a series of initiatives undertaken by FAO to promote strategic wood energy planning and policy formulation. As in many countries all over the globe the wood energy sector suffers from a widespread lack of recognition in national planning contexts, especially in forest and energy policies.

The complex cross-sectoral character of wood energy, which touches energy, forestry, agriculture and rural development, often translates into fragmentation of institutional competencies, thus leaving the wood energy issue "nobody's child". WISDOM, which was developed by FAO, takes into account particularities of national wood energy systems and meets the needs for a planning tool that integrates relevant socio-economic information and data on woodfuel production and consumption provided by forestry and energy agencies. Thus, WISDOM is an effective tool to enhance the recognition of the wood energy issue and to make this complex issue more readable to policy makers.

The results of the WISDOM project open the prospects of developing a holistic vision and a clear definition of priorities related to wood energy, formalizing wood fuel trade, as well as streamlining the collection and analysis of information on wood fuel demand and supply.
The FAO Regional Office for Europe and Central Asia wishes to express its gratitude to the Ministry of Agriculture and Environmental Protection of Serbia for the kind support.

Vladimir Rakhmanin
Assistant Director-General
Regional Representative for Europe and Central Asia

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During the development of the WISDOM geodatabase for wood energy in Serbia, a large number of activities were realized in accordance with the multidisciplinary character of wood energy. In light of this, the research conducted as part of this project represents the most comprehensive research in the field of wood energy to date in Serbia. Many researchers, national and international consultants, interviewers, public enterprises, institutions, organizations, wood industry companies, associations of private forest owners, representatives of religious facilities, owners of commercial facilities, representatives of public facilities, entrepreneurs and other persons took part in this research. All of them contributed to the creation of a clear picture of the most significant segments of the wood energy system in Serbia.

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SYMBOLS AND ABBREVIATIONS

€	euro
$	United States dollar unless otherwise specified
CARDS	Community Assistance for Reconstruction, Development and Stabilisation
EU	European Union
GDP	Gross Domestic Product
FRA	Forest Resources Assessment
GIS	Geographic Information System
ha	hectare
kWh	kilowatt hour
MAI	Mean Annual Increment
MWh	megawatt hour
Mtoe	Million tonne of oil equivalent
m^3	cubic metre
NFI	National Forest Inventory
pcs	pieces
stacked m^3	the stacked cubic metre is the unit of measurement used for neatly-stacked log woods
SWBAP	Serbian Woody Biomass Action Plan
SWEIS	Serbian Wood Energy Information System
toe	tonne of oil equivalent
m.t.	metric ton or tonne
TJ	terajoule
VAT	Value added tax
UNECE	United Nations Economic Commission for Europe
WISDOM	Wood fuel Integrated Supply/Demand Overview Mapping

SUMMARY

Serbia has vast potential for using woody biomass for energy. However, despite this potential, wood plays a sub-optimal role in meeting energy needs. The main reason for this seems to be a widespread lack of understanding of how indigenous supplies of woody biomass could provide clean energy from a renewable source and of the added benefits that wood offers. For Serbia, some of these benefits include increased investment in forest development resulting in increased forest economic activity, increased sustainable management of forests, a considerable reduction in the import bill for fossil fuel and reduced greenhouse gas emissions. With more than 11 million tonnes[1] of agricultural and woody biomass produced annually from agricultural residues, Serbia has further potential to develop its bioenergy sector, especially for electricity and power generation.

Starting from these facts, and with the wish to develop a reliable planning system for the needs of national policy in the wood energy segment, the Government of the Republic of Serbia, supported by FAO, implemented the project "Wood Energy for Sustainable Rural Development in Serbia", TCP/YUG/3201 between 2009 and 2011. This Working Paper summarized the results and main methodological principles which were used in the process of collecting, processing and analyzing data for the purpose of this project.

The overall objective of this project was to increase the competence of the Forest Administration and the Ministry of Agriculture, Forestry and Water Management[2] regarding the formulation, assessment and development of a coherent strategy, programs and projects for bioenergy, compatible with sustainable management in the sectors of forestry, energy and agriculture. More specifically, the objectives were to contribute to the creation of the Serbia Wood Energy Information System (SWEIS) and to develop a series of thematic wood energy maps, following the WISDOM (Wood fuels Integrated Supply/Demand Overview Mapping) methodology.

In accordance with the overall objectives, the project defines an adequate methodological concept aimed at obtaining primarily relevant and reliable data on woody biomass potential and consumption. Then, by using the WISDOM methodology and suitable GIS software packages, the project team performed their analysis, mapping, table, and graphic representation. One of the most significant elements of the methodological concept that was adopted was the field research, which was conducted in industrial wood processing companies, wood-based panel production companies, lime production companies and wood fuel production companies (charcoal, wood chips, wood briquettes and wood pellets). Apart from this, field research was also conducted at numerous commercial facilities (restaurants, bakeries, meat roasters, car repair services, tourist facilities) and public facilities (schools, health-care centres, ambulances and Serbian Orthodox Church facilities). In this way, the research involved all the most significant groups of woody biomass consumers across Serbia

[1] In the report tonnes refers to metric tonnes

[2] Within the context of this report the Ministry of Agriculture and Environmental Protection is referred to as Ministry of Agriculture, Forestry and Water Management as being the predecessor of the present Ministry.

with the purpose of obtaining an overall image of its total consumption and participation of certain consumer categories.
The main output is Serbia WISDOM, which includes a geodatabase at municipality level, which provides details on current and potential wood fuel production and consumption patterns, the first version of the Serbia Wood Energy information System (SWEIS) and the first Serbian Woody Biomass Action Plan (SWBAP).

WISDOM - Woodfuels Integrated Supply/Demand Overview Mapping

WISDOM is a spatially-explicit method oriented towards supporting strategic wood energy planning and policy formulation, through the integration and analysis of existing wood fuel demand and supply related information and indicators.

The Serbia WISDOM analysis was based on 161 municipalities with 25 administrative regions and cartographic references. The application of the standard WISDOM analysis produces supply and demand balance mapping at the local level and involves five main steps with a modular and open structure:

1. Definition of the minimum administrative *spatial* unit of analysis.
2. Development of the *demand* module.
3. Development of the *supply* module.
4. Development of the *integration* module.
5. Selection of the *priority* areas under different perspectives

The base map supporting the whole analysis, are the Corine land cover map with appropriate spatial resolution and the map of forest compartments from Srbijašume company with relatively high selected spatial resolution.

Main findings and conclusions

The project's main contributions can be roughly grouped into two categories: (i) determining actual consumption of woody biomass in Serbia and (ii) identification of the main woody biomass sources available to Serbia has and a quantification of their potential. To that effect, the main results of WISDOM and SWEIS are:

- Forests are the largest and the most important source of woody biomass (contributing 58.2 percent). They are followed by non-forest areas of trees, bushes, and trees with bushes which account for 32.4 percent, while woody biomass from industry contributes 9.4 percent.

- If allowable cut from management plans and allowable cut as 70 percent of the Mean Annual Increment (MAI) are taken into consideration, the total wood supply for energy is 6.3 million m^3 in the first case and 7.8 million m^3 in the second.

- Comparative analysis of the values of an increased allowable cut of 9.66 million m^3, as well as the values of a predicted current cut of 8.9 million m^3 shows that there is potential for an additional 728 000 m^3 of woody biomass compared to the values currently used.

- In 2010, total demand of woody biomass for energy purposes in Serbia was 6.7 million m^3, and for non-energy purposes it was 710 000 m^3 (wood based panels, wood fuels production, lime production)

- Total consumption of woody biomass for heating purposes in households in Serbia in the 2010-2011 heating season was 6 416 693 m^3, out of which 6 360 788 m^3 was firewood and 55 905 m^3 was solid wood residue from sawmills and packaging production.

- Total consumption of wood pellets in households in the 2010-2011 heating season was 7 722 tonnes while the consumption of wood briquettes in the same period was 13 189 tonnes.

- The total amount of energy consumed from wood fuels in households in the 2010-2011 heating season was 1.28 million tonnes of oil equivalent (Mtoe).

- The largest amounts of woody biomass in 2010 were used for firewood production. 382 300 m^3 were used for the production of other wood fuels (charcoal, wood pellets, briquettes and wood chips).

- Significant segments in which woody biomass is used are: production of wood based panels, energy generation for internal needs of wood processing industry, lime production, bakeries, meat roasters, schools, facilities of Serbian Orthodox Churches, restaurants, facilities in health care systems and car repair services. Total consumption of woody biomass in stated segments in 2010 was 615 900 m^3, out of which 25 900 m^3 in the form of wood chips and the rest in the form of firewood, long-length roundwood and large-sized residues from sawmills. The biggest part of woody biomass amounts is used for the production of wood based panels (53.8 percent), followed by energy generation for internal needs of industry (35.7 percent), schools (4.1 percent) and lime production (1.8 percent). Other consumer categories contributed 4.6 percent in this segment.

- Out of the total of 7.41 million m^3 of woody biomass, which was consumed for energy and non-energy purposes in Serbia, 94.94 percent (7.03 million m^3) was woody biomass in the form of wood (firewood, long-length roundwood, branches, buttresses and tops). The second two types contributed significantly less, especially sawdust, which contributed 0.75 percent in the total consumption of woody biomass, while large residue from industry contributed 4.31 percent or 319 300 m^3.

Local supply/demand balance

About two thirds of municipalities (99) in Serbia have a negative balance in the sense that their actual consumption of wood fuels is higher than that officially registered. At national level, the difference is -1.17 million tonnes.

Such a situation results from two factors:

- Many municipalities (especially in Vojvodina and central Serbia) have modest forest resources but large wood consumption, and
- An insufficiently reliable statistical record of wood fuel production which is several times higher than that officially recorded.

In practice, this means that large amounts of wood fuels from municipalities with rich forest resources and where wood fuel production is developed are transported to the municipalities with modest forest resources and large consumption of wood fuels.

Almost half of all municipalities (77) in Serbia have a negative balance in the sense that their actual consumption of wood fuels is higher than the predicted real cut of their production. The largest deficit is in the municipality of Kragujevac -93 447 tonnes and the largest surplus is in near the municipality of Ivanjica (+73 911 tonnes). At national level, the difference is +37 900 tonnes.

Almost half of municipalities (80) in Serbia have a negative balance in the sense that their actual consumption of wood fuels is higher than the current allowable cut of production. The largest deficit is in the municipality of Kragujevac -103 308 tonnes and the largest surplus is in the municipality of Ivanjica (+64 609 tonnes). At national level, the difference is -254 992 tonnes.

Less than half of municipalities (75) in Serbia have a negative balance in the sense that their actual consumption of wood fuels is higher than the increased allowable cut of their production in particular municipality. The largest deficit is again in the municipality of Kragujevac at -87 306 tonnes and the largest surplus is in the municipality of Ivanjica (+100 551 tonnes).

This comparative analysis of actual consumption of wood fuels in relation to increased allowable cuts leads to the conclusion that there is potential for an additional 532 200 tonne increase of consumption.

SWEIS - Serbian Wood Energy Information System

SWEIS summarizes national level production, imports, exports and consumption of wood fuels. The results are mainly different from past estimations, which were done for various institutions and organizations in the country and abroad. These results are also very different from the data of the official statistics. Thus, for example, the real consumption (production) of the fuelwood is almost four times larger than the statistical records suggest.

Wood energy balances

According to the official energy balance (Serbian Statistical Office 2011), total consumption of final energy for energy purposes in Serbia in 2010 was 376 436 TJ with the participation of wood energy of 3.1 percent.

Based on TCP results and calculations performed it can be concluded that the total amount of energy consumed from wood fuels in households and other consumers in the 2010-2011 heating season was 1.37 million tonnes of oil equivalent (Mtoe) (table 10). This amount is 4.9 times higher than the value of energy from wood fuel which is contained in the energy balance of the Republic of Serbia for 2010 (0.281 Mtoe)

Based on these results and calculations it can be concluded that wood energy (57 301 TJ) contributed 13.6 percent of the total final energy consumption (421 978 TJ) of wood energy for energy purposes in Serbia in 2010.

The contribution of wood fuels to climate change mitigation and the economy of Serbia

- Current use of wood energy substitutes imports of light heating oil in the value of EUR 1.3 billion or EUR 650 million in the case of substituting natural gas (Serbian GDP in 2010: EUR 60 billion).
- Use of wood fuel prevented CO_2 emissions of about 7 million tonnes from fossil fuels. The theoretical value of these carbon emission currently value EUR 55 million (EUR 8 per tonne).

1. INTRODUCTION

1.1. Background

In much of Europe, municipalities and individual consumers are strongly encouraged to switch to wood fuel due to the perceived environmental, economic and social benefits. In Serbia an opportunity exists to build a culture that encourages municipalities in areas with abundant wood resources to use indigenous wood supplies as the fuel of first choice, replacing imported fossil fuel to the fullest extent possible. This is especially true since many district heating systems are inefficient and in disrepair, resulting in the waste of precious energy. In addition, a lack of markets for smaller sized, lower quality trees, does not give forest owners any incentive to engage in sustainable management. Forest residues from timber harvesting remain unexploited. Further, an EU-funded study under the CARDS programme[3], indicated that much of the wood industry's co-products are more likely to find their way to landfill sites, producing methane, rather than to be used for energy. At the same time, there is an urgent need to update the skills within the heating sector so that heating engineers and installers attain basic knowledge of wood heating technology that is equivalent to that for gas and oil. This lack of expertise was identified in Austria as one of the principal barriers to the development of wood energy. The combination of expertise and solid practical experience in near other European countries, especially Austria, Slovenia, Croatia and Italy, should be drawn on to fill the gap in Serbia.

Serbia is currently investing heavily in the overhaul of local, regional and national space heating networks. Many heavy fuel oil boilers are being renewed and refurbished, without taking a fuel switch into consideration. Unless immediate action is taken to persuade the government, local authorities and the public that wood may be a realistic option to meet energy needs efficiently and cost effectively, the opportunity to adopt wood as the fuel of choice will be lost.

For these reasons, FAO's assistance was urgently needed to develop a sound wood energy programme, which encompasses both the forestry and energy sectors. The main gaps that required urgent justification for FAO involvement are the following:

- Assessment of the actual potential of woody biomass that Serbia has at its disposal by using an internationally acknowledged methodology as well as data from the national forest inventory;
- Examination of actual consumption of wood fuels and the related consumption of wood energy for heating households, public facilities, industry and other consumer categories;

[3] **REGIONAL ENERGY APPROACH IN WEST BALKANS – ENVIRONMENTAL ACQUIS, European Commission CARDS 83816_2040836,** Supply of Services No. 2004/83816
CARDS- Community Assistance for Reconstruction, Development and Stabilisation

- Strengthening professional capacities of staff in forest administration and in the Ministry of Energy to correctly conduct data collection and data assessments in the future.
- Production of new national energy balances for wood and wood fuels based on previously conducted research, which would include data of great importance for Serbia in the context of fulfilling its obligations to meet 2020 targets.
- Quantification of macro and socio-economic significance of woody biomass for rural development in Serbia.

Starting from these facts, and with the wish to develop a reliable planning system for the needs of national policy in the segment of wood energy, the Government of the Republic of Serbia, supported by FAO, implemented the project "**Wood Energy for Sustainable Rural Development in Serbia", TCP/YUG/321** in the period 2009-2011.

The content of the Project is wide and it captured all areas important for the utilization of woody biomass in Serbia for energy purposes. The entire project included the following elements:

- Woody biomass maps;
- Wood energy information system;
- Macro and Socioeconomic aspects of wood energy;
- Analysis of wood fuel market;
- Wood energy technologies;
- Legal aspects of the production, trade and use of wood fuels;
- Extension on the field of wood energy;
- Dissemination of knowledge and strengthening of public awareness

Bearing in mind that the WISDOM methodology was developed within FAO, its implementation in Serbia was more than necessary. WISDOM is a spatial-explicit method for highlighting and determining priority areas of intervention and supporting wood energy and bioenergy planning and policy formulation (http://www.wisdomprojects.net/).

It will help to determine the current revenue generating importance of woody biomass for the rural population, and will contribute towards creating conditions for the future development of rural wood fuel entrepreneurship.

1.2. Objectives

The main objective of the project is FAO support to the Serbian Government in overcoming the existing gaps in terms of relevant data and information on potential, consumption and contribution of wood energy. The support should contribute towards achieving national targets for how much renewable energy sources contribute towards total final energy consumption by 2020. Additionally, it should enhance the capabilities of the **Directorate of Forests (DF),** Ministry of Agriculture, Forestry and Water Management, in formulating, evaluating and developing sound bioenergy strategies, programs and projects compatible with sustainable management of the forestry, energy and agricultural sectors.

In particular the project assisted the **Directorate of Forests** in:

1. Developing a Geographic Information System (GIS) database created with wood supply, demand and integration module;
2. Preparing the Serbian Wood Energy Information System (SWEIS), which provides statistical data on fuelwood, charcoal, wood chips, briquettes and pellet production, consumption and trade (import, export);

3. Preparing a **Wood Energy Action Plan** for the sustainable production, utilization and trade of wood fuels. This plan is properly integrated with existing forestry, energy, environment and development policies and programs.

4. Identifying the zones most suitable for the development and implementation of wood energy projects

5. Improving national capabilities, especially those of the Directorate of Forests and associated partners, for developing and planning bioenergy programs.

These objectives are realized by conducting comprehensive field research in the segment of woody biomass and wood fuel consumption as well as by using WISDOM methodology to identify and quantify Serbia's potential in terms of woody biomass.

2. WISDOM DEVELOPMENT

2.1. WISDOM methodology

WISDOM is a spatially-explicit method oriented to support strategic wood energy planning and policy formulation, through the integration and analysis of existing wood fuel demand and supply related information and indicators. Rather than absolute and quantitative data, WISDOM is meant to provide relative/qualitative values such as risk zoning or criticality ranking or highlighting, in the highest possible spatial detail, the areas that deserve attention and, if needed, additional data collection. In other words, WISDOM serves as an ASSESSING and STRATEGIC PLANNING tool to identify priority places for action (Wisdom Slovenia 2006).

WISDOM is based on:
a) The use of geo-referenced socio-demographic and natural resource databases integrated within a geographical information system;
b) A minimum spatial unit of analysis at sub-national level;
c) A modular, open, and adaptable framework which integrates information of relevance to wood energy from multiple sources; and
d) A comprehensive coverage of wood fuel resources and demand from different energy users.

In the development of WISDOM Serbia, a methodology was used whose most significant elements are as follows:

Main phases	Activities
Preparatory actions and GIS analyses	Selection of spatial base, data structure and projections, Corine land cover map, map of settlements, digital elevation model data, statistical yearbook data analyses, map of average annual temperature and map of protected areas
Definition of the minimum administrative *spatial* unit of analysis	 Administrative regions, municipalities, forest compartments or Corine landcover data differ in their geographic coverage. It was therefore necessary to develop a minimum administrative spatial unit as vector data.

Development of the *demand* module	One of the most significant elements of development of the demand module was a piece of empirical field research based on a questionnaire (with appropriate questionnaires). It was conducted in households, industrial wood processing companies, wood-based panel production companies, lime production companies and wood fuel production companies (charcoal, wood chips, wood briquettes and wood pellets). The field research was also conducted at numerous commercial facilities (restaurants, bakeries, meat roasters, car repair services and tourist facilities) and public facilities (schools, health-care centres, ambulances and Serbian Orthodox Church facilities). The number and structure of woody biomass consumers among which field research was conducted was as follows: 36 946 households, 4 892 school facilities, 112 health-care centres, 168 bakeries, 111 meat roasters, 153 car repair services, 193 restaurants, 81 lime-burning factories, more than 1000 facilities of the Serbian Orthodox Church, 3 factories of wood-based panels, 378 companies for sawn timber production, 42 producers of wood packaging, 34 producers of wood pallets, 41 producers of wood briquettes, 11 producers of wood pellets, 5 producers of wood chips, and 173 producers of charcoal. This way, the research involved all most significant groups of woody biomass consumers across Serbia with the purpose to obtain the overall image of its total consumption and participation of certain consumer categories.
Development of the supply module	Input, analysis and display of the following data on Serbian forest fund (based on the National Forest Inventory): forest area, growing stock, annual increment, number of trees, ownership, the primary purpose, the categorization of high conservation value forests, protection of forests to hide objects, nature park -1st degree of protection, special Nature Reserve-1st degree, National Park-1st degree, Strict Nature Reserve -1st degree, The landscape of exceptional quality -1st degree. In the state forests for which data is available the information was used at the compartment level (data from "Srbijašume" company). For other areas (private or without data) forest masks were used from CORINE data and NFI sample plots located in this area (at municipality level). To determine the amount of tree and shrub biomass from non-forests land types, a simple and quick sample survey was performed. After selecting important land use types, a systematic sample grid (4x4km) with the 4 665 sample plots with radius of 250 m for the whole country was produced. The survey used available Corine land use

	map and satellite ortophotos coverage from Google Earth. Each cover type was digitized as a closed polygon and coded according to cover type. Sawmills and other wood processing industries are important sources of woody biomass that could be useful (or already used) for energy production. To evaluate these quantities the amount of felling and/or timber harvest potential by individual municipalities was used.
Development of the *integration* module	The main product of the Integration Module, which is the supply/demand balance analysis, is done at cell level by subtracting current consumption from supply potential for all relevant assortment categories (Drigo 2011). The mapping procedure to spatially distribute the estimated woody biomass parameters is the following: Rasterization of Municipality layer (Opštine) on the ID code; Rasterization of Administrative regions layer (Okruzi) on the ID code; Calculation of amounts per pixel (kg per ha); Rasterization of all supply and demand maps at the selected resolution (100 m); Integration of all produced rasters to four balance rasters (actual official balance (bal_cut), actual predicted balance (bal_cu2), theoretical official balance (bal_etat) and theoretical increased balance (bal_et2): Sum of all pixel values on a municipality level and on an administrative region level.
Selection of the *priority* areas under different perspectives	Supply/demand balance data is also composed to define the suitable locations for biomass plants. In this case the locations for hypothetical plants are not defined preliminarily as for the woodshed analysis presented above. In this case the analysis is done at once over the entire country and the scope is to determine the supply potential of each map pixel assuming a certain supply radius.
Development of the new *Wood Energy Balances*	Energy value of consumed woody biomass (wood fuels) in households and other consumers in the 2010-2011 heating season was calculated based on the consumption of certain types of wood fuels for each county individually.

2.1.1. Spatial base and geodatabase structure

The creation of WISDOM Serbia followed the main idea of WISDOM principles developed by FAO.

As in most countries, the information about production and consumption of biomass in Serbia is fragmented, incomplete and almost systematically underestimates the actual production and consumption levels (Drigo 2011).

The application of the standard WISDOM analysis producing supply and demand balance mapping at the local level involves five main steps with a modular and open structure (Masera et. *al*., 2003):

1. Definition of the minimum administrative *spatial* unit of analysis.
2. Development of the *demand* module.
3. Development of the *supply* module.
4. Development of the *integration* module.
5. Selection of the *priority* areas under different perspectives.

The base map supporting the whole analysis, are the Corine land cover map with appropriate spatial resolution and the map of forest compartments from Srbijašume company with relatively high selected spatial resolution.

Once the analysis of wood fuel supply, demand and balance had been completed at vector level, the results were rasterized and then summarized (any administrative level can be chosen).

For the scope of this report two main levels are selected:

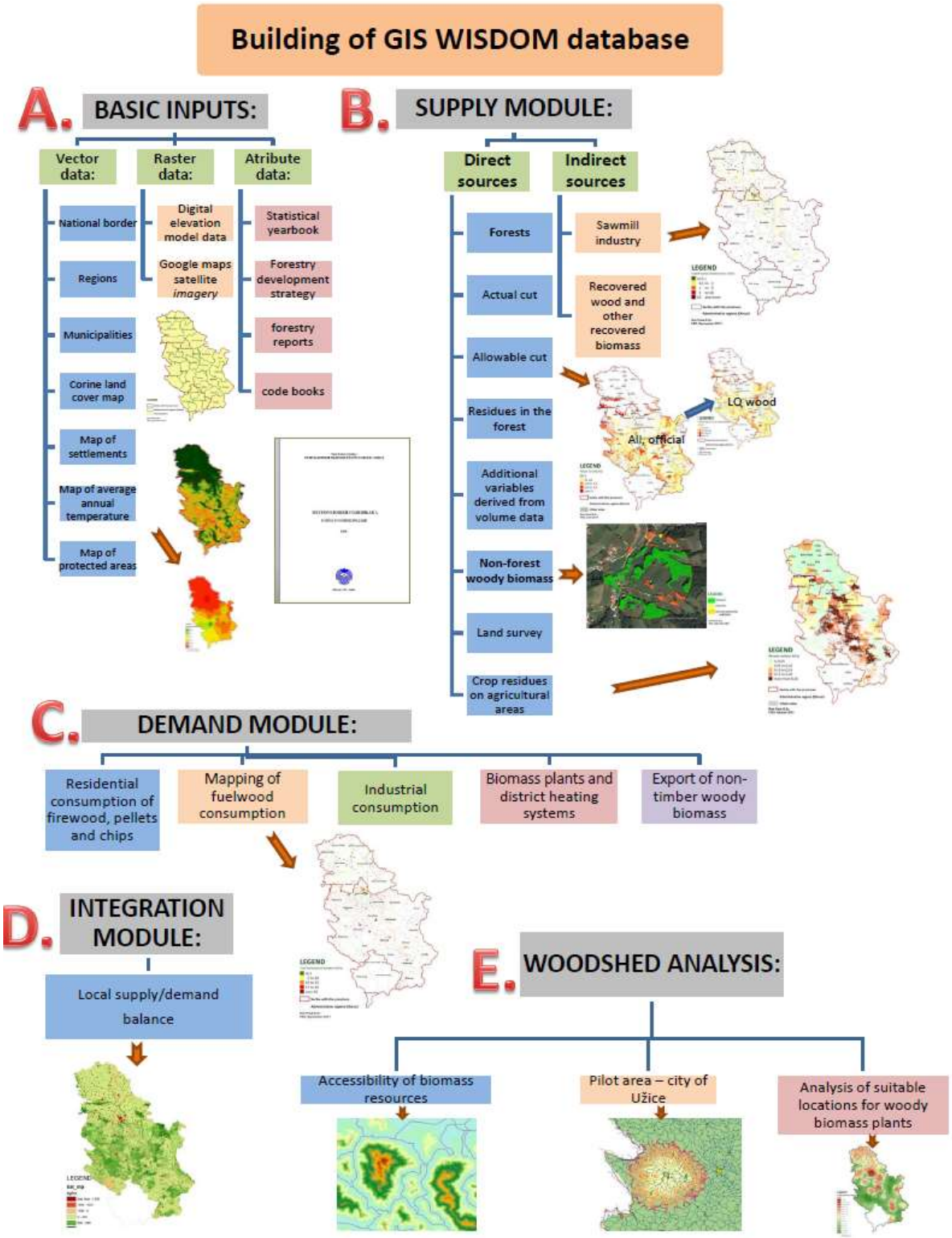
- **municipalities (opština)** with 161 units and cartographic references: vector: Občine_WGS84.shp, raster: P_obcine
- **administrative regions (okrug)** with 25 units and cartographic references: vector: Okruzi_WGS84.shp, raster: okrug_BK

The first steps of all WISDOM analyses are calculated on vector data (different levels: administrative regions, municipalities, forest compartments or Corine data [depending of content]). These administrative levels were also maintained for aggregation of pixel-level results for reporting purposes.

Final analysis was carried out on medium-resolution raster data. The chosen cell size of 100 m (1 cell covering 1 hectare) of a raster is a compromise between high spatial detail and manageable file size and the complexity of processing. The 100 m raster data supports enough spatial detail of analysis, to make the information adequate for local operational planning level and not only for strategic planning.

All next steps are presented in Figure 1.

Figure 1 Main WISDOM analytical steps with woodshed analysis and preliminary analysis of suitable locations for woody biomass plants



Source: Pisek R. 2011.

3. RESULTS AND FINDINGS

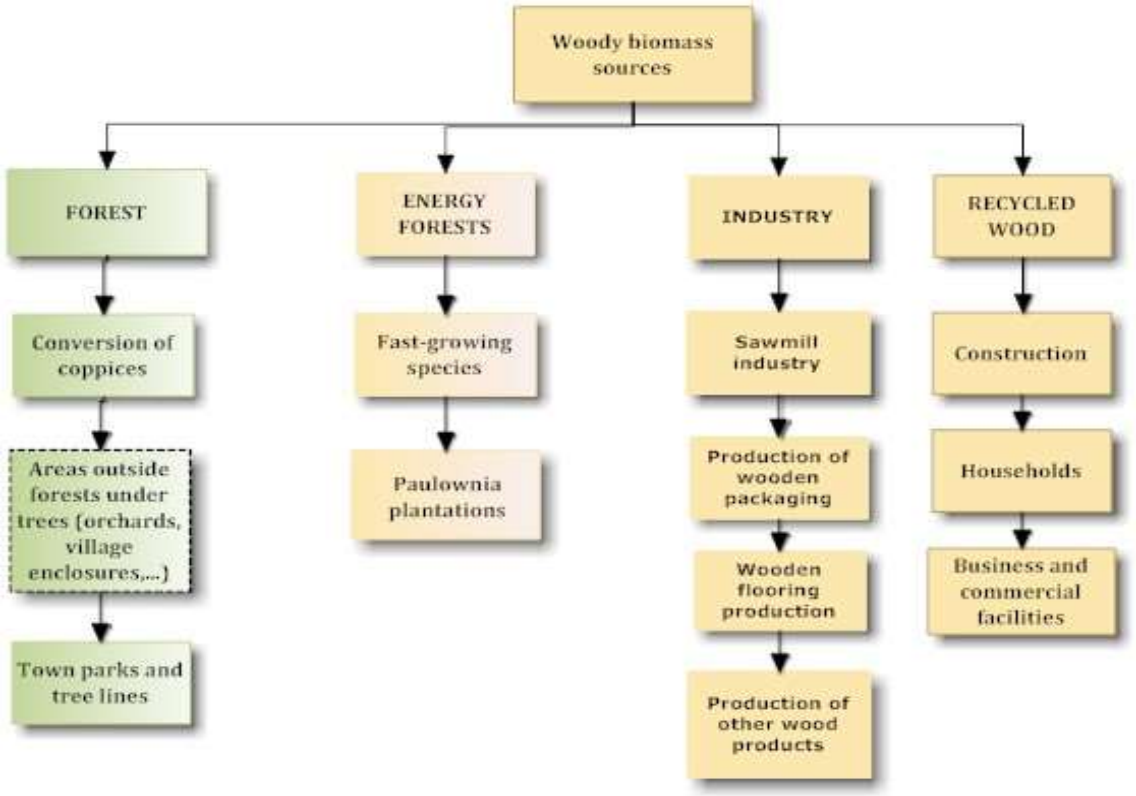
3.1. Wood supply for energy

The main sources for the supply of woody biomass in Serbia can be roughly divided into four categories (Figure 2). Main criteria for the division into the stated categories were:

- The form in which woody biomass is produced
- Origin

Thus, for example, woody biomass in the form of wood chips, large sawmill residue, firewood and sawdust is used in the production of wood pellets. Unlike wood fuels, in the segment of household consumption, woody biomass in the form of firewood, briquettes, pellets and large wood residue from sawmill wood processing are used.

Figure 2 Main sources of woody biomass supply in Serbia



Source: Glavonjić B. 2011.

In order to calculate the amounts of woody biomass originating from various sources, the starting point was the consumption of certain types of woody biomass for all the most significant categories of consumers.

3.1.1. From forests

Detailed research into the potential existing in the Serbian forest fund and the potential of woody biomass in non-forest areas with trees, wood residue in areas classified as agricultural and wood residue from forestry was carried out for the purpose of the TCP/FAO project. The summary results show that Serbia has at its disposal significant potential for woody biomass outside forests, apart from the areas under forests, growing stock and annual increment recorded in the National Forest Inventory (Table 1).

Table 1 Review of summary results of forest and non-forest woody biomass survey for energy

FOREST AREA[1)]		
Field	**Unit**	**Sum (1000)**
Total forest area	ha	2 252.4
Growing stock in forest area	m^3	362 487.4
Annual volume increment	m^3	9 079.7
NON-FOREST AREA		
Total non-forest area *(LU codes 243, 242 and 324)* [2)]	ha	2 682.1
Area covered with trees, bushes and trees with bushes [3)]	ha	657.8
Growing stock in non-forest area [3)]	m^3	72 408.8
Annual volume increment in non-forest area [3)]	m^3	1 921.9
Sustainable possible cut [3)]	m^3	1 441.4

Source: [1)]Statistical Yearbook of Serbia 2009. Belgrade, 2010, [2)]CORINE Land cover, 2006. [3)]Pisek R. 2011..

The national forest inventory from 2008 finally defined basic data on forest resources in Serbia (without Kosovo and Metohija) at 29.1 percent, with very unfavourable state of afforested area in Vojvodina region of 7.1 percent (Figure 3). The total forest area is 2 252 400 ha, with high nature forests on the area of 621 200 ha (27.6 percent), coppice nature forests on 1 456 400 ha (64.6 percent), 174 800 ha (7.8 percent) of forest plantations. Other forest land covers 382 400 ha (Figure 4) so that the total area of forests and other forest land is 2 634 800 ha.

The total number of trees in Serbian forest fund is 2 114 635 853 or 939 per ha.

Concerning the ownership structure, state forests represent 53.0 percent (1 194 000 ha) and private forests 47.0 percent (1 058 400 ha) (Figure 5).

Figure 3 Spatial distribution of forests in Serbia

Figure 4 Stand types in Serbian forest fund

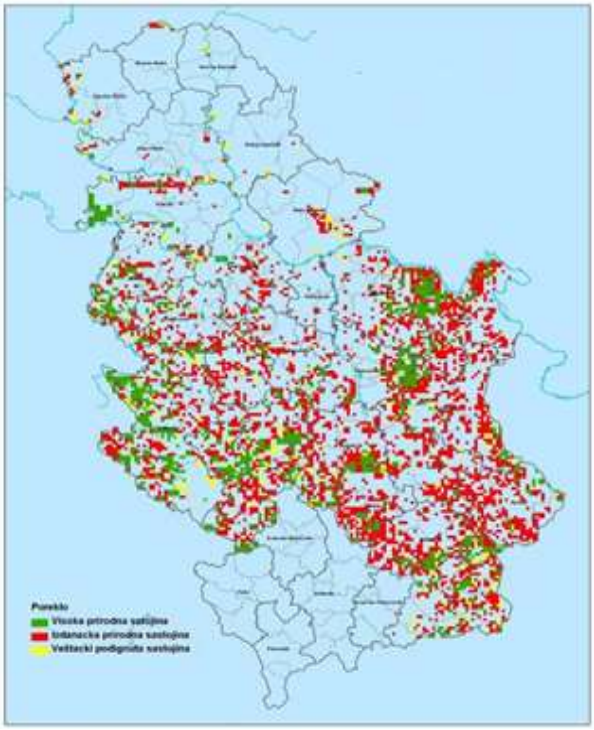


Figure 5 Ownership structure in Serbian forest fund

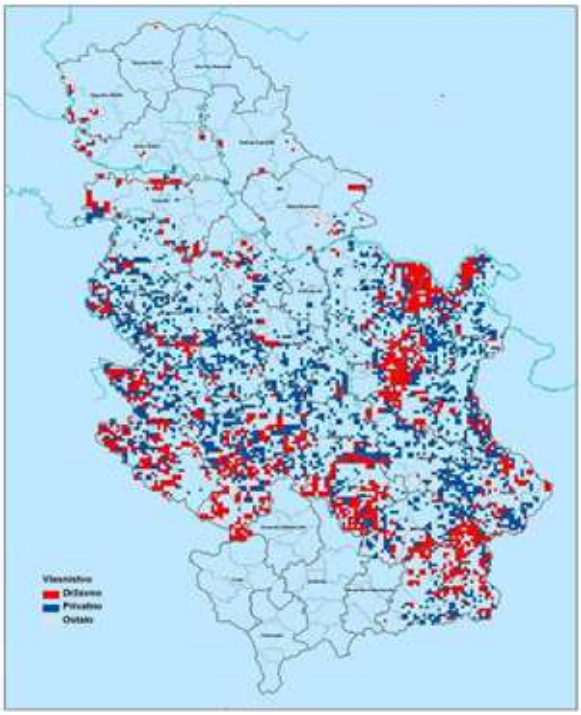
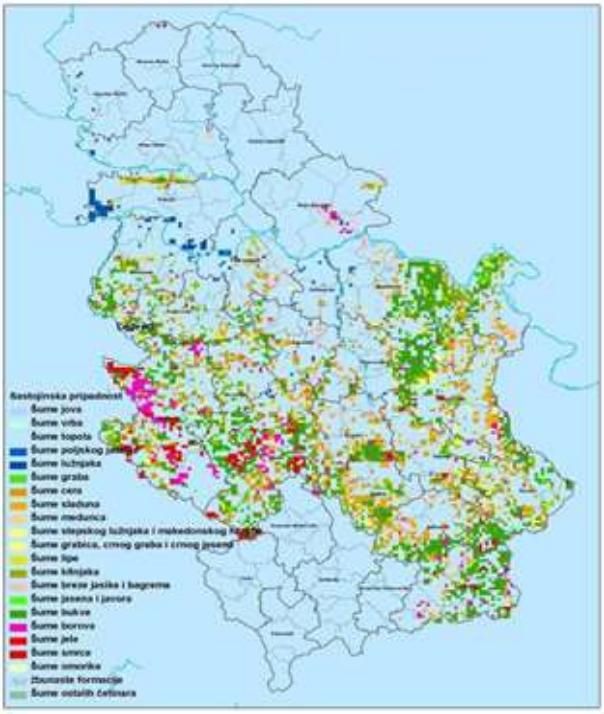


Figure 6 Presence of certain tree species in Serbian forest fund



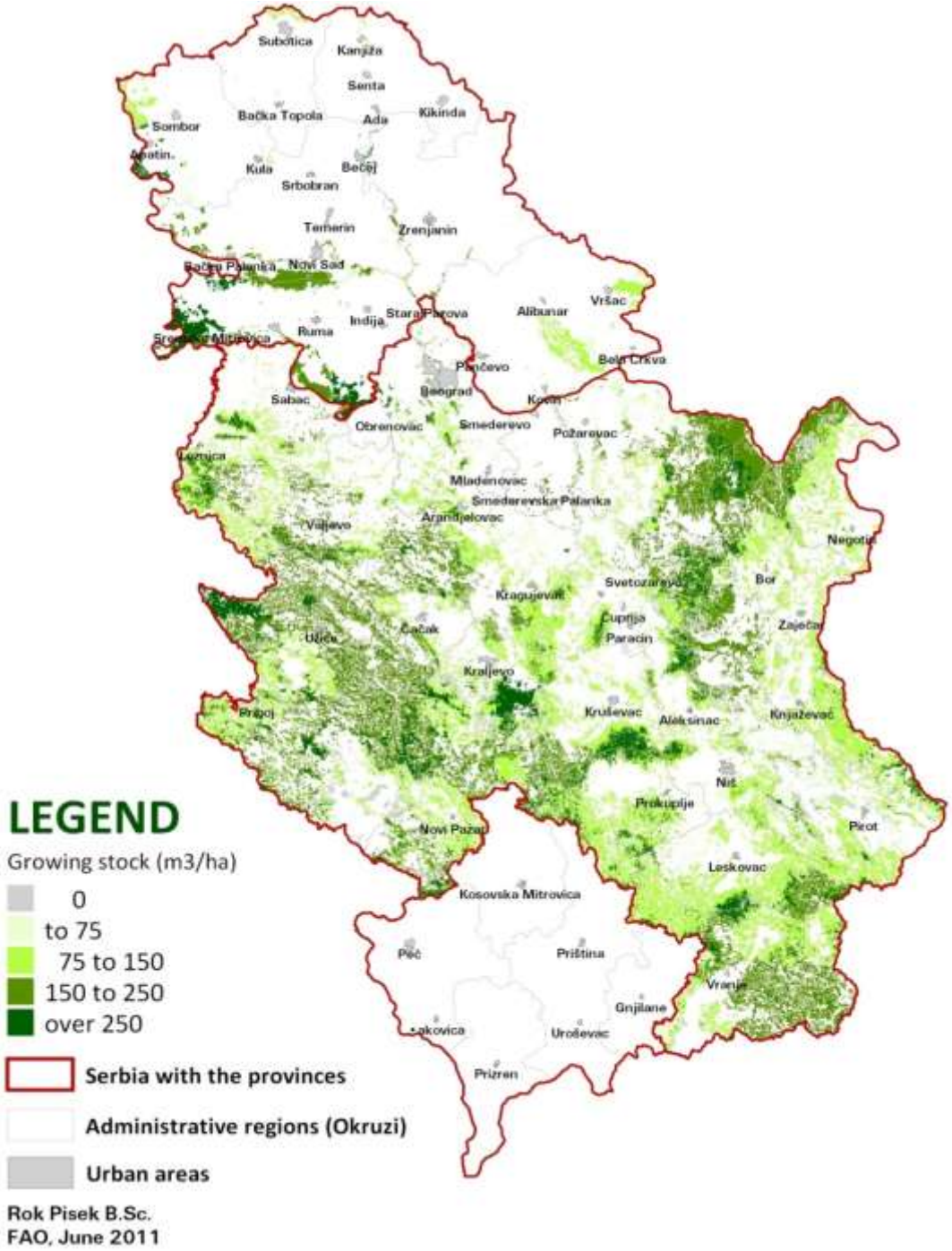
Source: NFI, 2010

Oak forests cover 720 800 ha or 32 percent of the total area under forests. Beech forests follow with the area of 660 400 ha or 29.3 percent, next are conifer forests with 243 200 ha or

10.8 percent, poplar plantations cover 48 000 ha or 2.1 percent and other forests cover 580 000 ha or 25.8 percent (Figure 6).

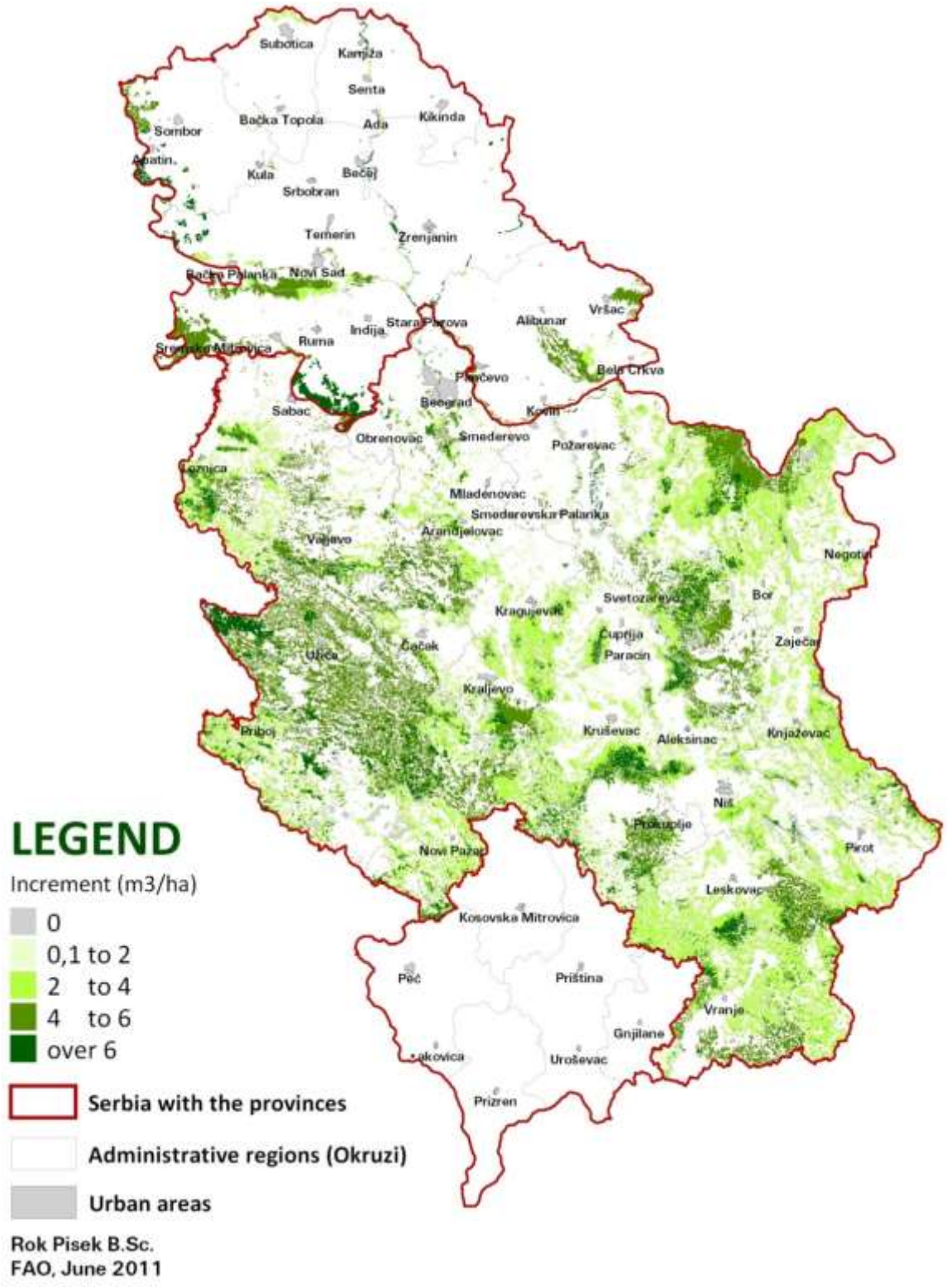
Total (standing) volume is 362 487 418 m^3 and annual volume increment of 9 079 773 m^3. Average stocking volume per hectare is modest at 160.9 m^3 per ha (Figure 7) with a Net Annual Increment of 4.0 m^3 per ha (Figure 8).

Figure 7 Spatial distribution of growing stock in Serbian forests (m3 per ha)



Source: TCP Serbia database

Figure 8 Spatial distribution of annual volume increment in Serbian forests (m3 per ha)



Source: TCP Serbia database

Besides unfavourable afforestation levels of 29.1 percent (compared to the optimal level of 41.4 percent), insufficient value of volume and volume increment per ha of 161.0 m^3 and 4.0 m^3 respectively, unfavourable forest condition is characterized by (Jović P, 2011):

- Unfavourable structure by origin: near two thirds (64.7 percent) of forests are coppice forests with barely half of potential inventory (124.4 m^3 per ha) and volume increment of 3.1 m^3 per ha per year of high nature forests (253.6 m^3 per ha; 5.5 m^3 per ha per year); low participation of unevenaged forests of 8.3 percent characterized by high values of volume and volume increment (312 m^3 per ha and 6.2 m^3 per ha per year);
- Unfavourable condition of forests by conservation status: on 29 percent of forest area there are 608 000 ha of dispersed forests with annual wood production of 3.1 m^3 per ha per year;
- Very unfavourable age structure of high nature forests with age class distribution (young: middle aged: mature : over matured = 38 : 20 : 13 : 29, and coppice forests of 51 : 33 : 7 : 9);
- Lack of planned natural regeneration on significant part of high forests on 268 000 ha;
- Unfavourable health, especially in oak forests (chronic decay of forests);
- Unfavourable assortment structure of wood volume: rate of roundwood and fuelwood is 33.5 : 66.5 percent;
- Unfavourable openness of forests by forest roads at the level of 11.86 m per ha for PE "Srbijašume", 9.09 m per ha for PE "Vojvodinašume"; in national parks from 14.88 to 18.3 m per ha; private forests one third to a half compared to forests managed by public forest enterprises;
- Other potential of forests (non-wood forest products, biomass production) are also unutilised in a possible measure.

According to official statistical data, total wood production was 2.6 million m^3 (net) in Serbia in 2010. The largest cuts are realized in east and west Serbia, followed by Jablanički, Raški and Rasinski districts. Apart from these regions, significant cuts were realized in Sremski and Zlatiborski district as well (Figure 9).

Figure 9 Map of actual official cut

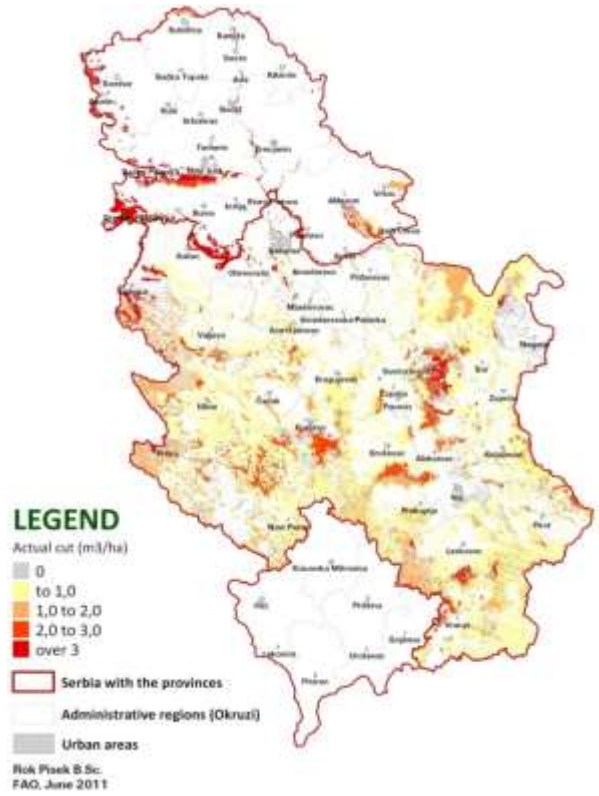
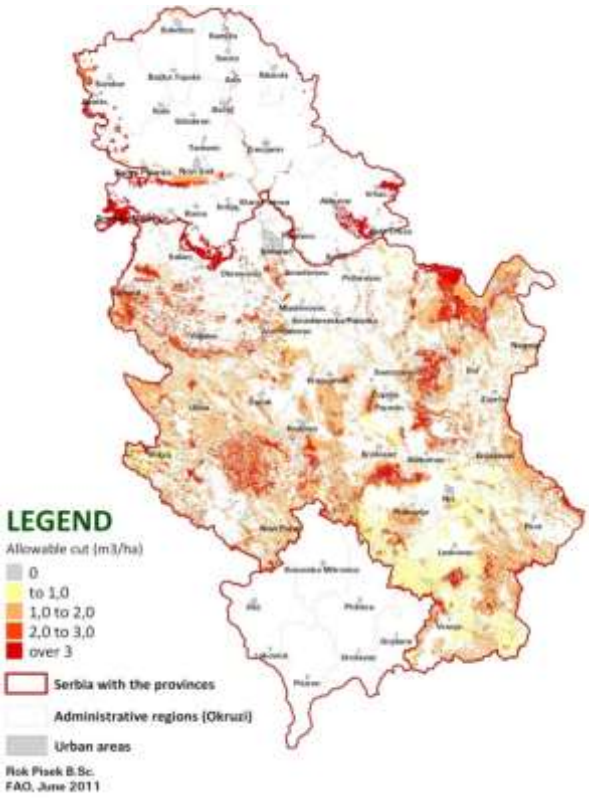


Figure 10 Map of allowable cut – current (marked in official management plans)



Source: TCP Serbia database

The differences between official cut and allowable cut marked in official management plans by municipalities are huge. According to research results and conducted analyses of the relation between official cut and allowable cut pursuant to management plans, in 25 percent of all municipalities this ratio is smaller than 30 percent and in 18 percent is bigger than 100 percent.

Figure 11 presents geographic distribution of realized cut by regions in Serbia obtained on the basis of conducted field researches on wood consumption in these regions. By comparing fig. Figure 11 with Figure 9 it is easy to conclude that realized cut is several times higher than the official cut. However, when realized cut (Figure 11) is compared with allowable cut (as a result of 70 percent of Mean Annual Increment - MAI) it can be concluded that there are certain regions where realized cuts have not reached yet the maximum amount of 70 percent of MAI. There are also regions where realized cuts have reached maximum values as regards 70 percent of MAI.

Source: TCP Serbia database

Figure 11 Map of realized cut in Serbia

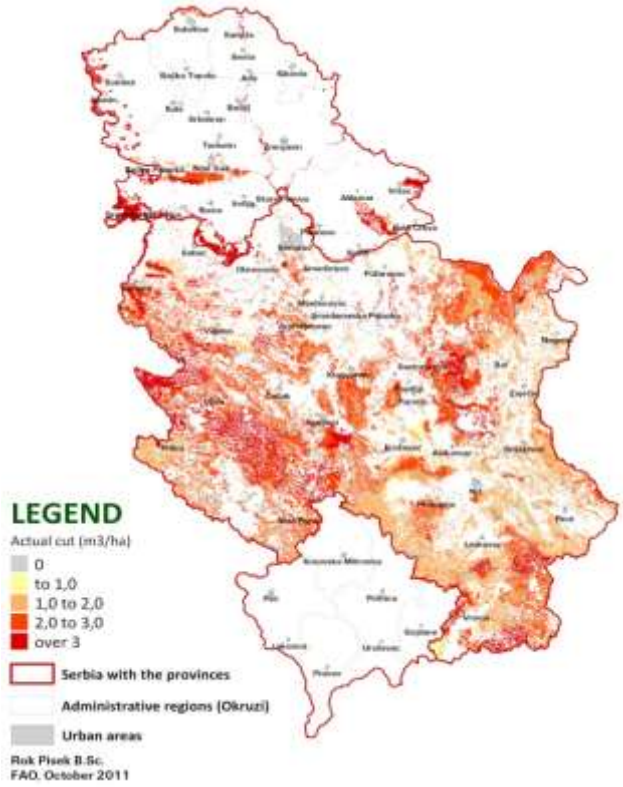
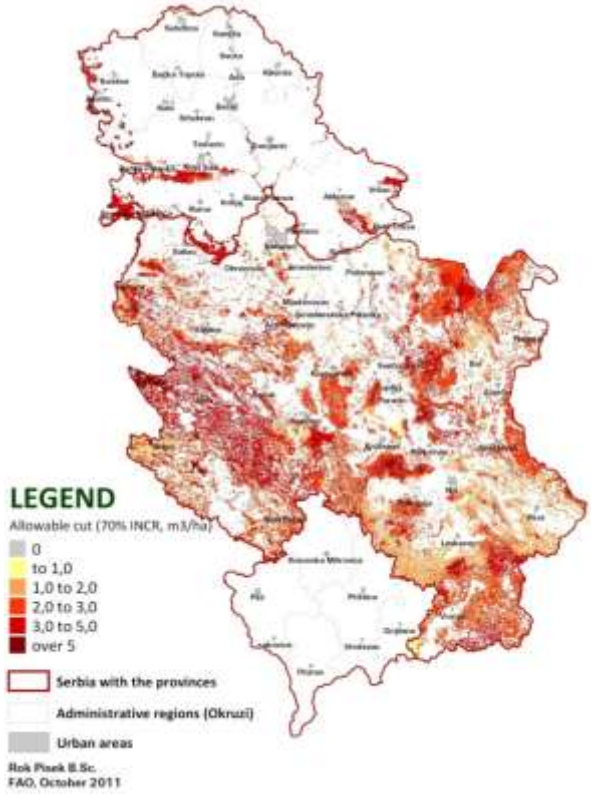


Figure 12 Map of allowable cut – predicted (Allowable cut as 70% of MAI)



Certain amounts of woody biomass are produced in so called devastated forests, which cover about 30 percent of the territory (National Forest Inventory 2008). According to the official data, amount of cut low quality wood was 1.92 million m^3 (gross) in 2010 (Figure 13) while the allowable cut of this wood category based on 70 percent of MAI is 4.1 million m^3 (gross) (Figure 14).

Figure 13 Map of official actual cut of low quality wood

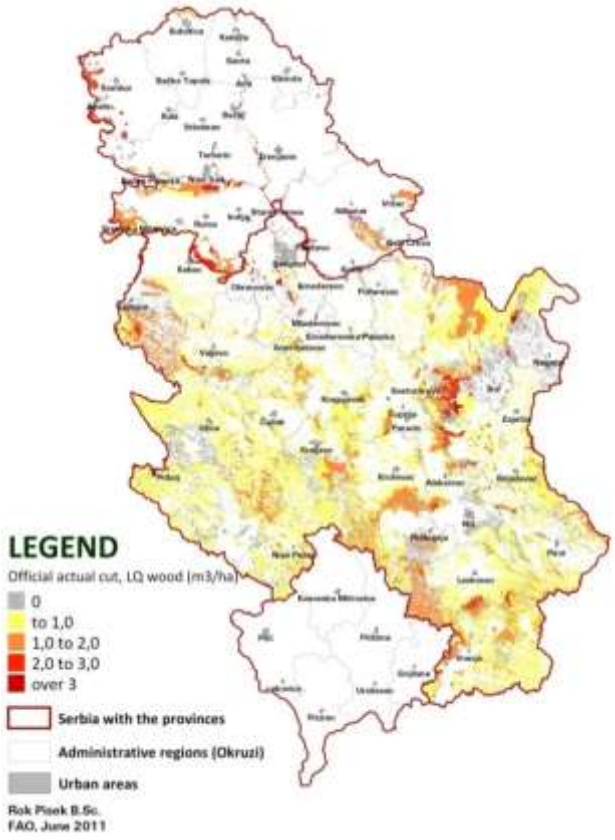
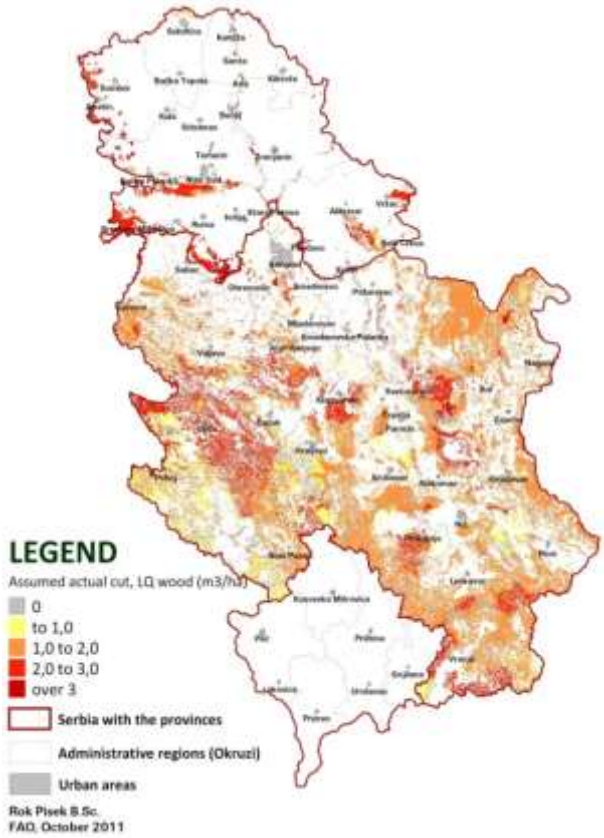


Figure 14 Map of current cut of low quality wood – predicted as 70% of MAI)

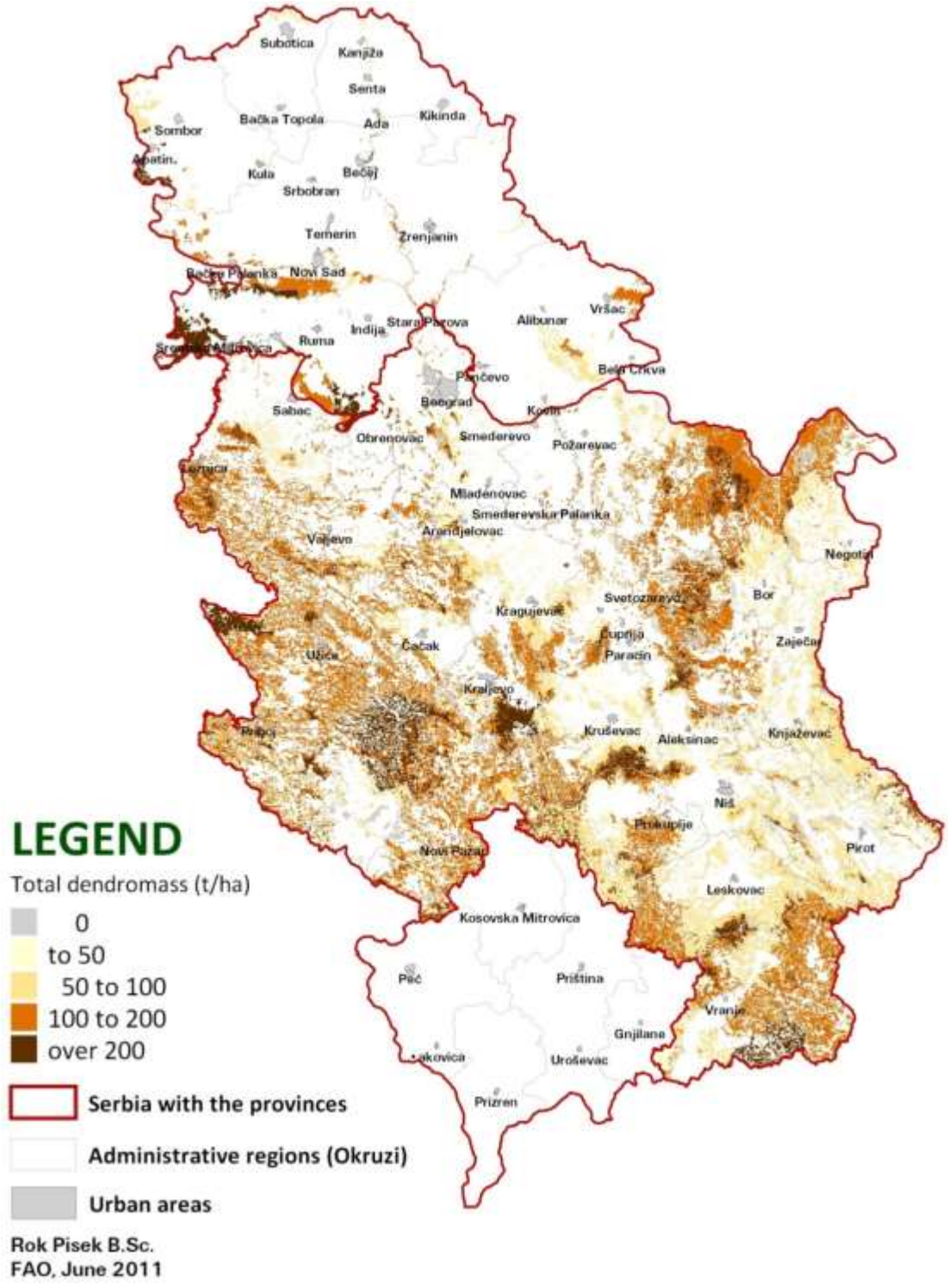


Source: TCP Serbia database

In the total amount of woody biomass produced in forests and outside forests, the largest amounts are produced in the form of firewood. However, wood residue is the by-product of wood assortment production, which is used for heating purposes, primarily by the rural population, and on a smaller scale it is also used for wood chip production.

The total sale of wood residue from Public Enterprises Srbijašume and Vojvodinšume as well as national parks in 2010 was 98 232 m^3. Besides wood residue used from state owned forests, wood residue occurring in privately owned forests is also an important source of woody biomass. The reason for this is the fact that private forest owners widely use it for heating, food preparation, brandy distilling and preparation of food for winter use. **There is no more precise data on the amounts of wood residue from privately owned forests used for energy purposes**. However, it can be assumed that those amounts are equal to or greater than the amounts of wood residue used in state owned forests bearing in mind the number of forest owners, the number of rural households and the tradition in food preparation and brandy distilling. Based on the abovementioned, it can be assumed with a high degree of certainty that annual consumption of wood residue originating from state and privately owned forests in Serbia is over 200 000 m^3.

Figure 15 Map of total woody dendromass



Source: TCP Serbia database

Analysis of the data obtained on the basis of the conducted researches shows that total dendromass (with roots) is 292 179 783 tonnes. The largest amounts of dendromass are in the regions of Kopaonik, Majdanpek, Boljevac, Tara, Kraljevo, Kruševac, Leskovac and Srem

(Figure 15). There is 141 119 643 tonnes of carbon (C) stock in 292.2 million tonnes of dendromass.

3.1.2 Non-forest woody biomass

Forest fragments and trees with bushes are often present on agricultural land in Serbia. This land has a certain amount of woody biomass that is not listed in any statistical surveys. On the other hand, this source accounts for – in some parts of Serbia – a significant share in fuelwood consumption.

To determine the amount of tree and shrub biomass on agricultural land, a simple and quick sample survey was performed. In the first phase six non-forest land types with suspected significant quantities of biomass was selected (Table 2).

Table 2 List of potential non-forest land types

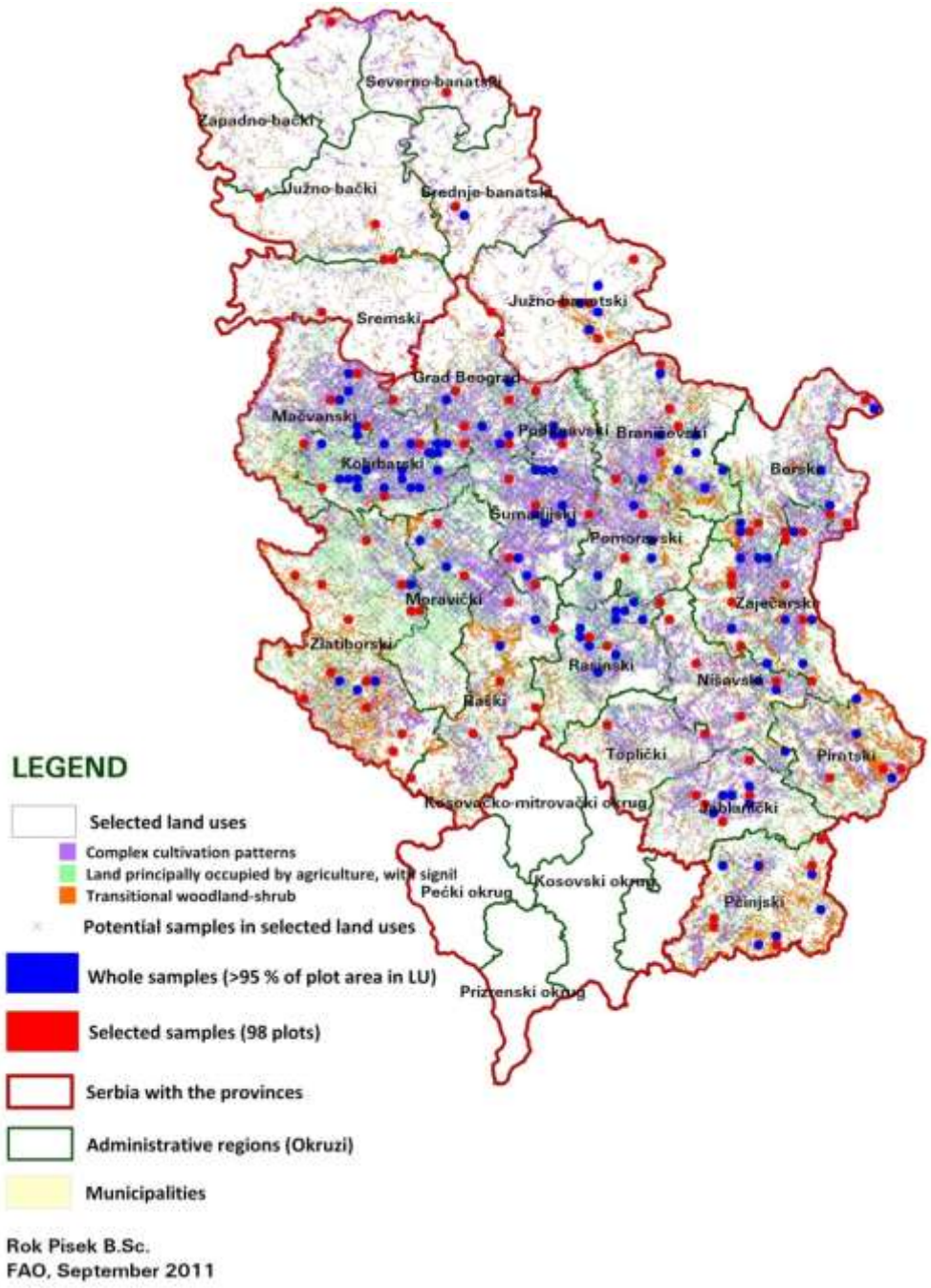
CLCLegen_6	Relevance for woody biomass	Area (ha)
Complex cultivation patterns	medium	1 249 734
Fruit trees and berry plantations	low	10 880
Green urban areas	medium	4 187
Land principally occupied by agriculture, with significant areas of natural vegetation	medium	1 003 343
Natural grasslands	low	235 971
Transitional woodland-shrub	high	508 230

Source: Rok Pisek, 2011.

Land uses with fruit trees and berry plantations and green urban areas could be important for the survey, but are only present on a relatively small area. Natural grassland areas do not include significant quantities of woody biomass. Selected land use areas, which were overlapped because of the imprecision of the digitization with the state forests (GIS compartments) were excluded from the survey.

After selecting important land use types, a systematic sample grid (4x4km) with the 4 665 sample plots with radius of 250 m for the whole country was produced. 1 602 sample plots fell into one of three selected land use types and 204 of them (196 ha) were entirely within the land use (more than 95 percent of surface). Of these sample plots were randomly selected 98 sample plots. The following figure (Figure 16) show the distribution of the whole sample 4x4 km grid (cross sign) and selected sample plots on land use classes of interest.

Figure 16 Theoretical sample grid with selected sample plots on one of three selected land uses



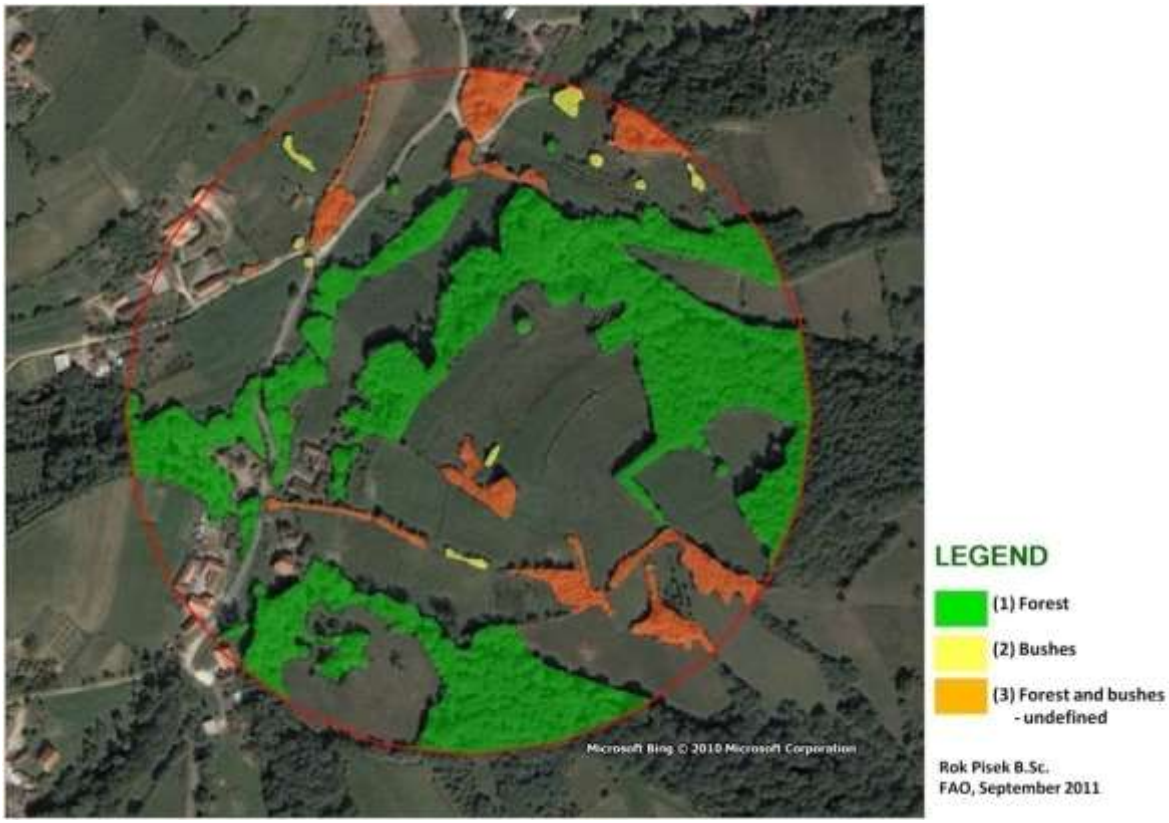
Source: TCP Serbia database

The whole interpretation was carried out visually on a computer. Each cover type was digitized as a closed polygon and coded according to cover type. The minimum interpreted crown area was 5 x 5 m (5 x 5 mm at scale 1:1000) (Figure 17). The survey used available Corine land use map and satellite ortophotos coverage from Google Earth. These layers were the basis for crown cover and type of woody vegetation estimation

Table 3 List of digitalized cover types with the corresponding codes

Code	Cover type
1	Forest, forest remnants and lines of trees
2	Bushes and young trees
3	Mixed trees and bushes or undefined

Figure 17 Example of cover type digitalization in land use »Land principally occupied by agriculture, with significant areas of natural vegetation»



Source: Corine land use map and satellite ortophotos coverage from Google Earth

Results

The forest area for individual land use types was calculated by using an average crown coverage estimation of sample plots.

The calculation of average wood stock value for individual non-forest land use types was done directly through shares of individual woody cover types inside individual land use types on the basis of an average wood stock (NFI, in m^3 per ha). For conversion of forest growing stock and increment following factors were used:

- Trees: 90 percent of growing stock or increment in forests in particular municipality;
- Bushes: 30 percent of growing stock or increment in forests in particular municipality;
- Trees with bushes (mixed): 60 percent of growing stock or increment in forests in particular municipality;

For the conversion to tonnes, factors of 0.5 (deciduous) and 0.4 (conifers) were used. The relationship between coniferous and deciduous trees was determined as a share of stock in the timber NFI data by municipalities.

Table 4 shows summary results of non-forest woody biomass survey and Figure 18 shows spatial distribution of woody biomass on non-forest areas by municipalities.

Table 4 Summary results of non-forest woody biomass survey

Field	Unit	Sum
1.Total area[4]	ha	2 682 148
Area_forest	ha	657 874
Gws_m^3	m^3	72 408 772
Incr_m^3	m^3	1 921 902
Etat_m^3	**m^3**	**1 441 427**
Gws_t	t	35 346 871
Incr_t	t	937 577
Etat_t	t	**703 183**

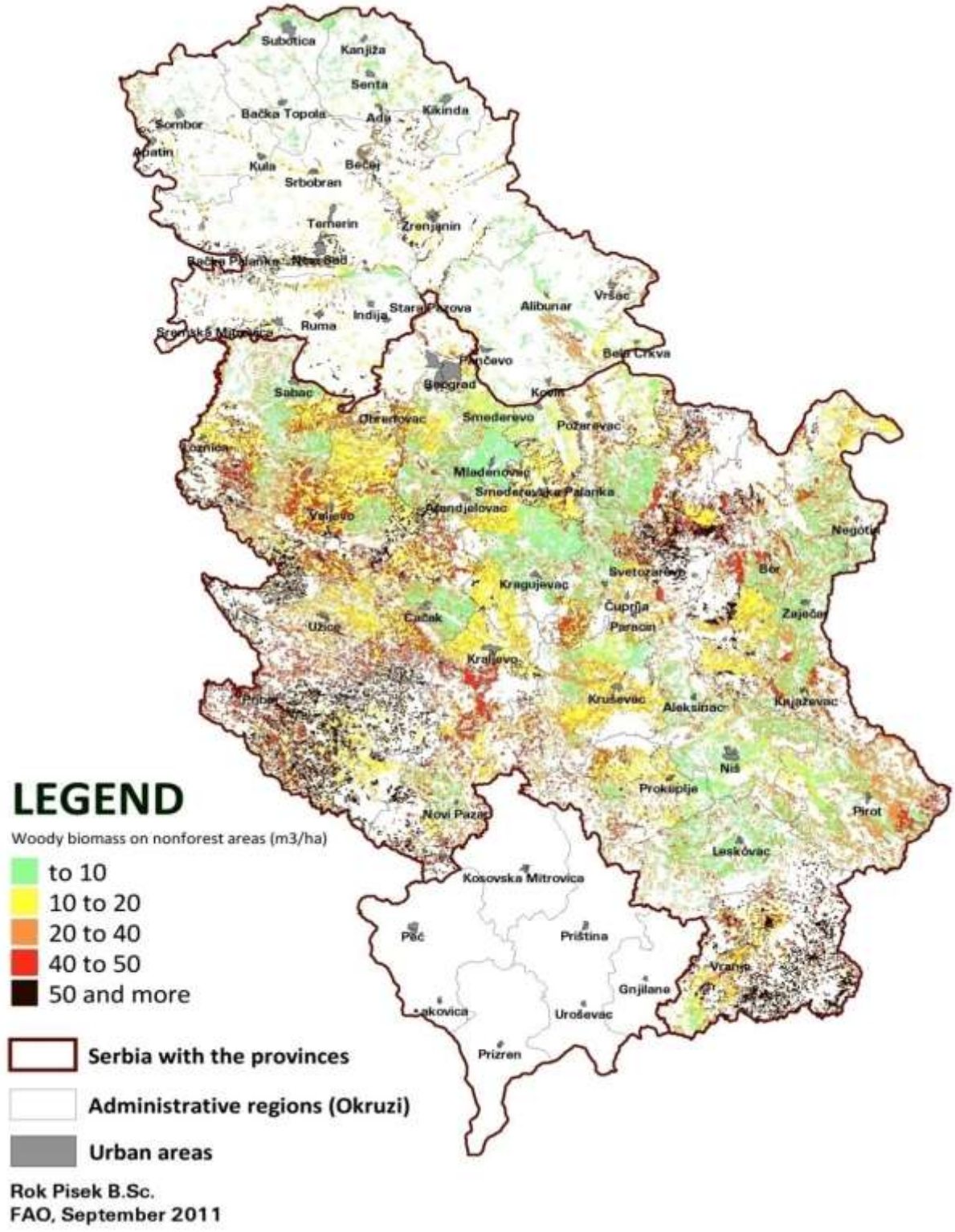
***Source**:* Pisek R., 2011.

Total woody biomass from the non-forest area is 1 441 427 m^3, which is 19.5 percent of total available woody biomass (Table 4).

The biggest sources of non-forest woody biomass are located in the regions of west, south west, south and east Serbia, followed by the regions in Raški, Rasinski and Kolubarski district.

[4] Total area include: Complex cultivation patterns +Land principally occupied by agriculture, with significant areas of natural vegetation +Transitional woodland-shrub

Figure 18 Amount of woody biomass on non-forest areas



Source: TCP Serbia database

3.1.3. Other direct sources

Town parks are also one of the segments of woody biomass production (primarily firewood), especially in large towns in Serbia (Figure 19).

Thus, for example, Public Enterprise "Gradsko Zelenilo" in Belgrade maintains about 3 000 hectares of public green areas (parks, tree lines and city areas under forests). In 2010, in the processes of maintaining parks, tree lines and smaller areas under forests in wider city areas, 280 m^3 of firewood was produced for commercial use (sale for heating). The stated amount of firewood was sold via the trade union for heating purposes of the workers in this Public Enterprise. According to the conducted research, the largest amounts of woody biomass produced in this Public Enterprise do not have satisfactory quality (rotten wood, small branches, etc.) and they are fragmented into wood chips by their own machines, which is used for spreading around young seedlings or for heating greenhouses where seedlings are produced. A part of woody biomass produced in the form of firewood is also used for heating greenhouses and other facilities (buildings, prefabricated facilities, etc.).

Figure 19 Firewood cut to 25 cm length from tree lines along the river Sava on Novi Beograd

Source: B. Glavonjić, 2011.

Results of the conducted questionnaire in the next 12 largest towns in Serbia (Niš, Kragujevac, Novi Sad, Subotica, Sombor, Zrenjanin, Kikinda, Pančevo, Sremska Mitrovica, Požarevac, Šabac and Užice) showed that firewood production in parks and other green areas managed by these enterprises was 742 m^3 for commercial purposes in 2010. This means that the total production of firewood in public enterprises for the management of parks and other green areas was 1 022 m^3 in 2010.

Energy plantations as a source of woody biomass supply in Serbia

In this moment, there are no energy plantations for producing woody biomass for energy purposes in their proper meaning. On the existing plantations of poplar and other fast growing tree species, wood assortments are produced which are mostly used as technical roundwood for the production of wood packaging and sawn timber, and on a smaller scale as firewood. Since significant amounts of wood residue (large and small) occur in the production of wood packaging and sawn timber, it is used for the energy needs of companies as well as for wood chip production which is afterwards used in the production of particleboards and wood pellets. In light of this, it can be concluded that plantations indirectly participate as a source of woody biomass supply for energy purposes in Serbia.

However, it should also be highlighted that there are initiatives to change legislation, which would enable energy plantations to be grown on agricultural land of poor quality, although the practical implementation of such legislation is still a long way off.

Concerning energy plantations as an earmarked special category of woody biomass source, poplar and paulownia plantations are fast growing species, with poplar plantations being used for woody biomass production for technical and energy purposes while paulownia plantations are symbolic both in terms of area and volume. However, research conducted at two leading national institutions, the Faculty of Forestry and the Institute of Lowland Forestry and Environment, indicate that paulownia plantations can represent an important source of woody biomass in future, as certain areas of devastated agricultural land can be used for these purposes. Concerning current amounts of woody biomass originating from plantation wood production, Serbia still significantly lags behind other European countries.

Recycled wood as a source of woody biomass supply in Serbia

Unlike some European countries, in Serbia there is no organized collection and use of recycled wood for energy purposes yet. Therefore, there is no reliable data or the estimations on the amounts of recycled wood used for energy purposes although secondary wood products (old flooring, furniture, joinery, scaffolds, etc.) are collected and used by households primarily with low income. Since there is adequate potential in this segment, more organized utilization of these resources can be expected in the near future.

Co-products from the Industry

Regarding industry as a source of woody biomass supply for energy, the most significant source is sawmill wood processing where the biggest amounts of large and small wood residue occur (Figure 20). The second position is taken by the production of rotary veneer for making packaging for fruit, while the third most significant source is the production of wood flooring where wood residue is used for heat generation for the needs of the companies themselves as well as for wood briquette production.

Figure 20 Sawmill residues in industrial area –real cut

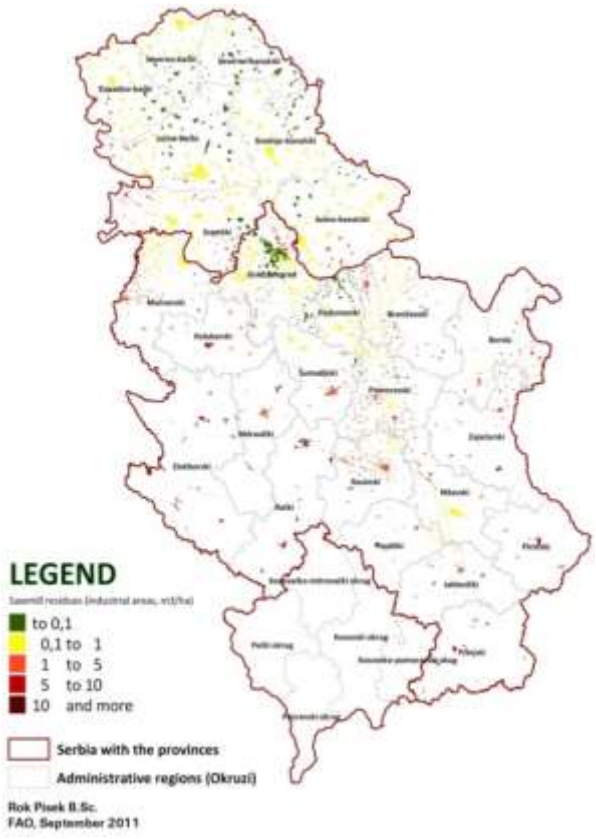


Figure 21 Possible sawmill residues as 70% of MAI

Source: TCP Serbia database

Total annual production of wood residues in the wood processing industry in 2010 was 599 600 m^3. Out of the total amount of wood residue occurring in industry, 49.2 percent is used for the energy needs of the companies themselves and the rest is placed on the market for the production of wood chips, pellets and wood based panels (data refer to 2010) [Glavonjić 2011].

Processed wood-based fuels (pellets and briquettes)

About 40 companies produce wood briquettes. Approximately two thirds of the total production of wood briquettes is performed in three factories, while other quantities are produced in small facilities for final wood processing (producers of floors, floorboards and other wood products) which use wood waste from the process of briquette production [Glavonjić 2011].

Continuous production is executed in those companies specialized in the production of wood briquettes, in which the base material is sawdust from wood processing. These companies represent the biggest producers of wood briquettes with special lines and high-capacity technologies (Figure 22).

In other companies the production of wood briquettes is executed in small hydraulic presses (Figure 22) in which the starting raw material is wood residue from the production of some final products such as parquet flooring, chairs, construction joinery and other products.

Figure 22 Line (a) and press (b) for the production of wood briquettes

Source: B. Glavonjić, 2011.

The predominant type of wood briquette is the solid briquette of 60-80 mm in diameter and 10 cm in length. Briquettes are also produced that are 30 cm long. Two producers make briquettes of 5.5 × 5.5 × 32 cm and that have an openings of 22 mm in the middle. In the majority of cases, briquettes are packed into boxes of 15 kg in which they are transported to consumers.

Total production of wood briquettes in 2010 was 21 719 tonnes. One of three big factories for the production of wood briquettes supplies one of several district heating plants in Belgrade using briquettes, while other factories distribute briquettes across Serbia, and export a certain quantity as well.

Wood pellets

In 2011, wood pellets were produced at 16 production plants in Serbia, and preparations are under way to start production in three more factories. The highest pellet quantities are produced from beech. Four factories produce beech pellets (including the factory with highest installed capacity). Total production of wood pellets in 2010 was 40 120 tonnes [Glavonjić 2011].

Production of wood pellets from coniferous trees, and from a combination of non-coniferous and coniferous trees is executed in three factories, and one factory produces wood pellets in combination 70 percent wood biomass and 30 percent soya biomass.

The most frequent dimensions that pellets are produced in are 6-8 mm in diameter and 12-15 mm in length.

The quality of wood pellets varies from extremely high to medium. All producers possess certificates on testing of quality of wood pellets, and the testing is performed in international laboratories (usually in countries to which wood pellets are exported from Serbia). In this respect, the quality of wood pellets produced and exported from Serbia corresponds to quality standards EN 14961, while pellets of medium quality (higher share of bark, impurities, etc.) are distributed to the local market.

Charcoal

Depending on the way it is performed, production of charcoal in Serbia can be generally classified into four groups: **production in earth cover kilns, production in brick kilns, production in portable steel kilns and production of charcoal in the industrial way** (Figure 23):

Figure 23 Types of charcoal kilns for the production of charcoal in Serbia

a) Brick charcoal kiln **b)** Earth charcoal kiln **c)** Portable steel charcoal kiln **d)** Retorts

Source: B. Glavonjić, 2011.

The predominant method of charcoal production in Serbia is in brick charcoal kilns. Portable steel charcoal kilns started to be used in the second half of 2009 (although this is not widely used due to low quality of the charcoal). Industrial production of charcoal started at the end of 2010 and at the moment is at the development phase. However, yields are very good in terms of quality of charcoal (C_{fix} over 85 percent). This is confirmed by the fact that the complete production of industrial charcoal is exported to Germany and distributed to silicon factories and factories for gunpowder production. Total production of charcoal in 2010 was 34 086 tonnes (Glavonjić 2011).

Agricultural biomass

The total agricultural biomass is 11.2 million tonnes (both agricultural and woody biomass) and out of this amount 473 104 tonnes or 0.42 percent is woody biomass. Calculated in m^3, wood residues on agricultural areas amount to 959 391 m^3. The largest amounts of wood residues on agricultural areas are situated in the regions of central Serbia (Figure 24 and Figure 25).

Figure 24 Map of residues from agricultural areas

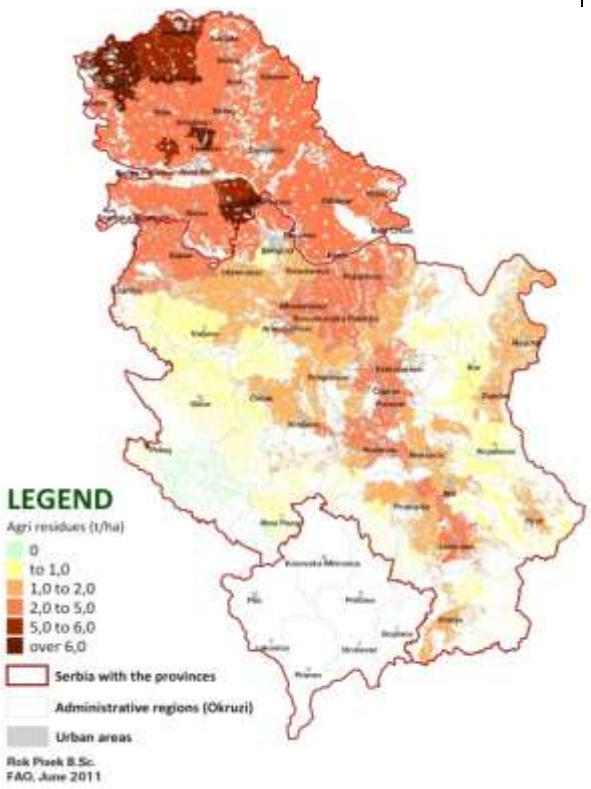
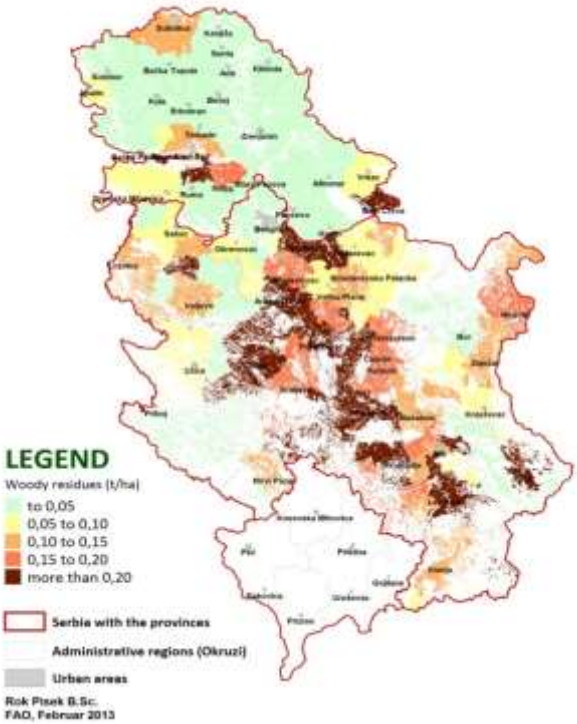


Figure 25 Map of wood residues on agricultural area



Source: TCP Serbia database

3.1.4. Total wood supply for energy

Taking into consideration the principles of sustainable forest management and by using the existing bases of forest management methodology as well as data on woody biomass consumption in industry, the total supply of woody biomass for energy in Serbia is presented by category below (the categories are in accordance with the form of balance defined within UNECE) in Table 5.

Table 5 Sources of all woody biomass at current cut in Serbia in 2010 (two scenarios)

	Sources	Unit	Scenario 1 Official current cut	Scenario 2 Predicted current cut
1.	Industrial roundwood from forest	[1000 m^3]	968	1 516.8
2.	Industrial roundwood outside the forest	[1000 m^3]	0	0.0
3.	Fuelwood from the forest	[1000 m^3]	1 451	3 589.1
4.	Fuelwood outside the forest	[1000 m^3]	-	1 441.4
5.	Logging residues	[1000 m^3]	277	715.6
6.	Woody biomass on agricultural land	[1000 m^3]	-	959.4
7.	Bark (6.5% of total industrial roundwood)	[1000 m^3]	-	98.6
8.	Primary industrial residues (including wood chips)	[1000 m^3]	-	599.6
9.	Undefined	[1000 m^3]	-	11.3
S1	SUM: Sources from 3-9	[1000 m^3]	1 728	7 415
P	INCREMENT-percentage			63%all forests
S2	SUM: Sources from 1-9	[1000 m^3]	2 696	8 931.8
Produced wood fuels				
1.	Wood briquettes	tonnes	-	21 719
2.	Wood pellets	tonnes	-	40 120
3.	Charcoal	tonnes	-	34 086

Sources: 1. Pisek R. 2011.; 2. Glavonjić B. 2011.; 3. Statistical yearbook of Serbia 2010. RZS, Belgrade

Based on the data from Table 5 it can be concluded that forests are the largest and the most important source of woody biomass, contributing 58.2 percent. They are followed by non-forest areas with trees, bushes and trees with bushes which contribute 32.4 percent while woody biomass from industry contributes 9.4 percent.

If allowable cut from management plans and allowable cut as 70 percent of Mean Annual Increment (MAI) are taken into consideration, total wood supply for energy is 6.3 million m^3 in the first case and 7.8 million m^3 in the second (Table 6).

Table 6 Sources of all woody biomass in case of realization of allowable cut (two scenarios)

	Sources	Unit	Scenario 1 Allowable cut	Scenario 2 Increased allowable cut
1.	Industrial roundwood from forest	[1000 m^3]	1 320	1 861
2.	Industrial roundwood outside the forest	[1000 m^3]	0	0
3.	Fuelwood from the forest	[1000 m^3]	2 775	3 761
4.	Fuelwood outside the forest	[1000 m^3]	1 441	1 441
5.	Logging residues	[1000 m^3]	575	797
6.	Woody biomass on agricultural land	[1000 m^3]	959	959
7.	Bark (6.5% of total industrial roundwood)	[1000 m^3]	86	121
8.	Primary industrial residues (including wood chips)	[1000 m^3]	519	720
9.	Undefined	[1000 m^3]	0	0
S1	SUM: Sources from 3-9	[1000 m^3]	6 355	7 799
P	INCREMENT-percentage		51%all forests 58% state forests	70% all forests
S2	SUM: 1+2+S1	[1000 m^3]	7 675	9 660

***Source*:** Pisek R. 2011.

Comparative analysis of the values given as a part of scenario 2 in Table 5 and Table 6 (increased allowable cut of 9.66 million m^3 as well as the values of predicted current cut of 8.9 million m^3) shows that there are potentials for additional 728 000 m^3 of woody biomass compared to the values currently used. Since this is optimistic scenario, adequate values should be determined through appropriate plans and management policy taking into consideration all elements in the process of making management plans.

3.2. Wood energy demand

Analysis of wood energy demands two aspects:

- Demand for woody biomass which is consumed in transformation processes; i.e. for the production of other fuels, and
- Final consumption of wood energy of the most significant consumer categories.

Analysis of woody biomass consumption for the production of wood fuels included the production of charcoal, wood pellets and briquettes, and households, own needs of industry and commercial facilities.

3.2.1. Transformation

Transformation processes imply consumption of certain wood energy-generating products for the production of another wood energy-generating product. The results of research conducted in this project show that there is production of charcoal wood pellets and wood briquettes in Serbia where adequate forms of woody biomass are used for the production of these categories of wood fuels through transformation processes. Results of woody biomass consumption for individual production of the stated wood fuel types are given hereafter.

Charcoal

A basic characteristic of charcoal production in Serbia is the predominant use of three traditional and one industrial method of production.

Production of charcoal in earth cover kilns

Charcoal is traditionally produced in earth cover kilns (Figure 26). This form of production is represented in South and South-east Serbia and represents the most primitive method of charcoal production.

Figure 26 Layout of earth cover charcoal kiln

Source: B. Glavonjić, 2011.

Production is conducted in earth cover kilns sunken up to 50 cm into the ground: first the base of beech roundwood is placed on the ground, and then split wood prepared for obtaining charcoal is placed over it. In these kilns 3-4 m^3 of wood is usually stacked. Hay or ferns are then placed over it. All of this is then covered with earth. Air holes for ventilation are placed on the front and back side of kiln.

The carbonization cycle lasts seven days, and from one such kiln around 400 kg of charcoal is produced. Water is used to extinguish the kiln after the completion of the carbonization process.

There are also earth cover kilns whose capacity ranges from 7-20 stacked m^3. However, such kilns are scarce and owned only by those households whose permanent activity is charcoal production. Unlike them, in the kilns with capacity of 3-4 stacked m^3, production is conducted usually from late autumn and winter months, while during other months, rural households perform other agricultural work.

Production of charcoal in brick kilns

Production process consists of kiln filling, wood carbonization, extinguishing and cooling of kiln and then packing of charcoal.

Figure 27 Air holes (so called ”raule” in Serbia) on the kiln

Source: P. Sretenović, 2011.

The process of kiln filling is usually performed by one or two workers. If the filling is performed by two workers, the process can be completed in 3-4 hours. Workers fill the kilns from the side door (about 1 m high and width 80 cm wide).

After wood is stacked in the kiln, and all the air holes (“raule”) are opened (Figure 27), the kiln can be lighted. The air holes are equally spaced across the bottom of the kiln. On average, there are 12 air holes on one kiln, although this depends on the size of kiln.

The process of dry distillation lasts from 7 to 10 days, which depends on the type of kiln, but also on the weather conditions. In brick kilns the process of carbonization lasts longer, but it takes less time to cool (with water it takes 24 hours), while in portable steel kilns whose capacity is three times smaller than brick kilns, this process lasts about three days, which makes that the productivity of both kilns approximately the same (on the monthly basis).

Figure 28 Mild wind which does not change direction can positively influence the production of charcoal

Source: B. Glavonjić, 2011.

The greatest influence of weather conditions is the influence of wind.

When the fire in the kiln is extinguished and charcoal is cooled, producers proceed to open the kiln. Charcoal is placed in knitted propylene sacks of about 15 kg. Sacks filled in this way are stored in dry buildings or directly loaded onto transport vehicles and transported to traders (middlemen) and sometimes directly to end buyers.

Production of charcoal in portable steel kilns

Figure 29 Layout of portable steel kilns with one ring

Source: B. Glavonjić, 2011.

Producing charcoal in portable steel kilns is another, more contemporary method. According to a survey conducted in the field of charcoal production in portable steel kilns (Figure 29) started in 2006 first in South Serbia. The main reason for appearance of this type of production was the significantly shorter duration period of one cycle compared to traditional way of production. Namely, one carbonization cycle in portable steel kilns lasts from 72-144 hours depending on the dimensions of the kiln; i.e. wood quantity which can be placed in it.

Portable steel kilns which consist of one bottom ring and a roof (narrow part). The diameter of the bottom ring is 1.5 m, and their capacity is about 3 stacked m^3 of wood from which about 300 kg of charcoal is obtained. The production cycle lasts from 48-72 hours depending on whether any wood is added to the kilns in course of cycle.

Charcoal is produced in the following way: first, the previously prepared wood is stacked in a circle with a diameter a little smaller than the diameter of the bottom ring. Wood is stacked up to the height of the bottom sheet metal ring after which the wood is ignited, and then the second sheet metal ring is placed on top.

The roof is then placed over it and this part of portable steel kilns is filled. It takes about 24 hours for the wood to burn, after which a certain quantity of water is added to speed up the cooling process which lasts another 24 hours. After 48 hours charcoal is extracted and packed into sacks.

Industrial production of charcoal (retorts)

Industrial production of charcoal in retorts started at the end of 2010 and has been giving very good effects in terms of quality of charcoal (C_{fix} 85-90 percent) up to date. This is supported by the fact that the complete production of industrial charcoal is exported to Germany and distributed to factories of sillicium and for the production of gunpowder. At this time, only one factory is producing of charcoal (in South-east Serbia), although there are also several initiatives for the establishment of new factories by foreign investors.

Charcoal production technology on retorts was imported from Netherlands (Figure 30), and the main principle on which it is based is the combustion of gases and use of their energy for wood carbonization. In this way, a minimal quantity of harmful gases is emitted into the atmosphere, which is very significant from an environmental viewpoint.

Figure 30 Layout of industrial retorts for the production of charcoal

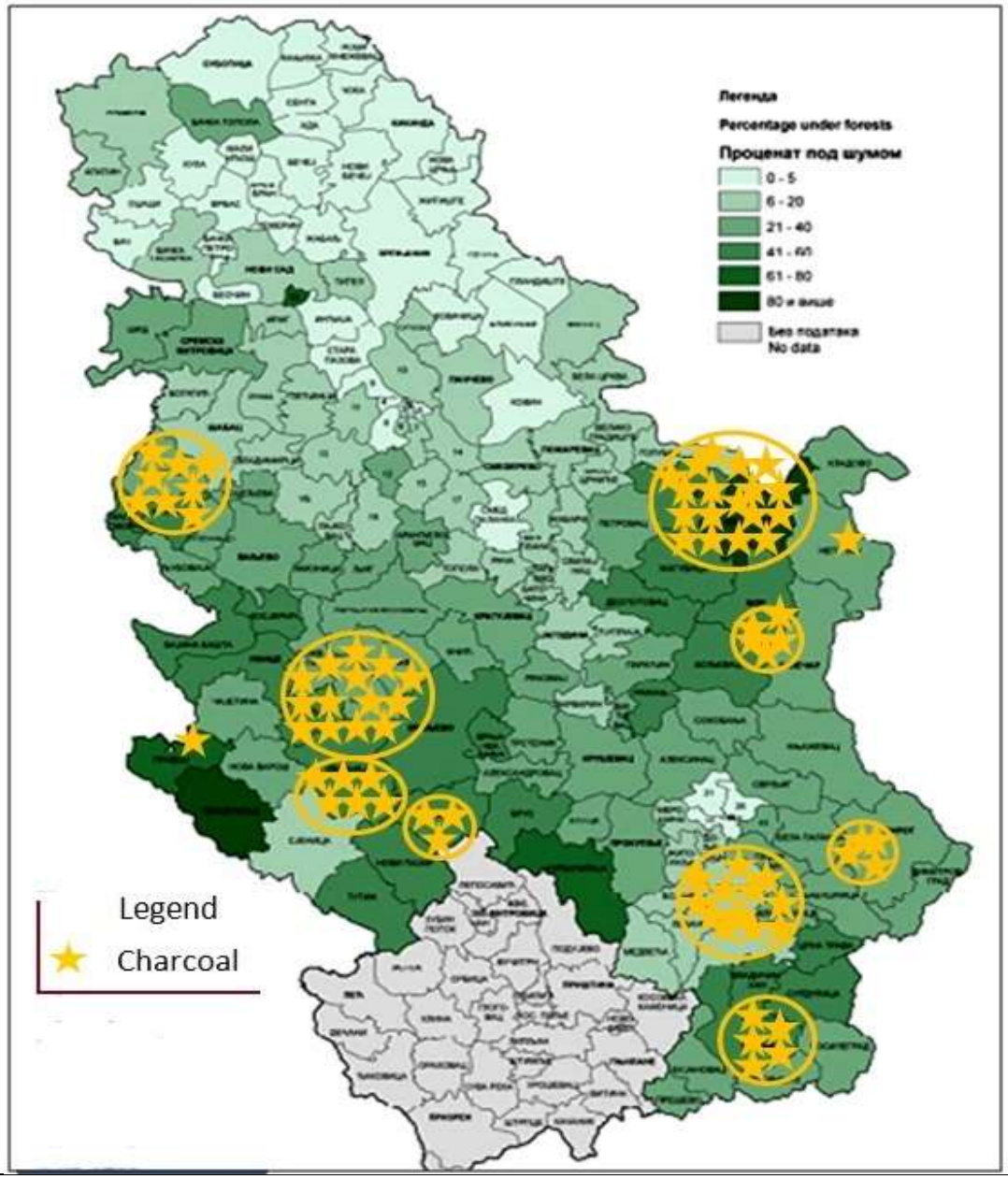
Source: B. Glavonjić, 2011.

Split metre wood and sawmill residues from processing of logs are used as the raw material from charcoal production. For the production of charcoal the company exclusively uses beech.

There were a total of 1 533 charcoal kilns (without industrial retorts) in Serbia in 2010 and 240 666 m^3 of woody biomass was used for charcoal production in the form of roundwood

and large wood residue from industry. Most charcoal kilns are situated in eastern and south-western Serbia (Figure 31).

Figure 31 Spatial distribution of charcoal kilns in Serbia



Source: B. Glavonjić, 2012.

Wood briquettes

There has been an increase in the demand for wood briquettes over the last few years. Demand for wood briquettes in Serbia is such that producers currently do not have any supplies of this wood fuel, and current production by individual producers is sold to consumers on waiting lists. Besides households, wood briquettes are increasingly used by bakeries. Considering that bakeries work throughout the year, and that they have constant demand for briquettes, they are the most favoured buyers, especially for those producers whose production ranges from 500 to 1 000 tonnes annually.

About 40 companies produce wood briquettes, and in the majority of cases the production process is continuous throughout the year. Certain companies produce only intermittently; i.e. when there is a surplus of raw materials.

The survey results show that households most often buy 3-4 tonnes of briquettes for the heating season, although there are also examples of significantly higher quantities (7-8 tons). The most common dimensions of briquettes on the market are: diameter 80 mm and length 90-100 mm (Figure 22), although some measure: diameter 90 mm and length 35 cm. Both of these types are solid briquettes.

The most popular wood briquette is produced from beech residue without any additives (impurities). Some producers add corn starch to the wood residue during the production process to achieve better adherence and compactness.

Wood briquettes produced in Serbia are most commonly sold to various consumers on the domestic market. Households are the main consumers of wood briquettes, followed by public district heating systems, bakeries, schools, health care centres, and other commercial consumers.

42 045 m^3 of woody biomass in raw or air-dried condition in the form of sawdust and small wood residue from industry were used for the production of 21 719 tonnes of wood briquettes in 2010.

Wood pellets

Wood pellets are experiencing an increase in consumption in private households, schools, and commercial buildings. In 2011, all sixteen factories for wood pellet production realized slight increases in production. However, this is still significantly below their designed capacities. One of the reasons is the lack of raw materials, due to intense competition from two factories for particleboard production.

Owing to the promotion activities of boiler producers in Serbia, as well as the distributor of boilers and stoves imported from abroad (primarily from Austria and Italy) and their arrangements with the pellet factories, the “more mass” consumption of wood pellets has also started in private households. Producers and distributors guarantee consumers (households) safe delivery of wood pellets in the required quantities and for guaranteed price for the entire heating season. Certain producers of wood pellet boilers and stoves give guarantees to their buyers that they will have provided supply with necessary quantities of wood pellets at least

five years at current prices. This approach has had positive results, which impacted on increased sales of boilers and stoves in October and November 2010.

According to data obtained from certain boiler producers, the most frequent quantities of wood pellets purchased by private households range from 4-6 tonnes for the heating season (which depends on size of the houses, number of heating hours and other factors).

In terms of public heating systems, currently only one district heating plant and one boiler room for heating one residential building in Belgrade use wood pellets. In other cities in Serbia wood pellets are still not used in district heating systems. The first example of use in the 2010-2011 heating season was recorded in one small school in Belgrade (7 tonnes).

Due to still relatively low consumption of wood pellets in Serbia, the highest quantities of this wood fuel are exported from Serbia.

61 168 m^3 of woody biomass in the form of firewood, long-length roundwood, sawdust and large wood residue from industry were used for the production of 40 120 tonnes of wood pellets in 2010.

3.2.2. Household consumption

Fuelwood is still the most commonly used type of wood fuel in Serbian households. The presence of certain fuel types for the purpose of heating households varies in different regions in Serbia. A graphic representation of the results of survey regarding the participation of certain fuel types for heating households is given in Figure 32 and Figure 33. In southern and south-eastern parts of Serbia, the main fuel for heating households is wood fuels. Thus, for example, in Jablanički county wood fuels are used in 65.6 percent of households, in Pčinjski county in 70.8 percent and in Pirot county in 69.3 percent. Together with electricity, wood fuels are the dominant source of energy for heating households in central, south-west and west Serbia. Thus, for example, in Zlatibor county (south-west Serbia), participation of electricity for heating households is 47.9 percent and wood fuels participate with 26.8 percent. In 13.7 percent of households in this region, combination wood/coal is present.

In Belgrade, the two most common types of heating are district heating systems (54.1 percent) and electricity (23.7 percent) and wood fuels take the third place (8.2 percent). Fuel combination wood/coal accounts for 3.6 percent. In the Vojvodina region, gas and district heating systems have high presence, and in certain counties such as north and west Bačka, wood along with gas is fuel with the highest participation. Participation of wood fuels in west Bačka is 39.9 percent and in combination with coal it is 17.2 percent (Glavonjić 2011).

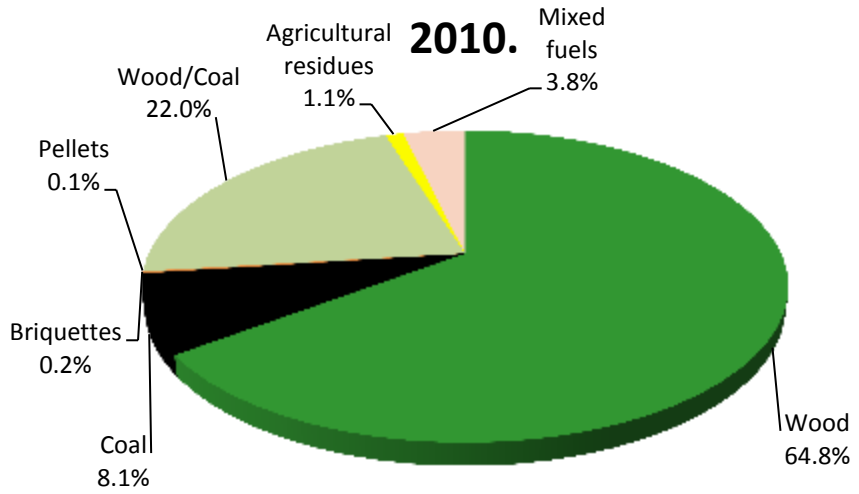
The second important characteristic of fuel consumption for heating households is the fact that a lot of fuel combinations are present in the consumption. Results of the questionnaires [16] showed that in the 2010-2011 heating season, 28 different fuel combinations were present (Figure 33). Here, it should be mentioned that the combination wood/coal was the most commonly used, while other fuel combinations were present to a lesser degree.

However, even with these relatively low percentages, they have to be taken into consideration when determining the amounts of certain fuels used for heating households.

Survey results showed that 23.2 percent of Serbian households used district heating systems, 25.2 percent used electricity, 10.6 percent used gas and 0.1 percent used oil. The largest number of households (40.9 percent) used solid fuels such as wood, coal, briquettes, pellets, agricultural residues and combinations of solid and other fuels (Glavonjić 2011).

Figure 32 shows that almost two thirds of households, which used solid fuels for heating, use wood, while the combination wood/coal is used in 22.0 percent of households. Compared to the total number of households in Serbia, the number of households which used only wood, combination wood/coal and combination wood/other fuels was 934 237 or 37.1 percent. Survey results on the presence and amounts of fuel consumed in households in Serbia showed that the total consumption of wood (urban and rural households collectively) was 6 416 693 m^3 of solid wood.

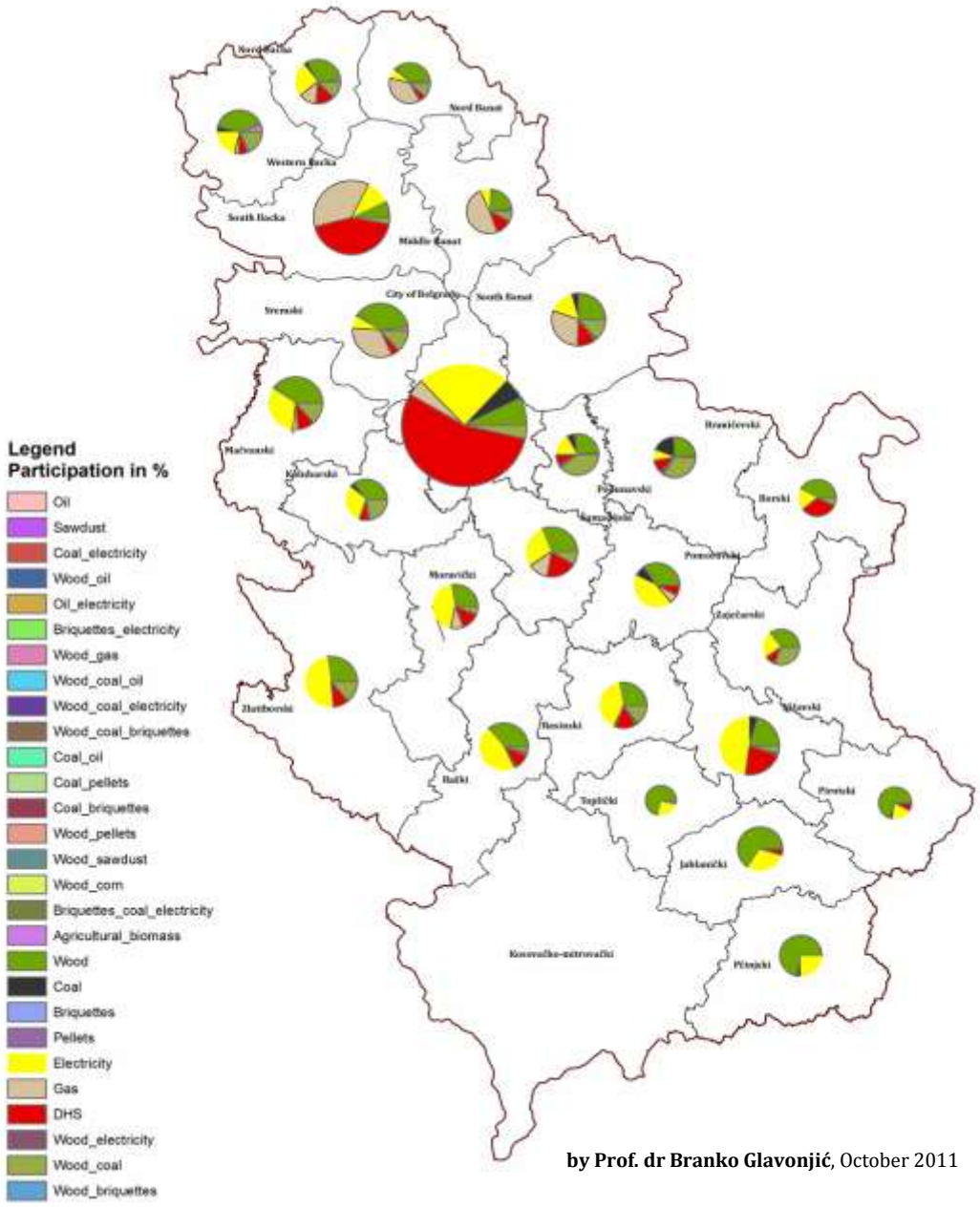
Figure 32 Contribution of certain types of solid fuels for heating households in the 2010-2011 heating season in Serbia



Sources: TCP Serbia database and Glavonjić 2011

In the total fuelwood consumption of 6.42 million m^3, households bought a certain proportion from sawmills, as well as from wood packaging production companies in the region of Vojvodina and Belgrade. Survey results showed that in the 2010-2011 heating season, total consumption of solid wood residue from sawmills and packaging production for heating households was 55 905 m^3, which means that the remaining of 6 360 788 m^3 was firewood. In this amount the biggest quantity of wood comes from forests, but other sources (mainly from village groves, orchards, logging residues and agricultural wood residues) also contribute. Particular quantities of fuelwood from mentioned sources will be the object of special research.

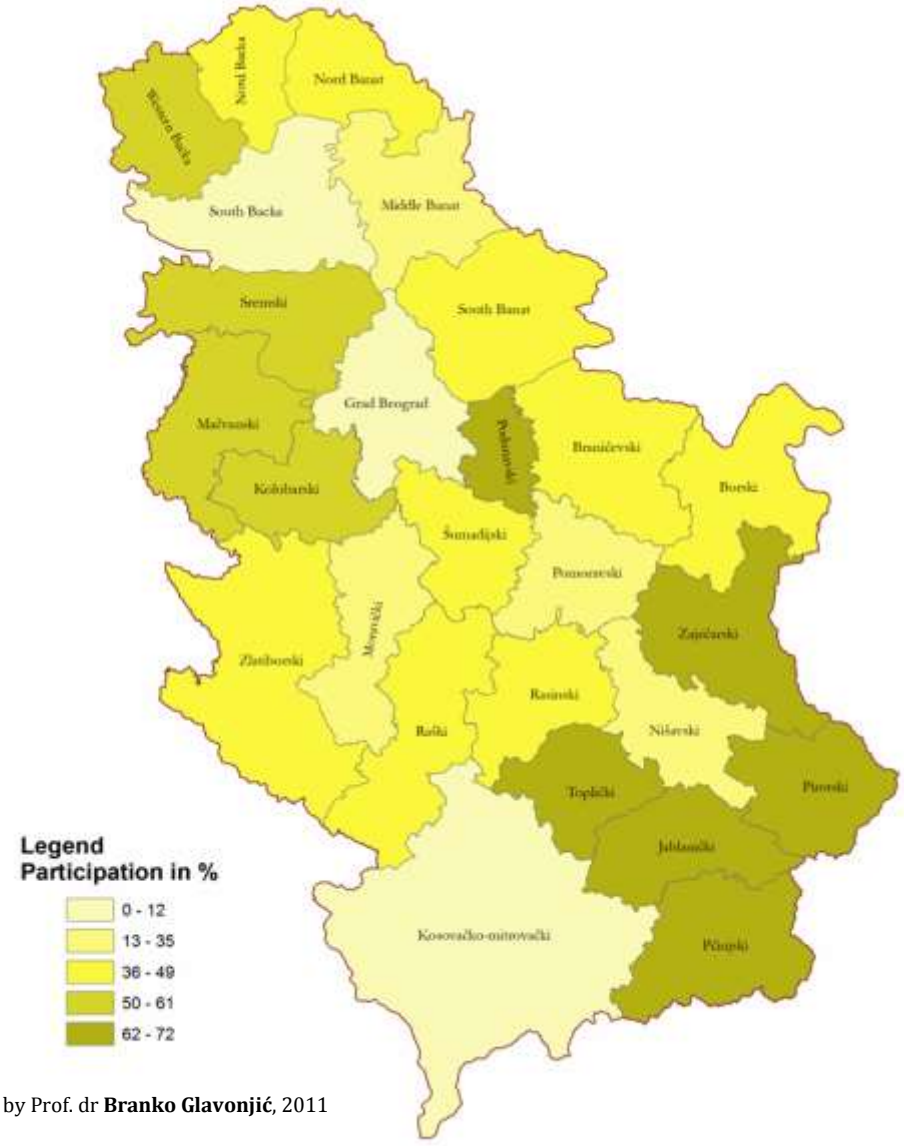
Figure 33 Presence of certain fuel types for heating households in the 2010-2011 heating season in Serbia



Source: TCP Serbia database and Glavonjić 2011

Graphic representation of households which use wood and wood fuels in the total number of households by counties is given in Figure 34.

Figure 34 Presence of households which used wood and wood fuels for heating in the 2010-2011 heating season in total number of households by counties in Serbia



by Prof. dr **Branko Glavonjić**, 2011

Sources: TCP Serbia database and Glavonjić 2011

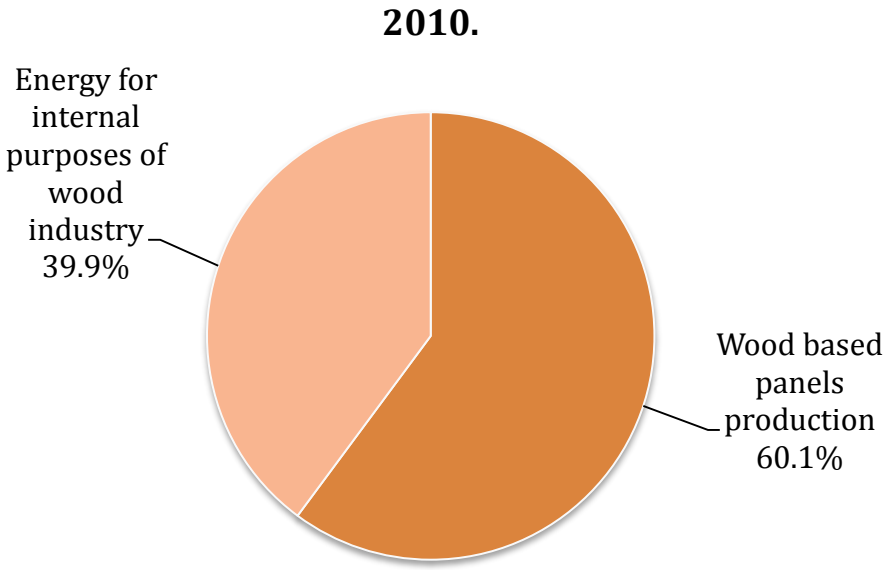
Results of field research and the questionnaire show that there are certain differences in the use of wood fuels in urban and rural households, both in terms of amounts and type.

3.2.3. Consumption by commerce and industry

Forest based industries internal use

The most significant segments of forest based industries that use woody biomass internally are: production of wood based panels and energy generation for internal needs of wood processing industry (Figure 35). Total consumption of woody biomass in the stated segments in 2010 was 551 400 m^3, out of which 25 900 m^3 was in the form of wood chips and the rest was in the form of firewood, long-length roundwood and residues from sawmills (Glavonjić 2011).

Figure 35 Participation of certain consumers in total woody biomass consumption for forest based industries internal use in 2010



Sources: TCP Serbia database and Glavonjić 2011

Particleboards are produced in two large factories with capacity of about 500 000 m^3 per year, and hardboard is produced in one factory with capacity of 40 000 m^3 per year. Since all three factories are in the phase of achieving full capacity after general overhauls or construction, it is realistic to expect an increase of their consumption of woody biomass in the following years.

The most significant forms of woody biomass for use in the industry of wood based panels are firewood, long-length roundwood, wood chips and sawdust (Figure 36 and Figure 37). Depending on the technology being used, long-length roundwood is dominantly present in one and firewood in the other particleboard factory, while the hardboard factory dominantly uses firewood of 1 m length.

In energy generation for internal needs of the wood processing industry, woody biomass in the form of sawdust and large wood residue is used. Energy produced in this way is mostly used for the purpose of heating production plants, drying and steaming of wood.

Figure 36 Woody biomass for the needs of particleboard production

Figure 37 Woody biomass in the form of firewood for hardboard production

Source: B. Glavonjić, 2011

Boilers that burn woody biomass are used to generate heat. The total installed capacity of boilers in wood processing industry is 149.6 MW, where most boilers are very old and are used with very low utilization.

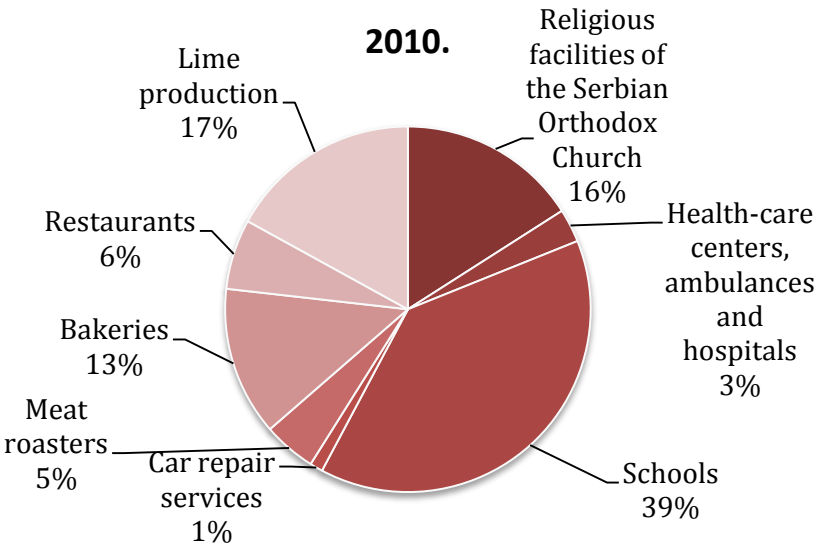
Commercial purposes

(restaurants, schools, health care centres, bakeries, churches, lime kilns)

The most significant other segments in which woody biomass is used are: lime production, bakeries, meat roasters, schools, facilities of Serbian Orthodox Church, restaurants, facilities in the health care system and car repair services. In 2010, total consumption of woody biomass in these segments was 64 500 m^3 (Glavonjić 2011). Participation of certain consumers in total woody biomass consumption for commercial purposes is shown in Figure 38.

A significant form of woody biomass consumption in this segment is lime production. Lime is produced in a traditional manner by using wood for burning stone. In Serbia there are 81 active lime-burning factories (Figure 40), although only some of them produce lime all year round (Figure 39), while in others the production is occasional depending on demand. Total consumption of woody biomass for lime production in Serbia in 2010 was 10 900 m^3 (Glavonjić 2011). The most commonly used woody biomass this purpose is wood waste from forests (branches, buttresses, tops) while firewood is used to a lesser extent. There are also several lime-burning factories where the combination of sawdust and wood waste from forests is used. The main reason why firewood is not used in significant amounts for these purposes is that lime producers also sell firewood for market requirements which is why it is more profitable for them to sell it than to use it for lime kilning.

Figure 38 Participation of certain consumers in total woody biomass consumption for commercial purposes in 2010



Sources: TCP Serbia database and Glavonjić 2011

Figure 39 Brick-built lime-burning factory in the village Veliki Šenj

Source: B. Glavonjić, 2011

Figure 40 Spatial distribution of lime burning factories in Serbia

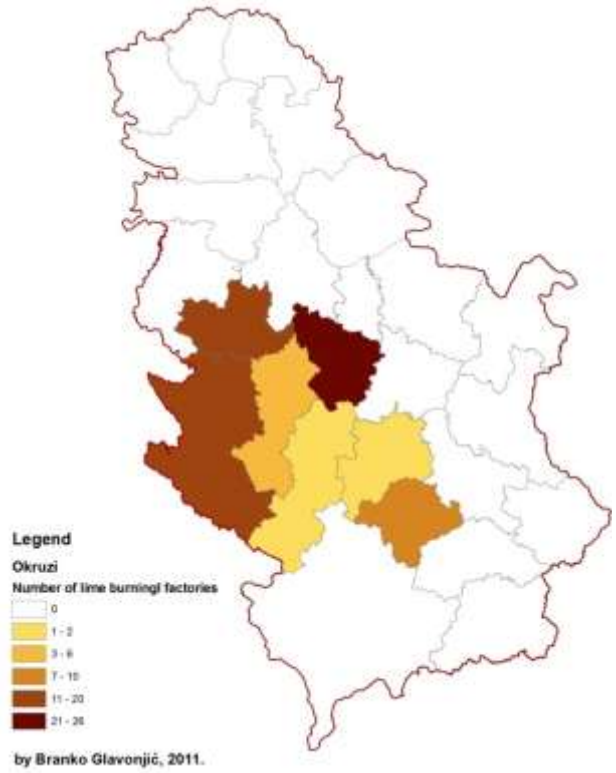
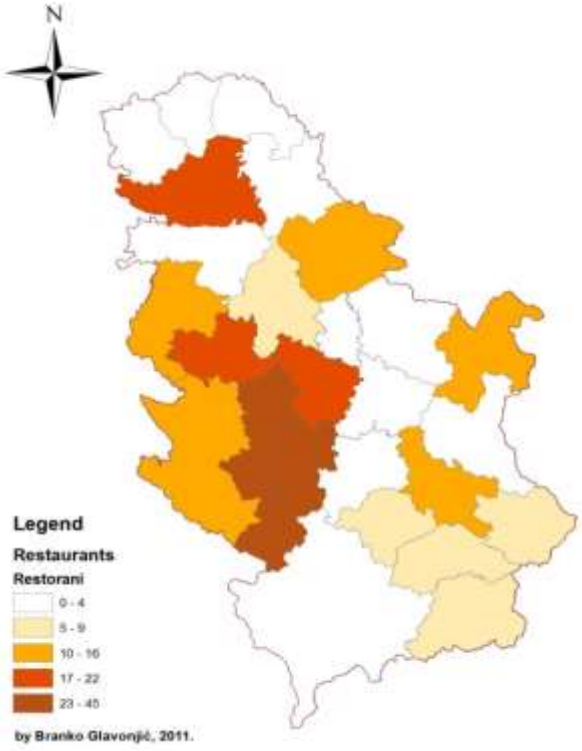


Figure 41 Spatial distribution of restaurants which use fuelwood for heating in Serbia



Sources: TCP Serbia database

For the needs of bakeries and meat roasters in Serbia in 2010, 11 500 m^3 of woody biomass was used, mostly in the form of firewood and in smaller amounts in the form of large wood residue from sawmill industry (primarily for big meat roasters). Two big meat roasters are situated in Leskovac and in the village of Gornja Sabanta near Kragujevac. These meat roasters roasted 14-15 tonnes of meat each annually. Most restaurants also use firewood for heating (Figure 41) (Glavonjić 2011).

Beside woody biomass in the form of wood, wood briquettes are also used for the needs of bakeries. Therefore, bakeries represent an important segment of consumers for many producers of wood briquettes in Serbia.

For heating purposes of schools and health care centre buildings in Serbia in the 2010-2011 heating season, 27 012 m^3 of fuelwood was consumed of which 93 percent was used in schools (Glavonjić 2011).

3. 3. Total wood energy (woody biomass) demand

The calculations showed that total demand of woody biomass for energy purposes in Serbia in 2010 was 6.7 million m^3, and for non-energy purposes it was 0.71 million m^3 (wood based panels, wood fuels production, lime production) (Table 7).

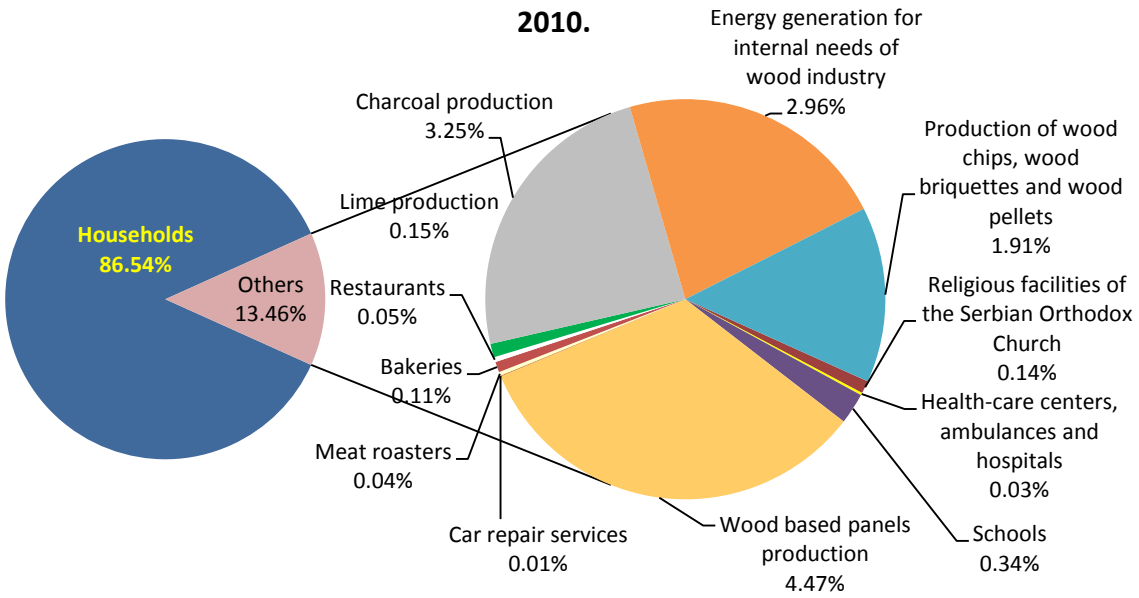
Table 7 Wood fuel consumption for energetic purposes in Serbia in heating season 2010/2011

Type	Unit	Quantity
Firewood	m^3	6 414 303
Wood residues from forestry and wood industry	m^3	281 129
Wood briquettes	tonnes	29 087
Wood pellets	tonnes	9 872
Charcoal	tonnes	27 603

Source: Author's calculations

From a total of 7.41 million m^3 of woody biomass that was consumed for energy and non-energy purposes in Serbia, 94.94 percent (7.03 million m^3) was woody biomass in the form of wood (firewood, long-length roundwood, branches, buttresses and tops). The second two types contributed significantly less, especially sawdust which contributed 0.75 percent in the total consumption of woody biomass, while large residue from industry contributed 4.31 percent or 319 300 m^3. The contribution of certain users in total consumption of firewood and large wood residue from industry and forestry is presented on Figure 42.

Figure 42 Households and other users in total consumption of woody biomass in forms of firewood and wood residues in Serbia



Sources: TCP Serbia database and Glavonjić 2011

In the category of other consumers, the largest consumption of small-diameter roundwood is realized in the segment of wood-based panels (particleboard and hardboard) and charcoal production, followed by energy generation for the internal needs of wood industry companies, production of wood fuel (chips, wood briquettes and wood pellets), and heating of school facilities.

3.4. Local supply/demand balance

The main product of the Integration Module, which is the supply/demand balance analysis, is done at cell level by subtracting current consumption from supply potential for all relevant assortment categories (Drigo 2011).
Several balance scenarios were considered:

- Actual cut (official and predicted-real actual cut)
- Theoretical (current and increased plan of cut)

Balances are summarized at municipality and administrative region level.

Figure 43 Balance map for official cut (pixel balance – left, municipality balance – right)

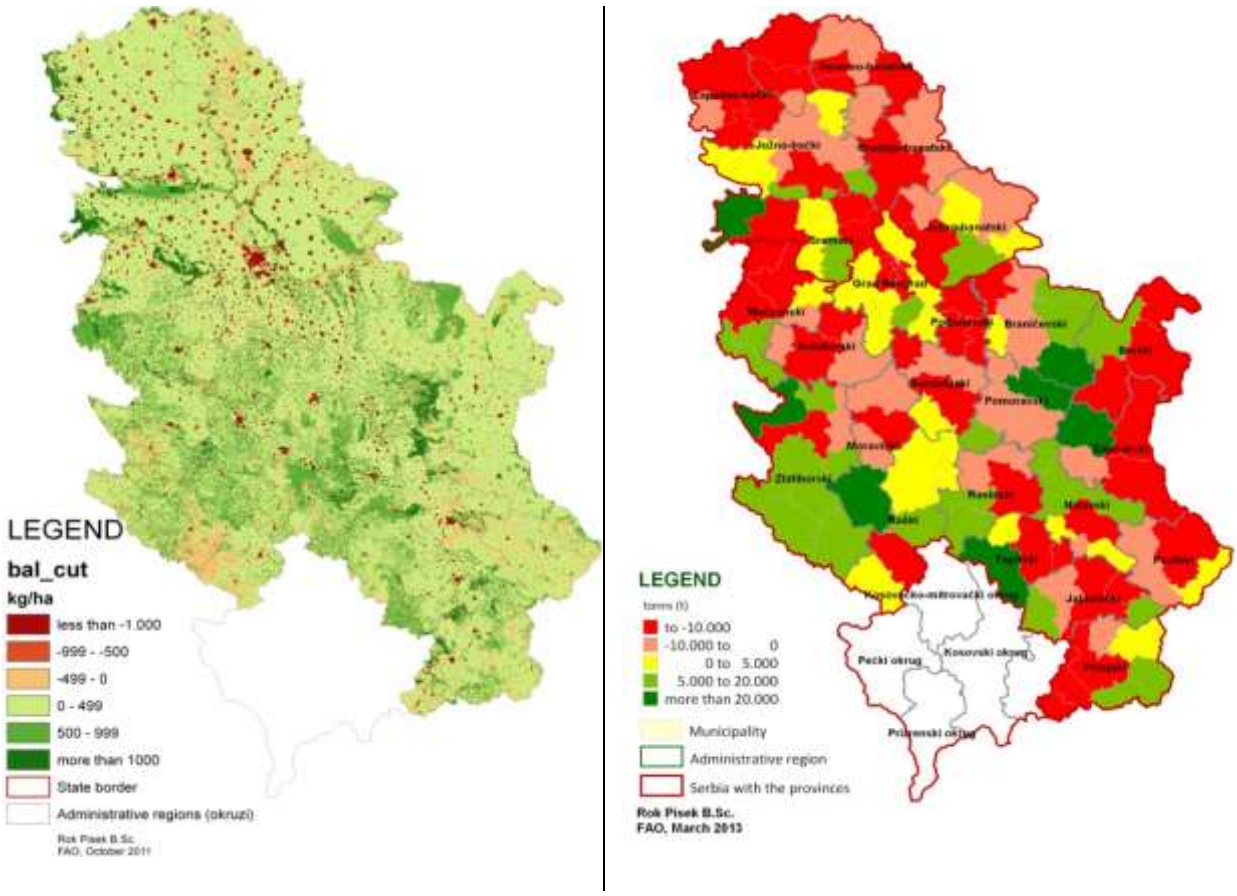


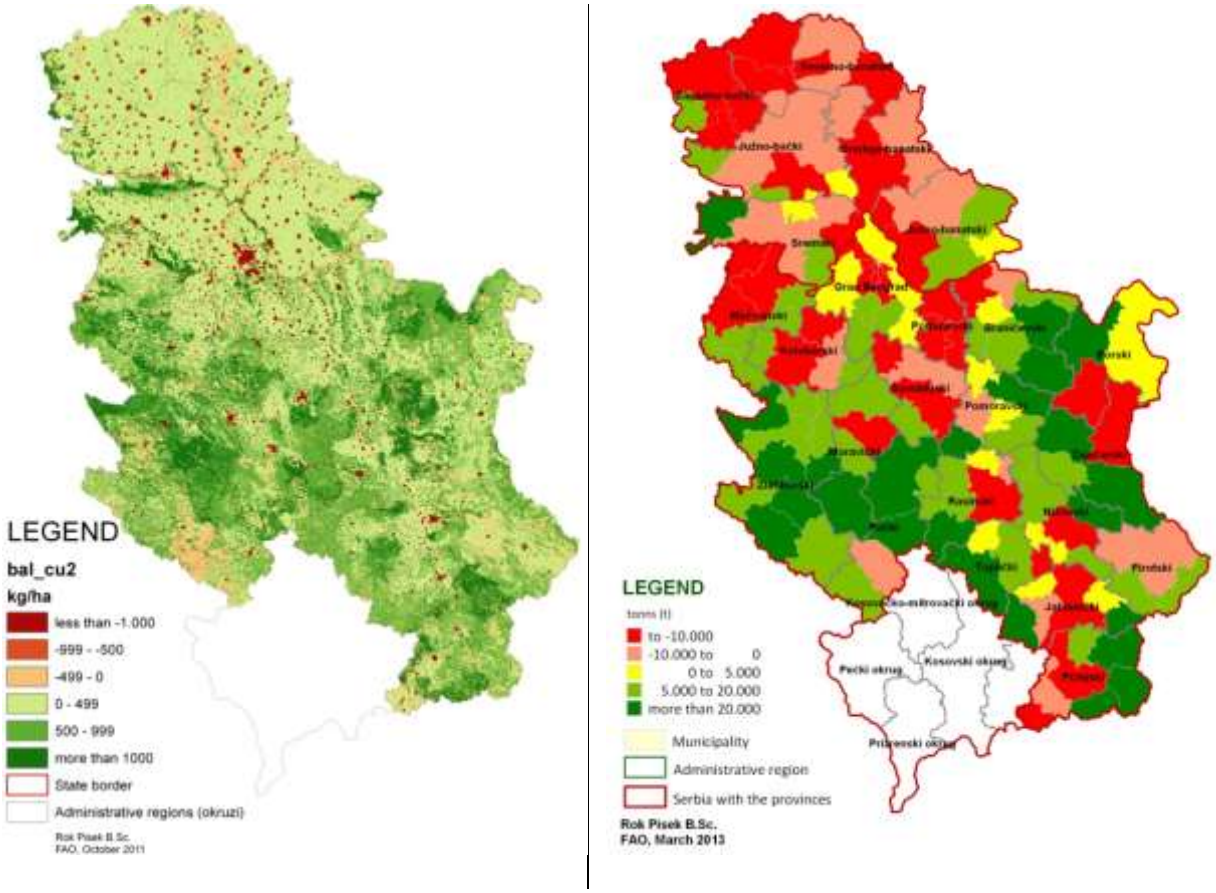
Figure 43 shows the low quality wood (wood fuel) balance scenario for the official cut (in total 4.88 million m^3 on a supply side). About two thirds of municipalities (99) in Serbia have a negative balance in the sense that the actual consumption of wood fuels is higher than the

officially registered production. The largest deficit is in the municipality of Kragujevac - 119 822 tonnes and the largest surplus is in the near (only 20 km away) municipality of Despotovac (+32 268 tonnes). At national level, the difference is -1.17 million tonnes.
Such a situation results from two factors:

- Large number of municipalities (especially in Vojvodina and central Serbia) which have modest forest resources but high wood consumption, and
- Unreliable statistical records of wood fuel production, which is several times higher than that officially recorded.

In practice, this means that large amounts of wood fuel from municipalities rich with forest resources and where wood fuel production is developed are placed in the municipalities with modest forest resources and high consumption of wood fuels.

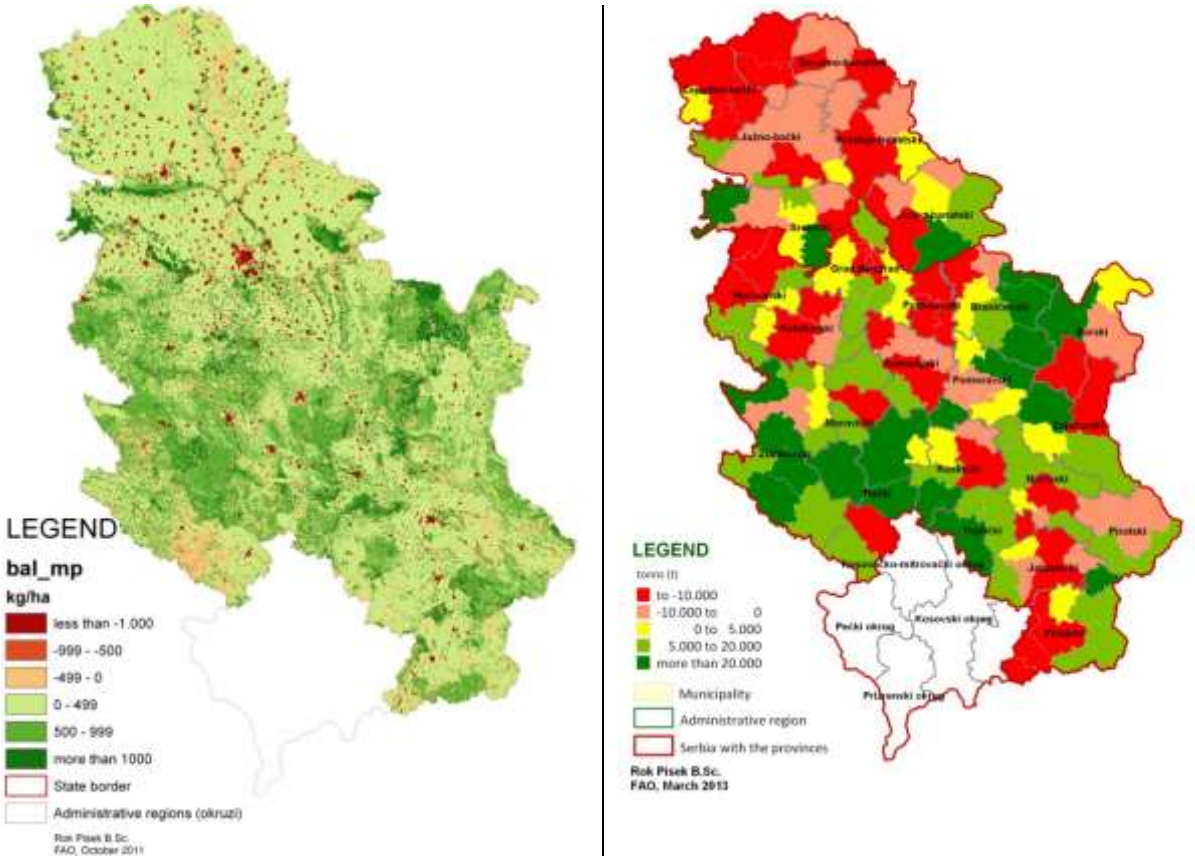
Figure 44 Balance map for predicted real cut (pixel balance – left, municipality balance – right)



Sources: TCP Serbia database

Figure 44 shows the low quality wood (wood fuel) balance scenario for the predicted real cut (in total 7.37 million m^3 on a supply side). Almost half of municipalities (77) in Serbia have a negative balance in the sense that actual consumption of wood fuels is higher than the predicted real cut. The largest deficit is in the municipality of Kragujevac with -93 447 tonnes and the largest surplus is nearby in the municipality of Ivanjica (+73 911 tonnes). At national level, the difference is +37 900 tonnes.

Figure 45 Balance map for the current allowable cut [set out in the forest management plans for state forests and according to calculation of possible wood production by regions for private forests (Proracun, 2010)], (pixel balance – left, municipality balance – right)

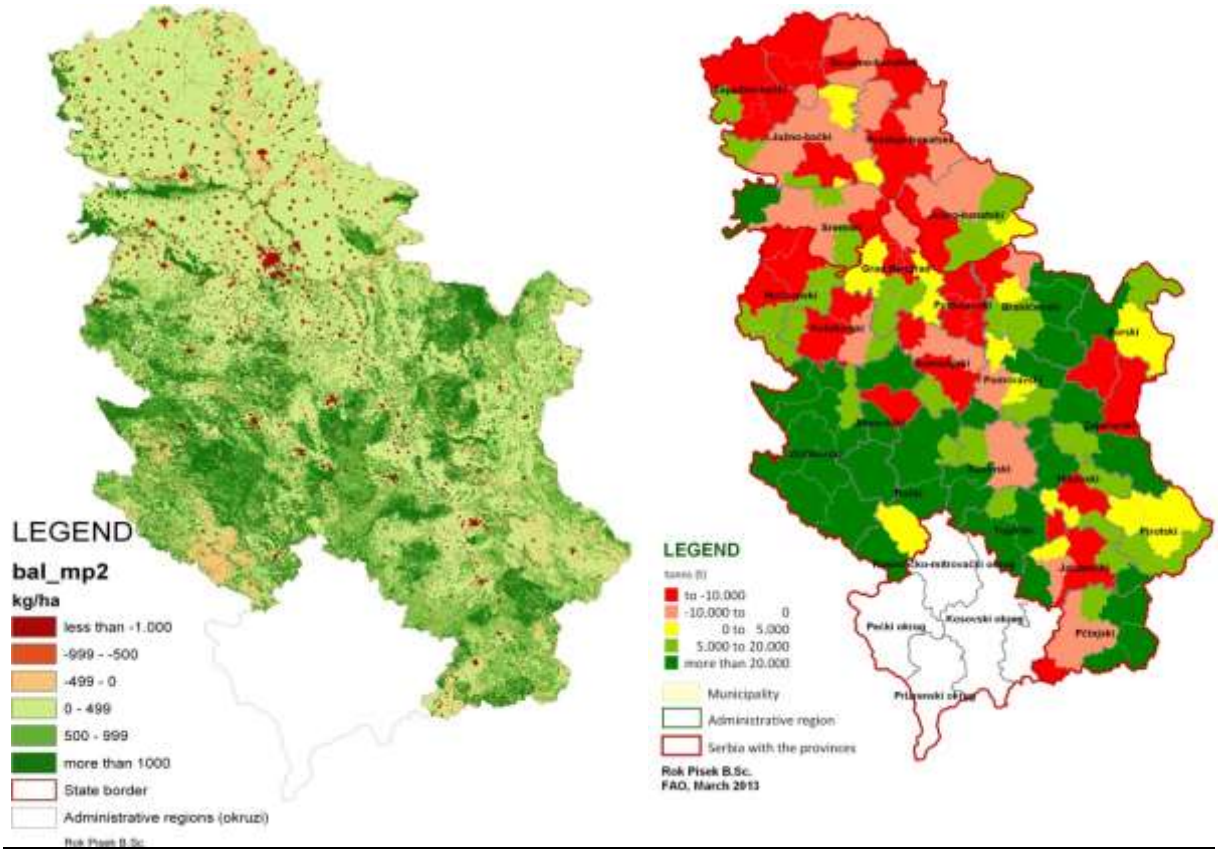


Sources: TCP Serbia database

Figure 45 shows the low quality wood (wood fuel) balance scenario for the current allowable cut (in total 6.35 million m3 on a supply side). Almost half of municipalities (80) in Serbia have a negative balance in the sense that the actual consumption of wood fuels is higher than the current allowable cut. In this scenario the largest deficit is in the municipality of Kragujevac with -103 308 tonnes and the largest surplus is in the municipality of Ivanjica (+64 609 tonnes). At national level, the difference is -254 992 tonnes.

Figure 46 shows the low quality wood (wood fuel) balance scenario for the current allowable cut (in total 7.79 million m^3 on a supply side). Less than half of municipalities (75) in Serbia have a negative balance in the sense that the actual consumption of wood fuels is higher than the increased allowable cut. In this scenario the largest deficit is again in the municipality of Kragujevac with -87 306 tonnes and the largest surplus is in the municipality of Ivanjica (+100 551 tonnes).

Figure 46 Balance map for increased allowable cut (allowable cut as 70% of Mean Annual Increment-MAI), (pixel balance – left, municipality balance – right)



Sources: TCP Serbia database

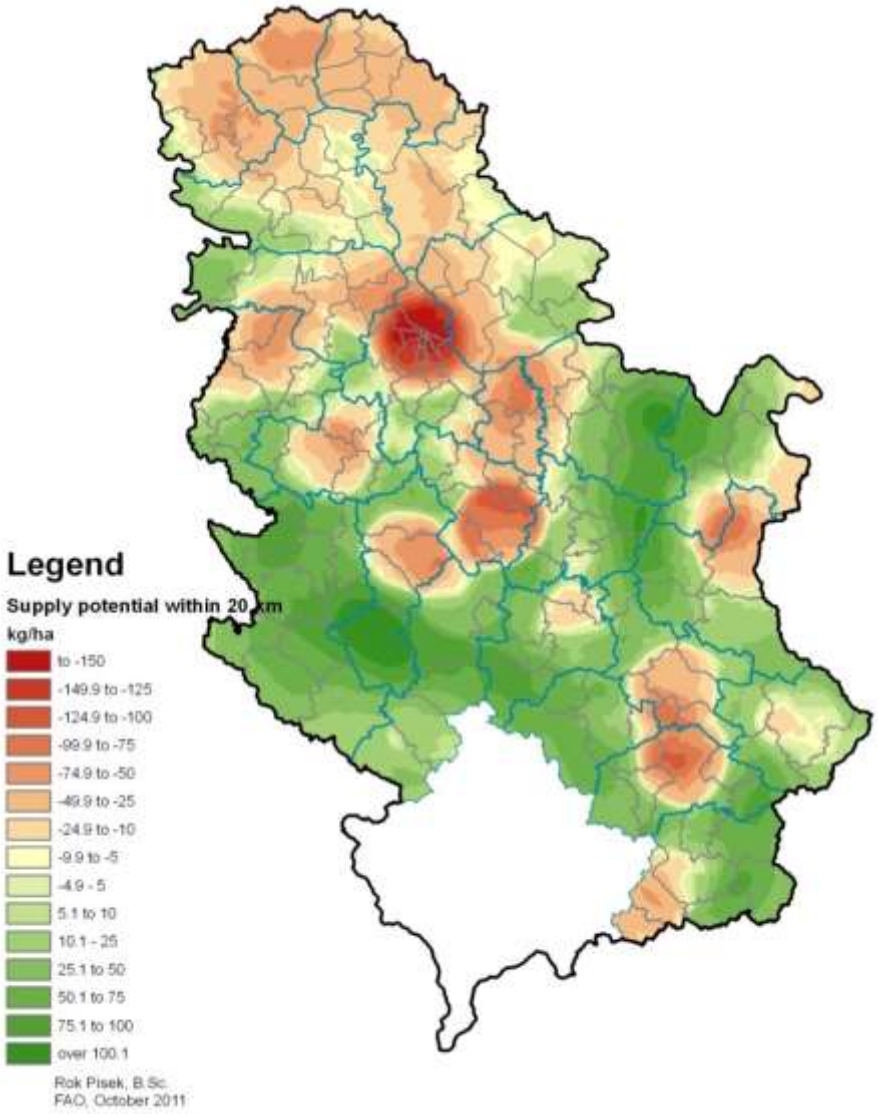
This comparative analysis of actual consumption of wood fuels in relation to the increased allowable cut leads to the conclusion that there is potential for a 532 200 tonne increase in consumption.

3.5. Woodshed analysis

Supply/demand balance data can be also used to define the suitable locations for biomass plants. If the locations for hypothetical plants are not preliminarily defined, the analysis is done at once over the entire country and the scope is to determine the supply potential of each map pixel assuming a certain supply radius (Drigo 2011).

The priority zoning was determined through a combination of the high wood surplus considering current local consumption and the potential sustainable productivity on the distances within the diameter of 20 km. Based on the data obtained, Figure 47 presents the zones suitable for erecting wood energy (fuel) plants. Results of this analysis are significant for policy planners in the field of renewable energy sources as well as for potential investors, because they clearly show the main areas with potential for the development of wood fuel production.

Figure 47 Map of suitable zones for woody biomass plants



Sources: TCP Serbia database

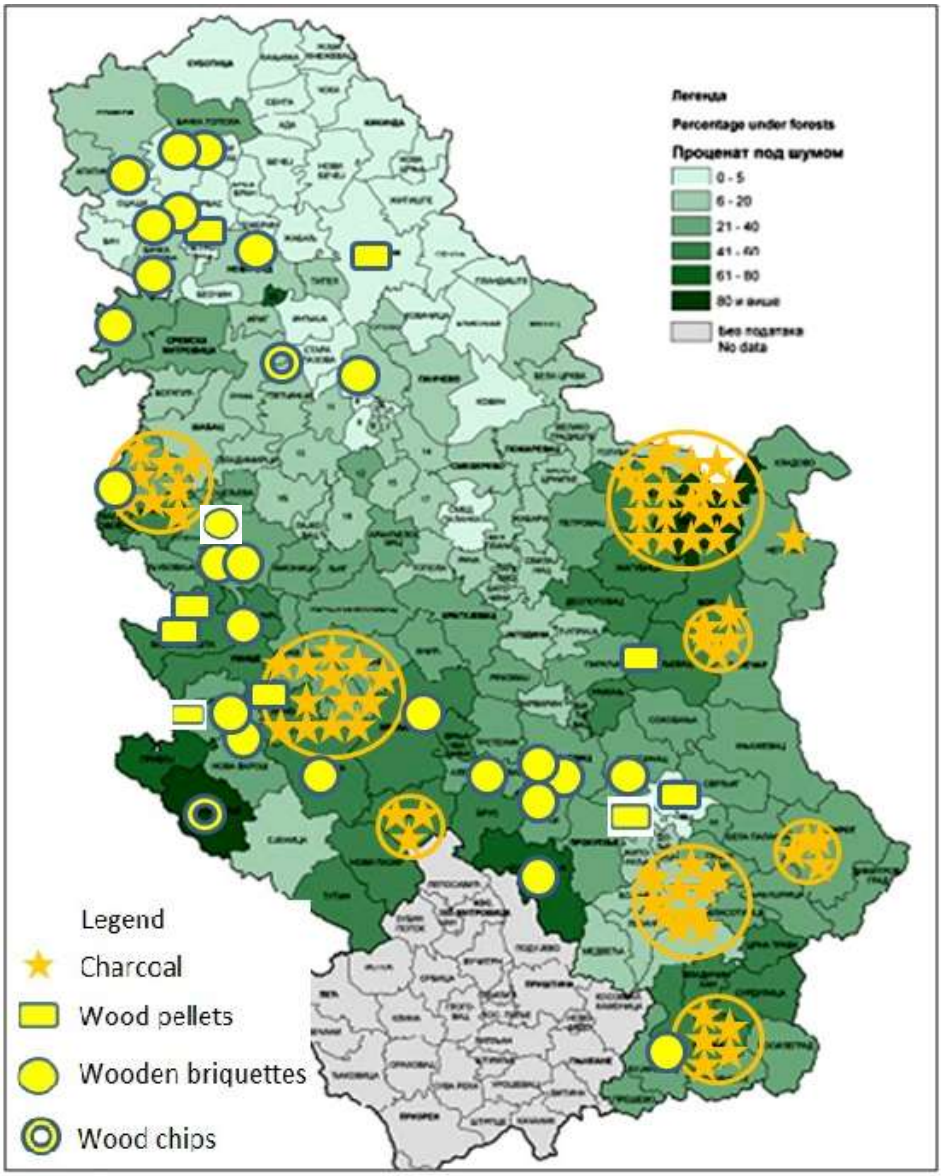
The analytical conclusions and priority zoning so far defined should be considered as the first step in the analysis of this sector and not the conclusion of a process.

4. SWEIS (Serbian Wood Energy Information System)

4.1. Production, import, export and consumption

Every type of wood fuel is produced in Serbia (fuelwood, wood chips, wood briquettes, wood pellets and charcoal). The majority of producers are located in the South-west and Western parts of Serbia, and the rest in Southern, Eastern and Central Serbia (Figure 48).

Figure 48 Map of producers of wood fuels in Serbia



Source: B. Glavonjić, 2011

Besides the relatively high number of producers, the second most important characteristic of production of wood fuels is the fact that their production includes both traditional and

contemporary methods. Furthermore, there are many more companies that use traditional production methods (pellets and charcoal).
Considering that 47 percent of forests in Serbia are privately owned, the majority of households get wood from their own forests.

Surveys showed that a number of private forest owners who live in the cities make arrangements with local contractors, authorizing them to cut wood from their forests in the ratio of 1 stacked m^3 for the owner and 1 stacked m^3 for the contractor. There are frequent cases when this ratio is not 1:1, but usually 1:2 and even more in favour of contractors, because owners often do not come to forest to control their work.

Considering that Serbia has about 530 000 private forest owners, it is very difficult to determine the number of producers of fuelwood from private forests.

In state forests, in the majority of cases private companies and entrepreneurs produce fuelwood, and also provide cutting and production of wood assortments for requirements and account of public enterprises. In the minority of forest estates, production of fuelwood is done by the employees of these estates. Considering the fact that private companies provide cutting and production of wood assortments, at the same time they execute production of technical roundwood and fuelwood, and they can be considered only as fuelwood producers. According to Srbijašume (public forest enterprise) data, the total number of private companies and entrepreneurs that carried out cutting, production of wood assortments and transport in 2009 was 459.

Besides public enterprises for forest management and private forest owners, the production of fuelwood is also executed by entrepreneurs who buy wood at the stump or in form of multi-meter roundwood, and then transport it to their work sites themselves, where they split it into 1 m lengths. They then transport the products to cities themselves. An example of such a work site in Central Serbia is shown in Figure 49.

Figure 49 Cutting and splitting of multi-meter roundwood on the work site of one entrepreneur in Central Serbia

Source: B. Glavonjić, 2010

Besides meter wood, offer on the market in the 2010-2011 heating season also included split wood assortments of 32-33 cm in length, packed in palettes or on trucks (Figure 50).

Figure 50 Offer of split wood in palettes and on trucks

Source: B. Glavonjić, 2010

The moisture of fuelwood in offer on the market varies depending on the season in which it was produced. In the majority of cases, wood is dry, which consumers find satisfactory.

The main way of measuring sales of fuelwood is in stacked m^3, which is the reason for frequent objections by consumers related to obtained and paid wood quantity.

Production of wood chips is currently executed by seven entrepreneurs, out of whom the first started production in the second half of 2009, and the other ones in the second half of 2010 and 2011. The majority of wood chips are currently used in wood pellet factories and particle boards. Wood chips produced from hardwood are distributed to wood pellet factories, and wood chips produced from coniferous tress for the production of particleboards.

The moisture of wood chips delivered to wood pellet factories ranges from 30-40 percent, and in the established payment system the price depends on the type of tree and the moisture.

4.2. Prices of wood fuels in Serbia

Prices of fuelwood vary depending on the types of sellers and assortments. In state forest enterprises, prices of fuelwood from class I beech range from EUR 28.8-29.4 per m^3 *fco* forest road depending on location. Prices refer to assortments of 1m in length and do not include VAT. VAT for fuelwood in Serbia is 8 percent (Glavonjić 2011). Together with several other products (bread, milk, etc.), fuelwood falls into category of products which have social character and to which the lower VAT basis is calculated, while for all other products the tax is 20 percent.

Prices of fuelwood in cities offered to end consumers (households) by private entrepreneurs (sales from truck) are higher than the prices on the forest road and range from EUR 30-45 per stacked m^3, including delivery. Cutting metre wood it is necessary to pay additional EUR 2 per stacked m^3. In smaller towns in South-west and Western Serbia, the prices of fuelwood range from EUR 30-35 per stacked m^3 and in the bigger cities (Beograd, Novi Sad, Kragujevac and Niš) the prices are up to EUR 45 per stacked m^3. Beside metre fuelwood, the consumers are also offered the split wood of 33 cm in length at prices of EUR 46-48 per stacked m^3 (Glavonjić 2011).

Briquettes are predominantly packed into 15 kg boxes and sold for EUR 1.5 per box or EUR 0.1 per kg. Prices without VAT are in the parity *fco* producer. Some producers pack briquettes in sacks of 35 kg, which are sold for EUR 3.3 per sack or EUR 0.09 per kg (without VAT). The highest quantities of briquettes are sold by producers to local consumers (households and bakeries), as this is more profitable than distributing them to other cities, which would require additional labour and logistics (Glavonjić 2011).

Prices of wood pellets on the market in Serbia range from EUR 140-150 per tonne (fco factory), although there are also individual cases of sales of pellets of lower quality at price of EUR 100 per tonne (EXW) (Glavonjić 2011).

The wood pellet market is still not fully established, and there are numerous examples of complaints by end users in the sense of non-harmonization of quality of wood pellets and furnaces for burning of wood pellets. This was even more evident in the 2010-2011 heating season when various models of imported furnaces were distributed on the market without adequate test certificates and quality certificates (primarily from China). Charcoal prices are relatively low and range from EUR 3.3-3.6 per 15 kg sack (EUR 0.22-0.24 per kg) on parity of fco charcoal kilns. Prices for end producers in cities are significantly higher and range from EUR 0.52-0.61 per kg. Comparative analysis of prices of wood fuels and other fuels in Serbia is given in the Table 8.

Table 8 Market prices of wood fuels and other fuels in Serbia

Name of fuel	Measurement unit	Price in €/ measurement unit (1€= 105,00 RSD)	Energy value in kWh/ measurement unit	Price in €/kWh
Fuelwood in length of 1 m	€/stacked m^3	30-35 (C. Serbia)	1840	**0.016-0.019**
	(M=30%)	43-47 (Vojvodina)		0.023-0.026
Split logs in length of 33 cm	€/stacked m^3	46-48	1840	0.025-0.026
	(M=30%)			
Solid wood briquettes	€/tonne	90-146	4600	**0.02-0.03**
Wood briquettes with a hole	€/ tonne	130	4800	**0.027**
Wood pellets	€/tonne	140-180	4900	**0.029**
Charcoal	€/kg	0.52-0.61	7,2	0.07-0.08
Coal Banovići	€/tonne	123	5140	0.024
Coal Pljevlja	€/tonne	113	2977	0.034
Coal Kovin (lignite)	€/tonne	62	2290	0.027
Gas	€/normal m^3	0.30-0.36	9.53	0.031-0.038
Fuel oil	€/litre	0.90	9.79	0.098
Electric energy (average for blue and red zone*)	€/kWh	0.028	1	0.028

***Sources**: Distributers of solid fuels in Belgrade, Elektroprivreda Srbije, gas distributers, Oil industry of Serbia. For the calculation of costs of electric energy, the average price of blue and red zone was taken for households with two-tariff metres in night regime of operation (accummulation of TA heaters)*

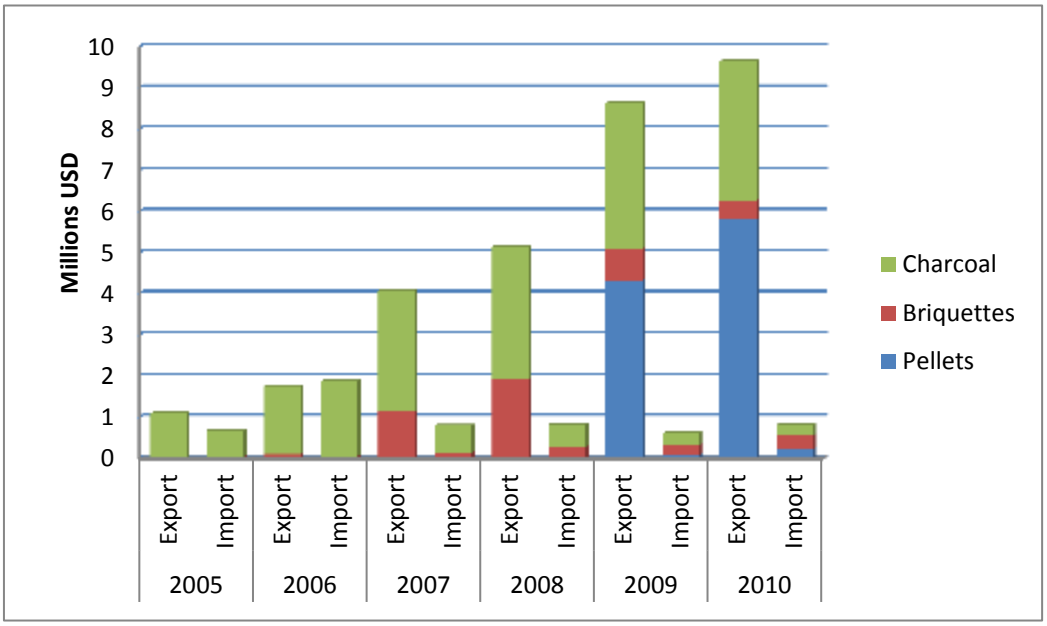
Comparative analysis of market prices of wood and other fuels shows that all types of wood fuels (except charcoal) are price-competitive to other fuels, which had an impact on increase of their demand in the 2010-2011 heating season.

4.3. Export and import of wood fuels

With the exception of charcoal, the significant export of wood fuels from Serbia started only after the construction of wood pellet factories (after 2006). The appearance of wood pellets in the external trade of Serbia since 2007 was not adequately accompanied by the official customs and statistical records in terms of their classification into separate customs tariff. For this reason, in the records of import and export wood pellets are classified in tariff group in which all the wood residue products are classified, regardless of whether they are in compressed or non-compressed form. With more mass export of wood pellets during 2007 and 2008, they were classified in the separate customs tariff, and from 2009 wood pellets have had the statistic records as a separate product group. That means that in the data on imports and exports in the period 2006-2008, the category of compressed wood (mostly briquettes) contains certain quantities of wood pellets as well.

Analysis of external trade of wood fuels shows the sudden growth of their export starting from 2007 (Figure 51).

Figure 51 Import and export of wood fuels of Serbia



Source: Statistical office of the Republic of Serbia, 2011

Total wood fuel exports from Serbia in 2010 were USD 9.6 million, with the majority being wood pellets (USD 5.8 million). The second most exported wood fuel is charcoal which achieved value of USD 3.4 million in 2010.

The most significant countries for the export of wood fuels from Serbia are Slovenia, Austria, and Hungary. Italy and Slovenia are the two most significant countries for export of wood pellets with a share of 96.5 percent in their total export. Austria, Hungary and Slovenia are three most significant countries for export of wood briquettes with a share of 94.4 percent in their total export.

Charcoal is mostly exported to Austria, Croatia, and Montenegro. Austria accounted for 74.4 percent of total charcoal exports from Serbia in 2010.

Serbia is a relatively small importer of wood fuels. The total import of all wood fuels in 2010 was USD 811 000, with the majority being briquettes of USD 324 000.

To analyse of state of the external trade balance of wood fuels it is necessary to add the current state in terms of import and export of fuelwood. Total value of import of this assortment in 2009 was USD 1.4 million, and export USD 111 000. These values show that Serbia is a very small importer and exporter of fuelwood, which leads to the conclusion that the highest quantities of fuelwood produced are used in consumption on the local market. The same statement refers to wood chips, considering the fact that it is also not separately statistically recorded, but in the framework of the customs tariff covering fuelwood, wood residues, wood chips and particle.

4.4. Overview of production, consumption, import and export of wood fuels in Serbia

Table 9 shows assumed data about production, exports, import and consumption of wood fuels in Serbia. It is necessary to note that the consumption of wood fuels includes consumption in households, industry, public district heating systems, public institutions (schools), charcoal kilns, bakeries, meat roasters, limekilns and wood based panel plants. The results are mainly different from past estimations which were done for various institutions and organizations in the country and abroad. These results are also very different from the data of the official statistics. Thus, for example, the real consumption (production) of the fuelwood is 3-4 times larger than statistics suggest.

Table 9 Overview of production, consumption, import and export of wood fuels in Serbia in 2010

	Fuelwood (m^3)	Wood chips (loose m^3)	Wood briquettes (tonnes)	Wood pellets (tonnes)	Charcoal (tonnes)
Production	7 419 167	118 923	21 719	40 120	34 086
Import	5 121	6 650	11 431	1 272	486
Export	9 263	508	4 063	31 520	6 969
Apparent Consumption	7 415 025	125 065	29 087	9 872	27 603

Sources: 1.Results of surveys and author calculations, 2. External trade of the Republic of Serbia, 3. Different enterprises

For all of the reasons stated above, this TCP/FAO project has a great importance for wood energy system in Serbia.

4.5. Wood energy balances

Taking into consideration the national renewable target the following text in the first place provides the analysis of the participation of renewable sources in total final energy consumption for energy purposes in 2010 with special highlight on wood energy participation. The stated analysis was done on two bases:

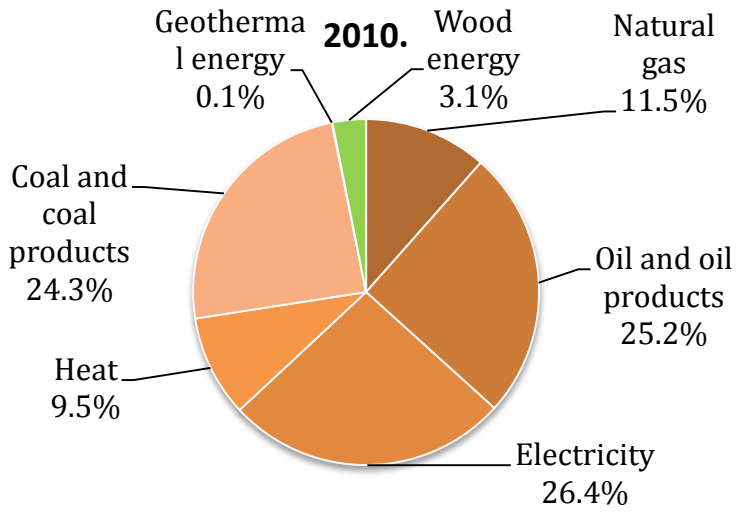
- Official energy balance produced by the Serbian Statistical Office
- Data on wood energy consumption in Serbia in 2010 based on the results of the TCP/FAO project

Such an approach was conditioned by the fact that there are big differences in wood energy consumption between statistical values and the values obtained in the TCP project.

According to the official energy balance (Serbian Statistical Office 2011), total consumption of final energy for energy purposes in Serbia in 2010 was 376 436 TJ with the participation of certain fuel types as presented on Figure 52.

Electricity, oil and oil derivatives and coal are three main fuel types in final energy consumption in Serbia. Such high participation of oil and oil derivatives results from their consumption in traffic.

Figure 52 Contribution of certain fuel types in total final consumption of energy in Serbia in 2010 (according to the energy balance of the Serbian Statistical Office)



Source: Statistical office of the Republic of Serbia, 2011

Regarding the contribution of wood energy to final energy consumption (376 436 TJ) in Serbia in 2010, it was 11 669 TJ or 3.1 percent. By calculating the amounts of wood based energy in final energy consumption officially adopted in the national energy balance into cubic metres of equivalent roundwood, with energy value of 1 m^3 of non-coniferous wood with moisture content of 35 percent in the amount of **7 677 MJ**, the amounts of **1 519 995 m^3** were reached. Obtained amounts of wood are the amounts calculated with in official energy balance. This means that the amounts of firewood calculated with in official energy balance are several times smaller than the amounts of wood actually consumed for heating in Serbia. It also implies that total final energy consumption is higher than the officially registered in the energy balance, and consequently the participation of wood as energy generating product (Glavonjić 2011/a).

The stated facts are one of the reasons why TCP/FAO project was initiated and implemented with one of the objectives to contribute to observing the realistic consumption of wood based energy in Serbia.

Based on TCP results and performed calculations it can be concluded that total amount of consumed energy from wood fuels in households and other consumers in the 2010-2011 heating season was 1.37 million tonnes of oil equivalent (Mtoe) (Table 10). This amount is 4.9 times higher than the value of energy from fuelwood which is contained in the energy balance of the Republic of Serbia for 2010 (0.281 Mtoe) (Glavonjić 2011/a).

The main reason for such a large difference between the values in the energy balance and actual value of consumed energy from wood fuels in Serbia results from the lack of data on overall consumption of wood fuels. Namely, official statistics calculates energy value of fuelwood only from officially registered amounts out of which mostly in state forests. However, the majority of fuelwood produced in private forests and from outside forests are not recorded, thus they could not be included in Serbian energy balance.

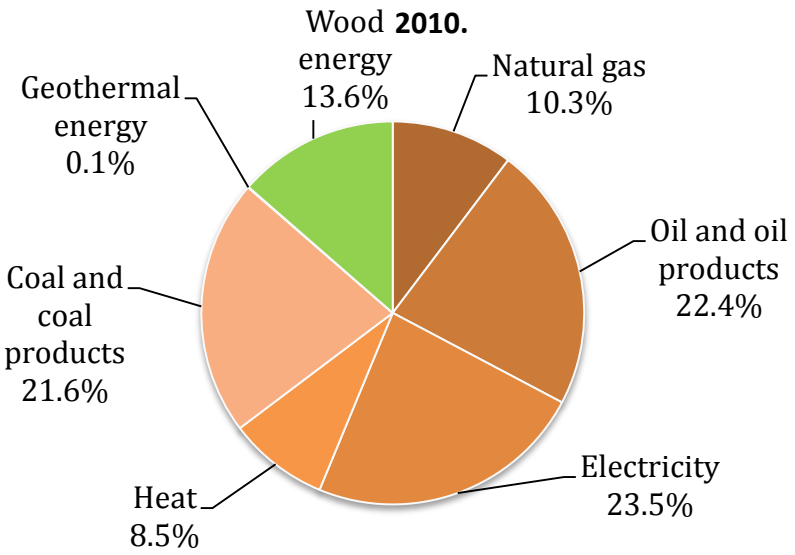
Table 10 Wood energy balance of Serbia in 2010

	Firewood and long-meter roundwood	Wood residue	Wood chips	Wood briquettes	Wood pellets	Charcoal	Total
	TJ	TJ	TJ	TJ	TJ	TJ	TJ
Primary production	59 359	1 099					60 458
Import	38	4	18	187	21	13	281
Export	71	6	1	67	531	199	875
Stock changes	-345						-345
Bunkers							
Statistical difference							
Gross inland consumption	**58 981**	**1 097**	**17**	**120**	**-510**	**-186**	**59 519**
Transformation input	**2419**	**595**	**81**	**23**	**38**	**0**	**3156**
Thermal power plants							
CHP							
Autoproducers							
District heating plants				23	38		61
Charcoal kilns and retotrs	1 798						1 798
Producers of wood pellets	401	108	81				590
Producers of wood briquettes		325					325
Producers of wood chips	220	162					382
Producers of wood residual							
Other							
Transformation output	**0**	**2 495**	**382**	**366**	**685**	**998**	**4 926**
Thermal power plants							
CHP							
Autoproducers							
District heating plants							
Charcoal kilns and retotrs						998	998
Producers of wood pellets					685		685
Producers of wood briquettes				366			366
Producers of wood chips			382				382
Producers of wood residual		2 495					2 495
Other							
Exchanges and transfers, returns							
Consumption in the energy sector							
Losses							
Energy available for final consumption	**56 562**	**2 997**	**318**	**463**	**137**	**812**	**61 289**
Final consumption	**56 562**	**2 997**	**318**	**463**	**137**	**812**	**61 289**
Final Non-Energy consumption	**3670**		**318**				**3 988**
of which: Chemical industry							
Final Energy consumption	**52 892**	**2 997**	**0**	**463**	**137**	**812**	**57 301**
Industry	1 097	1 488		3	10	4	2 602
Construction		11					11
Transport							
Households	51 299	1 481		226	126	342	53 474
Agriculture		17					17
Other users	496			234	1	466	1 197

Source: Glavonjić B. 2012.

Based on above presented results and calculations it can be concluded that final consumption of energy in Serbia in 2010 was 421 978 TJ or 10.08 Mtoe with the participation of wood energy in the amount of 57 301 TJ or 13.6 percent (assuming that the values of other fuels are as presented in the official energy balance) (Figure 53).

Figure 53 Contribution of certain fuel types in total final energy consumption in Serbia in 2010 (according to the TCP/FAO project)



Source: TCP Serbia database, calculations: Glavonjić 2011

This means that wood energy has a significant position and role in meeting energy needs in Serbia. However, due to the lack of reliable data it is extremely underestimated.

On the other hand, taking into consideration the amount of woody biomass used for energy purposes in Serbia in the form of firewood and long-length roundwood, its consumption for non-energy purposes (production of wood-based panels, production of wood fuels and lime) as well as the consumption of technical roundwood for industrial purposes, it can be concluded that that the consumption of firewood and long-length roundwood has reached its peak. Such a conclusion results from the fact that annual increment in Serbian forest fund is **9.08** million m^3 and annual allowable cut is even smaller and that wood consumption should not exceed these values in order not to jeopardize the principle of sustainability. Since about **1.4** million m^3 of woody biomass can be used from the non-forest areas with trees, the principle of sustainability in forestry is not jeopardized yet.

4.6. Wood fuels contribution to the climate change mitigation and economy of Serbia

Share of wood-based energy in total GDP is below 0.5 percent and is not such high as in case of other products. However, in spite of relatively low share of GDP, the significance of energy obtained on the basis of wood for household and energy system of Serbia is high.

- Current use of wood energy substitutes imports of light heating oil in the value of EUR 1.3 billion or EUR 650 million in the case of substituting natural gas (Serbian GDP in 2010: EUR 60 billion) (Steierer 2011);

- Use of wood fuel prevented emissions of about 7 million tonnes of CO_2 from fossil fuels. The theoretical value of these carbon emission currently value EUR 55 million (EUR 8 per tonne) (Steierer 2011);

Considering that Serbia settles half of its energy requirements from import, as well as the fact that the energy consumption in Serbia increases on the yearly level, each form of local production of energy products is of great significance for reduction of import dependence of the country.

5. CONCLUSIONS AND FURTHER DEVELOPMENT OF WISDOM SERBIA

The main conclusions that can be drawn based on the presented research results are.

- Wood energy consumption is much higher than anticipated in energy and forestry statistics. Survey results indicate that the total amount of wood used for energy purposes was 1.37 million tonnes of oil equivalent (Mtoe) in the 2010-2011 heating season. This amount is 4.9 times higher than the value reported in the official energy balance of the Republic of Serbia for 2010 (0.281 Mtoe).
- According to project results, wood energy accounts for about 13 percent of Serbia's total final energy consumption. Future energy scenarios require revision, based on this new data.
- Current use of wood energy substitutes imports of light heating oil in the value of EUR 1.3 billion or EUR 650 million in the case of substituting natural gas (Serbian GDP in 2010: EUR 60 billion).
- Use of wood fuel prevented emissions of about 7 million tonnes of CO_2 from fossil fuels. The theoretical value of these carbon emission currently value EUR 55 million (EUR 8 per tonne).
- About 6 000 jobs are being maintained mainly in rural areas for the production and distribution of wood fuels.
- Serbian forests are managed sustainably. Despite the much higher rate of wood consumption for energy, forests are increasing in area (+1.85 percent in the period 2005-2010) as well as standing volumes (+5.8 percent in the period 2005-2010) [Source: FAO FRA 2010]. Currently, it is estimated, that only 70 percent of the net annual increment is being utilized. Thus there is even potential for additional wood production.
- Total wood energy consumption was 7.4 million m^3 in Serbia in 2010.
    - 37 percent or slightly less than one million households in Serbia depend on wood fuels for cooking and/or heating either exclusively or in combination with other fuels. Urban and rural households collectively consume wood fuels amounting to 6.4 million m^3 of solid wood equivalent.

  - Other users, namely: schools, health care centres, lime production, charcoal production for restaurants and meat grills wood processing companies consumed another 1 million m^3 for energy in 2010.

- Fuelwood cut and split is the main type of wood fuel in Serbia. 90.6 percent of wood fuels come from direct sources (58.2 percent forests and 32.4 outside forests). Only 9.4 percent of wood fuels consumed in Serbia arise from wood processing co-products.

FURTHER DEVELOPMENT OF WOODY BIOMASS CONSUMPTION IN SERBIA

Consumption of woody biomass in the form of firewood and long-length roundwood has reached its peak, so the increase of wood energy consumption has to be based on using those forms of woody biomass which are currently not used at all or are used on a much smaller scale than their potential allows. In figures, this means:

- 70% of all wood pellets produced annually in Serbia will be consumed within Serbia, marking the first time that more pellets will be used domestically rather than exported abroad.

- increase of wood briquette participation in consumption up to the level of about 30 000 tonnes annually, which is a symbolic increase of about 3 percent compared to the consumption level in 2010,

- reaching the consumption of wood residue from forests in the amount of 250 000 m^3 annually, which would represent an increase of about 65 percent compared to the consumption level in 2010 (estimation of 150 000 m^3)

- reaching the consumption of woody biomass obtained in the conversion of coppices to the level of about 200 000 m^3/year

By calculating the proposed amounts of certain woody biomass types into energy values, it would mean that additional **69 500 toe** could be obtained from their consumption. Proposed targets, amounts and energy value result from the observation of current situation in wood energy system in Serbia, primarily of the existing situation and problems which wood fuel producers face, slow decision making in public enterprises and Government institutions, lack of funds for investments and incentives and other limitations.

Proposed targets do not take into consideration the consumption of woody biomass from energy plantations or from recycled wood even though there is the possibility and potential, because growing of energy plantations and organization of recycled wood collection require a certain period of time during which stakeholders will primarily adopt the idea itself and afterwards make steps towards the elimination of barriers that exist in this area. Therefore, these two sources of woody biomass are long term targets concerning Serbia. Also, wood chips is not separately stated in the proposed targets by certain woody biomass types since it

will be produced from wood residue from forests and woody biomass which will be obtained from the conversion of coppices.

Proposed target for wood energy increases its consumption quantitatively, however its percentage participation in Gross Final Energy Consumption in 2020 reduces by 0.4 percent (compared to 2010) because of the need for other renewable energy sources to increase their participation in order to reduce the pressure on woody biomass and that it would remain on the level of consumption in accordance with the principles of sustainable management.

FURTHER DEVELOPMENT OF WISDOM SERBIA

Results of this Project will offer a better basis for decision-making, but it is necessary in the future to abolish some deficiencies and to make the following improvements:

• At the national level is necessary strive to better spatial definition of the specific land uses. The land use map will be also needed from other users which are involved in spatial planning. If in the future will be made more detailed map of land uses, analysis in this Project must be re-adjusted for all parameters of non-forest woody biomass.

• In the future it is necessary to monitor consumption of wood for energy purposes by households and especially use of lower quality wood for industrial purposes. Any observed change must be recorded (where, what) and implement it in demand module at Wisdom renovation.

• In the future it would be appropriate to monitor more closely the felling in private forests. If the recording on site is not appropriate because of economic or social aspects, it is possible to monitor this phenomenon on the NFI grid model at repeated measurements, of course, with sufficiently dense network of sample plots.

• Based on the results of NFI measurements and observed increment in forests, it would be appropriate from a national perspective to determine, an appropriate sustainable allowable cut, which would also include private forests. Of course, determination the amount of the sustainable allowable cut itself is not enough. In both categories of forests (public and private forests) is necessary to monitor the realization of this cut. Ideally, it would be appropriate to include also private forests in the planned forest management.

• For analyses of availability of biomass is necessary to supplement the existing road map with all existing roads, also forest roads. It would be great to integrate into this module also major forest tracks.

• All layers of the model Wisdom must be arranged in a single geodatabase. It is necessary to provide protocol to renew basic input forestry data. All the necessary links between the descriptive and spatial data must be reviewed and in case of discrepancies this must be edited.

• It should be determined who is formal administrator of the entire WISDOM system, and which will be also responsible for maintenance and renovation. An administrator should have a good knowledge of the content and have sufficient knowledge to be able to identify any deficiencies and will to update them competently. GIS skills and tools are evolving very rapidly. To keep up with all new features, usually requires some time, so it is appropriate that this process would be supplemented by an exchange of views in the wider group.

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