Using Geographic Information System for Estimation of Available Biomass Potential

Oğuz H. Çoban*, Mehmet Eker
Süleyman Demirel University, Faculty of Forestry, 32260, Isparta, Turkey
oguzcoban@sdu.edu.tr

Abstract:
Biomass has been recently used for generating electricity, producing gas or bio-fuels as well as direct heating for industrial requirements or domestic use. Although forested areas are more than one-quarter of country's area, bioenergy procurement from forest biomass is a developing concept for Turkish energy sector. The inventory and estimation of utilizable woody biomass for bioenergy is a time consuming and labor intensive task for especially beginner countries. Some aerial and/or terrestrial inventory methods could be successfully used in calculation of forest biomass potential during a long term concept. However, rapid operational inventory of available biomass potential is a considerable process for engineer, supplier, and investor because of determining biomass resource center and landing or plant location. The aim of the study is to introduce the methodology based on Geographic Information System (GIS) applications for effectively estimation available forest biomass. In a GIS environment, it was used digital terrain model, stand types, harvesting sites and other thematic maps to calculate parameters related with biomass potential. Within a managing period, harvestable stem volume (annual allowable cut) of all stands in a planning unit was identified from stand type maps as individual polygons by means of manipulated geographic database. Overall biomass potential was estimated by using stem volume of each stand polygon. According to results, it was stated that the GIS-based operational inventory methodology could be used to determine the actual and potential harvesting sites for sustainable accumulation of forest biomass for illustration to investor and other stakeholder.

Keywords: forest biomass, GIS, biomass potential, biomass inventory

1 Introduction

The production of bioenergy from forest biomass is a growing trend in the worldwide, as well in Turkey. The increasing demand of users for forest biomass requires knowing biomass potential for sustainable utilization in especially bioenergy sector. There is a strong and significantly relationship between inventory of substantial biomass potential and investment cost because of balancing and amortization total cost.

As well known, the forest biomass is called for total above and underground mass of roots, stumps, stems, limbs, barks, needles, tops, and leaves of all live and dead trees in the forest (Röser et al. 2008). In this study, the forest biomass term refers logging residues, unmerchantable stems, small diameter trees, and other tree parts and by-products for bioenergy production. The biomass has been used in a widespread area from raw material to fuel source. The forest industry and also the energy sector have recently focused on the use of forest biomass for green energy, fuels and raw materials for reducing the dependency on fossil fuels and petroleum, because of many factors such as exhaustion of renewable natural resources, global warming, carbon sequestration, sustainable development, etc. (Eker 2011). The utilization of forest biomass in a various fields is affordable; it allows business possibilities and employments, generates profit from unused materials, provides energy self-sufficiency for industry and rural communities and enables the reduction of fire and insect attack due to the removal of fuel materials and the dead woody biomass (Eker et al. 2009).

Although growing strategically importance of forest biomass as a modern bioenergy resource, it has been traditionally used in directly combustion for heating in developing and undeveloped countries. On the other hand, the modern utilization way of forest biomass converting from wood to heat and power is a costly and difficult task because of technical, economical and societal factors. Additionally, it is a longer time consuming process more than classical use for heat energy production. The investment and operational costs of combined heat and power plant for modern utilization are very high more than traditional ways. Therefore, it is required a computational feasibility analysis on forest biomass quantity. The first step of a feasibility analysis is based on inventory, so forest biomass inventory is a supportive information base for this goal. In a conceptual framework, the systematical availability process of forest biomass follows three steps, that are; inventory, procurement, and utilization as respectively.

The forest inventory is a widespread subject and has growing trend in recent. The aerial and terrestrial inventory technologies have quickly provided primer inventory data and information about forest, area, species, etc. and other subjects. In the forestry, the secondary inventory, which is based on terrestrial method and also geodatabase analysis of primer inventory data, could be used in operational inventory purposes such as harvesting and transportation activities of forest products and by-products.

Furthermore, GIS is an auxiliary tool to storage of forest inventory data and to provide manipulation of the data by means of spatial and tabular database. Especially, it can be theoretically and practically used in the management and analysis of forest resources through inventory on the increment, growing stock, standing tree volume, etc. for the various purposes. However, rapid operational inventory of available biomass potential is a considerable process for engineer, supplier and investor since the determining quantity of forest biomass resources, distributing over wide forest area, is a difficult job. Therefore, GIS has been also used in inventory, planning, management, and controlling of forest biomass utilization (Ranney and Cushman 1980, Graham et al. 2000, Beccali et al. 2009).

In this concept, the aim of study is to develop a practical estimation module and introduce its methodology based on Geographic Information System (GIS) applications for effectively estimation of available forest biomass.

2 Material and methods

2.1 Study site

The study area is the Aşağıgökdere Forest Sub-district located in the southwestern part of the Eğirdir Forest Directorate depending on Isparta Forest Regional Directorate, approximately 30 km away from Isparta city (Figure 1). The study area has rugged terrain and has an elevation from 290 m to 1735 m. The Brutian pine (*Pinus brutia* Ten.) is dominant species in this region, distributing more than 60% of the study area and remaining stand types are mixed or deciduous species. There are a small amount of settlement and agricultural areas in this region. While three-fourths of forest areas in the region are productive, remaining forests comprise degraded areas due to non-canopy closure. Non-forest areas including settlement, agricultural areas, rocky areas etc. are 1% of whole study area. The study area has a typical Mediterranean climate conditions.

2.2 Materials

The map of stand types and topographic map of 1/25000 scale were used in this study. The stand type map was originally interpreted by means of stereo infrared (IR) aerial photographs with an average scale of 1:15.000 and the ground measurements were carried out on grids of 300x300 meters, which was prepared by the organization of forestry. For obtaining the data relating to digital elevation model of the area digital topographic map including 10-meter interval contour lines was used (Çoban and Eker 2009). Georeferenced data were assessed by ArcGIS 10.0 geographic information system software. Additionally, Microsoft (MS) Office 2010 software was used.

The stand type map of the study area was produced in ArcGIS environment by the Isparta forest organization. The stand type data consist of graphic data and its attributes table. Each of the stand type in graphical data was represented by polygons. For the polygons, a lot of attributable data including stand type symbol, canopy closure, stand development stage, forest function, site index, tree species etc. listed in the table. In here, one of the stand type symbols mentioned in this study explained with an example:

"*Çzcd2*". In this symbol, "*Çz*" represented Brutian pine tree species, "*c*" represented dominant stand development stage, "*d*" represented second stand development stage and "*2*" represented class code of canopy closure (Table 1).

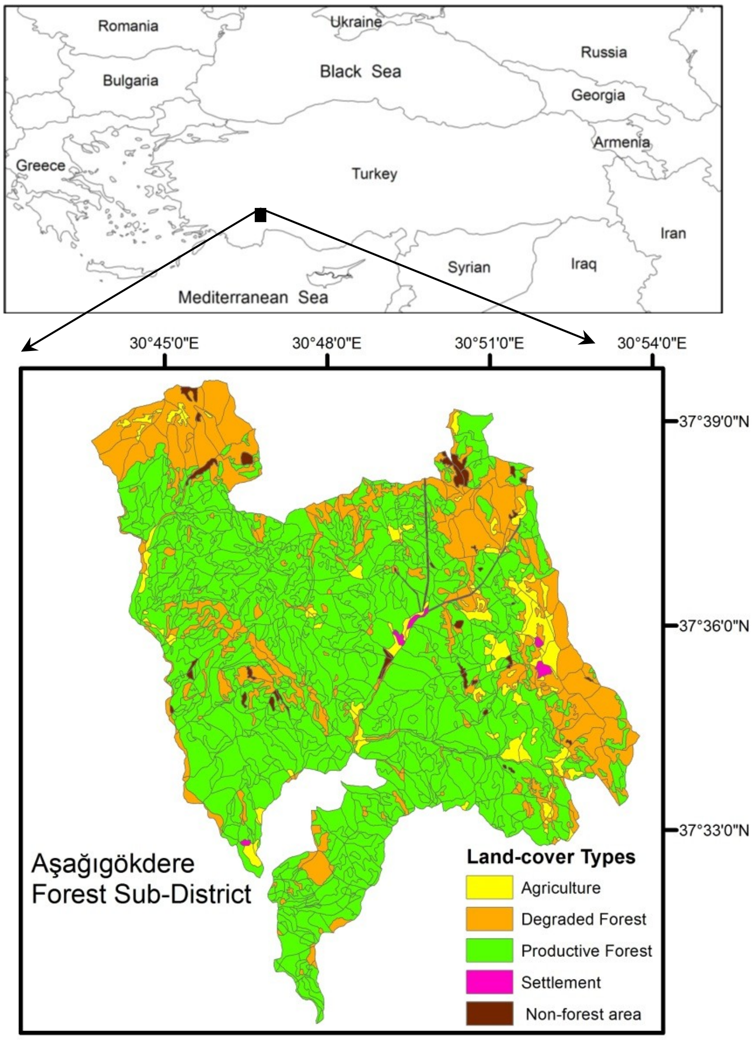

Figure 1: Study site

Table 1: Definition of stand development stage symbols and canopy closure codes

Stand development stage symbol	Average distance at breast height [cm]	Class code	Canopy closure [%]
a	0 - 7.9	0 (Open)	0 - 10
b	8 - 19.9	1 (Light)	11 - 40
c	20 - 35.9	2 (Medium)	41 - 70
d	36 - 51.9	3 (Dense)	> 70
e	> 52		

2.3 Method

In order to create geographic database, stand type data were evaluated together with forest management plan data. Work stages of this study were shown in Figure 2. For graphical data of stand types, topology was created. At the end of the topological assessment, these data were exported a geodatabase produced by ArcGIS. In addition, stand volume and allowable cut values (per hectare) listed as MS Excell format in forest management plan were imported to the geodatabase. Volume and allowable cut values were assigned to the stand polygons by using MS Access queries. Then, new tables were obtained via these queries. Thus, a new two columns containing stand volume and allowable cut values of each polygon were added in the geodatabase. For calculating allowable cut value of each polygon, the value in the allowable cut column was multiplied by corresponding area of the polygon. Polygon's volumes were calculated in the same way.

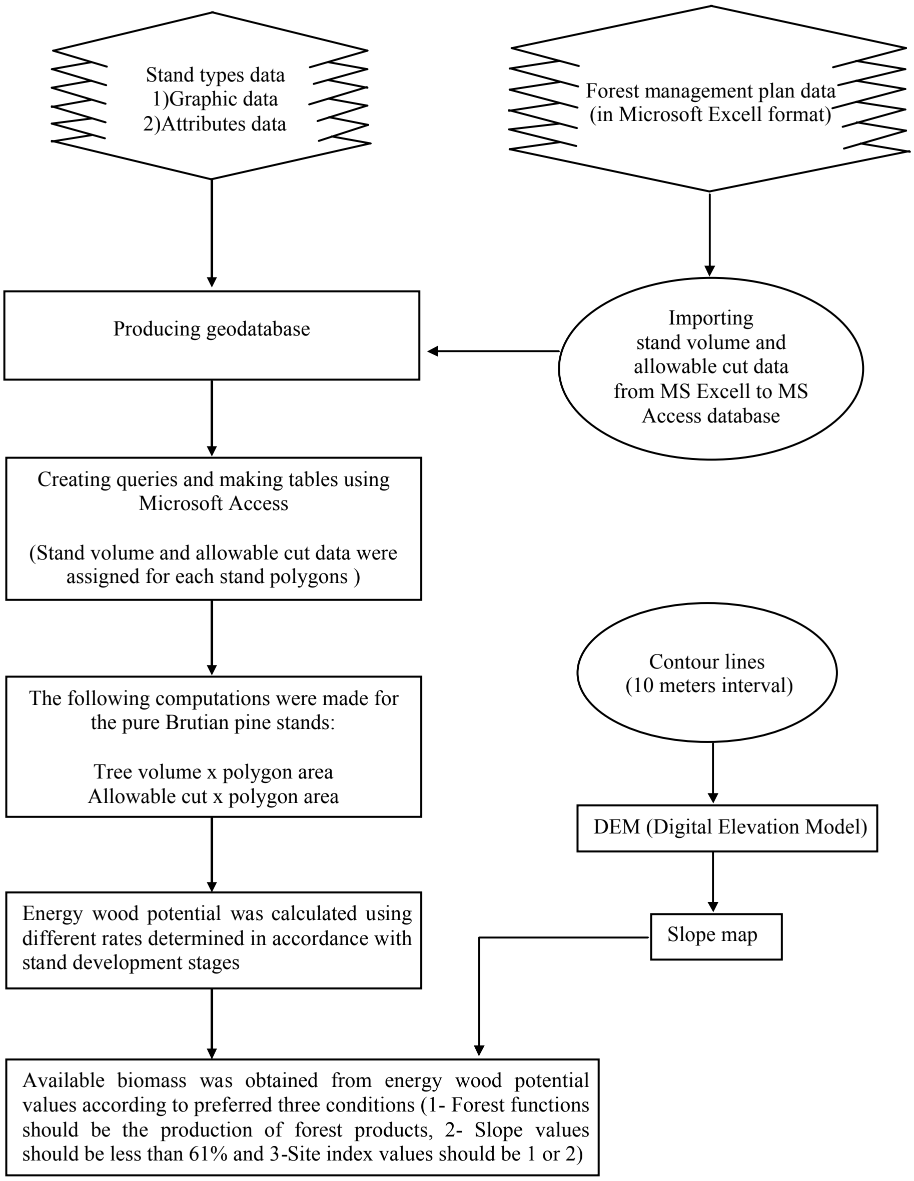

Figure 2: Flowchart of the work stages

To obtain terrain slope in the study area, contour lines with 10 meters interval were used. TIN (Triangular Irregular Network) model was generated by ArcGIS software and raster surface data was derived from the TIN data. Raster slope map was produced from the surface data. The data transformation from raster to feature was applied to the raster slope map and areas of small than one hectare were eliminated in this feature data.

To find energy wood potential in the region, stand development stages in the geodatabase were questioned. It was considered as a biological or theoretical energy wood potential. However, because of some ecological and/or technical reasons, it was impossible to utilize from this potential completely. In order to found available energy wood potential, ratios based on stand development stages were chosen as follows: ab (35%), b (25%), bc (22%), c (20%), cd (18%), d (15%) (Eker 2011, Eker et al. 2012). These ratio values were multiplied by allowable cut values and available energy wood potential was computed. In this point, three criteria were determined to found how much of energy wood potential could be operable. These restrictive criteria were as follows: (1) Forest function should be production of forest products, (2) Site index values should be 1 or 2 and, (3) Terrain slope should be less than 61%. MS Access queries were made in the geodatabase by using the criteria.

3 Results

Overall energy wood potential and its available portions were computed by creating queries in the geodatabase (Table 2). As shown in the Table 2, pure Brutian pine stands were selected according to their development stages and then computations were made for each of them. Total forest biomass of target stands was found 1278695.72 m^3. Total energy wood potential and the amount of the total available energy wood were calculated as 28749.758 stere (stacked cubic meter) and 19286.535 stere, respectively. The data in the Table 2 represented values for 10-year period that was validity time of the forest management plan.

Table 2: The amount of energy wood of pure Brutian pine stands in the study area

Stand type	Area	Volume [m^3]	Allowable cut [m^3]	Energy wood potential [stere]	Available energy wood [stere]
Çzab2	52.969	888.709	0.000	0.000	0.000
Çzab3	275.268	6018.191	392.257	137.290	117.734
Çzb3	374.731	21957.365	2328.953	582.238	415.982
Çzbc2	155.711	9827.729	641.218	141.068	111.003
Çzbc2-T	36.568	2115.872	70.284	15.462	0.000
Çzbc3	598.522	84170.723	7016.473	1543.624	1205.674
Çzc2	45.399	4933.016	173.515	34.703	5.465
Çzc2-T	15.861	1677.901	70.867	14.173	0.000
Çzc3	200.751	41799.441	2407.205	481.441	458.061
Çzcd1	397.137	44103.701	1992.833	358.710	154.480
Çzcd1-T	488.836	58365.017	284.014	51.122	0.000
Çzcd2	2088.428	421488.598	21274.816	3829.467	2469.128
Çzcd2-T	200.796	40879.964	2063.179	371.372	0.000
Çzcd3	1411.270	438717.141	32923.518	5926.233	4882.110
Çzd1	84.648	14744.714	14744.714	2211.707	1803.427
Çzd2	191.525	60637.230	60637.230	9095.585	4786.835
Çzd3	58.410	26370.408	26370.408	3955.561	2876.636
Total	6676.83	1278695.72	173391.484	28749.758	19286.535

The maps of the terrain slope, forest functions, site index, distribution of the pure Brutian pine forests were produced (Figure 3). When these maps were observed, the effects of the criteria selected for determining available part of the total energy wood potential were seen clearly. Furthermore, distributions of the energy wood potential and the available energy wood could be seen in Figure 3.

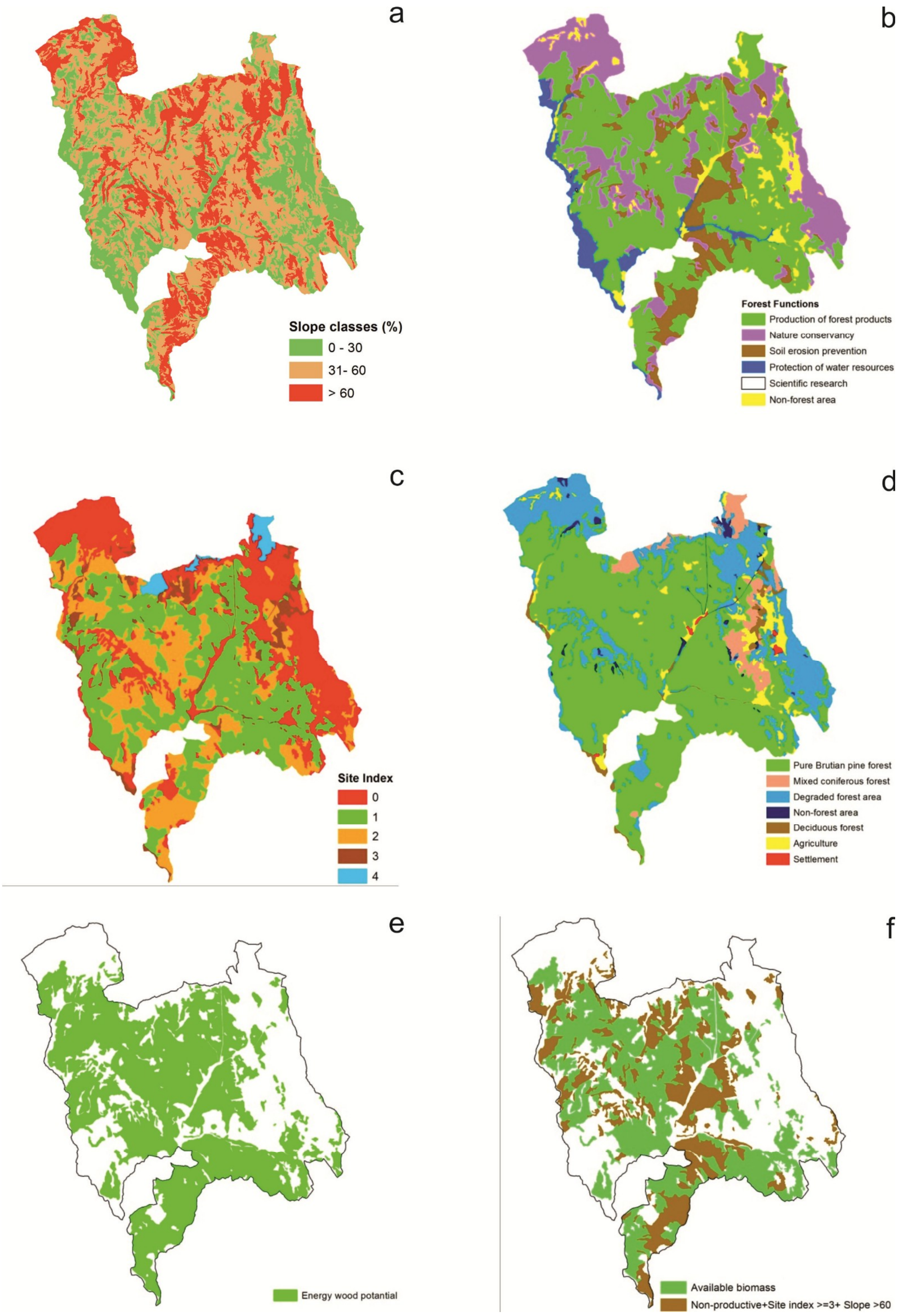

Figure 3: a) Slope classes, b) Forest functions, c) Site index, d) Distribution of Pure Brutian pine, e) Energy wood potential, f) Available energy wood

According to the results, approximately 80% of energy wood (forest biomass for bioenergy) potential was in the 31-60% slope class (Table 3). Except for the area of ecological and social functions reserved area for forest production was 6193.478 ha in the study area and it was 51% of all area. Considering some of the ecological effects, at first, energy wood production would be performed on only production function areas. In this regard, potential in only production forests was 28749.76 stere. On the other hand, areas having good site index (1 or 2) were selected in the study. The aim of this selection was to protect the plant nutrients in the soil, which could be important in terms of recovery time of the forest ecosystem. These areas covered 52% of total area. Energy wood potential was found up to 73% and 26% of total potential in the site index value 1 and 2 respectively (Table 4).

Table 3: The distribution of energy wood of pure Brutian pine stands as to the slope classes

Slope class [%]	Area	Volume [m^3]	Energy wood potential [stere]	Available energy wood [stere]
0 - 30	455.527	77108.393	3073.948	2261.810
31 - 60	5068.446	1015706.290	22686.972	15140.659
> 60	1152.857	185881.037	2988.840	1884.067
Total	6676.83	1278698.72	28749.760	19286.536

Table 4: The distribution of energy wood of pure Brutian pine stands as to the site index values

Site index	Area	Volume [m^3]	Energy wood potential [stere]	Available energy wood [stere]
1	3664.970	766891.501	21030.653	14209.303
2	2723.911	469918.878	7485.599	4996.432
0, 3 and 4	287.949	41885.341	233.510	80.802
Total	6676.83	1278695.72	28749.762	19286.537

Total energy wood potential for pure Brutian pine forest reserved as the production function could be calculated 28749.76 stere. The amount of available energy wood was found 19286.54 stere by using criteria in respect of forest function, slope and site index. Herewith, it was computed 4.3 stere/ha for potential energy wood and 2.9 stere/ha for available energy wood. In this way, helpful findings could be presented to be used in different feasibility methods for interest groups.

The study shows that GIS could be successfully accomplished the application of the theoretical inventory method to collect data for feasibility studies. Until now, strategical and tactical level inventories have been applied in forest management by means of various inventory methods. It could be considered that it is possible to make an operational inventory by using integration the tabular data of forest management plan with spatial database. Increasing of spatial constraints related to forest geodatabase, the different queries and manipulations are made through spatial analysis. For example; applicability of the extraction, chipping and transportation activities could be managed by the GIS module as well.

5 Conclusion

Although theoretical potential of energy wood has been determined in the GIS based study, it is possible to obtain detailed results by using different analysis (surface, network, accessibility analysis) and other data such as facility location, road and electricity network. However, in the feasibility studies, because the potential quantity of energy wood resources and its spatial distribution are very important, GIS could provide incontrovertible benefits in the critical process. A rapid assessment could be realized by GIS techniques to establish a new supply chain system for energy wood utilization in any forest region. On the other hand, it is required to collect forest biomass from larger forest area (in watershed level) than the study site for the sustainability of biomass resources supply and amortization of investment cost. Thus, taking into account more precise spatial criteria, GIS based module for estimation of biomass potential could offer available information for investor, managers and other stakeholders. In the forthcoming study, it should be tested the performance of the GIS based module in operational inventory by using multiple criteria with multidimensional approach.

Acknowledgement

We thankful to TUBITAK (Turkish Scientific and Technological Research Council of Turkey) for their financial support by the project number 110O435.

6 References

Beccali, M., Columba, P., D'Alberti, V., Franzitta, V., 2009: Assessment of bioenergy potential in Sicily: A GIS-based support methodology. Biomass and Bioenergy 33, 79–87.

Çoban, H.O., Eker, M., 2009: Some topographic analysis using SRTM data: an example of Forest Regional Directorate of Isparta. Süleyman Demirel University Faculty of Forestry Journal, A (2), 76-91.

Eker M., Çoban, H.O., Acar, H.H., 2009: The procurement problem of logging residues in Turkish forestry. Proceedings in FORMEC´09, June 21st-24th, Prague-Czech Republic, 115-124.

Eker, M., 2011: Assessment of procurement systems for unutilized logging residues for Brutian pine forest of Turkey. African Journal of Biotechnology 10(13), 2455-2468.

Eker, M., Acar, H.H., Özçelik, R., Alkan, H., Gürlevik, N., Çoban, H.O., Korkmaz, M., Yılmaztürk, A., 2012: Investigation on Supply Possibilities of Logging Residues in Turkish Forestry, The Third Semi-Annual Progress Report of Project No: 110O435, (TUBITAK) Turkish Scientific and Technological Research Council of Turkey (Unpublished inner report)

Graham, R.L., English, B.C., Noon, C.E. (2000): A Geographic Information System-based modeling system for evaluating the cost of delivered energy crop feedstock. Biomass and Bioenergy 18, 309–29.

Ranney, J.W., Cushman, J.H., 1980: Regional evaluation of woody biomass production for fuels in the Southeast. In: Biotechnology and bioengineering symposium no.10, New York: Wiley, 10–20.

Röser, D., Asikainen, A., Rasmussen, K.R., Stupak, I., 2008: Sustainable use of forest biomass for energy: synthesis with focus on the Baltic and Nordic Countries. Managing For. Ecosyst. Volume-II, Netherlands, 232.