Carbon stock sequestered from the atmosphere by coniferous forests of Eastern Georgia in conditions of global warming

G.S. Vachnadze a, Z.T. Tiginashvili a, G.V. Tsereteli b,*, B.N. Aptsiauria a, Q.G. Nishnianidze a

a Agrarian University of Georgia, Vasil Gulisashvili Forest Institute, 240 D. Agmashenebeli Alley, Tbilisi, 0131, Georgia
b Agrarian University of Georgia, Mikheil Sabashvili Institute of Soil Science, Agrichemistry and Melioration, 240 D. Agmashenebeli Alley, Tbilisi, 0131, Georgia

A R T I C L E   I N F O

Article info:
Received 14 March 2016
Accepted 10 May 2016
Available online 16 June 2016

Keywords:
Pinewood
Stand fractions
Biomass
Absorbed carbon
Annual growth
Young plants
Underbrush

A B S T R A C T

As well as worldwide the acceleration of extreme climate events, directly related to climate change, is observed in Georgia. The warming process is continuing, which may result in significant changes in forest expansion and forest diversity. Unfortunately these processes are already under way.

In the present study we assessed the total biomass stocking in the pinewood cenosis in East Georgia and the carbon stock sequestered in it from the atmosphere.

In Eastern Georgia pine-dominated forests make 66.7 thousand hectares, thus amounting to 72.6% of pinewood in Georgia. The total biomass of pinewood cenosis makes 8.74 Tg, where 4.45 Tg of carbon (is sequestered. In the above-ground and underground biomass of the primary floor 3.04 Tg are sequestered, in the shrub layer (underbrush, young plants) – 350.8 Gg; in the herbaceous layer – 10.4 Gg and in the forest floor there are 1.05 Tg of carbon. Average annual growth of pinewood biomass makes up to 123.7 Gg and annual carbon accumulation is 59.6 Gg. In the living biomass of pine-tree forests of East Georgia annually up to 220 Gg of carbon dioxide is sequestered.

© 2016 Agricultural University of Georgia. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Today, climate change is one of the most significant problems on our planet. The process of global warming on Earth is developing even more intensively, than it was predicted. In 1990–2014 CO₂ concentration in the air increased for 36% followed with abrupt changes of climate conditions [1]. Expected danger of global warming has significantly increased the role of a forest as possible sink in the carbon global cycle. If greenhouse gas emissions increase with the existing rate, CO2 concentration is expected to reach 495 ppm in the near future [2]. According to climatological estimates
irreversible processes will start if the warming process does not slow down in conditions of increase of the air temperature for 2 °C [3].

Numerous intergovernmental summits and conferences are dedicated to this problem. It is worthy to mention the Summit held in Paris in December of 2015 and XXI Climate Change Conference, where participating countries undertook the liability to reduce greenhouse gas emissions [3]. Georgia undertook a liability to reduce greenhouse gas emissions for 15% and in case of pecuniary aid — up to 25%. The Conference calls to undertake measures for reduction of anthropogenic emissions and intensification of CO₂ absorption. Role of forests in the atmospheric carbon sequestration process is extremely significant for this purpose [4,5].

As well as worldwide the acceleration of extreme climate phenomena is observed in Georgia (storms, gales, floods, avalanches, landslides, thermal waves), directly related to climate change processes [6,7]. The warming process is continuing, which may result in significant changes in forest expansion and forest diversity. Unfortunately these processes partially are already under way.

Objectives and methods

Guidelines [8,9] and Instructions [10] of the Intergovernmental Panel on Climate Change include typical methods of estimation of greenhouse sources and flows, used when there are no better data and methods available, but it is emphasized that it is always better to use local, so-called national data and existing methods, stipulating country’s specifics.

Estimation of phytomass and carbon resources of the stands’ overstory was done according to the conversion volumetric method [11–13]. Namely pinewood area and wood stock indicators, per specific age groups, were taken from forest management data. Stock (in m³) of pine biomass compartments (trunk, branches, green mass of the crown) were derived by using biometric tables [14], root biomass is calculated according to FAO recommendations [15]. Biomass fractions and sequestered carbon stocks are calculated by multiplying their stock indicators (in m³) with density of the wood substance of the respective species [ρ, in Gg m⁻³] and applying the biomass to carbon conversion coefficients.

Annual growth of biomass and carbon stock in conifer forests was assessed by the method used in inventory taking: namely, calculated differences between wood stock volumes of adjacent age groups are divided by respective group’s age interval and in that way an annual wood increment (m³ y⁻¹) is calculated per each age group. Received data are translated into biomass and carbon annual growth by using density and conversion coefficients [10,16,17]. Root growth was estimated following the method recommended in the “Guidelines” [10].

Assessment of the biomass and sequestered carbon for the young growth and underbrush was made by weighting method: the biomass weight of trunks, branches and leaves were taken from model trees (n = 10). (in absolutely dry condition) which the was multiplied by number of trees, wood density and a conversion factor for carbon (k = 0.45).

The herb layer biomass and carbon contained in it was assessed in the following way: the strata were mowed in each of the 10 sample plots. The resulting biomass was weighed after over-drying (~105 °C). The numbers were adjusted according to percentage of cover. A conversion factor to carbon was used (k = 0.45).

Carbon stock was assessed in the forest floor dead biomass, t·ha⁻¹, by multiplication of forest floor stock, coverage percentage and conversion coefficient (k = 0.579) [18–20].

The object of the study were pine forests of the Forest Fund of the Samtske-Javakheti Forestry Service. Namely pine-dominated forests of Borjomi-Bakuriani, Adigeni, Akhalsikhe, Aspindza and Akhalkalaki Forest Fund tracts.

Results and analysis

The total area of forests with dominating Pinus sspinosky in Georgia amounts to 91,886 ha with stock being 10.995 million m³ [21]. Pine-dominated forests lands predominantly are situated in the comparatively more continental sites of Eastern Georgia (Samtskhe-Javakheti, Matushteti), making in total 66,721 ha (72.6% of Georgia total) with stock being 8.073 million m³ (73.4%)

Total biomass and carbon stock of pine forests were studied in the Samtskhe-Javakheti Region as the region is the richest one in pine forests. Currently pine-dominated stands amount to 58.2% [22] of pine forests in Eastern Georgia. Samtskhe Region needs to be especially emphasized in this respect.

The amount of biomass and carbon stock in the forest overstory directly depends on the age of the stand, stand density and bonitet class i.e.eventually on the forests’ total wood stock. As for the understory layer, with the underbrush and young growth. Its biomass depends on stand’s canopy openness and location-based plant growth conditions. But this interrelation is less predictable. Participation of young growth, especially underbrush, in forests of one and the same type is variegated.

In pine-dominated forests biomass and carbon stock of underbrush and young growth is classified in five age groups (young, middle-aged, pre-mature, mature and over-mature) and also per type of forests.

To establish biomass and carbon stock of understory, and also for soil’s live and forest floor’s dead covers we selected 34 sample areas within pilot regions with typical soil conditions, namely pinewoods of the Borjomi-Bakuriani Territorial Forestry Service, Borjomi State Reserve and Adigeni Forest Area. Their total area is 23,592 ha amounting to 35.4% of total area of pinewoods in Eastern Georgia. This allows generalizing the data in order to get estimates for pine forests of Eastern Georgia.

In order to calculate masses of different forest components (trunk, branch, leaf, soil live and forest floor) country or region specific allometric functions are needed [5]. However in Georgia such specific functions do not exist. Therefore for this study we used literature values and data obtained from the field works.

According to Gigauri [23] one of the most significant determinants of biological diversity of forests in Georgia, as well as in other countries, is the dynamics of accumulation of
In total, in Georgia pine forests covering 66,721 ha and 4.46 million tons of carbon are accumulated therein. Pine forests have absorbed up to 16.4 million tons of carbon dioxide from the atmosphere.

During examination of the issues of global warming in the atmosphere main attention is paid to annual mean growth of biomass in the forest and carbon sequestered therein. The numbers given demonstrate the significance of carbon sequestered from the atmosphere [13, 29, 30].

The data of mean annual growth of the living biomass and carbon stocks existing in the Forest Fund of single administrative forest services of Eastern Georgia are shown in Table 3.

The table gives mean annual stock of biomass and carbon of all components: main stand, young trees, underbrush and herb layer (excluded is deadwood and dead plants and soil carbon stocks) within the single regions; additionally mean annual increase of the living pine biomass as well as sequestered carbon and its stock per area unit, stratified according to territorial forest services.

It is stipulated that young trees and underbrush annually lose part of their living foliage mass, therefore the existing foliage mass and the carbon sequestered in it is considered as dispersed carbon [10] and is not calculated as annual growth. The same can be said about the herb layer. The green mass of evergreen pine plants, in our case pine is annually half renewed (pinewood needles live for 2–3 years), therefore the annual growth is calculated as a half of their biomass and carbon stock. Therefore the mean annual growth numbers of sequestered carbon stock is less if compared to annually sequestered carbon stock.

The carbon stock fixed in pine forests shows a slightly different picture. The carbon stock of the total biomass of the main stand amounts to 68.4%, while young trees contain 7.4; underbrush – 0.5; herbaceous 0.2 and the forest floor 23.5%.

### Table 1 – Phytomass and carbon stock of pine stand, excluding understory, in Eastern Georgia in thousand tons

<table>
<thead>
<tr>
<th>Territorial forest service</th>
<th>Stand area, Hectare</th>
<th>Stock, thousand m³</th>
<th>Fractions Ph, C</th>
<th>Mean annual stock, Total</th>
<th>Mean Age, year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Trunk</td>
<td>Branch</td>
<td>Needle</td>
</tr>
<tr>
<td>Kakheti</td>
<td>2975</td>
<td>156.98</td>
<td>19.19</td>
<td>20.74</td>
<td>39.32</td>
</tr>
<tr>
<td></td>
<td>309.0</td>
<td>78.49</td>
<td>9.6</td>
<td>19.66</td>
<td>117.09</td>
</tr>
<tr>
<td>KvemoKartli</td>
<td>7394</td>
<td>181.37</td>
<td>27.12</td>
<td>26.41</td>
<td>45.55</td>
</tr>
<tr>
<td></td>
<td>358.7</td>
<td>90.68</td>
<td>13.56</td>
<td>11.89</td>
<td>22.77</td>
</tr>
<tr>
<td>Mtsekhta-Mtianeti</td>
<td>6165</td>
<td>183.01</td>
<td>23.38</td>
<td>24.10</td>
<td>45.83</td>
</tr>
<tr>
<td></td>
<td>388.8</td>
<td>91.49</td>
<td>11.70</td>
<td>10.85</td>
<td>22.92</td>
</tr>
<tr>
<td>ShidaKartli</td>
<td>6947</td>
<td>263.74</td>
<td>36.05</td>
<td>36.95</td>
<td>66.16</td>
</tr>
<tr>
<td></td>
<td>520.0</td>
<td>131.86</td>
<td>18.03</td>
<td>16.53</td>
<td>33.07</td>
</tr>
<tr>
<td>Samtskhe-Javakheti</td>
<td>38813</td>
<td>3150.71</td>
<td>368.04</td>
<td>398.69</td>
<td>788.62</td>
</tr>
<tr>
<td></td>
<td>6192.0</td>
<td>1757.35</td>
<td>184.01</td>
<td>179.42</td>
<td>394.3</td>
</tr>
<tr>
<td>Samachablo</td>
<td>2154</td>
<td>106.45</td>
<td>13.34</td>
<td>14.08</td>
<td>26.67</td>
</tr>
<tr>
<td></td>
<td>209.6</td>
<td>53.21</td>
<td>6.67</td>
<td>6.34</td>
<td>13.33</td>
</tr>
<tr>
<td>Former Tbilisi Forest–Park Complex &amp; GeoForest Selection.a*</td>
<td>2273</td>
<td>44.92</td>
<td>7.52</td>
<td>6.86</td>
<td>11.30</td>
</tr>
<tr>
<td>Total Eastern Georgia</td>
<td>66721</td>
<td>4087.18</td>
<td>494.64</td>
<td>527.83</td>
<td>1023.45</td>
</tr>
<tr>
<td></td>
<td>8072.7</td>
<td>2043.54</td>
<td>245.93</td>
<td>257.56</td>
<td>511.70</td>
</tr>
</tbody>
</table>

*a Services discontinued due to reorganisation.
### Table 2 – Phytomass and carbon stock of vegetation strata of pine forests in East Georgia (in absolutely dry condition in Ph/C thousand tons).

<table>
<thead>
<tr>
<th>Territorial forest services</th>
<th>Pinewood areas and total stock Hectare/thousand m³</th>
<th>Average age, year</th>
<th>Overstory and root layer</th>
<th>Understory: Ph C</th>
<th>Soil cover: Ph C</th>
<th>Phytocenosis biomass and carbon total</th>
<th>Absorbed CO₂ mln. tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kakheti</td>
<td>2975</td>
<td>68</td>
<td>236.23</td>
<td>32.81</td>
<td>2.39</td>
<td>1.04</td>
<td>574.01</td>
</tr>
<tr>
<td>ShidaKartli</td>
<td>6165</td>
<td>63</td>
<td>276.32</td>
<td>58.46</td>
<td>4.26</td>
<td>2.43</td>
<td>486.17</td>
</tr>
<tr>
<td>Total in East Georgia</td>
<td>8072</td>
<td>69</td>
<td>613.10</td>
<td>726.583</td>
<td>52.91</td>
<td>23.06</td>
<td>8741.19</td>
</tr>
</tbody>
</table>

### Table 3 – Average annual stock and growth of live biomass of the Pinewood cenosis main components and carbon sequestered in it in East Georgia.

<table>
<thead>
<tr>
<th>Territorial Forest Services</th>
<th>Total area, stock hectares/thousand m³</th>
<th>Average age, year</th>
<th>Annual stock of cenosis live biomass and carbon (ave.)</th>
<th>Mean annual growth of cenosis live biomass and carbon</th>
<th>Absorbed CO₂ mln. tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kakheti</td>
<td>2975</td>
<td>68</td>
<td>5.540</td>
<td>1.86</td>
<td>5.156</td>
</tr>
<tr>
<td>ShidaKartli</td>
<td>6165</td>
<td>63</td>
<td>8.204</td>
<td>2.27</td>
<td>8.212</td>
</tr>
<tr>
<td>Total Eastern Georgia</td>
<td>8072</td>
<td>69</td>
<td>132.094</td>
<td>64.82</td>
<td>123.67</td>
</tr>
</tbody>
</table>
The mean annual stock of the pine forests’ live biomass in East Georgian is up to 132.1 thousand tons, the mean annual sequestration in it is up to 64.5 thousand tons of Carbon. The pinewood biomass annual increase amounts to 123.7 thousand tons, corresponding to up to 218.5 thousand tons of carbon dioxide being sequestered.

Conclusion

In Eastern Georgia pine-dominated forests make 66.7 thousand hectares, thus amounting to 72.6% of pinewood in Georgia. The total biomass of pinewood censos makes 8.74 Tg, where 4.45 Tg of carbon is sequestered. In the above-ground and underground biomass of the primary floor 3.04 Tg are sequestered, in the shrub layer (underbrush, young plants) − 350.8 Gg; in the herbaceous layer − 10.4 Gg and in the forest floor there are 1.05 Tg of carbon. Average annual growth of pinewood biomass makes up to 123.7 Gg and annual carbon accumulation is 59.6 Gg.

In the living biomass of pine-tree stands of East Georgia up to 220 thousand tons of carbon dioxide are sequestered annually. The specified amount is not high, but the air exchange process is pine forest has certain positive influence on the regional climate in deceleration of undesirable effects of carbonic gases.

Comparatively small carbon stock sequestered in pine-stands is caused by their low productivity (120 m3 ha−1). The mentioned fact is basically a result of low (0.51) stand density. In order to increase the carbon stock sequestered in pine-stands we believe it to be necessary to increase their density up to 0.7–0.8, the average European level.

Acknowledgements

The Article was prepared with support of the Shota Rustaveli National Science Foundation (Grant Agreement N FR/398/10-120/13).

REFERENCES

[27] V.A. Solovoyv, Chan Tkhi Tkhu Nyan, E.V. Shorokhova, Carbon distribution according to phytomass fractions of...


[29] Georgia’s Third National Communication to the UNFCCC, Georgia, Tbilisi, 2015, pp. 68–70, 288.