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How to optimize the operational technologies of contemporary forest landscape restoration: process control algorithm †

Tatyana P. Novikova [1,*]

[1] Faculty of Computer Science and Technology, Voronezh State University of Forestry and Technologies Named after G.F. Morozov, 8, Timiryazeva, 394087 Voronezh, Russia; novikova_tp.vglta@mail.ru

* Correspondence: novikova_tp.vglta@mail.ru

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Abstract: The paper is interest to forest management & policy scientists and forest farmers, when deciding on the choice of frontier reforestation techniques. Today, the reforestation processes is considered either from a technical operational point of view or from an economic point of view in order to reduce costs. A multi-factor integrated approach will make it possible to make effective decisions and improve the efficiency of forest landscape restoration. The paper presents the development of an algorithm for managing the process of reforestation in modern conditions in order to optimize individual stages, the adequacy of the choice of the necessary operational technologies, taking into account the climatic and geomorphological characteristics of sites. Based on the initial data (characteristics of the area for reforestation), the algorithm will determine the optimal combination of reforestation stages, identify the stages that do not significantly affect the result of reforestation, determine the necessary operational technologies for previously defined stages, and determine the necessary reproductive material based on the selected operational technologies. Using this algorithm will reduce the ratio of reforestation costs by at least 15 %.

Keywords: forest landscape restoration; optimize algorithm; operational technologies; reduce the ratio of reforestation costs

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1. Introduction

With the development of fundamental sciences, engineering and technologies, general automation and computerization of human activity processes, changes are also taking place in the forest ecosystem. On the one hand, there are processes of destruction of the forest ecosystem: deforestation, fires, emergencies, anthropogenic impact. On the other hand, people have begun to realize the importance of preserving forests on our planet. In many countries, forest conservation is supported by law [1–3], and international forest landscape restoration (FLR) programs [1,4–8] are being created. All this motivates scientists to develop and create new technologies [9,10] and technical means [11–15] for reforestation (for example, developments in the field of improving the quality of forest reproductive material [16–23], UAV-based sowing [24–27], etc.), to study the relationship between the volume of logging and the carbon balance. For example, Díaz-Yáñez et al (2020) [28] showed that the carbon balance and the amount of dead wood positively correlate with each other, and both of them negatively correlate with the volume of harvested wood and the economic profitability of forestry. Due to the anthropogenic impact of humans, there are more and more areas that are difficult to access for reforestation, where it is not possible or significantly difficult to use classical technologies for planting or sowing reproductive seed material. Areas that are difficult to restore are understood as [9,24]:

– areas that have been freed up as a result of logging, including fire-based, which are ineffective for ground seeding or planting operations;

– released as a result of pyrogenic disturbance (burning), ineffective for ground seeding or planting operations;

– inaccessible to land-based mechanization facilities for climatic (with waterlogged soils, restored from desertification) and geomorphological (slopes with a slope of more than 60 degrees, gully-beam networks, forest canopy) reasons;

– inaccessible to people due to the complication of the radiation background and (or) after man-made disasters.

– allocated for the construction of industrial campaigns that subsequently restore ecological biodiversity (compensatory reforestation).

Due to the development of interdisciplinary research, new approaches to reforestation are emerging. Qualitatively new machines and equipment for reforestation are being designed and developed. However, classical technologies with an established set of machines and mechanisms are also used. The variety of operational technologies (each of which includes its own set of technical means), types of restored areas, geomorphological and climatic data, stand compositions creates a difficult task of optimal selection of a group of technological operations that take into account natural and climatic conditions that ensure cost reduction and energy efficiency of the reforestation process.

To date, reforestation is considered from three positions:

1) technical, by which we mean a set of technical means, machines and mechanisms for the preparation of forest seed material, soil preparation, planting/sowing, care;

2) biological – the study of growth, the influence of external factors on young plantings;

3) economic, the purpose of which is currently to reduce the costs of reforestation.

However, very often, the results of research on each of the positions are inconsistent and even contradict each other. Thus, a comprehensive management approach is needed to the problem of reforestation, which would take into account all positions and expert opinions and, based on the mathematical apparatus of fuzzy logic, optimization models and management theory, without prejudice assess the effectiveness and expediency of using certain technologies, technical means, a set and sequence of operational technologies.

2. Material and methods

The theory of algorithms was used to represent the sequence of operational technologies and to evaluate a possible set of technologies and technical means. At almost every step of the presented algorithm, a mathematical justification of the choice is required. To "assess the need and possibility of preparing areas (tillage)", a method of expert assessments is needed. Its application will ensure the objectivity, versatility, complexity and competence of practical decisions made. For a comprehensive assessment of the site, for making a decision on the choice of machines and mechanisms, it is advisable to apply the theory of fuzzy sets.

The comprehensive assessment of the condition of the sites is based on taking into account the influence of all natural and climatic data and anthropogenic influences. To take into account all the indicators in the integral assessment of the state of the site, it is advisable to formalize the decisions of experts using the methods of the theory of fuzzy sets. Then the expert assessments will be in the form of linguistic variables. The assessment of the site condition will be presented in the form of a formalized set of such variables. This situation is called a fuzzy situation. If you set a possible threshold for including the existing situation in the acceptable options, then in this case it is possible to make decisions on the inclusion of a particular operating technology during reforestation.

3. Results

Figure 1 shows a simplified FLR-algorithm, in which we tried to take into account most of the common operational reforestation technologies and modern theories and developments in this area.

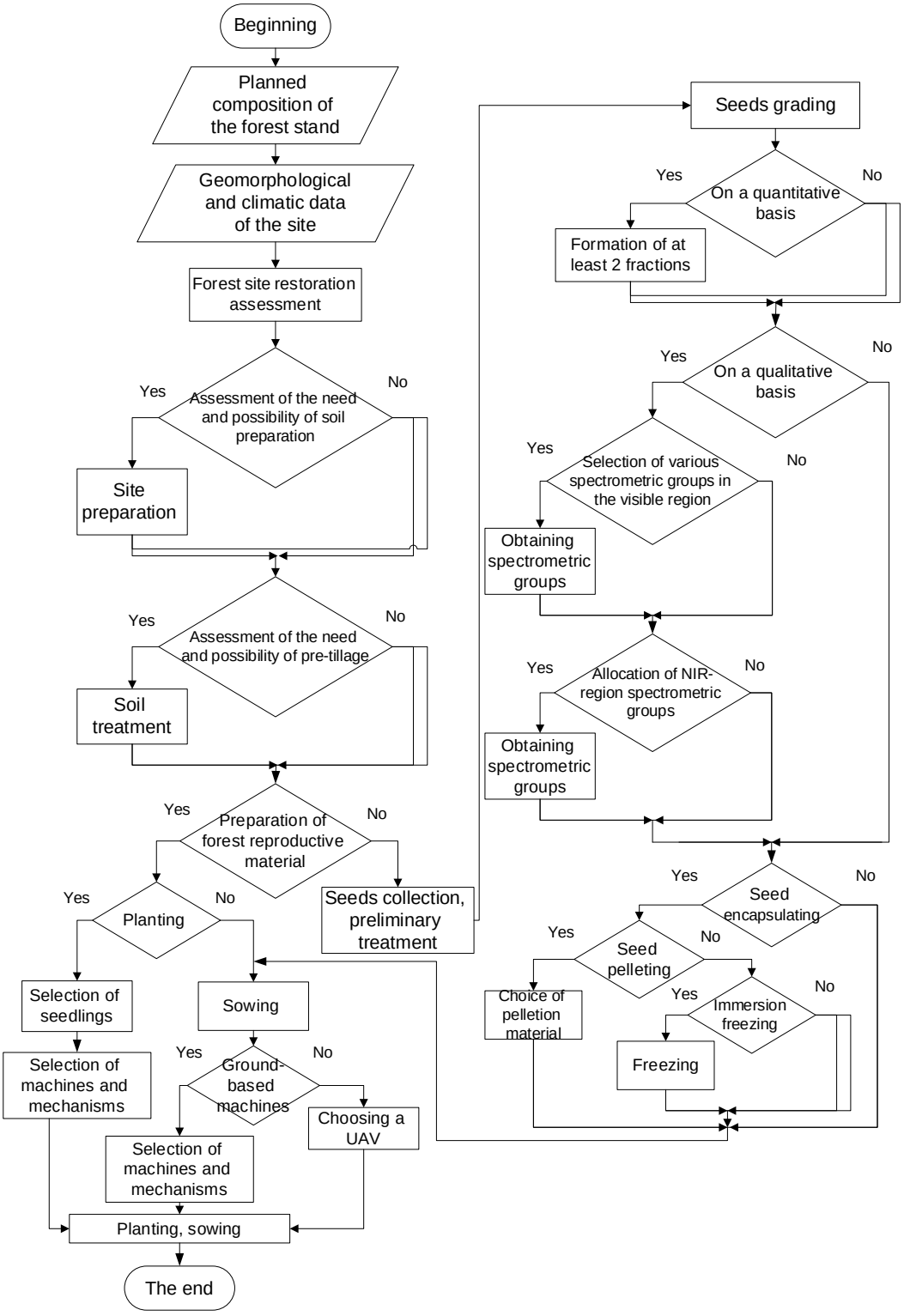

Figure 1. FLR-algorithm.

This algorithm is planned to be integrated into FRM-Library [19] in the future to select a rational FLR technology.

5. Conclusions

An algorithmic basis has been developed for optimizing the operational technologies of contemporary FLR to minimize costs and maximize energy efficiency. This algorithm will be tested on a specific example of restoring different forest sites.

According to preliminary calculations, the use of this algorithm will reduce the cost of reforestation by at least 15%, by optimizing the set of technological operations and reducing the time for decision-making.

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