Carbon sequestration after pine afforestation on marginal lands in the Povolgie region of Russia: A case study of the potential for a Joint Implementation activity

Eldar Kurbanov, Oleg Vorobyov, Aleksandr Gubayev, Lyubov Moshkina, Sergey Lezhnin

Department of Sustainable Forest Management, Mari State Technical University, Yoshkar-Ola, Russia

Online Publication Date: 01 January 2007
To link to this article: DOI: 10.1080/02827580701803080
URL: http://dx.doi.org/10.1080/02827580701803080

PLEASE SCROLL DOWN FOR ARTICLE
ORIGINAL ARTICLE

Carbon sequestration after pine afforestation on marginal lands in the Povolgie region of Russia: A case study of the potential for a Joint Implementation activity

ELDAR KURBANOV, OLEG VOROBYOV, ALEKSANDR GUBAYEV, LYUBOV MOSHKINA & SERGEY LEZHNIN

Department of Sustainable Forest Management, Mari State Technical University, Yoshkar-Ola, Russia

Abstract
According to the Kyoto Protocol, a Joint Implementation project is a mechanism whereby one industrialized country can finance a greenhouse gas-reducing project in another country. The investors in the project can, in return, claim credits for the reduction in carbon (C) emissions and carbon sequestration. The purpose of this case study was to investigate the potential for carbon sequestration from such projects. The study covers afforestation with Scots pine on unforested land (burnt areas, cleared spaces, gaps, etc.) in the Povolgie region of Russia. Three scenarios were compared: (1) no afforestation (baseline scenario); (2) afforestation with pine, and carbon sequestration only considering above-ground tree biomass; (3) afforestation with pine, but accounting for carbon sequestration in all pools. On average, carbon sequestration in the above-ground tree biomass could be around 80 t C ha⁻¹ during 50 years of pine (Pinus sylvestris L.) plantation growth with 54 t C ha⁻¹ in equilibrium storage. A considerable amount of carbon will be bound in the lower layer of the pine forest stand (24 t C ha⁻¹), which is usually underestimated in afforestation Joint Implementation projects, and wood-based products (35 t C ha⁻¹). Sequestered carbon in equilibrium storage is allocated in the following proportions: 46% in pine stands, 21% in the lower level and 33% in wood-based products. To extend the carbon sequestration, harvested wood should be used to manufacture products for long-term use. The results indicate good potential for such projects in the investigated territory in a long-term perspective, in compliance with international costs for sequestered carbon.

Keywords: Boreal forest, climate change, Joint Implementation, Kyoto Protocol, Russian forests.

Introduction
According to the Kyoto Protocol, Joint Implementation (JI) projects could be a useful mechanism in the mitigation of consequences of global warming (Kyoto Protocol, 1997). By definition, JI is a project-based approach that enables one industrialized country to finance a project to reduce “greenhouse gases” in another country, and to receive “emission reduction units” representing the emissions not generated by the second country (Article 6 of the Agreement). Investors financing JI projects would be allowed to claim credits for the reduction of carbon (C) emissions or for carbon sequestration. These credits should be equivalent to the carbon sequestration derived from the investment, and the investors would be allowed to use the credits to lower greenhouse gas-related liabilities (e.g. carbon taxes, emission caps) in their home countries.

The rationale of JI is that the marginal costs of emission reduction or carbon dioxide (CO₂) sequestration are generally lower in developing than in developed countries (Moura-Costa, 2001). For developing countries, the benefits of this activity are additional investments and enhanced sustainable development.

Over the past 20 years several studies have analyzed the cost-effectiveness and carbon sequestration capacity of forest projects all over the world (Nordhaus, 1991; Dixon et al., 1994; Alig et al., 1997; Stavins, 1999; De Jong et al., 2000; Richards & Stokes, 2004; Pohjola & Valsta, 2007). The studies show a great potential to capture significant stores of...
carbon by forest plantations at an average cost of $3–100 per tonne of carbon per year. In 2006, JI projects from economies in transition showed increasing interest from buyers, with 16.3 Mt CO₂e (million tonnes carbon dioxide equivalent) transacted (up 45% over 2005 levels), with Russia, Ukraine and Bulgaria providing more than 60% of transacted volumes so far, at an average price of $8.70 ($6.70). Preliminary data for the first quarter of 2007 indicate that at least the same volumes had already been transacted in the first 3 months alone (Capoor & Ambrosi, 2007).

In the forestry sector such projects could reduce net carbon emissions through increased carbon sequestration into forests. Because of their great importance in mitigation activities, JI projects in forestry are strongly emphasized at the international level and in intergovernmental agreements (McCarl & Schneider, 2001; UNFCCC, 2007).

Implementation of Articles 6 and 12 of the Kyoto Protocol also requires baseline and additionality components of JI projects, which are fundamental and challenging. The baseline corresponds to the expected level of carbon emissions and sequestration in a business-as-usual scenario (the scenario without payments for carbon sequestration). The additionality is usually assessed by comparing the carbon stocks and flows of the project activities with those that would have occurred without the project. If there is biomass accumulation without project intervention (natural regeneration of shrubs and trees), this should be subtracted from the CO₂ sequestration achieved by the reforestation or afforestation (FACE Foundation, 2007). Similarly, afforestation projects are additional if they provide environmental benefits (e.g. regulation of water flow, wildlife habitat and recreational purposes) not captured by the usual forest management and would not be undertaken in the absence of economic incentives.

Establishing the baseline scenario requires knowledge of historical series of conventional practices in the affected area, the local socioeconomic situation, local and regional economic trends that affect the outputs of a project, and relevant policy factors. Baseline studies could be done at a project scale by defining the constrained limits of the project area, or at a programme scale by evaluating the patterns of land use in the entire region (Gustavson et al., 2000). When baselines are limited to the project area, there is a risk that some changes in carbon stocks caused by the project activity will remain unaccounted for (leakage effect). Leakage refers to unexpected carbon losses related to a particular carbon sequestration project. For example, leakage occurs when project activities change the wood supply/demand equilibrium, such as if demand is unmet because the project reduces supply or increases demand (Cathcart, 2000).

Activities such as conversion of agricultural land to forest, reducing deforestation, improving forest management and reducing forest fires are management options that could also increase the stock of carbon in the forests.

Experience over the past decade through international JI programmes has shown that tropical developing countries offer the lowest cost carbon-offset opportunities (Totten, 1999). This is due to lower costs for land and labour, despite higher transaction costs and risks relative to the developed countries. In addition, trees in tropical countries have higher potential growth rates than in temperate and boreal zones owing to warmer climates.

The boreal forests of higher latitudes, unlike the forest ecosystems of the tropical and subtropical zones, are formed by a small number of tree species and are characterized by a slow biological cycle. The amount of annual litterfall in such ecosystems is greater than the annual decomposition rate. In this connection, the boreal forests accumulate carbon not only in the wood biomass but also in litter, coarse woody debris (woody detritus), soil organic matter and peat (Harmon et al., 1986; Kurbanov & Krankina, 2000; Sohngen et al., 2005). Moreover, boreal forests are estimated to be a carbon sink because many are recovering from past disturbances and they are actively managed (Karjalainen et al., 2002, 2003; Nabuurs et al., 2003). Reduced deforestation and afforestation are most important in tropical regions, whereas afforestation also becomes important in temperate and boreal regions.

Recent works suggest that although Russian forests have undergone significant changes in the last century they still have great potential for carbon sequestration (Shvidenko & Nilsson, 2002; Kurbanov & Post, 2002; Liski et al., 2003; Krankina et al., 2005; Sohngen et al., 2005). During the period 1700–1910 the European part of the former Soviet Union lost 63 ± 3 million ha of forests, because of the transfer to agricultural use. From 1961 to 1993 forested areas in Russia increased by 68 million ha (9.8%), mainly in forests managed by the state. During the same period the total growing stock of all forests increased by 3.2 billion m³, although the growing stock of forests under state forest management decreased by 1.1 billion m³ (Shvidenko & Nilsson, 1998). Total carbon stocks in the forest biomass in the Russian Federation (RF) have been estimated at between 29.5 and 50.4 billion t C (Isaev et al., 1995; Alexeyev & Birdsey, 1994) with annual net carbon sequestration rates of 0.06–0.49 billion t C (Krankina et al., 1996).
Meanwhile, there are other good opportunities for JI in the Russian forest sector. The most well known is the RUSAFORE afforestation project, launched in 1993 in the Saratov region of Russia, 1100 km south-east of Moscow, through a co-operative agreement among the Russian Federal Forest Service, Oregon State University, the Environmental Defense Fund and the US Environmental Protection Agency (Isaev et al., 1995; Vinson et al., 1996). The project focused on reversing soil erosion and increasing carbon on marginal agricultural land and previously burned forest stands by establishing broadleaf and pine plantations on four forest sites totalling 900 ha. About 80,000 t C will be cumulatively sequestered, at a cost of approximately US $3.75 t\(^{-1}\).

Another example is the project in the Voronezh region of the RF, which focused on planting forested shelterbelts through agroforestry (Stetsenko et al., 2002). This project is a prime example of collaboration between an environmental non-governmental organization and the local government in attempting to use potential future mechanisms for carbon trading. The project is estimated to sequester around 0.4 t C ha\(^{-1}\) year\(^{-1}\).

The purpose of this paper was to investigate the carbon sequestration potential of afforestation projects on marginal lands in the Povolgie region. The carbon sequestration potential is analysed on the basis of the present rules and definitions for JI projects. The possible impact of future inclusion of the harvested wood product pool in carbon sequestration is also assessed. Finally, a cost-benefit analysis is carried out and compared with similar studies from different parts of the world. There are many methodological issues concerning the establishment of a JI project, such as which carbon pools are to be included into the final credits, how to provide reliable monitoring of the carbon accumulation in the forest biomass and institutional questions of the forest land ownership. All of these aspects will be discussed, along with the management options for increasing carbon sequestration in the pine stands of the region under investigation.

Materials and methods

The area and forest fund

The investigated region (Figure 1) is located in the eastern part of the Russian plain, where it covers an area of 265,000 km\(^2\), which is equal to the total area of the UK together with the Netherlands. Forests cover 50% of the region and play an important environmental role in the republics of Mari El, Mordovia and Chuvashia, Nizhegorodskaya and Kirovsakaya oblasts. The region is of particular interest because it represents wide areas of natural forests in Europe and western Russia that are reported to be a large terrestrial carbon sink (Kurbanov & Krankina, 2000; Nilsson et al., 2000). Dominant species are pine (Pinus sylvestris L.), birch (Betula pendula Roth.), spruce [Picea abies (L.) Karst.] and aspen (Populus tremula L.). Pine stands occupy 32% of the total forest area in the region (3.2 million ha) and are the dominant forest type of the landscape. Pine is especially common in Mari El and Nizhegorodskaya oblast. The current amount of growing pine stock (stem only) is enormous, nearly 510 million m\(^3\) (Russian Federal Service, 1998). About 77% of the pine stands in the region are on high-productivity lands (site class I-III), with growing rates of about 1 m\(^3\) ha\(^{-1}\) year\(^{-1}\) and higher (Table I).

Owing to its being resistant to frost and drought, and hardy to soil-ground conditions, pine grows on the plains and in the mountains, forming island stands in the forest-steppe and steppe zones. Pine is a native tree species in terms of biodiversity. All these features speak in favour of using this species for the carbon sequestration plantations in the region.

Land availability for Joint Implementation projects

The RF’s Forest Fund is the aggregation of forest lands and non-forest lands (NFL) of an administrative unit (forest enterprise, region, republic and country). In turn, forest lands are designated as stocked forested lands (SFL) and non-stocked forested lands (NSFL). SFL are the areas covered by forests with relative stocking rates of 0.4 or more for young stands and relative stocking rates of 0.3 or more for other stands (Pisarenko et al., 2001; Kurbanov & Post, 2002). NSFL include burned areas, dead stands, sparse forests, cuts and grassy glades. NFL include two land types: areas that are unable to support forest growth under current conditions (miens, stone fields, tundra areas, arable lands, sands, etc.) and lands set aside for forestry purposes (rides, roads, swamps, yards, etc.).

For the JI projects in the Povolgie region there are sufficient areas to fulfil the obligations on additionality requirements of the Kyoto Protocol. The wider area of NFL is under unregenerated cleared spaces (Figure 2), which account for 150,000 ha (60%). A considerable part of these lands comprises hayfields (30%) and abandoned territories (7%). Besides, some arable lands of the region could be used for the creation of forest plantations in JI projects.

NSFL are usually taken out of forest management owing to difficulties in their reforestation and the availability of other huge territories in Russia to produce forests. Therefore, carbon sequestration on these lands could be considered as additionality with
baseline studies including biomass of shrubs and small trees that will grow there without the JI projects. The creation of carbon sequestration pine plantations in the region includes the following basic expenses: planting and further maintenance for one rotation (Table II).

The overall average cost for creation (planting, payment to workers, soil preparation and planting material) and maintenance of 1 ha of pine forest in the region is about €510. This amount can vary depending on the use of category of NSFL for the forestation projects and their inaccessibility. For calculations of the cost-effectiveness of JI, the average price of €8.0 ton-1 of sequestered carbon is used here.

This study considers three alternative carbon accounting scenarios (strategies) on the lands (NSFL) that are currently not forested, but are potentially ready for reforestation under the rules of JI. In the first scenario (baseline) the land will continue to be as the NSFL, with minimum storage of carbon sequestration in the grass and remaining woody detritus. In the second scenario, the land is reforested by a pine stand, with the aim of gaining emission reduction units through the activities of JI. In this scenario, estimation of the carbon sequestration is focused only on the biomass of pine trees (stem and crown). In the third scenario, along with the tree biomass, other pools of carbon in the second layer (undergrowth, shrubs, forest floor, coarse woody debris) and wood-based products are included in the accounting. In the third scenario carbon sequestration in all pools is considered during two rotation periods. The growing biomass
Table I. Distribution of pine stands in the investigated region by site class and relative stock a (thousand ha).

<table>
<thead>
<tr>
<th>Republic, oblast</th>
<th>Total of forest lands</th>
<th>Bonitet b classes</th>
<th>Groups of the relative stock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>II and higher</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>1.0–0.8</td>
<td>0.7–0.5</td>
<td>0.4–0.3</td>
</tr>
<tr>
<td>Nizhegorodskaya</td>
<td>1218</td>
<td>328.2</td>
<td>610.7</td>
</tr>
<tr>
<td>Kirovsakaya</td>
<td>1390</td>
<td>166.5</td>
<td>269.5</td>
</tr>
<tr>
<td>Mari El</td>
<td>447</td>
<td>115.8</td>
<td>231.8</td>
</tr>
<tr>
<td>Mordovia</td>
<td>161</td>
<td>59.4</td>
<td>80.9</td>
</tr>
<tr>
<td>Chuvashia</td>
<td>155</td>
<td>49.3</td>
<td>88.8</td>
</tr>
<tr>
<td>Total</td>
<td>3371</td>
<td>719.2</td>
<td>1282</td>
</tr>
</tbody>
</table>

Note: a relative stock of 1.0 implies a fully stocked stand. b Site classes: the highest class (I) characterizes the best known growth condition of the forest stand, and the lowest class (V, Va) the poorest one.
of the pine stand will be harvested after the first rotation for the production of wood-based products for long-term use (in construction and furniture). All these carbon pools of the pine stand over a period of two rotations (160 years) are better characterized by the long-term equilibrium (average) carbon storage. This criterion clearly shows the capacity of forest ecosystems to sequester carbon if not disturbed by fires and insects.

Carbon accounting was based on previous studies (Kurbanov, 2000, 2002). A pine stand of site class I will accumulate 26.7 t C ha\(^{-1}\) in the main components of the ecosystem within 20 years’ growth (Table III). One tonne of carbon in the woody biomass is equivalent to 3.67 t of CO\(_2\) (IPCC, 2000).

Results

The three carbon sequestration accounting scenarios lead to different results for the JI projects on the NSFL in the Povolgie region of the RF (Table IV). In the first scenario (baseline), carbon sequestration is minimal, because of the absence of afforestation activities on the NSFL, and the carbon store on these lands is between 1 and 3 t C ha\(^{-1}\). The second scenario shows stable growth of the carbon sequestration during the rotation period in the pine stand. Carbon sequestration in the stem and crown of the pine stand of site class I starts from its planting or natural regeneration, and by the time of harvesting reaches 101 t C ha\(^{-1}\) (Figure 3), with the equilibrium storage over the two rotations of 54 t C ha\(^{-1}\). This kind of scenario is usually applied in the JI accounting according to the guidelines of the Kyoto Protocol.

The third scenario includes more pools of carbon and estimates the sequestration process over the two rotations of growth of the pine stand. After the first rotation forest clear-cut, 3 t C ha\(^{-1}\) remains in the lower level of the stand (undergrowth, shrubs, forest floor and coarse woody debris). Over the next 80 years the ecosystem continues to sequester carbon up to the previous level, followed by the next harvest (Figure 3a). Therefore, the maximum amount of carbon in pine stands is observed at the time of harvesting (end of rotation). During harvesting, part of the wood remains as felling residues that enlarge the pool of woody detritus. In Figure 3(b) this can be seen by the increased storage of carbon in

Table II. Cost of creating 1 ha of pine stands on non-stocked forested lands in the Povolgie region.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost (rubles)</th>
<th>Cost (euros)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting material</td>
<td>10,000</td>
<td>285</td>
<td>Pine seedlings</td>
</tr>
<tr>
<td>Transportation expenses</td>
<td>350</td>
<td>10</td>
<td>Gasoline</td>
</tr>
<tr>
<td>Payment to workers</td>
<td>350</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Soil preparation</td>
<td>1,100</td>
<td>30</td>
<td>Depends on the land category</td>
</tr>
<tr>
<td>Inventory and monitoring</td>
<td>2,200</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Maintenance of forest plantations</td>
<td>4,000</td>
<td>115</td>
<td>Thinnings, add-ins, fertilization</td>
</tr>
<tr>
<td>Total ha(^{-1})</td>
<td>18,000</td>
<td>510</td>
<td>Cost could be higher in distant areas</td>
</tr>
<tr>
<td>Age (years)</td>
<td>Height (m)</td>
<td>Diameter at breast height (cm)</td>
<td>Crown biomass</td>
</tr>
<tr>
<td>------------</td>
<td>------------</td>
<td>-------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site class I (Bonitet)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>8.5</td>
<td>8.2</td>
<td>1.9</td>
</tr>
<tr>
<td>30</td>
<td>12.5</td>
<td>12.8</td>
<td>3.0</td>
</tr>
<tr>
<td>40</td>
<td>16.4</td>
<td>17.1</td>
<td>4.7</td>
</tr>
<tr>
<td>50</td>
<td>19.7</td>
<td>21.0</td>
<td>6.1</td>
</tr>
<tr>
<td>60</td>
<td>22.4</td>
<td>24.4</td>
<td>7.1</td>
</tr>
<tr>
<td>70</td>
<td>23.6</td>
<td>27.4</td>
<td>7.8</td>
</tr>
<tr>
<td>80</td>
<td>25.8</td>
<td>30.1</td>
<td>8.1</td>
</tr>
<tr>
<td>90</td>
<td>27.7</td>
<td>32.4</td>
<td>8.3</td>
</tr>
<tr>
<td>100</td>
<td>28.8</td>
<td>34.4</td>
<td>8.4</td>
</tr>
<tr>
<td>110</td>
<td>29.6</td>
<td>36.2</td>
<td>8.4</td>
</tr>
<tr>
<td>120</td>
<td>30.2</td>
<td>37.7</td>
<td>8.4</td>
</tr>
<tr>
<td>130</td>
<td>30.9</td>
<td>39.0</td>
<td>8.4</td>
</tr>
<tr>
<td>140</td>
<td>31.2</td>
<td>40.2</td>
<td>8.3</td>
</tr>
</tbody>
</table>
the pool of the lower level of the pine forest. In the next 10 years this pool decreases during the decay process of the woody detritus. With the next rotation of the pine stand the pool continues to increase. Harvested wood is transformed into different products which continue to retain carbon (Figure 3c). The pool of wood-based products has maximum carbon in the year of harvesting. After 100 years of use only about 10% of carbon remains are bound in the long-term products (construction and furniture).

For the pine stands of site class I, equilibrium storage in the pool of the lower level reaches 24 t C ha\(^{-1}\), the pool of wood-based products 38 t C ha\(^{-1}\) and the whole ecosystem 95 t C ha\(^{-1}\) (Figure 3d). The sequestered carbon in equilibrium storage is allocated in the following proportions: 46% in pine stands, 21% in the lower level and 33% in the wood-based products.

With 250,000 ha of plantations on NSFL in the JI project, the sum of the estimated sequestration by the pine stand in the Povolgie region, according to accounting scenarios 2 and 3, is 3.8/5.6 million t C by the age of 20 years, 12.2/17.0 million t C by 40 years and 25.2/34.8 million t C by 80 years (Table V).

At the average investment cost of €8 t\(^{-1}\) C, the carbon sequestration in pine stands could return the expenses for scenario 2 of JI within 50 years, while scenario 3 could return the expenses within 35 years of the afforestation of the NSFL and will continue to bring in the carbon income for at least the next 100 years.

**Discussion**

Many countries have responded to the Kyoto Protocol by intensifying their efforts to quantify current carbon storage in forests, and some countries (including Russia) have engaged in implementation projects aimed at testing the potential for sequestering additional carbon in forests.

Russia has approximately 30% of the boreal forests (FAO, 2006), and together with Canada and the USA is known to be one of the largest carbon reservoirs in the world. Therefore, JI projects in the forest sector of Russia are very important for the international strategies aimed at mitigation activities in the framework of global climate change.

Today, there are large unforested areas in the Povolgie region of Russia on the lands of the forest fund, which amount to 250,000 ha. There is enormous potential to use carbon management strategies to offset CO\(_2\) emissions and, thereby, mitigate the negative effects of climate change. After harvesting and disturbances, these areas have not met the requirements of forested lands, so they can be used for the creation of carbon sequestration pine plantations under international JI projects.

The baseline determination (scenario 1) on the NSFL, where natural regeneration is unlikely over a few decades unless assisted, was easier to assess since the situation without the project is clear. The leakage factor in the forest sector of the region is minimal because of two factors. Firstly, the use of unforested lands will not affect the most productive forest sites of the region, where intermediate cuttings and forest logging are carried out. Secondly, according to official statistics, harvesting of coniferous trees in the region is about 50–60% from the established norm of the annual allowable cut, which means that there is no need for extra logging activities. Other unforeseen events such as extreme weather, pests, forest fires, or cancellation of a contract with consequent logging of established forest, fall into the category of project risks.

This study shows that important factors in carbon sequestration in Russia are effective forest management, an optimal accounting scenario and
Figure 3. Carbon sequestration in different pools of pine stands of site class I over two rotations. The horizontal lines mark the equilibrium (time-averaged) carbon storage values.
lengthening rotations. In all the scenarios examined, the carbon stored in the biomass of the pine stand and wood products is sensitive to forest management practices (intermediate thinning and harvesting). After the creation of a pine plantation, special care should be taken during 10 years’ growth to maintain sustainable carbon sequestration.

By applying carbon budget estimates from previous studies (Kurbanov, 2002), carbon sequestration in pine plantations (stem and crown biomass) in the region could reach 54 t C ha⁻¹ in the long term of equilibrium storage (scenario 2). A considerable amount of carbon will be bound in the lower layer of the pine forest stand (24 t C ha⁻¹), which is usually underestimated in the JI, and wood-based products (35 t C ha⁻¹). The amount of carbon that is sequestered in timber products depends on whether the timber is used for paper, sawnwood, board or firewood. Other studies show that where the harvested timber is used for sawnwood, the average carbon storage in timber products is about 30% of the storage in above-ground vegetation (Pingoud et al., 2001; Masera et al., 2003). Although the Kyoto Protocol excludes accounting for carbon storage in timber products for the first commitment period, in scenario 3 of this research this huge carbon pool is counted in the total potential sequestration with regard to future international agreements, which will accept wood-based products for carbon crediting in JI projects.

It is important to use different scenarios during the estimation of carbon sequestration in forest ecosystems. Application of scenario 2 of this research can underestimate carbon sequestration by the ecosystem in the long term. For example, net carbon sequestration by a pine stand of site class I at the end of the rotation reaches 101 t C ha⁻¹ (scenario 2), with equilibrium storage of only 54 t C ha⁻¹ (Table IV), whereas scenario 3 leads to the sequestration of 139 t C ha⁻¹, with equilibrium storage of 95 t C ha⁻¹. Consequently, for estimation of carbon sequestration in pine stands for the JI, the following criteria could be applied: equilibrium storage over two or three rotations (t C ha⁻¹) and carbon store of the forest ecosystem on the definite time of the stand growth (t C ha⁻¹). Several other studies have also suggested that incentives for carbon sequestration could lead to longer rotation periods (Adams et al., 1999; Sohngen & Brown, 2006).

The research shows that carbon sequestration in the forests of Russia is more expensive than previously thought. The JI project (scenario 2) will return the expenses only in 50 years after plantation, taking into account only the carbon bound in the stem and crown of the trees. The third scenario will return the investments within 35 years. However, there are prognoses that the cost of sequestered carbon will be sufficiently higher in this century (Stavins, 1999; Sohngen & Mendelsohn, 2003), with growing concern about global warming and increased emissions of greenhouse gases. Consequently, the carbon market of JI projects on vast Russian territories could be attractive to investors.

Given the current international low prices of between US $3 and $10 t⁻¹ fixed CO₂, it is evident that the income from the creation of pine sequestration plantations on NSFL in the RF will not cover the cost of the JI project in the short term. However, boreal forests have always been managed in long perspectives, meaning that sufficient carbon credits in pine stands will be obtained in 40–80 years. Scale has always been an important factor in forest carbon sequestration policy (Harmon, 2001).

Lower prices for carbon credits will discourage reforestation projects and could decrease the financial attraction of the JI. Many studies refer to these costs in other countries. For example, the plantation cost for pine is about $1000 ha⁻¹ in Argentina (Sedjo, 1999) and $890 ha⁻¹ in Chile (Noe, 1999). The corresponding carbon prices in the present estimations range from $5 to $10 t⁻¹ C, while afforestation projects in industrial countries, including those in transition (Russia), can be pursued at costs of $5–136 t⁻¹ C (Sedjo, 1999).

All forest lands in the RF are state owned. The basic unit in Russian forestry is the forest management enterprise, which consists of several rangers’ districts (Kukuev et al., 1997). These forest enterprises can participate directly in the JI. However, a more convenient option could be the involvement of several interested Russian partners in the project. For example, the JI project can be carried out by the forest enterprise and the forestry university in the region. The forest enterprise provides necessary technical actions: creation of the carbon sequestration plantations, further maintenance and inventory. The team from the university could prepare the project, co-ordinate it with the foreign or domestic investor, provide monitoring and produce publications. The credits would be owned by the investor, unless carbon credit sharing had been agreed.
A direction for future research in this field is to evaluate the possibility of targeting multiple benefits of carbon sequestration in the concept of JI projects in forestry, e.g. water and air quality, improved wildlife habitat and recreational services. In general, such policies will be more efficient and cost-effective than those that benefit from carbon sequestration only.

Acknowledgements

This study was financed in the framework of the Russian federal scientific and technical programme, grant 2006-RI-19.0/001/342. We also are grateful to the anonymous reviewers for the useful comments and suggestions provided for completing the paper.

References


