Value of Forest Ecosystem Natural Potential in the Areal Regional Richness Structure

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Abstract. Value of forest ecosystems’ natural potential is examined as composition of forest resources (timber and non-timber forest products) as natural capital. Also, value is examined as composition of environment-forming and social functions of forest objects as part of ecological potential of forest areas. Regional (national) richness includes all natural resources, all tangible and intangible assets made by nature and humanity in this region. By calculation results, value of forest resources (natural capital of forest ecosystems) is about 12-16% of total value of forest site for commercial forests of Middle Ural. Value of ecological potential is about 84-88% of total. It grows to 92-96% for protection forests. Natural potential of forest ecosystems is comparable to production potential of agriculture, mining or power generation.

1. Introduction
At the present time, economic growth limitation type is changed. Earlier, production potential (existing fixed assets) was the main limit, but now it is the natural potential of area. Beginning from the last quarter of XX century society started to actively react for limitation of economic growth because of lack of natural resources (natural capital). In modern times society has recognized the limitation of economy by the whole natural potential complex (not only capital). The role of ecological potential (as part of natural potential) deficiency has grown significantly. The main part of ecological potential is environment-forming function of natural (including forest) landscapes. These limitations lead to opinion of necessity of economical investment to the ecological potential sphere. World Bank, UNEP, UNDP have started investment to ozone layer protection, greenhouse gases emission reduction, international water resources protection, biodiversity conservation [1].

According to sustainable development goals, world society is close to creation of price system for all types of resources which includes full consideration of damage to environment and future generations. Also it became necessary to apply environmental pollution quotes. So, basis for development of sustainable forest use tools contains:
- system social-eco-economic evaluation of natural resources condition, environmental potential and social necessity [2];
- system social-eco-economic evaluation of natural resources and environmental potential usage limits condition [3];
- evaluation of natural and production potential comparability [4, 5].

Natural potential of forest ecosystems contains natural (forest) resources and ecological forest functions. N F Reimers [6] considered natural potential as ability of natural systems to yield (without
self-damage) social necessary production (natural resources) and to perform useful work (to implement environmental processes) in the limits of economy of historical period under review.

On Figure 1 we propose the structure of forest ecosystems’ natural potential as part of regional richness. Forest ecosystems’ natural potential contains [7, 8]: natural resources (as natural capital in economics); environment-forming and social functions of forest objects briefly named as ecological potential (in environmental economics frequently considered as non-market natural capital).

Natural capital in economic sphere is value of natural resources [9]. Term “capital” is connected with market orientation of economics.

“Natural capital” by Yu G Lavrikova [10] provides four functions: resources – providing with natural resources; ecological amenities – providing with natural regulation functions; aesthetic, moral, cultural and historical amenities; environment and health protection providing. In this term “natural capital” is all range of natural goods and services which corresponds to “natural potential” term in our understanding.

Figure 1. Forest ecosystems’ natural potential structure (as regional richness).

Rio-92 conference participants gave significant attention to biological (including forest) resources of natural capital [11, 12]. In Brundtland commission report (chapter 6, Species and Ecosystems: Resources for Development) biota is considered as natural resource for economic development.

From the perspective of economical evaluation of forest ecosystems’ natural capital, forest resources are part of forest produce and provide material production.

Taking into account the importance of natural capital (natural resources) in economics, ecological potential (environment-forming function) also becomes more and more important.
According to Al Pisarenko, forestry growth economical doctrine should be complemented with biosphere doctrine. It is necessary for the aim of forest resources profitability growth and forestry contribution to GRP increase. Ecological potential of forest ecosystems contains environment-forming functions realizing on forest lands constantly (commercial and reserved forests) and social functions realizing during specific social service (protection forests). In economic literature these forest amenities usually named as “environmental services” [4, 9, 13]. From the point of economic evaluation of forest amenities ecological potential, environmental-forming functions create favorable conditions for flora and fauna and for material production. Social functions create favorable conditions for human physical well-being (recreation and health improvement) and creativeness, for spiritual requirements providing.

Dividing of area natural potential by natural capital and ecological potential makes possible to realize the principle of natural capital participation in economic life of society. Ecological potential concept provides an opportunity to consider forests (forest ecosystems) as human living base.

National richness is an aggregate of natural resources, created means of production, material assets owned by state [14], at the same place “material assets” are material values in the tangible form.

According to V Yu Katasonov [15], national richness is an aggregate of manufacturing and natural products, all tangible and intangible assets created by human and nature on the territory of country or region. That representation of national (regional) richness may be considered as its eco-economic form.

During forest ecosystems’ natural potential evaluation in the regional richness structure one should take into account that forest lands (forest ecosystems) are in state property in Russia. State property on forest lands is not evaluated in present time and not proper registered by government management. Moreover, forest lands as state property are still not accounted as intangible asset [16].

2. Materials and methods

We use discounted rent income as a criterion of forest ecosystems evaluation. It is calculated as difference between total potential economic effect from all forest amenities for long-term period and forestry costs for reproduction, conservation and protection of forests. In general terms evaluation criterion $E$ is functional dependence from annual effects sum $R_i$ for $n$ years determined be meanings of natural indicators $K_i$, economic equivalents $C_i$ and corresponding forestry costs $Z_i$, which in turn depends from time instants $t_i$, i. e.

$$E = f\left(\sum_{i=1}^{n} R_i f(K_i, C_i, Z_i, t_i)\right)$$

Cumulative effect is calculated considering dynamics of spatiotemporal functional relations of separate forest sites and components, nature and forest management peculiarities, monetary values discounting. Spatial aspect in forest evaluation consists in considering of forest type change from native (mostly conifer forests) to secondary (broadleaf forests). Temporal aspect consists in considering of forest biometric parameters and biological processes (photosynthesis, ecosystem production, absorption and conversion of gaseous and aerosol atmospheric pollution etc.) intensity changes. Considering of nature and forest management types consists in different approaches to forest resources harvesting periods and forest sites legal status changing.

In economists opinion, main and the most difficult challenge of temporal factor considering during natural complexes evaluation is justification of discount rate [17]. Discount rate value depends on discounting period. It changes from 0.01-0.02 to 0.15-0.17 according to different age classes of forest stand [7]. Preferable values of discount rate and corresponding discount factor are presented in Table 1.
Table 1. Discount rate and discount factor values according to discount period (by compound interest model).

| Discount period, years | Discount rate \( P \) | Discount factor \( d \) | Discount period, years | Discount rate \( P \) | Discount factor \( d \) |
|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| ≤5                     | 0.1726                 | 0.392                  | 40                     | 0.0409                 | 0.188                  |
| 10                     | 0.1071                 | 0.322                  | 50                     | 0.0346                 | 0.172                  |
| 15                     | 0.0820                 | 0.277                  | 70                     | 0.0264                 | 0.153                  |
| 20                     | 0.0667                 | 0.251                  | 90                     | 0.0214                 | 0.142                  |
| 30                     | 0.0502                 | 0.213                  | 100                    | 0.0196                 | 0.138                  |
| 35                     | 0.0450                 | 0.199                  | ≥150                   | 0.0132                 | 0.134                  |

Evaluation of forest resources as single harvesting forest amenities is carried out by primary compound interest formula and its modifications; in special conditions one can use simple interest formula too.

Total value of discount effect from single timber harvest for one rotation period is determined by equation (2):

\[
E_{P} = \sum_{j=1}^{n} \left[ \frac{q_{j}}{(1 + P_{j})^{T}} \right] + \frac{Q}{(1 + P_{T})^{T}}
\]

where: \( m \) – amount of intermediate fellings; \( q_{j} \) – timber cost for \( j \) intermediate felling, RUB/ha; \( t_{j} \) – age of \( j \) intermediate felling, years; \( Q \) – timber cost for main felling, RUB/m³; \( T \) – rotation period, years; \( P_{j} \), \( P_{T} \) – discount rate for \( j \) time period and for rotation period.

For environment-forming functions evaluation we set them as effects \( R_{i} \) in equation (1). Effects are calculated as environment-forming function summarized annual values for successive age classes \( R_{i}^{0} \).

For one rotation period (e.g., for 6 age classes) environment-forming function evaluation is provided using equation (3):

\[
E = \sum_{i=1}^{6} \frac{R_{i}}{(1 + P_{i})^{t_{i}}} = \sum_{i=1}^{n} R_{i} d_{i}
\]

where: \( P_{i} \) – discount rate for time point \( t_{i} \) (Table 1); \( d_{i} \) – discount factor for time point \( t_{i} \) (Table 1).

Pattern of natural potential summarized economic evaluation corresponds to forest division by commercial and protection ones. For commercial forests, value of forest site consists of value of forest resources and value of environment-forming functions inherent to all forest areas: air quality maintenance, water-protective, water-regulative, climate-forming and soil-forming functions. Protection forests evaluation additionally consists of other environmental-forming functions (Table 2).

Table 2. Forest amenities considered (marked with “+”) during economical evaluations of different protection forests

| Protection category                       | Forest amenities of commercial forests | Environment protection functions |
|-------------------------------------------|---------------------------------------|----------------------------------|
|                                           |                                        | Soil protection                  |
|                                           |                                        | Water purification               |
|                                           |                                        | Air purification                 |
| Forestry part of landscaped areas         | +                                     | +                                |
| Park part of landscaped areas             | +                                     | +                                |
3. Results and Discussion

Results of forest resources evaluation (for forests of Middle Ural) are provided in Table 3.

Table 3. Value of forest resources (forest natural capital) for Middle Ural.

| Tree species | Group of forest types | Value of forest resource, kRUB/ha |
|--------------|-----------------------|----------------------------------|
|              | Timber                | Non-timber forest products       |
|              |                       | Collateral forest use            |
| Pine         | Herbosa               | 18.0                             |
|              | Oxalis/Myrtillus      | 17.1                             |
|              | Vaccinium vitis-idaea | 15.0                             |
|              | Pleurozio-Equisetosa  | 9.9                              |
|              | Sphagnosa and         | 6.6                              |
|              | Uliginosoherbosa      |                                   |
| Birch        | Herbosa               | 5.1                              |
|              | Oxalis/Myrtillus      | 4.2                              |
|              | Pleurozio-Equisetosa  | 2.7                              |
|              | Sphagnosa and         | 1.5                              |
|              | Uliginosoherbosa      |                                   |

\[ E_a = \sum_{i=1}^{n} q_i \cdot W(1+V_1 \cdot Y_{1i} + V_2 \cdot Y_{2i}) \cdot t_i \cdot (P_c S_c + P_o S_o) \cdot d_i, \text{RUB/ha} \]  

(4)

where: \( n \) – number of age groups (saplings, middle-aged, ripening, mature); \( q_i \) – current mean periodic increment of stem wood for \( i \) age group, \( \text{m}^3/\text{ha} \); \( W \) – wood density for \( i \) age group, \( \text{ton/m}^3 \); \( V_1 \) – stump and root wood increment comparison ratio; \( V_2 \) – main and side branches wood increment comparison ratio; \( Y_{1i}, Y_{2i} \) – phytomass increment comparison ratios for specific stand elements in different age periods; \( t_i \) – duration of \( i \) age group, years; \( P_c, P_o \) – intensity of carbon-dioxide absorption and oxygen production during oven dry ton formation, \( \text{ton/ton} \); \( S_c, S_o \) – values of “replacing assets” for this forest function evaluation, \( \text{RUB/ton} \); \( d_i \) – discount ratio for \( i \) age group.

Example. Role of forests in atmosphere protection is evaluated with following parameters: \( q_1 = 3.2 \text{ m}^3/\text{ha}, q_2 = 2.6 \text{ m}^3/\text{ha}, q_3 = 1.5 \text{ m}^3/\text{ha}, q_4 = 1.4 \text{ m}^3/\text{ha}, W = 1.54 \text{ ton/m}^3, V_1 = 0.10; S_c = S_o = 485 \text{ RUB/ton}. It equals:

\[ E_a = [(3.2 \cdot 0.54 \cdot (1 + 0.13 \cdot 0.8 + 0.10 \cdot 0.85) \cdot 40 \cdot 0.25 + \]
\[ + 2.6 \cdot 0.54 \cdot (1 + 0.13 + 0.10) \cdot 40 \cdot 0.161 + \]
\[ + 1.5 \cdot 0.54 \cdot (1 + 0.13 \cdot 0.8 + 0.10 \cdot 0.9) \cdot 20 \cdot 0.142 + \]
\[ + 1.4 \cdot 0.54 \cdot (1 + 0.13 \cdot 0.7 + 0.10 \cdot 0.7) \cdot 20 \cdot 0.137)] \cdot (1.802 \cdot 485 + \]
\[ + 1.389 \cdot 485) = 56964 \text{ RUB/ha}. \]

Value of water-protective and water-regulative role of forests \( E_a \) is defined by annual incremental value of groundwater runoff. We calculate it as the difference between forested watershed actual runoff and theoretical groundwater runoff from forestless area in the same conditions.

Primary effect of the water-regulative role figures out mostly at the summer period. In this case, value of groundwater runoff increment equals:
where: \( X \) – summarized precipitation amount; \( \alpha \) – stream flow coefficient; \( \beta \) - forested areas precipitation increment coefficient; \( C_1 \) and \( C_2 \) – groundwater runoff coefficients for forested and forestless areas correspondingly; \( K_1 \) – swampliness coefficient; \( \mu \) – proportion (unit fraction) of summer precipitation in annual precipitation; \( K_2, K_3 \) – age and yield class adjustment coefficients; \( K_4 \) – stand density adjustment coefficient; \( t_i \) – duration of \( i \) age group, years; \( r \) – water cost (water rent) RUB/m³.

**Example.** Value of water-protective and water-regulative roles of forests per 1 ha is calculated using following parameters: annual summarized precipitation amount \( X = 800 \) mm; stream flow coefficient \( \alpha = 0.14; K_1 = 0.95 \); proportion of summer precipitation \( \mu = 0.78 \); forested areas precipitation increment coefficient \( \beta = 0.10 \); groundwater runoff coefficients \( C_1 = 0.85, C_2 = 0.40; K_2 = 1; K_3 = 1; K_4 = 1; r = 13.8 \) RUB/m³. It equals:

\[
E_b = \left[ 800 \cdot 0.14 \cdot 0.95 \cdot 0.78 \cdot (0.85 \cdot 0.28 \cdot 1 \cdot 1 – (1 – 0.10) \cdot 0.40) \cdot 40 \cdot 0.250 + \\
+ (0.85 \cdot 0.27 \cdot 1 \cdot 1 – (1 – 0.10) \cdot 0.40) \cdot 40 \cdot 0.160 + \\
+ (0.85 \cdot 0.92 \cdot 1 \cdot 1 – (1 – 0.10) \cdot 0.20) \cdot 20 \cdot 0.142 + \\
+ (0.85 \cdot 0.92 \cdot 1 \cdot 1 – (1 – 0.10) \cdot 0.40) \cdot 20 \cdot 0.137 \right] \cdot 13.8 = 44896 \text{ RUB/ha.}
\]

We use the same approach for other environmental-forming and environmental-protective functions (Figure 1) evaluation.

Table 4 contains the results of commercial forests evaluation.

Value of forest resources (natural capital of forest ecosystems) is about 12-16% of total value of forested area for commercial forests of Middle Ural. Value of ecological potential is about 84-88% correspondingly. For protection forests it grows to 92-96%.

Table 5 contains results of forest areas ecological potential evaluation (carbon-dioxide absorption and oxygen production) as part of its cadastral value (discounted annual effects for long-term period). For comparison, it also contains values of primary incomes (production potential created for long-term period) for Sverdlovsk oblast’ [18].

**Table 4.** Value of forest lands in commercial forests of Sverdlovsk oblast’, kRUB/ha (Yekaterinburg forestry region)
Table 5. Forest lands natural richness evaluation in structure of Sverdlovsk oblast’ regional richness

| Factors                                      | year 2012 |
|----------------------------------------------|-----------|
| **Fixed assets value, billion RUB**          | 3 663.5   |
| by economic activity types:                  |           |
| – agriculture, billion RUB                   | 63.2      |
| – mining, billion RUB                        | 52.2      |
| – manufacturing, billion RUB                 | 608.6     |
| – power generation, billion RUB              | 238.8     |
| **Forest lands ecologic potential, billion RUB** |           |
| value of carbon-dioxide absorbed, billon RUB |           |
| by Kyoto protocol:                           |           |
| 6 USD for 1 ton of carbon-dioxide            | 121.5     |
| 10 USD for 1 ton of carbon-dioxide           | 243.0     |
| 500 RUB for 1 ton of carbon-dioxide          | 368.7     |
| value of oxygen produced, billon RUB         | 316.7     |

4. Conclusions
Value of forest ecosystems natural potential, created by nature without any finance or labor costs [19], is comparable with the value of production potential created by society in certain economic sectors (agriculture, mining [20], power generation). Understanding and comprehension of this fact should create fundamental scientific basis for greening of regional economy [21], become foundation of environmental safety and form conditions for transition to sustainable development.

Acknowledgements
The paper is written with the support and as part of The Russian Foundation for Basic Research grant № 17-06-00433.

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