Procedural framework of the resources cost effective use of cutting works technologies

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Abstract. With a variety of technologies for the cutting works, the choice of them should be determined by a combination of various factors that allow us to estimate the possible level of resource savings at each stage of such work. At the moment, the ecological effect extended for a certain period of time cannot be calculated precisely. It must be taken into account when evaluating the economic effect of resource savings at the enterprises of the timber complex. Using the structural-logical diagram of methodological approaches in order to establish factors and indicators of the resource-saving effect, a system analysis is carried out, which allows us to draw up an algorithm for generating an estimate of the resource-saving effect of various cutting works.

1. Introduction
An intensive environmental management model is supposed to preserve non-renewable mineral resources, the needs of which are covered by the use of waste products, the volume of which in the function of the recyclables is due to innovative technological methods of production.

The evaluation of economic effect requires considering the economic and environmental consequences of the natural resources removal. The factor of exhaustion and non-renewability of the majority of natural resources determines the search for alternatives to traditional technologies in acquisition of a variety of benefits provided by nature.

Technological methods of the industrial stock and timber processing are characterized by a variety of indexes that evaluate the level of resource saving at each stage of cutting works.

The ecological effect should be considered as a significant but accompanying characteristic of the economic effect. The ecological effect is evaluated as a result of the efficient use of resources extracted out of a biota aimed at producing benefits that provide a synergetic effect for the consumer of these benefits.

The limit of the industrial resources does not fully allow meeting the requirements for absolute environmental safety against the footprint. “Necessity” and “opportunity” are the conditions to establish the economic efficiency of the resource saving at the enterprise and they should identify the priority of various indexes of economic effect, which will act as follows: the main ones are economic, the related ones are environmental and the adverse ones are image-building.
According to the GOST 30166-2014 “Resources saving. Basic principles” the recourse saving are "activities (organizational, economic, technical, scientific, practical, informational), methods, processes, a set of organizational and technical measures and actions that accompany all stages of the product life cycle, stages of the waste technological cycle and aimed at rational and economical use of resources”[1].

Resources are "exploitable sources to satisfy the needs of society" [1]. The economic aspects of the resources exploitation should be correlated to the ecological requirements to support the balance of production needs and opportunities of natural potentials. Hence, the evaluation of the effect should be built on the ratio of the volumes of resources involved into the production and the amount of benefits provided by the level of maximum use of resources.

A high level of competition in home and international markets requires the company to constantly increase the image of environmentally friendly production, which is ensured by involving the significant investments, and hereby requires an adjustment of the criterion of their effectiveness.

The indexes of the resource-saving effect shown in table 1 should be adopted as framework rates, specification of which depends on the nature of the resources, technological methods for their processing, volumes and characteristics of waste production.

**Table 1.** Classification of the resource saving effect indexes at the enterprise.

| ECONOMIC                | ECOLOGICAL                      | IMAGE BUILDING                      |
|-------------------------|---------------------------------|-------------------------------------|
| Saving on waste recycling | Reducing polluting emissions   | Availability of Certificates of      |
| Resource saving per unit of | Decrease in waste disposal areas| Conformity with international       |
| output                  | CO₂ reduction                   | standards of the product quality    |
| Reducing pollution charges | in the air                      | and technologies                     |
| Savings on ensuring the environmental risks | Saving on volumes of recoverable resources | State support for the |
| Decrease of the losses caused by the occupational diseases | Reduction of morbidity of the population | environmental projects of the company | preferential loans |
|                         |                                 | “Green” economy status               |

Primary resources accumulated in bio-natural (natural) conditions are exhaustible and, in most cases, non-renewable. Secondary resources created in anthropogenic (man made) conditions of economic activity are close in their volume to the primary ones. The generated and accumulated secondary material resources are the resources of secondary raw materials.

Timber, as a primary resource, during processing generates significant amounts of wood waste, recycling of which ensures a significant economic effect in the national economy. However, in the face of the aggravation of climate change problem due to increased anthropogenic pressure, the role of trees plantations as a resource to recompense carbon emissions into the atmosphere is increasing.

Related to species and structural parts of forest biocenoses and their edaphic conditions determine the direction of reforestation processes such as seminal or vegetative, change of species and storeyed structure. Knowledge of the biological and environmental properties of woody plants allows us to ensure the natural reforestation by means of using the certain types of felling.

The timber industry enterprises using resource-saving technologies contribute to the conservation of the forests, which leads to savings in the costs of cultivation the new forests, since forests on the preserved lands of the forest fund do not require reforestation.

Preserved forests provide the constant ability of forests to absorb the carbon dioxide and hereby, reduce the level of greenhouse effect. Thus, the economic effect is complemented by the environmental effect, namely by decreasing the concentration of carbon dioxide in the atmosphere. The use of wood storage and processing waste as fuel, compared to the mineral one which has a higher calorific value, reduces carbon dioxide emissions. In addition, wood fuel waste can replace the exhaustible types of mineral fuel resources, providing a significant level of efficiency of public production costs while reducing the greenhouse effect. Although carbon dioxide is emitted during the burning up of these wastes, it has a beneficial effect on the climate, given that the logging wastes are being decomposed anyway and thus, release carbon and other greenhouse gases [2-6].
Timber harvesting, a variety of machine systems and work methods significantly affect the types and volumes of secondary resources, and determine the degree of concentration of their formation and gathering patterns, and courses for their use as well. The specifics of the conditions of the timber waste origin at all stages of timber harvesting should be characterized by a framework of indicators in resource saving.

2. Materials and methods
The system-wide approach allows us to build up an algorithm to form an evaluation of the resource saving effect of various cutting works. Figure 1 shows the structural-logical diagram of methodological approaches to establish the factors and indexes of the resource-saving effect. A graphical representation of the problem in the form of Ishikawa [7] diagrams allows you to visualize and evaluate the cause-effect relationships of technological, economic and environmental markers to estimate the effect of resource saving.

A general evaluation of the level of resource saving of the cutting works is determined by the matrix method, which allows systematizing private estimates of various indexes. Evaluation of indexes is carried out by the expert method. Expert methods are related to the non-formalized techniques for describing economic problems and are based on intuition and past experience [8].

3. Results and Discussion
The enquiry of the experts is carried out by the Delphi method, by sending out a questionnaire (table 2) to evaluate the level of resource saving of technologies that is used in Russian and foreign practice.
of cutting (table 3), and allowing to identify the independent opinion of each expert, in which experts from the forest industry should be involved and designers of logging equipment.

**Table 2.** Matrix of evaluation of the resource saving effect in diverse technologies in cutting works.

| Resource saving effect indexes | Range of the resource saving effect of cutting works technologies |
|-------------------------------|---------------------------------------------------------------|
| **TECHNOLOGICAL**             | №1   №2   №3   №4   №5   №6   №7   №8   №9   №10                  |
| - degree of waste concentration |                                |                                |                                |                                |                                |
| - proportion of waste for the production of technological chips |                                |                                |                                |                                |                                |
| - specific weight of the fuel waste |                                |                                |                                |                                |                                |
| - specific weight of the green mass |                                |                                |                                |                                |                                |
| **ECOLOGICAL**                |                                |                                |                                |                                |                                |
| - loading rate on the soil |                                |                                |                                |                                |                                |
| - volumes of the young growth destruction |                                |                                |                                |                                |                                |
| - conditions of reforestation |                                |                                |                                |                                |                                |
| **ECONOMIC**                  |                                |                                |                                |                                |                                |
| - energy intensity of products |                                |                                |                                |                                |                                |
| - percentage of waste usage |                                |                                |                                |                                |                                |
| - profitability of waste processing |                                |                                |                                |                                |                                |
| - specific weight of the waste in the volume of felling |                                |                                |                                |                                |                                |

**Table 3.** Technological processes of the cutting works [9].

| Groups technological works of tech.proc | № of tech.proc | Works in the cutting area | Type of timber to be trailed | Works in the upper timber landing or loading ramp | Type of logged materials |
|-----------------------------------------|----------------|---------------------------|-------------------------------|--------------------------------------------------|-------------------------|
| Tree length system                      | 1              | Tf - B                    | T                            | L                                                | T                       |
|                                         | 2              | Tf - B                    | T                            | Tdl - L                                          | S                       |
|                                         | 3              | Tf – Tdl - B              | S                            | L                                                | S                       |
| CTL technology                          | 4              | Tf – Tdl - B              | S                            | Cer - L                                          | P2                      |
|                                         | 5              | Tf - B                    | T                            | Tdl - Cer - L                                    | P2                      |
|                                         | 6              | Tf - Tdl – Cer - B        | P2                           | L                                                | P2                      |
|                                         | 7              | Tf - Tdl - Ccr – B - L    | -                            |                                                  | P2                      |
| Added-value wood processing             | 8              | Tf - B                    | T                            | Tdl – Cer – Cr - L                               | P1                      |
|                                         | 9              | Tf - Tdl – Cer - B        | P2                           | Cr - L                                           | P1                      |
|                                         | 10             | Tf - Tdl – Cer – B; Chw - L | P2                           | Tdb – Ch - L                                     | P4                      |
|                                         |                |                           |                               |                                                  |                         |

where, Tf – tree felling; Tdb – debarking; Tdl – tree deliming; L – loading; Cr – rip-cutting; Ccr – cross cutting; Ch – chipping; Chw – felling waste chipping; B – bundle formation; T – trees; P1 – timber; P2 – assortment; S – stems; P3 – technological chips; P4 – fuel chips.
The enquiry of the experts is carried out by the Delphi method, which is used along with others, such as SAW, the Preference Ranking Organization Method for Enrichment Evaluations and the Analytical Hierarchy Process and allows you to identify the independent opinion of each expert [10]. The latter should be recruited from the forestry experts and designers of timber cutting equipment. Experts assign a significance coefficient \( k_{i,p} \in [-1; 1] \) to each factor called \( i \). Based on the data obtained by the formula, the total assessment of the timber harvesting technology \( Q \) is calculated:

\[
Q = \sum_{i=1}^{n} \sum_{p=1}^{m} k_{i,p},
\]

where, \( Q \) – total evaluation of the timber harvesting technology; \( n \) – numbers of evaluation criteria, in this case, see table 1, \( n = 9 \); \( m \) – number of experts called \( p \), in compliance of the Delphi method not less than 20 people; \( k_{i,p} \) – significance factor coefficient called \( i \), assigned by the \( p \) expert \( k_{i,p} \in [-1; 1] \).

The maximum value of the total rating will determine the preferred timber cutting technology that can be considered as resource-saving from the standpoint of economic, ecological and technological effect.

An evaluation of the technology's weaknesses and strengths will allow further research to justify the most promising ones from the point of view of the most economical and environmentally acceptable technologies for timber harvesting in the context of the development of the timber industry complex which ensure a high level of use of various forest benefits, both production and bioprotective.

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